FINAL
REPORT
August 2021

Sustainable Fleet Strategy

Background Review and Analysis Report

PREPARED FOR THE CITY OF BRAMPTON

LEAD AUTHORS: ROGER SMITH, MATTHEW PITTANA, JANA CERVINKA. CHIEF DATA ANALYST: HUGH ROBERTS

RICHMOND
Sustainability Initiatives

TABLE OF CONTENTS

Terms and Abbreviations

AEC – Annual equivalent cost
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
Capital Replacement Ratio – Capital (for vehicle replacements) as a percentage of NPV
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
Controllable operating costs – For this report and benchmarking, operating expenses directly controllable by fleet management, including fuel, cost of capital, repairs & maintenance, inflation, and downtime
CO_2 or CO_2e – Carbon dioxide or carbon dioxide equivalent
CVOR – Commercial Vehicle Operating Registry
Downtime – Period when a vehicle is unavailable for use during prime business hours
E85 – A blend of around 85% ethanol and 15% gasoline
ECM – The electronic control module that manages a vehicle's computerized engine function
ELD – Electronic logging device
EV – Electric vehicle
FAR™ – Fleet Analytics Review™ (Fleet Challenge Excel software tool)
FMIS – Fleet management information system
GHG – Greenhouse gas (expressed in CO_2 equivalent tonnes)
GHG Intensity – A measure of GHGs produced relative to VKT or VMT (see below)
GVW – Gross vehicle weight
HD or HDV – Heavy-duty vehicle (Classes 7-8)
HEV – Hybrid-electric vehicle
HOS – Hours of service
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 – Liquid propane gas
LTCP – Long-term capital planning
LOF – Lube, oil, filter

Terms and Abbreviations (cont'd.)

Maintenance Ratio – Ratio of dollars spent on reactive (unplanned) repairs to preventive (planned) maintenance
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
OOS – Out of service
Opex – Operating expense
Outlier – Vehicle with operating statistics outside of averages for similar fleet units
PDIC – Professional driver improvement course
PHEV – Plug-in hybrid electric vehicle
PM – Preventative maintenance
PMCVI – Periodic mandatory commercial vehicle inspection
Retention Cycle – The period that a vehicle remains in active service
RNG – Renewable natural gas
ROI – Return-on-investment
Solution – A technology, best management practice, or strategy to reduce fuel use and GHGs
SOP – Standard operating practice
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

Disclaimer

The Sustainable Fleet Strategy: Background Review and Analysis Report (including any enclosures and attachments), has been prepared for the exclusive use and benefit of the City of Brampton and solely for the purpose for which it is provided. Unless Richmond Sustainability Initiatives (RSI) provides prior written consent, no part of this report should be reproduced, distributed, or communicated to any third party. RSI does not accept liability if this report is used for an alternative purpose from which it is intended, nor to any third party in respect of this report.

Analysis in this report is based on fleet data prepared by the City of Brampton. RSI is not responsible for errors or omissions, or for the results obtained from the use of this information. All information in this site is provided as-is, with no guarantee of completeness, accuracy, timeliness, or the results obtained from its use.

The information in the report is not an alternative to legal, financial, taxation, or accountancy advice from appropriately qualified professionals. For specific questions about any legal, financial, taxation, accountancy or other specialized matters, the City of Brampton should consult appropriately qualified professionals. Without prejudice to the generality of the foregoing paragraph, we do not represent, warrant, undertake, or guarantee that the use of guidance in the report will lead to any particular outcomes or results.

Foreword

The Sustainable Fleet Strategy: Background Review and Analysis 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- and medium-duty vehicles, 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 this report as meaningful and relevant as possible to the City of Brampton, in line with its corporate GHG emissions reduction target of 50% by 2041 compared to 2016 levels. In preparing this report, our team has analyzed and evaluated baseline fleet results, and we have 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 of the Sustainable Fleet Strategy: Framework and Action Plan Report, these solutions will be modelled and scenario analysis results will be 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). Fleet baseline data were analyzed using FAR, and lifecycle analysis (LCA) was performed using a complementary software tool to determine optimal replacement cycles for vehicle categories.

The Background Review and Analysis Report presents the City of Brampton's near current-day fleet baseline based on the 2019 review period. The report presents modelling results for long-term capital planning (LTCP) based on optimal replacement cycles and return-on-investment (ROI), and proposes a range of fuel-reduction solutions consisting of best management practices (BMPs), fuel switching, and transitioning to battery-electric vehicles (BEVs).

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.

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.

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 fleet 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.

...

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]. 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.

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. This report addresses Focus Area One: Background Review and Analysis.

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
- Increase 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.

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 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

[2] Source: https://climateactiontracker.org/countries/canada/

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[3], 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[4]. 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.

Sustainable Fleet Strategy: Background Review & Analysis – Objectives

The primary objectives of the Background Review and Analysis Report were to:

(1) Provide an overview of the City's current key green fleet policies, practices, and procedures.

(2) Analyze the City of Brampton's near current-day (2019) fleet data and develop a GHG inventory and baseline for current fleet assets;

(3) Review current best management practices and identify potential areas of improvement;

(4) Present findings of RSI-FC's green fleet survey to gauge the current receptiveness of employees to greening Brampton's fleets;

(5) Undertake lifecycle analysis (LCA) to determine optimal replacement cycles; and

(6) Propose potential solutions to reduce GHG emissions from fleet vehicles.

The Background Review and Analysis Report will support Part Two of the Sustainable Fleet Strategy: Framework and Action Plan Report.

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

Overview of Analysis

Using RSI's Fleet Analytics Review™ (FAR) software, the Background Review and Analysis Report includes:

- Fleet and GHG emissions baseline from near current-day (2019) vehicle data provided by the City;
- Lifecycle analysis (LCA) for select vehicle categories and determination of their optimized economic lifecycles based on data provided;
- A balancing exercise of fleet capital budgets with LCA-optimized lifecycles through consideration of return-on-investment (ROI) for units due for replacement, to improve operational efficiency and asset management; and
- A review of low-carbon fleet options to inform Part Two of the Sustainable Fleet Strategy: Framework and Action Plan.

We propose fuel-reduction solutions that have potential for the City of Brampton to optimize vehicle replacement practices, transition away from fossil fuels, optimize the use of capital towards battery-electric vehicle (BEV) replacements and charging infrastructure, and ultimately achieve deep GHG reductions while maintaining stability in capital budget planning.

Fleet & GHG Emissions Baseline

The Sustainable Fleet Strategy 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 and equipment 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- and medium-duty vehicles, 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).

Some quick facts about each of Brampton's in-scope sub-fleets for the one-year review period (2019) are shown below. Please see *Section 3.0* for a more detailed breakdown of select key performance indicators (KPIs) per unit for each vehicle class.

Fleet Services

- There were 231 gasoline-powered units, 225 diesel-powered units, and one battery-electric vehicle (BEV), a Ford Focus (2016).
- In terms of ownership, 422 units were owned and 35 rented.

- The original purchase price for the fleet was $24,786,291.
- The current-day estimated replacement cost was $31,610,118.
- The estimated market/trade-in value was $2,478,629.
- The total cost of repairs and maintenance, fuel, capital & downtime was $4,205,465.
- Total kilometres-travelled was 4,217,024.
- Total fuel used was 1,063,788 litres.
- Total tailpipe GHG emissions were 2,663 metric tonnes CO_2e.
- The average fuel consumption for the fleet was 27.0 l/100km.
- The average unit age was 6.1 years.

Fire & EMS

- There were 68 gasoline-powered units, 37 diesel-powered units, and 2 plug-in hybrid-electric vehicle (PHEVs).
- In terms of ownership, all 107 units were owned.
- The original purchase price for the fleet was $24,500,175.
- The current-day estimated replacement cost was $41,174,687.
- The estimated market/trade-in value was $3,062,522.
- The total cost of repairs and maintenance, fuel, capital & downtime was $1,855,564.
- Total kilometres-travelled was 892,422.
- Total fuel used was 294,258 litres.
- Total tailpipe GHG emissions were 775 metric tonnes CO_2e.
- The average fuel consumption for the fleet was 28.1 l/100km.
- The average unit age was 7.0 years.

Transit

- There were 51 gasoline-powered units and 10 diesel-powered units.
- In terms of ownership, 18 units were owned and 43 rented.
- The original purchase price for the fleet was $620,367.
- The current-day estimated replacement cost was $1,242,000.
- The estimated market/trade-in value was $62,037.
- The total cost of repairs and maintenance, fuel, capital & downtime was $314,962.
- Total kilometres-travelled was 1,276,710.
- Total fuel used was 171,241 litres.
- Total tailpipe GHG emissions were 413 metric tonnes CO_2e.
- The average fuel consumption for the fleet was 13.6 l/100km.
- The average unit age (owned units) was 5.2 years.

Lifecycle Analysis

Lifecycle analysis (LCA) was undertaken for selected vehicle categories in Brampton's Fleet Services and Transit (non-revenue) fleets with sufficient historical data over the review period. Our team chose to exclude Fire & EMS units from our LCA, a decision precipitated by data which was skewing the overall averages. This is due to the exceptionally high maintenance costs and, to a lesser extent, radically high fuel consumption per km – typical of, and expected for, all Fire fleets due to the nature of their operations.

The LCA took into consideration the cost of downtime (as caused by reduced reliability), the year-to-year "rollup" of weighted average cost of capital (WACC), inflation, worker cost/hour, salvage and market values, inflation, and average kilometres-driven data. The results are summarized in *Table 1*. In *Appendix C*, we have included the LCA charts for each applicable vehicle category in Brampton's fleet.

Table 1: Lifecycle Analysis Results Summary

*Vehicle Category	Current Planned Lifecycles (years)	Optimal Lifecycle Calculated through LCA (years)	Recommended Change (+ or -) (years)
Class 1 car	8	11	+3
Class 1 pickup, van	8	11	+3
Class 1 SUV, wagon	8	9	+1
Class 2 van	5-8	5	0 to -3
Class 2 pickup	8	8	Unchanged
**Class 3 pickup, cargo van	8	12	+4
Class 5 truck	8 to 10	10	0 to +2
Class 8 truck	10	12	+2

*Fire & EMS units are excluded for all vehicle categories

**Class 3 Transit pickups are ideally kept on 8-year lifecycles due to significant maintenance and repair cost increases after this life span experienced in the past at Transit.

Business Case Optimization

Once optimized economic lifecycles were modelled, it was apparent that some vehicles deliver better return-on-investment (ROI) than others. Lower ROI would result if a vehicle, still in good condition, was replaced prematurely; value will be lost.

The approach used by RSI-FC was to defer some vehicles to ensuing capital budget years to ensure full value is received from each unit. In our data-modeling, without knowledge of the physical condition of units due for replacement based on vehicle ages, our analysts instead deferred vehicles showing low/no ROI to following budget years in order to balance annual year-over-year capital budgets. This step was intended to be an example of balancing long-term budgets using optimized economic lifecycles and ROI.

We selectively and strategically made deferrals over the budget cycle to maximize operating expense (Opex) benefits and balance capital expenses (Capex). As a result, the annual capital budget over the 15-year cycle ranged from $4.9-10.8 million as compared to the business-as-usual[5] (BAU) range of $1.9-28.2 million over the same budget period.

Proposed Fuel-Reduction Solutions

RSI-FC completed extensive research into known, credible, proven, and potentially viable fuel-reduction solutions for the City of Brampton, currently or in the near future. Using balanced Capex and optimized lifecycles, for Part Two of the Sustainable Fleet Strategy: Framework and Action Plan Report, we propose three groups of solutions (see below). For every solution, we will assess the impacts relative to the 2019 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 B20 biodiesel for use in summer months) and alternate fuels (CNG and LPG)
- Group Three: Hybrid-electric and battery-electric vehicles (HEVs and BEVs, respectively)

For Part Two of the Sustainable Fleet Strategy: Framework and Action Plan Report, RSI-FC’s proprietary Fleet Analytics Review™ (FAR) software will be used to evaluate these options in the context of the Brampton fleet. That is, after optimizing lifecycles, balancing capital budgets, and implementing “house-in-order” strategies, fuel-saving options will be modelled for units due for

[5] Business-as-usual (BAU) refers to Brampton’s current-day vehicle replacement cycles.

replacement to estimate operating and capital cost changes as well as GHG emissions reductions over subsequent fiscal years (2021-2036) relative to baseline year 2019. For the purpose of data-modelling, the baseline fleet data provided by the City was for 2019 but we propose to treat 2020 as the baseline year using 2019 data as a proxy for 2020. Therefore, all scenarios will be data-modelled from 2021 onwards to evaluate the potential impacts of each low-carbon solution relative to actual data from the in-scope Brampton fleet at the time of analysis.

Our approach is based on analysis of 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.

...

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[6]." The term includes major changes in temperature, precipitation, or wind patterns, among others, that occur over several decades or longer[7].

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[8]. While there are several GHGs[9] to consider, when calculating emissions the most commonly used measure is carbon dioxide equivalent (CO_2e)[10]. 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[11]. 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[12]. According to the American Medical Association, globally, an estimated 3.3

---

[6] Source: United Nations Framework Convention on Climate Change 1992: https://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf
[7] Source: EPA. https://www3.epa.gov/climatechange/glossary.html
[8] Source: https://www.merriam-webster.com/dictionary/greenhouse%20gas
[9] 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).
[10] "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
[11] 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).
[12] 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[13], 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[14]. In Brampton, transportation accounts for almost 60% of community-wide GHG emissions[15]. In addition, 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[16]. 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.

RSI-FC has employed our innovative, leading-edge data modelling techniques and our proprietary software for the development of this Sustainable Fleet Strategy. Fleet Analytics Review™ (FAR) is a software tool designed and developed by our company specifically for complex green fleet planning. It 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

[13] Source: https://jamanetwork.com/journals/jama/article-abstract/2667043
[14] Source: https://climateactiontracker.org/countries/canada/
[15] Source: City of Brampton. Our Energy Transition: Community Energy and Emissions Reduction Plan.
[16] Source: ChargePoint. Trends & Prediction in Fleet Electrification [pdf]. June 2020.

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

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[17] 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[18]. 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.

Sustainable Fleet Strategy: Background Review & Analysis – Objectives

The primary objectives of the Background Review and Analysis Report were to:

(1) Provide an overview of the City's current key green fleet policies, practices, and procedures.

(2) Analyze the City of Brampton's near current-day (2019) fleet data and develop a GHG inventory and baseline for current fleet assets;

(3) Review current best management practices and identify potential areas of improvement;

(4) Present findings of RSI-FC's green fleet survey to gauge the current receptiveness of employees to greening Brampton's fleets;

(5) Undertake lifecycle analysis (LCA) to determine optimal replacement cycles; and

(6) Propose potential solutions to reduce GHG emissions from fleet vehicles.

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

The Background Review and Analysis Report will support Part Two of the Sustainable Fleet Strategy: Framework and Action Plan Report.

...

Section 2.0: Touchpoints of Guiding Documents

The Sustainable Fleet Strategy will be informed by and align with existing visions and plans for Brampton's sustainable development and GHG emissions-reductions goals. With this in mind, we provide touchpoints of the guiding documents in relation to the topics and objectives for the Sustainable Fleet Strategy being developed.

Brampton Grow Green Environmental Master Plan

Brampton's Environmental Master Plan (EMP) was approved by City Council in 2014, and refreshed in 2020, with the objective of serving as a blueprint for environmental sustainability at both the corporate and community level. The EMP contains performance metrics and targets which allow for measuring the City's progress towards its sustainability goals. In the Brampton Grow Green Environmental Master Plan: 2020 Refresh Report, it was noted that Brampton's GHG emissions were increasing in large part to the City's fleet. With the population projected to reach almost 900,000 by 2041, the fleet size requirements for the provision of services will increase. To reverse this trend, the City prioritized the development of this Sustainable Fleet Strategy, which is a specific action recommended in the EMP.

In addition to calling for the development and implementation of a Sustainable Fleet Strategy, the EMP Action Plan included the following items:

- Establish policies/procedures for new City facilities to provide 10% of the parking spaces with electric vehicle supply equipment (EVSE), and 25% of remaining parking spaces designed to permit future EVSE installation; and
- Develop and commence implementation of a targeted enforcement strategy for the City's anti-idling policy.

Living the Mosaic: Brampton 2040 Vision

Living the Mosaic: Brampton 2040 Vision was completed in 2018 with the objective of providing a bold new vision for the future of Brampton. Central to the Vision are seven ambitious vision statements dealing with sustainability and the environment, transportation, creating and retaining jobs, recreation, health, social issues, and arts and culture. Vision 1 (Sustainability and the Environment, Vision 4 (Transportation and Connectivity), and Vision 6 (Health) can all be supported by the development and implementation of a Sustainable Fleet Strategy.

Our 2040 Energy Transition: Community Energy and Emissions Reduction Plan

The objective of the Community Energy and Emissions Reduction Plan (CEERP) is to position the City of Brampton to address the climate emergency while realizing the economic, social, and environmental opportunities during the transition to clean energy and a low-carbon economy. This report states that, in 2016, 35% of energy used and 59% of GHG emissions in the City of Brampton came from transportation. Furthermore, 42% of energy costs in 2016 came from gasoline, and 9% came from diesel.

With the City's population expected to grow from about 600,000 to 900,000 by 2041, municipal leaders must manage the growth and development of the community by planning and designing with smarter, more energy-efficient approaches.

Items in the CEERP Action Plan relevant to the Sustainable Fleet Strategy include:

- Increasing the number of EV charging stations at municipal facilities;
- Developing a Green Purchasing Strategy and by-law to require climate change considerations;
- Updating the Fleet Strategy to reflect CEERP targets; and
- Developing operational procedures to minimize GHG emissions, i.e., enforcement of anti-idling policy for Fleet.

Corporate Energy and Emissions Management Plan 2019-2024: A Zero-Carbon Transition

This plan engaged the City of Brampton's Energy Management Team with the goal of meeting the challenge of a zero-carbon transition consisting of three key objectives:

1) Minimize Energy Intensity
2) Minimize Emissions Intensity
3) Maximize Cost Recovery

Of particular relevance to the Sustainable Fleet Strategy are EV charging stations/ infrastructure. Since 2015, the Brampton's EV charging station network has expanded, with the City (as of 2019) owning and operating 52 stations across 13 municipal parking lots, making EV ownership more convenient for residents and businesses. All stations consist of Level-2 chargers, which operate at 208 or 240 V AC.

In the near future, the City intends to improve its EV charging infrastructure, both through expansion in the number of stations as well as upgrading the current non-networked stations to allow for real-time monitoring of electricity usage and payment processing. The Energy Management Team is looking to determine optimal locations for future charging stations to maximize their usage. The Team Supervisor is also part of the Peel LEV Strategy Working Group, which was formed to research, prioritize, and plan for EV adoption within the Region of Peel.

Corporate Asset Management Plan

In 2016, the City of Brampton developed its first Corporate Asset Management Plan (CAMPlan) to assess the current state of all its infrastructure and fleet assets to ensure that levels of service were maintained in the most cost-effective manner. In 2019, the City developed the State of Infrastructure Report to provide a snapshot of the estimated overall value and condition of its assets.

In relation to the Sustainable Fleet Strategy, this report provides the following key findings for 2019:

- 16% of the Corporate Fleet was considered to be in poor to very poor condition; however, most of these units are off-road equipment (not in-scope).
- 17% and 29% of the Parks and Recreations fleets, respectively, were considered to be in poor to very poor condition.
- 93% of the Animal Services fleet was considered to be in poor to very poor condition.
- For Fire Services, 21% of licensed vehicles and apparatus were considered to be in poor to very poor condition. 39% of fire equipment (not in-scope) was considered to be in poor to very poor condition (36% very poor).

Transportation Master Plan

Completed in 2015, the Transportation Master Plan (TMP) addressed existing transportation challenges and provided strategic solutions to the population and employment growth that the City is anticipating to experience to 2041. The City is currently in the process of updating the TMP.

To improve the environment in the City and surrounding areas, a low-carbon transportation system is needed, as motor vehicles produce a variety of emissions that contribute to climate change as well as reduced air quality.

Relevant to the Sustainable Fleet Strategy, solutions for the increasing population and employment trends are for the City to purchase hybrid-electric and electric vehicles (HEVs and EVs) for its fleet, and for the City to expand EV infrastructure (charging stations).

Active Transportation Master Plan

The Active Transportation Master Plan (ATMP), completed in 2019, focused on prioritizing active mobility and complete streets, supporting a future with more integrated transportation choices.

Light Duty Fleet Management Review

This review, completed in 2019 by WSP, was intended to provide recommendations on cost-saving strategies, service efficiencies, and potential green fleet options for Fleet Services' light-duty fleet.

The following is a list of WSP's main findings in relation to the Sustainable Fleet Strategy:

- The City should conduct a GHG baseline for all fleet vehicles to gain a more comprehensive picture of their environmental impacts. The current review can serve as a starting point for a broader green fleet study involving a more sophisticated analysis of green fleet options.
- A holistic green fleet strategy for all fleet vehicles (not limited to light-duty) is recommended with a focus on the full triple bottom line (environment, economics, social) assessment of the benefits of transitioning to a green fleet for the City. This would enable the City to maximize green fleet benefits from both an environmental viewpoint (addressing climate emergency) and economic viewpoint (replacement units that would provide the maximum return-on-investment).
- Fleet would like to see greater adoption of EVs and greater support for training for green fleet vehicle operations.
- Fleet is currently most interested in exploring fully-electric, hybrid-electric and plug-in hybrid-electric options, particularly regarding light-duty vehicles.
- Fleet would like increased funding for and expansion of fast-charging stations.

Section 3.0: Fleet & GHG Emissions Baseline and Benchmarking

A fleet baseline analysis provides a starting point for setting targets and measuring progress towards fuel- and GHG-emissions reduction. It is important that a baseline be as accurate as possible as it provides a snapshot of the current state of a fleet and is the foundation of a green fleet plan. With this in mind, RSI-FC diligently collected and analyzed vehicle data provided by the City of Brampton for in-scope fleet assets, and made careful estimations and assumptions, where needed, to fill in data gaps.

The Sustainable Fleet Strategy 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 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- and medium-duty vehicles, 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).

RSI-FC collected baseline data of the City of Brampton's in-scope fleet from fleet managers. 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). Our team then loaded input data into our proprietary software, Fleet Analytics Review™ (FAR), and completed a baseline analysis.

We filled in data gaps by applying assumptions and algorithms in our FAR software. Downtime data was not available; as a workaround, we estimated downtime based on an algorithm that assumes a unit is out of service when being repaired and, thus, repair costs are commensurate with downtime costs.

For each in-scope fleet (*Tables 3-8*, overleaf), we provide (1) a summary of fleet-wide results (all units combined) and (2) a more detailed breakdown of select key performance indicators (KPIs) per unit – for the total fleet and for each vehicle class. The baseline analysis is for the one-year review period (2019).

Next, in *Table 9* (overleaf), we provide a peer fleet comparison for select KPIs as a benchmarking exercise to assess how the City of Brampton's fleets are performing in comparison to other municipalities of various sizes. From over 15 years of working with municipal clients, RSI-FC has developed a municipal peer fleet database with metrics on thousands of vehicles of all classes.

A breakdown of the gross vehicle weight (GVW), as well as included vehicle types for the City of Brampton, corresponding to each class is provided in *Table 2*.

Table 2: Gross Vehicle Weight (GVW) for all Vehicle Classes as well as Unit Types included for the City of Brampton.

Category	Gross Vehicle Weight	Included Unit Types
Class 1	0–6000 lb. (0–2722 kg)	Car, pickup, van, SUV, wagon
Class 2	6001–10000 lb. (2722–4536 kg)	Pickup, van
Class 3	10001–14000 lb. (4536–6350 kg)	Pickup, cargo van
Class 4	14001–16000 lb. (6351–7257 kg)	Van
Class 5	16001–19500 lb. (7258–8845 kg)	Van, dump truck, hook-lift truck, aerial truck, garbage truck
Class 6	19501–26000 lb. (8846–11793 kg)	Dump truck
Class 7	26001–33000 lb. (11794–14969 kg)	Step van, multi-lift truck
Class 8	33000 lb. and up (14969 kg)	Aerial (Fire & EMS), squad (Fire & EMS), pumper (Fire & EMS), dump/plow truck, flusher

Fleet Services

Table 3: Baseline Results for Brampton Fleet Services. Values are for the entire fleet for the one-year review period (2019).

Fleet Breakdown by Fuel Type[19]	Fleet Breakdown by Ownership	Original Purchase Price	Estimated Replace Cost	Estimated Market/Trade-In Value	Total Cost (R&M, Fuel, Capital & Downtime)	Total KM-Travelled	Total Fuel Used (litres)	Total GHG Emissions (tonnes CO2e, combustion – fossil diesel)	Total GHG Emissions (tonnes CO2e, combustion – B5[20])
231 G units, 225 D units, 1 BEV	422 owned units, 35 rentals	$24,786,291	$31,610,118	$2,478,629	$4,205,465	4,217,024	1,063,788	2,744	2,663

Table 4: Baseline KPIs for Brampton Fleet Services by Vehicle Class. Values are averages per unit for the one-year review period (2019). B5 for diesel-powered units has been modelled.

Category & No. of Units	KMs Travelled	Fuel Used (litres)	Fuel Economy (L/100 km)	GHG Emissions (tonnes CO2e, combustion)	GHG Intensity (kg CO2e/km, combustion)	Preventive Maintenance (PM) Costs	Repair Costs	Fuel Costs	Cost of Capital	Downtime Costs	Total Cost (R&M, Fuel, Capital & Downtime)	Cost per KM	Unit Age (years)
Total Fleet	**9,228**	**2,328**	**27.0**	**5.8**	**0.7**	**$ 1,392**	**$ 3,457**	**$ 2,536**	**$ 551**	**$ 1,265**	**$ 9,202**	**$ 1.00**	**6.1**
Class 1 (143)	10,416	2,027	17.5	4.9	0.4	$ 711	$ 1,574	$ 2,287	$ 281	$ 383	$ 5,236	$ 0.50	4.5
Class 2 (156)	8,897	1,873	22.1	4.6	0.6	$ 750	$ 2,188	$ 2,060	$ 255	$ 532	$ 5,785	$ 0.65	6.4
Class 3 (53)	9,371	2,390	25.8	6.2	0.7	$ 1,879	$ 3,394	$ 2,533	$ 323	$ 825	$ 8,955	$ 0.96	7.5
Class 4 (1)	6,565	3,181	48.4	8.2	1.3	$ 2,194	$ 1,763	$ 3,371	$ 966	$ 429	$ 8,724	$ 1.33	2.7
Class 5 (66)	8,704	2,580	33.1	6.7	0.9	$ 1,748	$ 6,235	$ 2,735	$ 899	$ 1,516	$ 13,133	$ 1.51	6.9
Class 6 (5)	8,746	2,502	29.5	6.5	0.8	$ 1,934	$ 3,775	$ 2,652	$ 967	$ 918	$ 10,246	$ 1.17	7.1
Class 7 (1)	4,557	1,855	40.7	4.8	1.1	$ 1,089	$ 4,575	$ 1,965	$ 1,724	$ 2,224	$ 11,579	$ 2.54	5.4
Class 8 (32)	6,673	5,225	80.3	13.5	2.2	$ 5,926	$ 12,400	$ 5,538	$ 2,750	$ 9,044	$ 35,658	$ 5.34	7.8

[19] G = gas-powered; D = diesel-powered; BEV = battery-electric vehicle

[20] B5 = 5% biodiesel, 95% fossil diesel. Fleet Services currently uses B5 for all diesel-powered units.

Fire & EMS

Table 5: Baseline Results for Brampton Fire & EMS. Values are for the entire fleet for the one-year review period (2019).

Fleet Breakdown by Fuel Type[21]	Fleet Breakdown by Ownership	Original Purchase Price	Estimated Replace Cost	Estimated Market/Trade-In Value	Total Cost (R&M, Fuel, Capital & Downtime)	Total KM-Travelled	Total Fuel Used (litres)	Total GHG Emissions (tonnes CO2e, combustion)
68 G units, 37 D units, 2 PHEVs	All 107 units owned	$24,500,175	$41,174,687	$3,062,522	$1,855,564	892,422	294,258	775

Table 6: Baseline KPIs for Brampton Fire & EMS by Vehicle Class. Values are averages per unit for the one-year review period (2019).

Category & No. of Units	KMs Travelled	Fuel Used (litres)	Fuel Economy (L/100 km)	GHG Emissions (tonnes CO2e, combustion)	GHG Intensity (kg CO2e/km, combustion)	Preventive Maintenance (PM) Costs	Repair Costs	Fuel Costs	Cost of Capital	Downtime Costs	Total Cost (R&M, Fuel, Capital & Downtime)	Cost per KM	Unit Age (years)
Total Fleet	**8,340**	**2,750**	**28.1**	**7.2**	**0.7**	**$ 3.997**	**$ 5,095**	**$ 2,693**	**$ 2,597**	**$ 3,289**	**$ 17,342**	**$ 2.08**	**7.0**
Class 1 (34)	5,966	704	11.4	1.7	0.3	$ 304	$ 456	$ 795	$ 191	$ 111	$ 1,857	$ 0.31	6.3
Class 2 (33)	8,964	1,335	15.5	3.2	0.4	$ 1,264	$ 1,896	$ 1,509	$ 507	$ 461	$ 5,636	$ 0.63	4.4
Class 3 (3)	8,848	2,034	23.3	4.9	0.6	$ 2,795	$ 4,192	$ 2,299	$ 316	$ 1,019	$ 10,621	$ 1.20	8.3
Class 5 (1)	1,503	568	37.8	1.5	1.0	$ 1,483	$ 2,224	$ 602	$ 392	$ 541	$ 5,241	$ 3.49	16.6
Class 7 (1)	511	271	53.1	0.7	1.4	$ 1,429	$ 2,144	$ 288	$ 1,225	$ 1,042	$ 6,129	$ 11.99	15.9
Class 8 (35)	10,435	6,267	54.9	17.0	1.5	$ 8,575	$ 12,863	$ 6,643	$ 7,202	$ 9,381	$ 44,663	$ 4.28	9.5

[21] G = gas-powered; D = diesel-powered; PHEV = plug-in hybrid-electric vehicle

Transit

Table 7: Baseline Results for Brampton Transit (non-revenue units). Values are for the entire fleet for the one-year review period (2019).

Fleet Breakdown by Fuel Type[22]	Fleet Breakdown by Ownership	Original Purchase Price	Estimated Replace Cost	Estimated Market/Trade-In Value	Total Cost (R&M, Fuel, Capital & Downtime)	Total KM-Travelled	Total Fuel Used (litres)	Total GHG Emissions (tonnes CO2e, combustion – fossil diesel)	Total GHG Emissions (tonnes CO2e, combustion – [23]B10 annualized)
51 G units, 10 D units	18 owned units, 43 rentals	$620,367	$1,242,000	$62,037	$314,962	1,276,710	171,241	425	413

Table 8: Baseline KPIs for Brampton Transit (non-revenue units) by Vehicle Class. Values are averages per unit for the one-year review period (2019). B10 for diesel-powered units has been modelled.

Category & No. of Units	KMs Travelled	Fuel Used (litres)	Fuel Economy (L/100 km)	GHG Emissions (tonnes CO2e, combustion)	GHG Intensity (kg CO2e/km, combustion)	Preventive Maintenance (PM) Costs	Repair Costs	Fuel Costs	Cost of Capital	Downtime Costs	Total Cost (R&M, Fuel, Capital & Downtime)	Cost per KM	Unit Age for Owned Units (years)
Total Fleet	**20,930**	**2,807**	**13.6**	**6.8**	**0.3**	**$ 682**	**$ 1,023**	**$ 3,120**	**$ 87**	**$ 249**	**$ 5,163**	**$ 0.25**	**5.2**
Class 1 (42)	21,388	1,834	8.6	4.4	0.2	$ 16	$ 23	$ 2,072	$ 4	$ 6	$ 2,121	$ 0.10	8.0
Class 2 (13)	20,790	4,869	22.4	11.7	0.5	$ 2,174	$ 3,261	$ 5,427	$ 166	$ 793	$ 11,823	$ 0.57	5.0
Class 3 (6)	18,020	5,149	29.6	12.6	0.7	$ 2,116	$ 3,173	$ 5,458	$ 504	$ 771	$ 12,023	$ 0.67	4.5

[22] G = gas-powered; D = diesel-powered
[23] B10 annualized = estimated 10% biodiesel, 90% fossil diesel used year-round given that Transit currently uses B4-5 during winter and B20 in summer all diesel-powered units.

Municipal Peer Fleet Comparison

Table 9: Baseline KPIs for Brampton fleets compared to benchmark values (peer fleet averages) based on a review of over 12,000 units of all classes from 62 fleets across British Columbia, Alberta, and Ontario. Some classes have been combined to reflect RSI-FC's E3 Fleet Review categorization.

KPI	Category	Fleet Services	Fire & EMS	Transit	Benchmark (Peer Fleet Average)
KM Travelled	Class 1	10,416	5,966	21,388	15,030
	Class 2	8,897	8,964	20,790	14,277
	Classes 3, 4	9,319	8,848	18,020	13,220
	Classes 5-7	8,649	1,007		13,022
	Class 8	6,673	10,435		13,254
Fuel Consumption (L/100 km)	Class 1	17.5	11.4	8.6	19.8
	Class 2	22.1	15.5	22.4	21.7
	Classes 3, 4	26.2	23.3	29.6	32.2
	Classes 5-7	33.0	45.5		51.7
	Class 8	80.3	54.9		67.5
GHG Intensity (kg CO2e/km, combustion)	Class 1	0.40	0.30	0.20	0.46
	Class 2	0.60	0.40	0.50	0.49
	Classes 3, 4	0.71	0.60	0.70	0.80
	Classes 5-7	0.90	1.20		1.37
	Class 8	2.20	1.50		1.97
Repair and PM Costs	Class 1	$ 2,285	$ 760	$ 39	$ 2,999
	Class 2	$ 2,938	$ 3,160	$ 5,435	$ 3,501
	Classes 3, 4	$ 5,249	$ 6,987	$ 5,289	$ 7,417
	Classes 5-7	$ 7,793	$ 3,640		$ 15,318
	Class 8	$ 18,326	$ 21,438		$ 16,002
Cost per KM	Class 1	$ 0.50	$ 0.31	$ 0.10	$ 0.45
	Class 2	$ 0.65	$ 0.63	$ 0.57	$ 0.52
	Classes 3, 4	$ 0.97	$ 1.20	$ 0.67	$ 1.03
	Classes 5-7	$ 1.50	$ 7.74		$ 2.05
	Class 8	$ 5.34	$ 4.28		$ 3.21
Unit Age (years)	Class 1	4.5	6.3	*8.0	5.1
	Class 2	6.4	4.4	5.0	5.6
	Classes 3, 4	7.4	8.3	4.5	6.3

KPI	Category	Fleet Services	Fire & EMS	Transit	Benchmark (Peer Fleet Average)
	Classes 5-7	6.9	16.3		6.9
	Class 8	7.8	9.5		6.3
Area Ratio (no. of units/km^2)	All Classes	2.3[24] (all 3 fleets combined)			**0.56
Population Ratio (population/no. of units)	All Classes	949[25] (all 3 fleets combined)			**1,998

* Owned units only.
** Average of 12 municipal fleets ranging in size from 19-1,307 units, serving populations ranging from 55,000-645,000 over land areas ranging from 50-4,800 km^2.

Synopsis

From the baseline data and benchmarking exercise, we have outlined key points for Brampton's fleets below:

Fleet Services

- Class 3, 5, and 8 units are comparatively older than other classes (as well as municipal peers except for Class 5) and account for a significant proportion of the total fleet; therefore, these classes are potential areas of focus in terms of extending lifecycles where possible and switching to battery-electric in the short- to mid-term as battery-electric vehicle (BEV) and battery-electric truck (BET) replacement models become available.

- Class 8 units have a significantly lower fuel economy, higher emissions intensity, and higher costs per kilometre than Class 8 units from municipal peers, highlighting a potential area of focus for interim solutions such as light-weighting and low-rolling resistance (LRR) tires for appropriate units while awaiting the arrival of BET replacement models.

Fire & EMS

- Class 1 and 2 units comprise the largest portion of the fleet. Class 1 units, which are on average almost two years older than Class 2 units, and all of which are hatchbacks and sedans, are prime candidates for switching to battery-electric when due for replacement in the short-term phase of our proposed low-carbon fleet plan (see *Section 8.0*), as these vehicle types are currently available as BEVs.

- Overall, Brampton's Fire & EMS fleet is performing well in comparison to municipal peers with the exception of age; units of classes 3 and up are substantially older than average peer

24 Land area of Brampton is taken from https://www.peelregion.ca/planning/pdc/data/quickfacts.htm.
25 Population of Brampton is taken from https://www.peelregion.ca/planning/pdc/data/quickfacts.htm.

ages, highlighting modernization (i.e. investing in new medium- and heady-duty vehicles) as a potential area of focus.

Transit

- Class 1 units comprise the largest portion of the fleet, and most of these units are sedan rentals. A potential area of focus in the go-forward analysis phase of the Sustainable Fleet Strategy (Part Two: Framework and Action Plan Report) is to determine the cost-effectiveness of replacing these gas-powered rental units by purchasing battery-electric units, as these vehicle types are currently available as BEVs. Given the reduced operating expenses of BEVs and the higher capital costs of rental units, purchasing BEVs may be more cost-effective.

Peer Fleet Comparison

- When compared to benchmark values, the area and population ratios suggest that Brampton's overall fleet (all three fleets combined) is relatively large for its area and population. This result is supported by the relatively low utilization (i.e., km travelled) in much of Brampton's fleet, particularly in Fleet Services. Our recommendation is that the City consider downsizing its fleet by examining underutilized units and stranded assets.

This preliminary analysis sets the foundation for the main purpose of the Sustainable Fleet Strategy – specifically, to inform and model several fuel-reduction solutions for the City of Brampton's in-scope vehicles and to provide an ambitious, yet feasible, long-term capital plan to achieve deep GHG emissions reductions and a structured, methodical pathway to electrification.

...

Section 4.0: Review of Current Fleet Processes & Practices

In this section, we will lay the groundwork for the Sustainable Fleet Strategy by providing a snapshot of the current state of Brampton's fleet and fleet management practices through the results of our signature process, "Best Management Practices Review™" (BMPR).

Best Management Practices Review™ (BMPR) is an RSI-FC process that provides our green fleet project team with an inside look at a fleet's operations. This is a critical first step in the fleet review process and in the development of a green fleet plan. It is a structured, systematic, and efficient review of a fleet's business practices, procedures, and policies based on our experience working with nearly 200 municipal and commercial clients of all sizes – ranging from tens to thousands of units.

The BMPR process enabled our team to become familiar with Brampton's fleet processes and practices, funding mechanisms, and more. This knowledge intended to ensure our recommendations align with Brampton's standard operating practices (SOPs). The review highlights any gaps and opportunities to improve the City's fleet policies, programs, and procedures. Importantly, the BMPR step informs and guides our team's work and our recommendations for Brampton's Sustainable Fleet Strategy Part Two: Framework and Action Plan Report, helping to develop a roadmap to green fleet planning that is realistic, practical, and viable for the City.

The BMPR is based on our in-depth discussions with Brampton's fleet management staff. Meetings were held with managers from Fleet Services (Corporate Fleet), Fire & Emergency Services, and Brampton Transit (regarding non-revenue Transit units).

The comprehensive BMPR process is comprised of the following specific areas of interest, each with its own set of focal points/topics:

1. Asset Management
2. Vehicle Specifications
3. Finance
4. Information Technology
5. Human Resources
6. Repairs & Preventative Maintenance
7. Fuel Management
8. Environmental Sustainability
9. Communications & Engagement

In the following sub-sections, for each area of interest we provide Brampton fleet staff comments from our BMPR discussions and, through the lens of green fleet planning, identify any gaps and opportunities for improvement for management's consideration. The fleets for which discussion points and gaps/opportunities apply to are indicated by an *italicized* subtitle.

1. Asset Management

Asset management has been described as "a systematic process of deploying, operating, maintaining, upgrading, and disposing of assets cost-effectively." Doing so effectively depends on having ready access to operating data, and then making wise asset-management decisions based on, and informed by, that data. In this area of the BMPR, we reviewed Brampton's cradle-to-grave handling of its fleet assets. From our in-depth discussions with Brampton's fleet management staff we learned the following:

Lifecycle Determination and Vehicle Replacement Planning

Fleet Services

- The AssetWorks M5 fleet management and tracking system lists vehicle categories and their estimated lifecycles, which includes the Corporate, Fire & EMS, and non-revenue Transit fleets; estimated lifecycles range from 8 years (cars) to 15 years (trailers).
- There are five factors in the "Fleet Replacement Plan" for determining vehicle replacement:
    - Condition assessment (flagged at specified vehicle age based on category, as stated in above point);
    - Replacement plan based on the approved budget;
    - Mileage (vehicles flagged at 100,000 km);
    - Known mechanical condition issues; and
    - Parts availability/compatibility (e.g., changes in fit for new electronic pieces).
- Based on the aforementioned "Fleet Replacement Plan" approach, Brampton management staff felt that between $4-7 million should be budgeted each year for vehicle replacements; however, the approved annual budgets have been below this range.

Transit

- In 2017, management of non-revenue transit vehicles were transferred to Transit; they were previously under Fleet's portfolio.
- The lifecycle and fleet replacement strategy was adapted from that practiced by Fleet.
- Many of the rental units are driven 3,000 – 4,000 km per month.

- Trends for repair costs and reliability are analyzed by staff to reassess suitable lifecycles for particular units.

Fire & EMS

- An asset management plan is presented to Council each year.

- Larger vehicles require approval from Council before purchase decisions are made. Quotes are obtained from different manufacturers.

- Lifecycles are determined by user groups; chief vehicles are typically 4 years and light-duty vehicles are typically 8 years, depending on usage.

- Front-line vehicles (fire pumpers, aerial units, etc.) typically have lifecycles of 12 years and are used for another 8 years as relief/backup spares or as support vehicles. These figures can vary depending on the capital available and the specific units coming due for replacement.

- The maximum lifecycle is 20 years – the use of units is maximized due to high acquisition costs ($1M plus).

- Immediate replacement occurs due to failure of an annual inspection.

Gaps and Opportunities for Improvement

All Fleets

- Monitoring maintenance cost spikes may result in an older, under-utilized vehicle being shown as costing less, when in reality it can be a stranded asset if it continues to be under-utilized until retirement/replacement.

- By following 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 (LCA) software).

- Green fleet asset management best practices recommended by RSI-FC are illustrated in a process flow chart (*Figure 1*, overleaf). This chart outlines a step-by-step guide for determining the optimal time to replace a fleet vehicle, as well as the most effective unit replacement type. Following these processes will result in a fleet becoming green, right-sized, and cost-efficient.

Process for User Department to Add a Vehicle to Its Fleet

Fleet Services

- The new capital program requires user group submission of a new vehicle request form to make the business case for an additional vehicle need. In 2020, there was about $600,000 of new (additional) vehicle requests.
- The fleet manager must approve the request by ensuring there is a need for an additional vehicle. If approved by the fleet manager, the request form must be approved by Council.

Transit

- A new vehicle request goes to Fleet Maintenance for addition to the annual capital budget.
- There is an internal budget meeting for Transit where the business case is presented.
- If the request passes internal approvals, it then goes to Council where it must then be approved.

Fire & EMS

- Additional units are usually based on requirements of additional staff due to City growth.
- City growth is accounted and budgeted for, with the addition of $50,000 to a development fund each year.
- Additional units must be approved by Council.

Gaps and Opportunities for Improvement

All Fleets

- Ensure that cost comparisons have been made to any alternatives to a City-owned vehicle (or equipment). For units with limited time of use, a cost-benefit analysis looking at total cost of ownership (TCO) may reveal that it is much less expensive to engage a contractor to do the work than it is to own an additional vehicle.

Real-Time Tracking of Vehicle Assets

All Fleets

- M5 was recently expanded; it now includes work codes (e.g., PM-A/PM-B oil change and FGI (fleet government inspection)) and condition reports. Condition reports also get uploaded to SharePoint for all M5 users to have access to the condition of vehicles.

- M5 contains data on acquisition cost at time of purchase, current book value, hours of usage, km-driven, user department, and owner department.

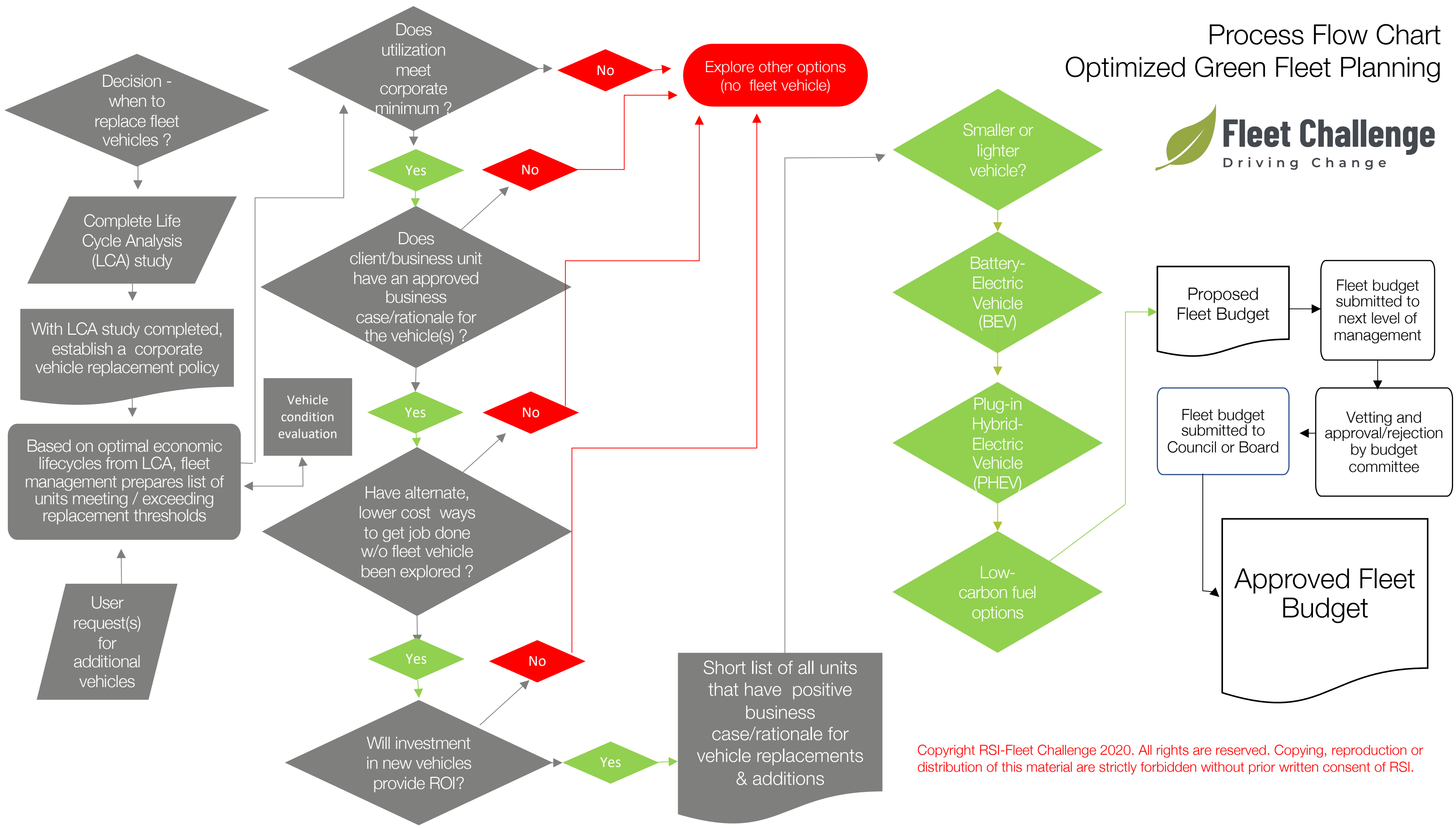
- Data is uploaded electronically (wi-fi) to M5 from the Coencorp fuel tracking system every time a vehicle passes a fuel site. For rental units, mileage is manually keyed in. For Fire & EMS units, fuel usage and mileage is manually entered into M5. For Fleet Services, a pilot project for transfer everything over to M5 for fuel is scheduled for 2022.

- Mileage is tracked for rental vehicles because, unless there is a damage or an abuse situation, routine maintenance is covered by the rental agency.

- A weekly report is run on M5 to detect any data that is not recording correctly.

- Coencorp is used for vehicle data units (VDUs) and Focus by Telus is used for GPS; both systems are managed by the IT department. GPS is in all units including those from contractors.

Figure 1: Process Flow Chart for Optimized Green Fleet Planning



2. Vehicle Specifications

Fleet management and/or administration should always prepare detailed specifications for new vehicles with consideration for past performance of similar vehicles (i.e., the past predicts the future). When planning the go-forward procurement of vehicles and vehicle components (such as engines and drivetrains), fleet managers should give preference to units that have demonstrated the lowest historical total cost of ownership (TCO) and highest reliability.

Management should avoid the pitfall of buying vehicles that simply cost the least to acquire and meet only basic requirements. Historical cost information about makes, models, and components should be frequently reviewed. This step enables informed procurement decisions based on TCO concepts, instead of purchasing vehicles based on lowest price.

Tender Process and Practices for New Units

Fleet Services

- Specifications are written internally for vehicles and equipment to release to bidders, and the lowest-compliant bid is selected. The bid selection is not based on user group or manager preferences, fuel economy, fuel consumption data, after-purchase costs, or wait time for parts.

- It is not possible to standardize due to the lowest-compliant bid process; however, tenders are often strategically issued to buy larger quantities of vehicles.

Transit

- Specifications are written internally. The bid selection is not based on fuel economy, fuel consumption data, or total cost of ownership (TCO).

- There is some upfitting done on light-duty units, including a lighting package, radio package, electronics, and an automatic vehicle location (AVL) system.

- Cost and intrusiveness prevent these upgrades for shuttle units, although it would beneficial for them to also have an AVL system and access to M5; this would enable a tablet for use by operators.

- Standardization and having one particular procurement model is generally not the approach employed, as the purchasing department's focus is on specifications and lowest-compliant acquisition cost rather than specific (and potentially better-performing) models.

- Pickups are highly specified with push bumpers. They are used for service calls, snow plowing, sanding, and salting of bus terminals, maintaining shelters using tanks and pressure washers, and making on-road repairs of shelter assets.

Fire & EMS

- Specifications are written internally for light-duty vehicles and a user committee (including firefighters, etc.) provides input for front-line apparatus (pumpers, aerial units, etc.) specification development.
- Typically, the tender process takes about one year plus acquisition cycles; however, it can take as much as two years to have apparatus built.

Gaps and Opportunities for Improvement

Fleet Services and Transit

- Employing a total cost of ownership (TCO) approach would demonstrate where Fleet Services and Transit can optimize the use of capital. Procurement should consider TCO in its competitive bidding proposal structures instead of the lowest-compliant bid approach.
- When going to tender, consider fuel consumption and GHG emissions data for vehicles under consideration as important parts of the TCO approach.
- Consider vehicle downsizing when going to tender for a specific unit; specifications should be aligned with the vocational and load requirements. This would require user group buy-in when outlining what is needed to perform job duties.
- Standardization, by limiting the number of brands, is known to reduce costs and challenges relating to preventive maintenance (PM) and repairs. Therefore, discussions between procurement and fleet managers regarding standardization should be considered.

3. Finance

A significant concern for all fleet managers is fiscal sustainability – ensuring that the fleet operating budget is sufficient to cover annual operational expenses (Opex), and the annual capital (Capex) budget is adequate for actual vehicle replacement costs. Among the primary goals for fleet managers everywhere is reducing vehicle capital and operating expenses without negatively affecting service levels (uptime). In this area of the BMPR, we aim to learn about vehicle Opex and Capex as well as how vehicle costs are recovered.

Vehicle Ownership

Fleet Services

- The majority of units are owned and there are 35 seasonal rental units. Fleet has an internal rental motor pool (owned) which is usually used in the summer and is parked in the winter.
- Rental units have increased due to Covid-19 and will be reduced post-pandemic.

Transit

- There are many rental vehicles for operators shuttles; it was determined that rentals were the most cost-effective approach. Supervisor vehicles, however, are owned.
- The rentals began in 2019 with rotating daily rentals. No statistics were kept reliably due to high turnover. The current rental pool came in 2020, and the vehicles turned over less quickly, allowing for fuel consumption statistics and mileage to be tracked.
- The number of rental units increased due to Covid-19; although the number may be reduced post-pandemic, the plan is to keep most rental units.

Fire & EMS

- All units are owned; ambulances are controlled by Peel Region.

Capital Budget, Reserve Fund, and Auction Proceeds

Fleet Services

- There is no Fleet reserve fund in place, but there is contingency funding for price shifts – e.g., increases in vehicle replacement costs are applied to new capital. Fleet is aware of the capital available for the upcoming year, and any unspent portions of annual capital budgets do not typically get rolled over into the next year's budget.
- Auction proceeds go back to the City (not to Fleet specifically), and specialty items are traded in whenever possible.
- There is a 5-10-year capital budget estimate in place; however, Capex must be submitted each year.

Transit

- Like Fleet Services, auction proceeds go into a corporate general recovery account/fund for the City.
- Capital budgets are prepared for a cycle of 3-5 years; however, Capex must be submitted each year.
- The purpose of the reserve fund is more for maintenance, buildings, and equipment than for purchasing of vehicles. For vehicle replacements, funds come out of the general fund (potentially competing with other needs of the community).

Fire & EMS

- There are two budgets – one for vehicle capital and one for City growth (development funds).
- A Fire Master Plan is prepared based on population growth and replacement budgets are planned for the long term. Also, response time and types of calls (e.g., medical, fire, etc.) are tracked to determine if different types of and/or additional vehicles are needed.
- Retired units are stripped of emergency gear and equipment and sent to auction. There is interest in donating trucks to Indigenous communities in Northern Ontario.
- There is no fleet reserve fund in place, and Fire & EMS must compete for priority as far as capital allocations for new vehicles.

Gaps and Opportunities for Improvement

All Fleets

- Consider allocating auction proceeds into a reserve fund for each Brampton fleet 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.

Vehicle Chargeback System

Fleet Services

- There is no chargeback system in place with the exception of the Building Division's Inspections group that pays back fuel costs. Users have vehicles assigned to them and Fleet is responsible for all costs, including fuel, at-fault accidents/ negligent damages, and insurance. With this system in place, there is little/no incentive for user groups to reduce fuel use and reduce maintenance and repair requirements.

Transit

- There is no chargeback system in place; vehicles are not charged to work orders, and Transit is responsible for all costs.

Fire & EMS

- There is no chargeback system in place. All work orders are captured, including contracted out work.

Gaps and Opportunities for Improvement

Fleet Services 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.

4. Information Technology

Fleet asset-management decision-making and analysis are best achieved by using dedicated and purpose-designed "best-of-breed" fleet management information systems (FMIS). For maximum management effectiveness and control, accurate and reliable fleet data is essential for managers to make well-informed, data-driven decisions for their fleet asset base.

Regardless of the system used, an FMIS must list and track all vehicles, department/divisional assignments, cost and maintenance histories, manage fuel usage and reconciliation, schedule preventive maintenance events, track spare parts inventories, ensure audit-readiness, produce management and exception reports, prepare cost analyses, evaluate vehicle performance, provide document trail, and much more.

Fleet Management Information System

All Fleets

- AssetWorks M5 Fleet Focus is the dedicated FMIS used by the City of Brampton.
- Maintenance scheduling, vehicle histories, profiles, etc. are stored in M5.
- All work orders and parts are tracked in M5. User groups can check the repair status of their units in real time.
- The transition to electronic logging devices (ELDs) is currently being investigated by IT (Fleet Services).

Gaps and Opportunities for Improvement

All Fleets

- Transitions to ELDs, as is being explored by IT, may increase the efficiency of record-keeping on vehicle history and daily inspections (for Fire & EMS).
- Canadian fleets must start transitioning to electronic logging devices (ELDs). The Transport Canada ELD mandate for commercial drivers is aimed at improving road safety and comes into effect in June 2021.

  Under the Ontario regulation[26], a driver is not required to keep a daily log for the day if:

  - On the operator's instructions, a commercial motor vehicle is driven solely within a radius of 160 kilometres of the driver's starting location.
  - The driver returns at the end of the day to the location from which they started.

  Log book exemption can create confusion when dealing with municipalities within 160 kilometres of the drivers starting location. Many believe this exempts municipalities from tracking hours of service. However, if a driver is not required to keep a daily log, RSI-FC believes the operator (the City of Brampton) may be obligated to maintain records for the day.

- RSI-FC recommends expert legal review of the ELD matter prior to the June 2021 deadline.

[26] Source: http://www.mto.gov.on.ca/english/trucks/commercial-vehicle-operators-registration.shtml

Work Order Process

All Fleets

- The vehicle and equipment maintenance and repairs process is generally as follows :
  - The Foreperson checks M5 for maintenance, creates work orders, and assigns work orders to mechanics/technicians. For vehicles or equipment requiring repairs, the Foreperson also checks for outstanding preventative maintenance (PM) work.
  - Fleet mechanics/technicians add job notes (locations, pictures, specs, billed invoice, and any recommendations) into M5.
  - The Fleet Manager/Supervisor inspects vehicles/equipment and signs off on completion of the work.
  - For vehicle or equipment repair and maintenance work needed to be completed by a vendor (Fire & EMS contract out all work), the foreperson first approves the estimate from the vendor before sending the unit.

5. Human Resources

Human resources pertains not only to a fleet's personnel but also to the drivers of vehicles. In this section of the BMPR, we focus on staff and driver training as well employee engagement in organizations and committees.

Driver Training

Fleet Services

- A new driver has a pre-hire screening, an in-class orientation, and an on-the-road orientation.
- After the City driver permits are issued, the new driver must take an internal defensive driving training course including classroom and on-the-road components. This training may include the transport of dangerous goods, ladder handling, and WHMIS, where applicable.
- A Train the Trainer program is offered to senior operators and for specific equipment types.
- After an accident, refresher training is required.
- Snow plow training is provided internally.

Transit

- All staff are provided driver training. Training is provided by an internal training group comprised of four full-time staff with part-time staff assistance.
- Refresher training is provided regularly for transit operators and as required for maintenance staff.

Fire & EMS

- There is a Training Division with driving instructors who provide driver training as part of recruitment.
- Refresher training is provided, the frequency of which is decided by the Training Division.

Gaps and Opportunities for Improvement

- Consider scheduling professional driver improvement course (PDIC) driver refresher training at regular intervals for a more risk-averse approach to driver management.
- For the Transit and Fire & EMS sections, consider including driver eco-training (see next sub-section) in present-day driver safety training.

Eco-Driver Training

Fleet Services

- In Fleet's driver training program, there is an entire module on eco-driving as well as anti-idling.

Transit

- There is no eco-driver training or anti-idling training provided.

Fire & EMS

- There is no eco-driver training provided.

Gaps and Opportunities for Improvement

Transit

- Eco-driver training is recommended for all drivers, existing and new.
- Natural Resources Canada (NRCan) Smart Driver program is highly recommended by RSI-FC. See: https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-transportation/greening-freight-programs/smartdriver-training-series/21048#city

Fire & EMS

- 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 scene.

Organization Memberships

Fleet Services

- Fleet is a member of the following organizations:
  - North American Fleet Association (NAFA)
  - American Public Works Association (APWA)
  - Canadian Association of Municipal Fleet Managers (CAMFM)
  - Municipal Equipment and Operations Association of Ontario (MEOA)
  - Transportation Maintenance and Technology Association (TMTA)
  - Sustainable Fleets Working Group (SFWG), Clean Air Partnership
- In addition to the above organizations, Fleet also subscribes to publications and electronic magazines including Today's Trucking and Truck and Trailer.

Fleet Advisory Committee

Fleet Services

- There is a Fleet Advisory Committee in the Parks Division. The group meets monthly to review all fleet-related issues, including equipment problems, changes to work scopes, and acquisitions.

- The Fleet Manager oversees the entire process of repairs and acquisitions, and considers feedback from all stakeholders, including manufacturers.

- Public Works did have a Fleet Advisory Committee, but it is no longer in place. There is interest in restarting the committee given the success of the team in Parks.

Transit

- There is an internal discussion with user groups on the creation of a Fleet Advisory Committee.

Gaps and Opportunities for Improvement

All Fleets

- Consider creating a Fleet Advisory Committee specifically for battery-electric vehicles (BEVs), which can serve as a bridge to educate any skeptical employees on the benefits of BEVs as well as aid in the procurement of BEVs as more models become available.

6. Repairs & Preventative Maintenance

A prime indicator of fleet management success is a high level of vehicle uptime. There are only two ways fleet managers can achieve increased uptime: (1) acquire newer, younger vehicles; or (2) ensure a highly effective preventive maintenance (PM) program is in place. If sufficient funds are not available for purchasing newer vehicles, then fleet management must ramp up PM activities; otherwise, availability and reliability will suffer while operating costs increase. Safety may also be negatively affected as the fleet's vehicles continue to age.

Repairs & PM Process and Scheduling

Fleet Services

- There are three PM levels:

  - PM A – minor, performed on light-duty units every 6,000 km
  - PM B – major, performed on light-, medium-, and heavy-duty units every 10,000 km (oil change, front end work, tire work)
  - Periodic mandatory commercial vehicle inspection (PMCVI) – performed annually on given date each year

- Vehicles can be down for more than one week depending on parts availability or the manufacturer's location of the piece of equipment.

- PM worksheets are stored in M5.

Transit

- Repairs and maintenance are primarily contracted out to a local contractor for greater efficiency, as there are a limited number of owned vehicles.
- Scheduling of minor and major inspections (e.g., oil change, etc.) is based on km-driven; government inspections (e.g., PMCVI) are tracked by time interval.

Fire & EMS

- Firefighters perform daily truck checks; these are noted in SharePoint but not recorded in M5. If there is a serious issue identified, the truck will be taken out of service.
- Repairs require entry into SharePoint, including type of truck and repair required, and are recorded in M5.
- All work orders are captured, including contracted out work. Work orders are completed internally as much as possible to ensure contracted out work is minimized.
- Prior to the Covid-19 pandemic, a road crew would go out to fix easier issues as staff prefer not to do a switchover because of all the equipment that needs to be moved.
- Frequency of PM work is based on manufacturers' recommendations in terms of time (e.g., every three months) and/or the discretion of the team (e.g., firefighters, etc.).
- PM for low-mileage and under-utilized units done as needed; the aim is to complete these inspections every 5,000 km, but in reality may go much longer due to low usage.
- PMCVI inspections are performed annually on the same date (for due diligence), and aerial ladder and pump inspections are performed annually or as needed.

7. Fuel Management

The cost of fuel is usually one of the largest controllable costs for most fleets. Proactive fleet managers will make it one of their top priorities to ensure their fleet is as fuel-efficient as possible. Reducing fuel use is critical, both fiscally and environmentally.

A best management practice aimed at reducing fuel usage is to monitor the fleet's corporate average fuel efficiency (CAFE). We feel that CAFE is one of the most important key performance indicators

(KPIs) for cost- and GHG emissions-conscious fleet managers to monitor and take actions for improvement.

CAFE is directly reflective of a fleet's footprint. It is a measure that encompasses many facets of fleet operations ranging from driver behaviours (such as unnecessary idling, harsh driving, and unnecessary trips) to right-sizing of vehicles for their assigned tasks (getting the job done with more fuel-efficient vehicles) to the use of alternate and renewable low-carbon fuels. CAFE is also impacted by a fleet's average age, since older vehicles are less fuel-efficient than modern units and, consequently, cost more to operate and produce more emissions.

In this area of the BMPR, we focus on fuel purchasing and tracking practices as well as the use of alternate/renewable fuels.

Fuel Purchasing and Tracking

Fleet Services

- Transit is the biggest purchaser of fuel and, generally, Fleet Services is in consortium with Transit.
- All gasoline and propane is purchased at retail stations.
- There are five diesel fuelling sites for Fleet Services.
- Every fuel transaction is tracked and documented.

Transit

- Fuel for both revenue and non-revenue vehicles is all tracked and part of the budget.
- Maximum fuel amounts are set up by vehicle types. Fuel efficiencies are tracked and exception units can be identified using M5; however, tracking is more for loss prevention and flagging of problems rather than for fuel economy.
- There is an electronic leakage detection system in place – the system flags deliveries and reconciles amounts of usage versus dispensed (will flag if there is a large gap between the two).
- Veedor-Root fuel pump/tank system is interfaced with M5 via the Coencorp fuel-tracking RFID system.

- Fuelling staff work overnight. There is onsite fuelling at the Sandalwood garage. Around 20 units from the Clark transit garage are fuelled offsite using a fuel card.

- Owned vehicles have a radio frequency identification (RFID) tag which reads the vehicle's mileage; maintenance staff must manually enter mileage readings for rental units.

- For rental units, Excel spreadsheets are used to track fuel usage.

Fire & EMS

- All fuel is purchased at retail stations. Retail fuel is used to ensure vehicles remain in respond areas and are not required to be taken out of service.

- A monthly statement is received from Petro/Esso with a breakdown of fuel usage. Charges for fuel usage to each unit. A report is also completed by prevention officers, which contains fuel usage in addition to important vehicle information.

- Fuel usage is manually input into M5 from credit card statements.

Gaps and Opportunities for Improvement

Fleet Services and Transit

- Consider including CAFE as a KPI, or as part of benchmark 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 (TCO)).

Alternate/Renewable Fuels

Fleet Services

- Off-road equipment and ice resurfacers are fuelled by propane and natural gas.

- B5 biodiesel is used year round for all diesel units. Higher blends were used in the past; however, Fleet experienced higher downtime and maintenance costs and has no interest in switching back to higher blends.

- Up until the early 2000s, Fleet had many 19,500 GVWR propane landscape dump trucks and pickups; however, Fleet had many complaints regarding high downtime and chose to discontinue the use of propane units.

Transit

- 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).
- Standard, regular unleaded gasoline is used (not using ethanol at a greater mix).

Gaps and Opportunities for Improvement

- As an interim GHG emissions-reduction solution, consider the use of E85 ethanol as a replacement to pure gasoline for all factory flex-fuel units. This potential interim or "messy-middle" solution will be modelled in our go-forward analysis in Part Two: Framework and Action Plan Report.

8. Environmental Sustainability

In Canada and around the world, leading companies and all levels of government have developed Green Fleet Plans to set out their short- and long-term carbon reduction targets; some may also include strategies for air/land/water pollution reduction.

A Green Fleet Plan may also include the fleet's green initiatives for its maintenance facilities and/or parking garages. For fleets that outsource maintenance, plans may also define eco-standards for contractors, such as third-party suppliers.

Corporate GHG Reduction Targets

- The City of Brampton has established a corporate GHG emissions reduction target of 50% by 2040 compared to 2016 levels.

LEED Certification of Fleet Facilities

Fleet Services

- Fleet facilities are LEED certified (silver).

Fire & EMS

- Several of the City's new fire stations are LEED certified. The corporate building and new buildings are LEED certified. Older stations do not have LED lighting.

Waste Management

Fleet Services

- The three Rs (reduce, reuse, recycle) are in place.
- Oil, oil filter, oil rag, and coolant recycling are in place.
- There is an automatic car wash (touchless drive through) on an outdoor heated concrete pad with an interceptor. However, this this system is not good at removing brine.
- There is containment for fuel and there are brine tanks.

Transit

- The three Rs are in place, there is oil and oil filter recycling, and there are interceptors/ oil separators.

Fire & EMS

- The three Rs are in place, there is oil and oil filter recycling, and there are interceptors/ oil separators.

Gaps and Opportunities for Improvement

Fleet Services

- Consider the use of wands and an inside wash bay (with interceptors) to more effectively remove brine.

Idling Reduction Policy and Systems

Fleet Services

- There is an anti-idling policy and training course in place for drivers.
- All diesel units have block heaters and some have auxiliary heaters on timers.
- Some units have anti-idle programs enabled.

Transit

- There is no anti-idling policy within Transit, resulting in idling of non-revenue units.

- There are future plans to upgrade the automatic vehicle location (AVL) system, which would enable management to identify excessive idling.

Fire & EMS

- Auto idling mitigation systems were ordered on new apparatus; the chassis diesel engine shuts down and switches to battery power only if specific conditions are met, including:
    - System is enabled
    - Idle time has expires (programmable)
    - Cab/hood is closed and/or down
    - Transmission in neutral
    - Parking brake applied
    - Pumper not active

- Rosenbauer offers a new electric pumper truck with a lithium-ion battery, which the City purchased and will put in service. The truck will meet National Fire Protection Association (NFPA) requirements prior to going into service.

Gaps and Opportunities for Improvement

Transit

- An anti-idling policy and training course for non-revenue unit operators is strongly recommended by RSI-FC.

- Consider an incentive program that recognizes drivers who idle the least and/or whose units have the best fuel economy.

Hybrid-Electric Vehicles

Fleet Services

- Fleet currently has a few Malibu and Camry hybrids, as well as eight XL Hybrid systems installed.

Transit

- There was a hybrid vehicle pilot/trial on the non-revenue side; however, reliability/suitability issues led to the decision to go back to standard vehicles.

Fire & EMS

- Fire & EMS currently has two Mitsubishi plug-in hybrid SUVs, and is looking to replace eight units with the plug-in hybrid Ford Explorer SUV and/or other plug-in hybrid SUVs; specifications will be written and the tender will be open to all interested OEMs.

Gaps and Opportunities for Improvement

All Fleets

- With battery-electric vehicle (BEV) options increasing and light-duty trucks (pickups) expected to be on the horizon within two years, as well as medium- and heavy-duty trucks in several years, our recommendation is that the City of Brampton allocate most of its capital towards BEVs (for appropriate units) as opposed to hybrid-electric vehicles. This approach makes technological sense as charging infrastructure expands and as vehicles with internal combustion engines become outdated in coming years. Importantly, it will also empower the City to reach its deep GHG-reduction goals; achieving deep decarbonization will not be possible unless there is a shift towards purchasing fully-electric vehicles.

Battery-Electric Vehicles

Fleet Services

- Fleet currently has one battery-electric vehicle (BEV), a Ford Focus (2016), with 120 km of range in summer and only 80 km in winter.

- There is slight hesitancy from user groups due to range anxiety and higher upfront costs of electric vehicles.

Fire & EMS

- 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 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.[27]

[27] Source: https://electricautonomy.ca/2021/06/21/brampton-electric-firetruck/

Transit

- The pilot project for revenue vehicles (transit buses, not in-scope) was part of the CUTRIC electric bus project; stage two of this project is likely not to include the non-revenue vehicles because these units comprise such a small portion of emissions compared to the revenue side.

Gaps and Opportunities for Improvement

All Fleets

- Operator feedback and employee engagement is important. Consider inviting frontline employees to take BEV test drives to build an affinity towards fully-electric vehicles.

- Consider creating a BEV educational piece for employees and operators summarizing the reasons to transition to BEVs, in terms of benefits to the environment, finance, performance, reliability, and improving charging infrastructure.

- With BEV options increasing and light-duty trucks (pickups) expected to be on the horizon within two years, as well as medium- and heavy-duty trucks in several years, our recommendation is that the City of Brampton allocate most of its capital towards BEVs (for appropriate units). Importantly, it will also enable the City to reach its deep GHG-reduction goals; achieving deep decarbonization will not be possible unless there is a shift towards purchasing fully-electric vehicles.

BEV Charging Infrastructure

Fleet Services

- Although public stations are available, there are no EV charging stations dedicated solely for Fleet.

- The installation of 100 Level 2 charging stations, with the potential opportunity for NRCan funding through the Zero Emission Vehicle Infrastructure Program, is currently under review with Building Design and Construction (BDC) for Williams Parkway Operations Centre (WPOC), Sandalwood Parkway (SW), and Flower City Community Campus (FCCC). The largest uncertainty is the extent of potentially significant upgrading to the electrical capability required in a couple of locations.

Fire & EMS

- 20 Level 2 charging stations are currently being installed at the Fire Campus, which has been partially funded by NRCan's Zero Emission Vehicle Infrastructure Program.

Gaps and Opportunities for Improvement

All Fleets

- With BEV options increasing and light-duty trucks (pickups) expected to be on the horizon within two years, as well as medium- and heavy-duty trucks in several years, our recommendation is that the City of Brampton allocate capital for charging infrastructure in the near-future to meet the demand in the mid- to long-term.

- The Zero Emission Vehicle Infrastructure Program by NRCan is accepting applications for funding until June 22, 2021. See: https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-transportation/zero-emission-vehicle-infrastructure-program/21876. The Government of Canada announced, through Budget 2019, $130 million over five years (2019-2024) to deploy a network of zero-emission vehicle charging (Level 2 and higher) stations focusing on public places, on-street, multi-unit residential buildings, workplaces, and light-duty vehicle fleets. Support is also available for strategic projects for electric vehicle and/or hydrogen infrastructure for corporate fleets, last-mile delivery fleets, and mass transit. This funding will be delivered through cost-sharing contribution agreements for eligible projects that will help meet the growing charging and refuelling demand. New charging infrastructure programs are expected and beginning to emerge – ensure to check regularly for potential future eligibility.

9. Communications & Engagement

Employee and community engagement are critical in every organization. Most employees like to feel engaged, empowered, and of value to their organization. Moreover, residents of municipalities appreciate hearing success stories from within their community. Good news stories about a fleet, whether regarding new cost-saving measures, safety, good deeds by its drivers, or eco-successes, are welcomed by most people. We believe that the Brampton Fleet should be a source of pride for the City, its employees, and its residents.

Media Releases Re: Greening Activities

Fleet Services

- An innovative all-electric equipment trailer, which is solar-powered, was recently put to use; it includes electric string trimmers and an electric zero-turn mower. This trailer was a Fleet initiative, and Parks has been challenged to fund a second trailer.

- A greenworks machine, which is the City's second all-electric utility vehicle, will be housed in the Brampton Soccer Centre Dome.

Fire & EMS

- The Fire Life Safety and Education department would likely be the group to become involved in any new internal and/or public green fleet messaging.

Green Fleet Accomplishments

Fleet Services

- 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 recieved an E3 Fleet Review and Fleet management's goal is to become E3 gold certified in the near future. 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. The Sustainable Fleet Strategy developed by RSI-FC will assist the City in achieving its goals of further greening its fleet, including transitioning to battery-electric vehicles (BEVs).

Gaps and Opportunities for Improvement

Fleet Services

- RSI-FC strongly recommends that news of Brampton's innovative all-electric equipment trailer be widely shared with the public and that the City invite the public to come in-person and see what the trailer has to offer (post Covid-19).

All Fleets

- RSI-FC recommends news of all Brampton's green fleet initiatives, other successes and achievements, and the new RSI-FC Sustainable Fleet Strategy be communicated internally to staff and widely to the public.

Section 5.0: Green Fleet Survey

Our organization recognizes the value of stakeholder engagement and user group participation in any go-forward plans under consideration by our fleet clients. With that focus in mind, RSI-FC set out to gain staff perspectives from the City of Brampton's Fleet user groups around their currently assigned vehicle types and opinions/views on environmental issues and green fleet initiatives.

In person, face-to-face discussions are, by far, our teams first choice of available options for gathering information, hearing stakeholder feedback and obtaining buy-in. Unfortunately, due to the coronavirus pandemic, in-person meetings are not currently possible. Knowing that feedback from stakeholders is critical to go-forward planning, as a workaround we opted to instead conduct web-based online surveys of fleet user groups.

RSI-FC understands the importance of hearing the opinions of *all* stakeholders including both management and staff. It was clearly communicated to all survey recipients that their responses were confidential and anonymous; as so, they were encouraged to express their opinions freely.

From experience RSI-FC knows that online surveys are not the ideal method for collecting opinions and gathering information. It is known in the industry that people are often reluctant to provide their personal opinions in this manner; typically, survey response rates are known to only be in the 10 to 15% range. However, in the absence of a better solution, such as face-to-face discussions, there were no other viable options.

A unique survey was designed for each in-scope fleet (Fleet Services, Transit (non-revenue units), and Fire & EMS) and was sent to a total of 275 individuals. Moreover, for Fleet Services and Transit, a separate survey was created for management and staff to gather specific information on job roles and responsibilities.

In total, we received a total of 59 responses (out of 275 potential participants) – 43 from Fleet Services, 12 from Transit, and 4 from Fire & EMS – which translates to an overall response rate of about 21%; this is well above the typical industry range of 10-15%. However, response rates were very different between fleets – Fleet Services had a response rate (management and staff combined) of 49%, whereas response rates for Transit and Fire & EMS were around 10%. We were pleased that, for all the surveys we released, responses were high-quality, rich in content, providing us with valuable feedback which we will discuss in this section. Key figures of survey results can be found in *Appendix A*.

Breakdown of Survey Participants

Fleet Services

Participants were from a variety of divisions, including Public Works, Parks Maintenance & Forestry, Roads Maintenance, Operations & Fleet, and Building. The majority of participants have worked at the City for 10 years or longer and are middle-aged. The most common vehicle types driven by survey participants are pickups and SUVs.

Transit

The majority of participants have worked at the City for 10 years or longer and are middle-aged. The most common vehicle types driven by survey participants are vans (management staff) and pickups (union staff).

Fire & EMS

The majority of participants have worked at the City for 10 years or longer. All participants were middle-aged and are male. Three out of four respondents drove either a car, pickup, or SUV.

Awareness of Environmental Issues

Fleet Services and Fire & EMS

The overwhelming majority of survey participants agree with and/or support Brampton's climate change emergency declaration, and there is very strong consensus that dealing with environmental issues is justified and should be a top priority. Climate change and air pollution are ranked as the number one and two environmental issues among participants (virtual tie), with water pollution ranked as a close third.

Transit

The majority of survey participants in the management group agree with and/or support Brampton's climate change emergency declaration; however, support among staff participants is divided, with only 50% of participants agreeing with and/or supporting the declaration. Overall, there is consensus that dealing with environmental issues is justified and should be a top priority.

Water pollution and climate change are ranked as the number one and two environmental problems among participants in the management group. Amongst staff, toxic waste, water pollution, and air pollution are tied for first; climate change is ranked as the second biggest environmental problem with a ranking of only 3.3/6. This may suggest that more education around climate change would be beneficial, since most experts agree climate change is the primary environmental problem facing the world today, while ground-level smog (air pollution) emissions have been, and are expected to continue, making steady improvements.

Views on Pollution Factors and Fuel-Reduction Solutions

In this section of the survey, we asked participants about their opinions on various pollution factors, fuel-switching options (i.e., alternate/renewable fuels), and battery-electric vehicles (BEVs), to gain a perspective of views and predominant concerns to address in the City of Brampton's Sustainable Fleet Strategy.

Fleet Services

Survey participants agree, overall, that all the pollution factors listed (age, fuel type, maintenance, driving habits, right-sizing, and trip planning) have moderate to large impacts on fuel-efficiency and pollution from fleet vehicles. Fuel type is the leading factor among respondents.

In terms of driving habits and behaviours, survey participants generally agree that eco-driver training would help them operate Fleet vehicles, as well as personal vehicles, more efficiently.

Regarding natural gas and propane as fossil-fuel alternatives to gasoline and diesel, survey participants generally agree that both natural gas- and propane-powered vehicles are more economical to drive than their conventional fuel counterparts, are reliable, and are safe.

Regarding biodiesel and ethanol as substitutes for standard diesel and gasoline, respectively, survey participants generally agree that biodiesel and ethanol are feasible and safe fossil-fuel substitutes. Participants are in higher agreement about the benefits of using ethanol compared to biodiesel. Moreover, there is some concern (particularly among staff) surrounding the production of plant-based fuels due to their use of food crops.

Overall, there is strong support for and understanding of BEVs from survey participants, particularly in regards to their range capabilities, power, heating/cooling, and pollution prevention. There is some doubt surrounding operating cost savings as well as availability of models now and in the near future to fulfil the City's requirements.

Survey participants are very receptive to a wide range of fuel-reduction solutions listed, including various best management practices (BMPs), alternate/renewable fuels, and BEVs. The highest rating (4.5/5) for the management group is for reducing unnecessary engine idling, and the highest rating (4.4/5) for the staff group is for having a younger and more fuel-efficient fleet. The lowest, yet still favourable, ratings for each group are for renewable fuels (biodiesel and ethanol) and alternate fuels (natural gas and propane), with scores ranging from 3.3-3.6/5. The switch to BEVs is highly favoured in both groups, with a rating of 4.2/5 for management and 4.0/5 for staff employees.

Transit

Survey participants agree, overall, that all the pollution factors listed (age, fuel type, maintenance, driving habits, right-sizing, and trip planning) have moderate to large impacts on fuel-efficiency and pollution from fleet vehicles. Fuel type is the leading factor among respondents in the management group, whereas driving habits of vehicle operators is the leading factor in the staff group.

In terms of driving habits and behaviours, survey participants generally agree that eco-driver training would help them operate Transit vehicles, as well as personal vehicles, more efficiently. Encouragingly, support for eco-driving training is particularly strong in the staff group.

Regarding natural gas and propane as fossil-fuel alternatives to gasoline and diesel, survey participants generally agree that both natural gas- and propane-powered vehicles are safe and are more economical to drive than their conventional fuel counterparts; however, respondents' overall rating of reliability is slightly lower.

Regarding biodiesel and ethanol as substitutes for standard diesel and gasoline, respectively, survey participants in the management group generally agree that biodiesel and ethanol are feasible, effective, and safe fossil fuel substitutes. However, there is no clear agreement on these statements among staff participants; in fact, there is general disagreement surrounding the reliability and benefits of biodiesel. Moreover, there is less familiarity regarding ethanol as compared to biodiesel among all participants.

Overall, there is strong support for and understanding of BEVs among survey participants in the management group, particularly in regards to their cost effectiveness, pollution prevention, and availability now and in the near future. However, respondents in the staff group are much less optimistic; the largest doubt is surrounding operating cost savings and pollution prevention, with rankings of 2.2 and 2.8/5, respectively.

Overall, survey participants are receptive to a wide range of fuel-reduction solutions listed, including various best management practices (BMPs) and BEVs. The highest rating (4.2/5) for the management group is for reducing unnecessary engine idling and using virtual meetings (tie), and there is three-way tie for the highest rating (4.4/5) in the staff group between having a younger and more fuel-efficient fleet, reducing unnecessary idling, and using virtual meetings.

The lowest ratings for each group are for renewable fuels (biodiesel and ethanol) and alternate fuels (natural gas and propane), with scores ranging from 3.0-3.3/5. The switch to BEVs is more highly favoured in the management group than the staff group, with a rating of 4.2/5 for management and 3.5/5 for staff employees.

Fire & EMS

Survey participants agree that all the pollution factors listed (age, fuel type, maintenance, driving habits, right-sizing, and trip planning) have moderate to large impacts on fuel-efficiency and pollution from fleet vehicles. Vehicle age is the leading factor among respondents.

In terms of driving habits and behaviours, survey participants generally agree that eco-driver training would help them operate Fire & EMS vehicles, as well as personal vehicles, more efficiently.

Regarding natural gas and propane as fossil-fuel alternatives to gasoline and diesel, survey participants are, overall, undecided as to whether these alternate-fuel vehicles are more economical to drive than their conventional fuel counterparts, are reliable, and are safe to drive.

Regarding biodiesel and ethanol as substitutes for standard diesel and gasoline, respectively, survey participants are, overall, undecided as to whether biodiesel and ethanol are feasible, effective, and safe fossil-fuel substitutes. Respondents generally have a higher level of knowledge surrounding ethanol than biodiesel.

Overall, there is some support for and understanding of BEVs from the survey participants, particularly in regards to pollution prevention and availability of models now and in the near future to fulfil the City's requirements. However, there is concern regarding the ability of BEVs to meet the daily needs for Fire & EMS vehicles, particularly in terms of sufficient range and power; the average rating for both of these factors was only 2.2/5.

In terms of infrastructure required for alternate fuels and BEVs, survey participants are in much greater support of BEV charging infrastructure as compared to natural gas and propane fuelling stations. For charging infrastructure, there is stronger agreement regarding investing in Level 3 charging stations (3.8/5) versus Level 2 charging stations (3.0/5). Moreover, respondents are in strong agreement that technician training would be needed for maintaining both fuelling and charging infrastructure.

Overall, survey participants are receptive to a range of fuel-reduction solutions listed, including various best management practices (BMPs) and hybrid-electric vehicles. The highest rating (4.2/5) is for using virtual meetings (4.2/5), followed closely by reducing unnecessary engine idling and having a younger and more fuel-efficient fleet (4.0/5). The lowest ratings are for alternate fuels (natural gas and propane) and renewable fuels (biodiesel and ethanol), with scores of 2.5/5 and 3.0/5, respectively. Respondents are, as a whole, somewhat undecided regarding the switch to BEVs, which has a rating of 3.5/5.

Comments and Concerns

For each survey question, participants were given the opportunity to provide their own comments and were provided a “freestyle” section that allowed for comments on greening of the City of Brampton’s fleet at large.

Several comments in particular, were eloquently written and were, overall, representative of participants’ view on the matters:

“The opportunity has never been better to introduce green initiatives to combat climate change. Even if some are non-believers, why not try our best to cut down on emissions? If the majority of citizens support change, now is our chance to try something new.”

“Any small step that moves away from the traditional gas-powered vehicles would be better than the status quo.”

There was another comment that really captured the current period we are experiencing – the support and readiness of (most) staff to move towards a greener fleet, but the challenge with implementation of low-carbon solutions due to the upfront costs and infrastructure, as well as new training and maintenance practices, required.

“From a learning/training perspective, I think the change to lower-emission vehicles would be a fairly easy task. With all of the knowledge we have now with regards to climate change and adverse weather events, the selling feature is already ‘built-in.’ We know it's an issue, so what are we going to do about it? Well, purchasing the equipment/fuel/charging facilities is the hard part. Our staff would be more than willing to be a part of the change. Driving the vehicle wouldn't be much different, it's our maintenance team that would have the steepest learning curve.”

There were several common areas of interest and/or concern which we have outlined below:

Right-Sizing and Fleet Downsizing

- Many respondents feel that vehicles are oversized for their use case and that smaller vehicles, sized appropriately for the task at hand, is a low-hanging fruit that would have immediate impact on emissions reduction.

- A smaller number of respondents feel that the number of fleet vehicles at large should be reduced.

Vehicle Age

- Some respondents feel that many units are older models and that modernizing the fleet would decrease idling pollution.

Eco-Driver Training and Incentives

- A small number of respondents feel that eco-driver training is not the best approach because vehicles are City-owned, therefore reducing incentives for the operators.

- Many respondents feel that there should be a rewards or incentive program to encourage fuel-efficient driving behaviours.

Alternate/Renewable Fuels

- Overall, many respondents feel that biodiesel is problematic for the City's fleet because of cold-weather performance concerns due to gelling as well as damage to after-treatment systems.

- There are fewer opinions on ethanol, likely due to less knowledge of this renewable fuel as compared to biodiesel; however, there are concerns regarding the impact of ethanol on engines and exhaust systems.

- Regarding natural gas and propane, there was a concern surrounding their safety in a collision, as well as the impact on groundwater from the fracking process to extract natural gas.

BEVs and Charging Infrastructure

- Overall, many respondents are onboard with switching to BEVs and are optimistic regarding their mileage (range capability) and power for successfully fulfilling job duties.

- There is some concern regarding the capability of an EV battery to last through three shifts in the winter.

- There were numerous concerns regarding GHG emissions produced from electricity generation, mining of materials for batteries, and the recycling of batteries.

- Many respondents voiced the importance of expanding the City's charging network in order to transition to BEVs – both for City vehicles as well as the public.

- One respondent expressed the need to educate workers on the performance capabilities of BEVs.

Hydrogen Fuel-Cell Vehicles

- Several respondents believe that hydrogen fuel-cell vehicles have high potential for the future for multiple reasons, including zero tailpipe emissions, the use-case for larger units that operate for extended hours and/or travel long distances, and easy and familiar refilling methods.

Synopsis

Based on the results of this survey and participant comments, it is clear that Brampton Fleet's user-group stakeholders are, overall, supportive of green fleet initiatives and aware of their benefits, particularly driver training, idling reduction, modernizing the fleet, right-sizing, and BEVs.

There are key similarities and differences between the management and staff cohorts, as well as between fleets. Reducing unnecessary idling is a generally the most common low-hanging fruit, particularly amongst management groups in Fleet Services and Transit. Modernizing the fleet is generally the most common opinion amongst staff in Fleet Services and Transit. In Fire & EMS, vehicle age is the leading concern for pollution from fleet units. Additionally, using virtual meetings to avoid vehicle trips ranks high among all fleets.

Overall, there is only moderate support of alternate and renewable fuels. Staff in Transit are particularly opposed, overall, to biodiesel.

There is, overall, strong support for BEVs in Fleet Services and Transit; however, Transit staff are generally more doubtful of this technology. In Fire & EMS, there is slightly more support for hybrid-electric vehicles than for BEVs.

Importantly, there appears to be a high level of willingness to participate in the City of Brampton's transition towards a low-carbon, green fleet. Efforts in educating employees on the benefits of BEVs would likely close any knowledge gaps and resistance towards this technology, allowing for a more seamless transition over the coming years.

...

Section 6.0: 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 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 B*.

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

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 D*):

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 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 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. The steps include:

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 a 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 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.

We propose the following steps, outlining go-forward actions to reduce fuel and GHG emissions, for Part Two of the City of Brampton's Sustainable Fleet Strategy: Framework and Action Plan.

6) **"House-in-Order" Actions.** Before making commitments to fuel-switching or low-carbon technologies, RSI-FC believes 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 tires, aerodynamic vehicles, light-weighting, idle-reduction technologies, etc.

- **Transportation Demand Management.** 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

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 is fuel-switching – transitioning away from fossil gasoline and diesel to alternate, lower-carbon fuels like propane and natural gas, or renewable fuels like ethanol and biodiesel.

RSI-FC has employed the most recent combustion (tailpipe) emission factors[28] associated with fossil fuels and renewable fuels as per GHGenius[29] Version 5.01a.

For compressed natural gas (CNG), to compare energy on an apples-to-apples basis, RSI-FC accounts 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.

Although propane has a significant GHG emissions reduction potential when compared to the same volume of gasoline, 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), we use "net vehicle operation" emissions factors, which account for 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.

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

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

[29] 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.

content of pure biodiesel (B100) is close to 8% lower than pure diesel[30]. 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).

8) **Battery-Electric Vehicle Phase-in Planning.** Despite the 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 the purpose of green fleet planning, after completing LCA and business case optimization for like-for-like vehicle replacements, our team then uses FAR to replace 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 (see *Section 7.0* of this report) 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.

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

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.

...

Section 7.0: Lifecycle Analysis

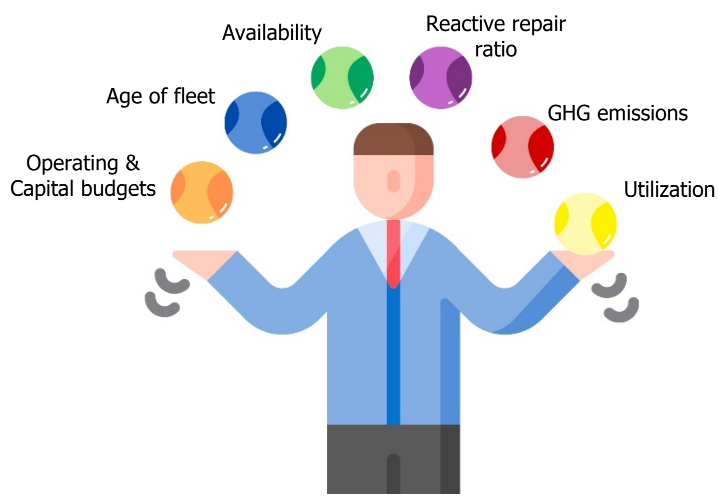
Lifecycle analysis (LCA) is a structured approach to determine the best time to replace vehicles and equipment in terms of age, mileage, or other pertinent factors. LCA provides the empirical justification for replacement policies and facilitates the analysis and communication of future replacement costs. As LCA identifies capital strategies that will optimize vehicle lifecycles and return-on-investment (ROI), it should be the first step in long-term capital budget planning (LTCP).

LCA illustrates the total lifecycle cost of fleet vehicle types/categories. LCA can help determine:

- The age at which units should be considered for replacement; and
- When replacement should occur, ideally before costs rise and reliability/safety is reduced, and before significant capital expenditure or refurbishment is necessary.

As shown in *Figure 2*, fleet management is a complex juggling act. Capital investment, operating expenses, depreciation, preventive maintenance levels, fuel consumption, aging of the fleet, availability, utilization, emissions, and inflation are interconnected issues. Making a change to any one of these critical considerations impacts all of them.

Figure 2: Fleet Management Juggling Act

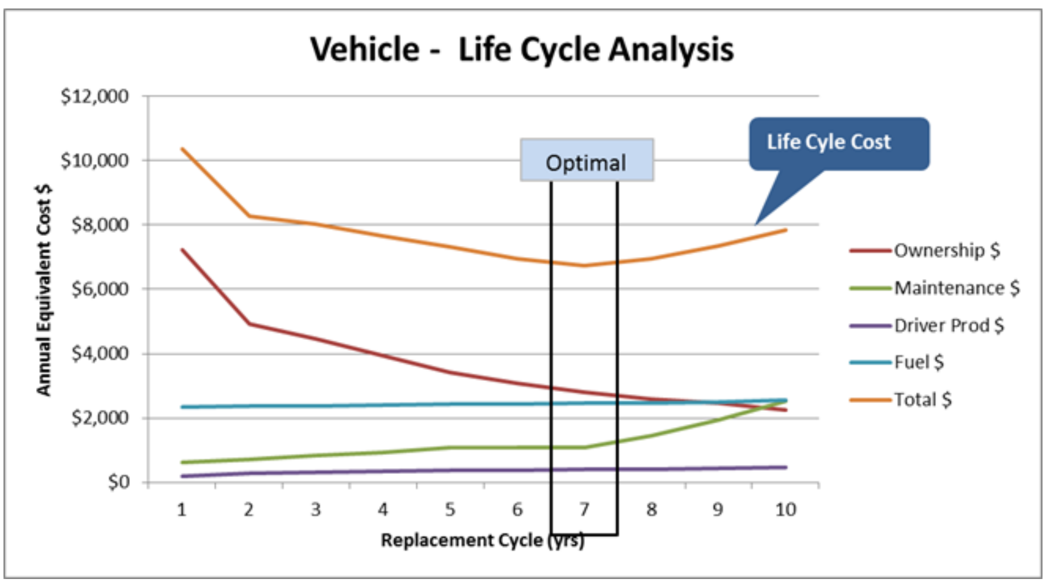


For example, deferred capital spending will result in an aging fleet, in turn resulting in higher reactive repair rates, more downtime, higher fuel consumption, (potentially) increased operating costs, and, ultimately, a larger overall fleet size to allow for more spare vehicles to compensate for the reduced reliability of primary vehicles. Counter to this, if vehicles are replaced too soon, value may be lost.

RSI-FC believes that the key to success is knowing the optimal economic lifecycle for each type of vehicle in a fleet. With that information, fleet managers can balance their go-forward capital spending to align with service level (uptime) and operating expenses (Opex), and other essential success measures.

Figure 3 illustrates the concept of LCA. As a vehicle's age at retirement increases, ownership costs decrease and operating costs increase. In this example, the operating costs include maintenance, loss of driver productivity caused by reduced vehicle reliability, and fuel consumption. The sum of operating and ownership costs represents the "lifecycle cost curve." The ideal time to replace vehicles is before the rise in operating expenses begins to outweigh the decline in ownership costs.

Figure 3: Lifecycle Analysis Example



The Lifecycle Cost Curve

The lifecycle cost curve and the ideal replacement cycle will be different for various types of vehicles and possibly even for individual vehicles of the same kind. Factors that can cause this variability include differences in vehicle makes/models, model year, equipment design, operating environment, and/or operator habits. Recommended replacement cycles for a class of vehicles is an approximation of the optimal time to replace most units within that class based on the category-average cost and performance data, by model year.

Replacement cycles should be considered a guideline only, as some vehicles in poor or unsafe condition may require replacement before the criteria are met. Conversely, some vehicles that exceed the criteria may be in good condition and may not warrant replacement. Fleet managers need to exercise judgment and fleet management principles in either advancing replacement or delaying replacement of individual vehicles case by case.

Lifecycles for vehicles are determined by modelling the expected cash flows for owning and operating the vehicle. The approach involves forecasting a stream of costs over a study horizon (future period) for each type of vehicle and determining the replacement cycle that results in the lowest total cost of ownership (TCO).

For the City of Brampton, a discounted cash flow analysis was completed for each vehicle class to complete the LCA. Net present value (NPV) was calculated for outgoing cash flows (vehicle purchase cost, maintenance cost, the impact of downtime on driver productivity cost, improved fuel efficiency of a new vehicle compared to the old vehicle) and incoming cash flows (vehicle residual value) to calculate the total lifecycle cost for various vehicle retention periods.

The NPV amounts for cash flows were converted to annual equivalent cost (AEC) to provide a dollar amount, which is easy to relate to and enables comparison of alternative lifecycle costs. AEC is the fixed annual payment that that would be required to pay back the total of capital and operating costs over the study period. The AEC can be viewed as an average annual cost that considers the time value of money for future cash flows.

Fleet Age and Reliability

Most drivers know from personal experience that older vehicles are less reliable, break down more frequently, cost more to repair, and burn more fuel. Multiply that reality many times over as in a commercial fleet, and the impacts can be significant. In general, as commercial vehicle fleets age, higher operating expenses are incurred due to increased reactive repairs (unplanned repairs and breakdowns). Due to decreased reliability, downtime costs for spare/loaner vehicles increase as does the cost of productivity loss for drivers who are dependent on fleet vehicles to perform their daily work routines.

Downtime costs increase exponentially when more than one person is dependent on a single vehicle to complete their work routines. In addition to the cost of less reliable, aging vehicles and the associated increased downtime are the additional expenses of owning, maintaining, licensing, insuring, and parking spare, back-up vehicles.

Even when downtime is minimized through a rigorous preventive maintenance program, downtime costs are unavoidable and can be substantial for a municipality. Ongoing, uninterrupted capital re-investment in modernizing the fleet is critical to any organization that depends on a reliable fleet of vehicles to achieve its objectives and mission, as is the case for all municipalities. The benefits of a newer fleet include better fuel economy, increased vehicle uptime, lower risk of repair, increased safety and, possibly, improved employee morale. Moreover, a more modern and reliable fleet may result in a reduced fleet size since fewer spares will be necessary.

Vehicle Replacement at the Rate of Depreciation

Providing capital to replace units each year with new vehicles is essential for any organization that relies on its fleet to provide its core services to customers. A guideline for fleet replacement is to invest capital at the rate of depreciation. For example, if vehicles are depreciated over ten years, then 10% of the total fleet replacement cost (current NPV) would be required each year to maintain the fleet's average age at the desirable level. However, this guideline is only valid if performance indicators such as uptime and fuel-efficiency are satisfactory. If not, a one-time increase in spending would help bring the fleet's average age and performance up to an acceptable level.

Vehicle Replacement Criteria

Today's vehicles are built better and last longer than ever before. With the right preventive maintenance, operating conditions, and driver behaviours, vehicle service lives can often be extended longer than in the past. The LCA completed for this report optimizes vehicle lifecycle costs based on vehicle age. Vehicle age was determined to be the best replacement criteria for the City of Brampton, given the relatively low average utilization rates in the fleet. Because annual kms-travelled are low, most vehicles will time-out versus mileage-out at retirement.

For most vehicle categories in Brampton Fleet Services and Transit fleets, we recommend extending lifecycles. That stated, we strongly recommend a cautious approach before doing so. Vehicles approaching their end-of-lifecycles should be assessed case by case with a thorough ground-up and top-down physical assessment of the vehicle's condition, as this would serve to inform and confirm decisions around extending their lifecycles.

For higher annual mileage vehicles in the fleet, it is recommended that the City of Brampton review the condition of high mileage vehicles at thresholds of 20,000 km/yr for light-duty vehicles (LDVs) and 25,000 km/yr for medium and heavy-duty vehicles (MHDVs) for potential early replacement. The recommended vehicle replacement age can be multiplied by these values to determine mileage thresholds. For example, if the recommended lifecycle is ten years for a vehicle type, the recommended replacement mileage is 10 x 20,000 = 140,000 km.

Environmental Considerations

LCA is used to evaluate whether the increased costs of capital for newer, more modern, and fuel-efficient vehicles will be offset by lower fuel, repair, and downtime costs. For low-mileage units, the amount of fuel saved may be minimal, often resulting in lifecycle extension being the better financial option. However, aging a fleet to extract full value from each unit may counteract the fleet's progress toward modernization and reduced GHG emissions.

When modelling battery-electric vehicle (BEV) replacement, some units do not show ROI due to increased cost of capital exacerbated by low utilization. Given the objective of green fleet planning is to provide a roadmap for deep GHG emissions reduction, we phase-in BEVs in accordance with the expected availability of BEV types until, by the end of the budget period, all units with anticipated battery-electric options in the market are replaced.

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.

Key Parameters and Assumptions

The key LCA parameters and assumptions used for all vehicle classes are listed in *Table 10*.

Table 10: Key LCA Parameters and Assumptions

Parameter	Value	Description
Net Acquisition Cost	Varies by vehicle class	Based on average vehicle acquisition cost data provided by the City of Brampton
Cost of Capital/ Lease Rate	2.45%	Cost of funds for vehicle acquisition (the prime interest rate at the time of the LCA)
Discount Rate for NPV	1.75%	Rate used to discount cash flows
Sales Tax Rate %	1.76%	HST rate – municipalities
Tech. Prod Loss Hrs./Touch	3.0	Average loss in driver productivity each time a fleet technician services a vehicle. Work orders are deemed equivalent to "touches"
Tech. Labour Rate $/Hr.	$75	Estimated/typical hourly labour rate
CIF[31] on Maintenance	1.8%	Cost increase factor or inflation on parts and mechanic labour

[31] CIF = Cost Inflation Factor

Parameter	Value	Description
CIF on Driver Rate	1.5 %	Cost increase factor or inflation on driver loaded labour rate
CIF on Vehicle	2.0%	Cost increase factor or inflation on vehicle replacement prices
CIF on Fuel	4.0%	An assumption based on market trends
Annual Vehicle Efficiency Improvement	2.0%	Fuel efficiency improvement factor for new vehicles compared to the vehicles being replaced (estimated by Fleet Challenge)
Average Km/Yr.	Varies by vehicle class	Annual distance travelled under the assumption that the new vehicle will travel the same distance as the old vehicle
Cash Flow Horizon (yrs.)	Varies by vehicle class	Discounted cash flow study period, adjusted based on the vehicle class (up to 20 years) and years of available data

LCA is based on average costs and utilization rates for each category of vehicles and provides a credible guideline to optimal vehicle replacement cycles. LCA does have limitations since its outcomes are based on average cost data for each category of vehicles. Some vehicles in poor or unsafe condition may require replacement before the LCA-calculated age criteria are met. Conversely, some vehicles that exceed the criteria may still be in good condition and not warrant replacement due to low usage or recent refurbishment. Therefore, the LCA-recommended replacement criteria should be used as a guideline and not an absolute rule. The physical condition of each unit should then be assessed case-by-case by trained and knowledgeable staff, familiar with the unit's usage and maintenance history before replacement decisions are finalized.

Data Challenges

The discipline of completing fleet LCA is dependent on historical cost data. LCA modelling software was designed and intended to be populated with a fleet's actual historical cost data. Without having cost data and performing LCA, vehicle replacement decisions may be based solely on intuition and personal observations – essentially the sentiments of someone who has a high degree of familiarity with the fleet. Often we have observed that “guesstimates” made by seasoned fleet managers can have a high degree of accuracy. However, today’s business decisions based on “gut” feelings often do not stand up to scrutiny and must be backed up by analytical data.

For the City of Brampton, our team used an LCA modelling tool developed by RSI-FC in 2013 and refreshed in 2017. Our tool is dependent on actual fleet historical data when available for the model years and vehicle types being studied.

The City provided our team with data for its three in-scope fleets – Fleet Services, Fire & EMS, and Transit (non-revenue units).

After conducting a preliminary LCA, our team realized that the Fire & EMS data was skewing fleet-wide averages due to their, characteristically, exceptionally high maintenance costs, and, to a lesser extent, high fuel consumption per km. For this reason, we chose to exclude all Fire & EMS units from our LCA and keep lifecycles for these units as-is.

For Fleet Services and Transit, sample sizes were insufficient for some categories for what is required to complete LCA. More data means larger sample sizes, across a range of vehicle ages, which are essential for completing LCA. As a workaround, RSI-FC chose to add the following vehicle categories with insufficient data to the following larger categories:

- Class 1 vans (only 3 units over 2 age points) were added to Class 1 pickups
- Class 3 cargo vans (2 units over 1 age point) were added to Class 3 pickups

For vehicle categories where merging with another appropriate category in the same class was not an option, we chose to not undertake LCA and instead retain the planned lifecycles provided by the City in our go-forward modelling. The following vehicle categories were excluded from the LCA:

- Class 3 15-passenger van (only 1 rental unit)
- Class 4 van (only 1 unit)
- Class 5 van (only 2 units over 1 age point)
- Class 6 dump truck (only 5 units over 2 age points)
- Class 7 step van (only 1 unit)
- Class 7 multi-lift truck (only 1 unit)

As a result of merging some vehicle categories and excluding others with insufficient data, LCA was completed for the following vehicle categories for Fleet Services and Transit based on Brampton's actual historical operational data:

- Class 1 car
- Class 1 pickup, van
- Class 1 SUV, wagon
- Class 2 van
- Class 2 pickup
- Class 3 pickup, cargo van
- Class 5 truck
- Class 8 truck

Our data analysts paid close attention to any data outliers which would have skewed results. For Class 5 trucks, a seven-year-old unit had a PM/repair cost of over $20,000 which clearly did not fit the cost curve shown by the bulk of their units; therefore, this data point was excluded.

Lifecycle Analysis Results Summary

LCA was undertaken for selected vehicle categories in Brampton's Fleet Services and Transit (non-revenue) fleets with sufficient historical data over the review period. The LCA took into consideration the cost of downtime (as caused by reduced reliability), the year-to-year "rollup" of weighted average cost of capital (WACC), inflation, worker cost/hour, salvage and market values, inflation, and average kilometres-driven data. The results are summarized in *Table 11*. In *Appendix C*, we have included the LCA charts for each applicable vehicle category in Brampton's fleet.

Table 11: Lifecycle Analysis Results Summary

*Vehicle Category	Current Planned Lifecycles (years)	Optimal Lifecycle Calculated through LCA (years)	Recommended Change (+ or -) (years)
Class 1 car	8	11	+3
Class 1 pickup, van	8	11	+3
Class 1 SUV, wagon	8	9	+1
Class 2 van	5-8	5	0 to -3
Class 2 pickup	8	8	Unchanged
**Class 3 pickup, cargo van	8	12	+4
Class 5 truck	8 to 10	10	0 to +2
Class 8 truck	10	12	+2

*Fire & EMS units are excluded for all vehicle categories
**Class 3 Transit pickups are ideally kept on 8-year lifecycles due to significant maintenance and repair cost increases after this life span experienced in the past at Transit.

Next Step After LCA: Vehicle Condition Assessments

The City of Brampton has Fleet Technicians complete vehicle condition evaluations during every preventive maintenance inspection. In this way, decisions around extending vehicle lifecycles are founded on data and a solid understanding of each vehicle's actual condition. Currently, vehicle condition evaluations are done using a paper-based system with sheets being scanned and stored.

Our recommendation is to store the vehicle condition information in Excel format or another database for easy access and tracking of summaries and/or analyses. A simple rating system such as a numerical 1 to 5 indexing where 1 = poor condition and 5 = good condition would greatly assist capital budget planners in determining the highest priority units for replacement. If each vehicle's condition rating (1 to 5) was posted in each vehicle's profile in Excel or a software program, it could be easily accessed for capital budget planning.

As we have described, vehicles approaching their end of lifecycle should be assessed case by case. A thorough ground-up and top-down physical assessment of each vehicle's condition, in conjunction with routine shop visits for preventive maintenance inspections, would serve to inform decisions around extending vehicle lifecycles.

...

Section 8.0: Long-Term Capital Planning

After completing lifecycle analysis (LCA), the Fleet Analytics Review™ (FAR) software tool enables methodical, well-informed business decisions for long-term capital planning (LTCP) purposes.

Vehicle data provided by the City of Brampton for the baseline year (2019) was input into FAR, and the tool calculated capital budgets for the ensuing fifteen years driven by vehicle lifecycles based on fleet management's vehicle retention practices (business-as-usual or BAU) and the optimized lifecycles that were calculated by LCA. On a unit-by-unit basis, FAR calculated:

(1) whether replacing units due for replacement would save Brampton operating expenses (Opex) or cost additional money; and
(2) the GHG-reduction impacts of vehicle replacements.

The tool also calculated and displayed the costs (operating and capital) and GHG impacts of those decisions for the fleet as a whole.

Fleet management does not usually have unlimited capital budgets; therefore, tough decisions must be made around which vehicles to replace and which to delay replacement. Typically, when a fleet manager uses LTCP for the first time, year one will show a cost spike caused by previously deferred vehicles. Replacement of some of these units can be again delayed because they are still in good serviceable condition, have low mileage, or perhaps have just received a costly refurbishment that will extend the unit's life. Other vehicles may no longer have a purpose in the organization and could potentially be eliminated from the fleet. These decisions can be aided by an LTCP tool by displaying to the user whether cost-savings are possible by replacing a unit.

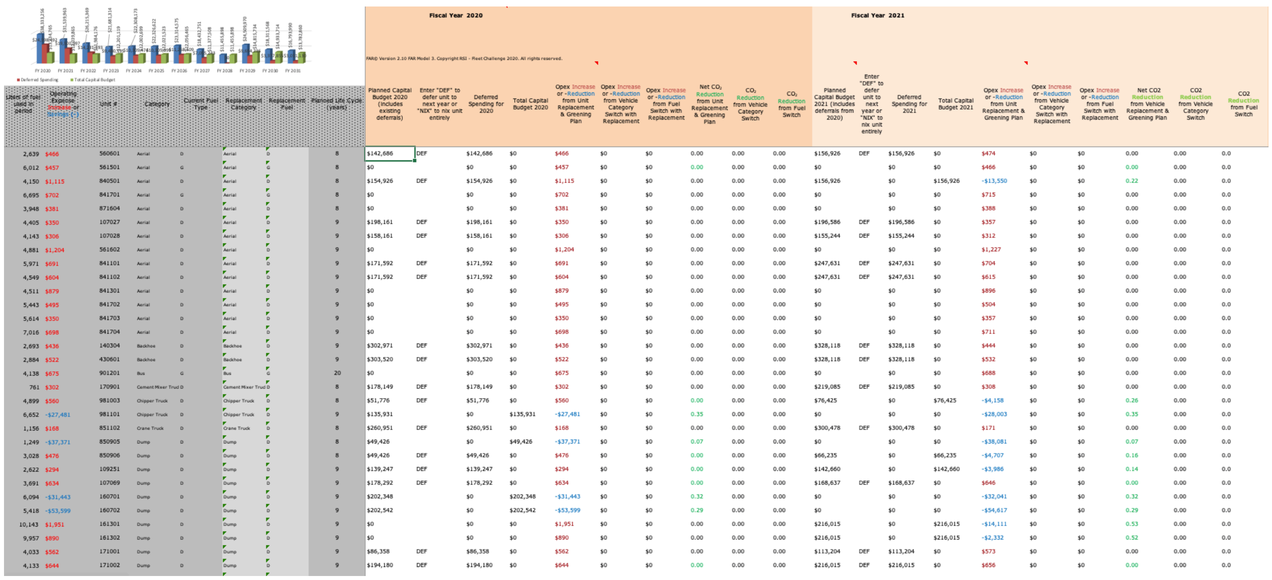
In FAR, replacement of units shown not to provide return-on-investment (ROI) can be deferred to the following year until replacement yields a net decrease in Opex. Following this method, a fleet manager can balance go-forward annual capital expenses (Capex) and avoid year-over-year cost spikes. This approach can keep the average age of the fleet at an acceptable level, provide the lowest cost and highest uptime, and reduce emissions.

While historical data in FAR will demonstrate whether a business case exists for vehicle replacement, the final step in LTCP depends on fleet management personnel's expertise. *No software tool can supplant this crucial role in capital budget planning.*

For the City of Brampton, we modelled a 15-year budget cycle (to 2036) for (1) business-as-usual (BAU) vehicle replacement practices, (2) optimized economic lifecycles, and (3) balanced Capex and optimized lifecycles (only replacing units with ROI).

A sample screen of the 15-year capital budgeting within FAR is shown in *Figure 4*.

Figure 4: Sample FAR Dashboard



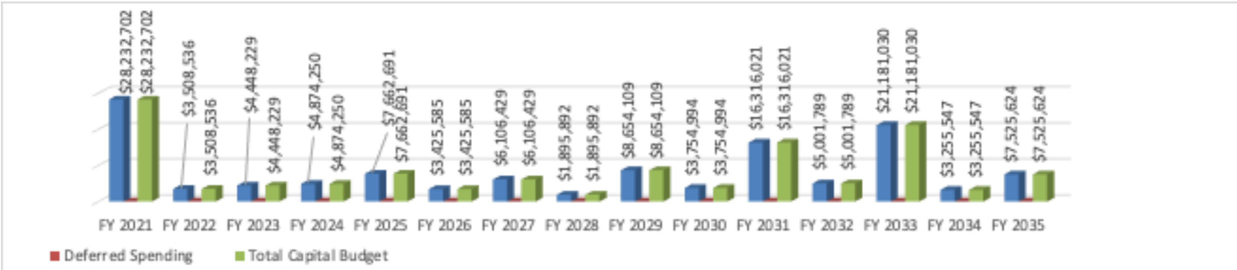
Business-as-Usual

FAR Scenario One modelled a 15-year budget cycle based on Brampton's present-day vehicle replacement practices. These BAU outcomes include the impacts of current replacement cycles on Opex, Capex, and GHG emissions for all in-scope fleet vehicles.

As illustrated in *Figure 5* (below), based on present-day replacement practices, it was estimated that $28.2 million would be required to replace all due or past-due units with new like-for-like vehicles (no BEVs at this stage). It should be noted that numerous vehicles in the Brampton fleet are beyond the current planned age for replacement – *significant "catch-up" is required to modernize the fleet.* In ensuing years, far fewer vehicles require replacement, bringing down capital spending to between $3.5 and $4.9 million in the following three fiscal years (2022-2024). However, there is an uneven capital spend projected in following years.

In the hypothetical event that all vehicles due for replacement in 2021 are indeed replaced, Opex is estimated to decrease by about $816,000 and GHG emissions are estimated to decrease by about 27 tonnes CO_2e (less than 1% of total emissions) due to the increased fuel efficiency of newer vehicles.

Figure 5: Planned capital budget (blue), deferred spending (red), and total capital budget (green) for BAU replacement practices

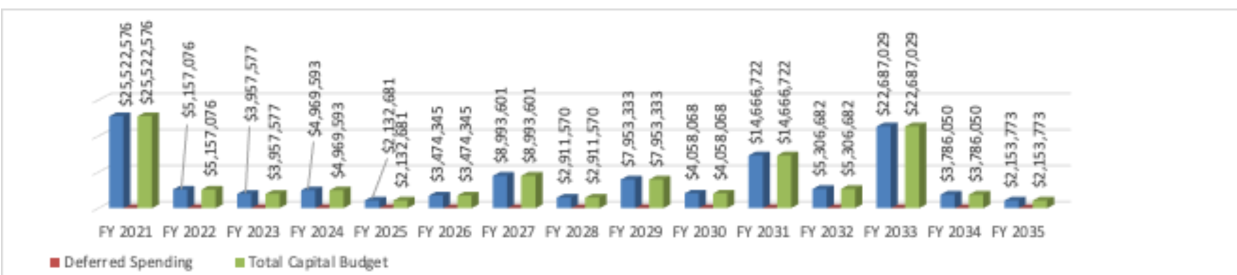


Optimized Economic Lifecycles

FAR Scenario Two calculated the impacts of optimized vehicle replacement cycles on Opex, Capex, and GHG emissions over a fifteen-year horizon for all in-scope fleet vehicles.

As illustrated in *Figure 6*, based on optimized economic lifecycles it was estimated that, in 2021, $25.5 million would be required to replace all due or past-due units with new like-for-like vehicles (no BEVs at this stage), which is significantly less than present-day replacement practices. Like BAU, there is an uneven capital spend projected in following years.

Figure 6: Planned capital budget (blue), deferred spending (red), and total capital budget (green) for optimized economic lifecycles



Balanced Capex and Optimized Lifecycles

Once optimized economic lifecycles were modelled, it became apparent that some vehicles deliver better ROI than others. Some vehicles in the fleet may have received lighter usage than other similar age units, which may have been worked harder. For vehicles in better condition, their service life can be extended to optimize their lifetime total cost of ownership (TCO). Lower ROI would result if a vehicle, still in good condition, was replaced prematurely; value will be lost.

For FAR Scenario Three, the approach used by RSI-FC was to defer some vehicles to ensuing capital budget years to ensure full value is received from each unit. In our data-modeling, without knowledge of the physical condition of units due for replacement based on vehicle ages, our analysts instead deferred vehicles showing low/no ROI to following budget years in order to balance annual year-over-year capital budgets. This step was intended to be an example of balancing long-term budgets using optimized lifecycles and ROI. In reality, fleet managers make similar decisions each year based on vehicle condition assessments and other information, such as maintenance history.

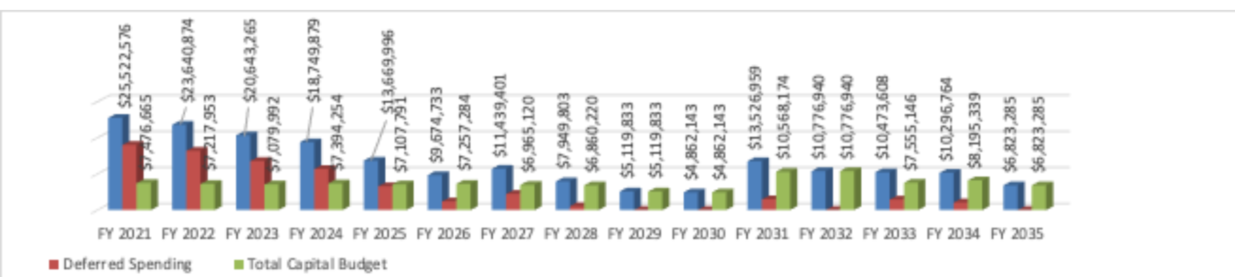
As third-party consultants without access to information to vehicle condition, and to reduce and apportion the required capital over a more extended period, we opted to defer using the following criteria:

(1) Units with low/no ROI
(2) Units that have most recently became due for replacement (to ensure past-due units get higher priority for replacement)
(3) Lower-mileage units (to ensure that higher-mileage units are replaced first)

Using this prioritization protocol, we selectively and strategically made deferrals over the budget cycle to maximize Opex benefits and balance Capex to the best of our ability. As a result, FAR Scenario Three has much more balanced Capex over the 15-year budget cycle than FAR Scenarios One and Two, with overall increasing capital spending towards the end of the period due to compounding inflation.

As illustrated in *Figure 7*, the net result was an annual capital budget ranging from $4.9-10.8 million as compared to the BAU range of $1.9-28.2 million over the budget period, with clustering around $7 million.

Figure 7: Planned capital budget (blue), deferred spending (red), and total capital budget (green) for balanced Capex and optimized lifecycles



Recommendations

- Consider adopting the RSI-FC recommended lifecycle analysis (LCA) approach to extract maximum value from each vehicle.

- When the fleet's average age and uptime rates are determined to be at acceptable levels, consider re-investing in the fleet at the rate of depreciation.

Proposed Low-Carbon Fleet Analytics Review™ Scenarios

Using balanced Capex and optimized lifecycles, we are proposing to perform a number of scenario analyses to assess the potential impacts of fuel-reduction solutions. For each scenario, Fleet Analytics Review™ (FAR) will calculate annual GHG emissions, operating costs, and capital requirements, and will provide a long-term capital planning (LTCP) outlook from baseline to 2035.

The solutions will be categorized into three groups (best management practices, fuel switching, and hybrid/battery-electric) and the potential impacts will be presented relative to the baseline. For the purpose of data-modelling, the baseline fleet data provided by the City was for 2019 but we propose to treat 2020 as the baseline year using 2019 data as a proxy for 2020. These "what-if" scenarios will 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 completed and proposed scenarios are described below and listed in *Table 12* (overleaf):

<u>Completed</u>

- FAR #1 is the baseline for the 2019 review period, which serves as a proxy for 2020.
- 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) 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).

<u>Proposed</u>

We propose to model the following scenarios to provide a range of fuel- GHG emissions-reduction options for Part Two of the City of Brampton's Sustainable Fleet Strategy: Framework and Action Plan.

- Starting from FAR #3, in FAR #4-6 we will assess 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 will data-model several "messy-middle" scenarios involving switching appropriate units to alternate and renewable fuels. The fuels we modeled 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).

- Starting from FAR #7, in FAR #12 we will assess 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 will assess the potential impacts of a long-term phase-in of BEVs. We will model 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 will model 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 propose to model BEV replacement for only LD units. *Table 12* shows the expected timeline of BEV types and some examples of original equipment manufacturers (OEMs) currently producing or expected to produce these vehicles.

Table 12: 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, 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

Table 13: City of Brampton – Proposed Low-Carbon Fleet Scenarios

FAR Scenario No.	Year of Implementation	Solution	Notes
1	2020	Baseline BAU	
2	2021	Optimized Lifecycles (all units)	Optimized via LCA
3	2021	Balanced Capex and Optimized Lifecycles (all units)	Balanced year-over-year based on LCA and ROI to year 2035; All subsequent models build on FAR 3
4	2021	Enhanced specs: light-weighting, LRR (all units)	
5	2021	Driver behaviours: eco-training & anti-idling policy/technologies (all units)	
6	2021	TDM: route planning/optimization & trip reduction (all units)	
7	2021	All house-in-order strategies (all of solutions 3, 4, 5 & 6) (all units)	All subsequent models build on FAR 7
8	2021	Fuel Switch: E85 (all flex-fuel units)	
9	2021	Fuel Switch: B10 (annualized blend – all diesel on-road units)	
10	2021	Fuel Switch: CNG LMHD (all applicable units)	Annual vehicle cost to include shared capital cost for one CNG fast refueller system costing $1.68m per 50 CNG units
11	2021	Fuel Switch: LPG LMHD (all applicable units)	Annual vehicle cost to include shared capital cost for one LPG fast refueller system costing $68k per 50 LPG units
12	2021	Hybrid conversion (Class 3-5 Fire & EMS units only)	Hybrid conversion cost to be $25k per unit with fuel efficiency increase of 25%
13	2021	BEV Phase-in: LD (cars & SUVs only)	Cost for replacement with BEV to be 20% more than ICE vehicle being replaced; Cost of charging infrastructure will be estimated separately (outside of FAR modelling)
	2022	BEV Phase-in: LD (cars, SUVs, pickups, vans only)	
	2023	BEV Phase-in: LD (cars, SUVs, pickups, vans only)	
	2024	BEV Phase-in: LMHD (cars, SUVs, pickups, vans, Class 3 to 8 trucks; Fire & EMS LD only)	
	2025	BEV Phase-in: LMHD (cars, SUVs, pickups, vans, Class 3 to 8 trucks; Fire & EMS LD only)	
	2026	BEV Phase-in: LMHD (cars, SUVs, pickups, vans, Class 3 to 8 trucks; Fire & EMS LD only)	
	2027	BEV Phase-in: LMHD (cars, SUVs, pickups, vans, Class 3 to 8 trucks; Fire & EMS LD only)	
	2028	BEV Phase-in: LMHD (cars, SUVs, pickups, vans, Class 3 to 8 trucks; Fire & EMS LD only)	

	2029	BEV Phase-in: LMHD (cars, SUVs, pickups, vans, Class 3 to 8 trucks; Fire & EMS LD only)	
	2030	BEV Phase-in: LMHD (cars, SUVs, pickups, vans, Class 3 to 8 trucks; Fire & EMS LD only)	
	2031	BEV Phase-in: LMHD (cars, SUVs, pickups, vans, Class 3 to 8 trucks; Fire & EMS LD only)	
	2032	BEV Phase-in: LMHD (cars, SUVs, pickups, vans, Class 3 to 8 trucks; Fire & EMS LD only)	
	2033	BEV Phase-in: LMHD (cars, SUVs, pickups, vans, Class 3 to 8 trucks; Fire & EMS LD only)	
	2034	BEV Phase-in: LMHD (cars, SUVs, pickups, vans, Class 3 to 8 trucks; Fire & EMS LD only)	
	2035	BEV Phase-in: LMHD (cars, SUVs, pickups, vans, Class 3 to 8 trucks; Fire & EMS LD only)	

...

Section 9.0: Overview of Green Fleet Options

Here, we provide an overview for all proposed fuel-reduction solutions to be modelled in Part Two of the City of Brampton's Sustainable Fleet Strategy: Framework and Action Plan Report. More details on all solutions that have been researched by RSI-FC, including the ones presented to the City, can be found in *Appendix D*.

Best Management Practices

Light-Weighting

Lighter vehicles consume less fuel, produce less emissions, and can carry larger payload. However, light-weighting may overstress some vehicles, increasing maintenance demand and lifecycle cost; therefore, fleet must exercise caution before choosing which vehicles to proceed with a light-weighting enhancement.

Low-Rolling Resistance Tires

Rolling resistance is the energy lost from drag and friction of a tire rolling over a surface[32]. The phenomenon is complex, and nearly all operating conditions can affect the final outcome. For heavy trucks, an estimated 15-30% of fuel consumption is used to overcome rolling resistance.

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 and/or auto-inflation systems can help fleets reduce fuel costs. It important to ensure proper tire inflation in conjunction with using LRR tires.

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.

Anti-Idling Policy and Technologies

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

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

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.

There are several idling-reduction technologies available that can aid in idle reduction, including auxiliary power units (APU), stop/start devices, auxiliary cab heaters, battery backup systems, and block heaters/ engine preheaters. Their functionality, potential, and costs vary considerably and are described in *Appendix D* (FAR models a cost of $5,000 for all vehicle categories). To reap the most benefits of any idling-reduction technology, installation should always be accompanied by behavioural solutions of driver training and motivation.

Driver Eco-Training (for all fleets)

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.

Further, driver training can promote good practices while on the road including progressive shifting, anticipating traffic flow, and coasting where possible.

Route Planning/Optimization and Trip Reduction

In addition to enhanced vehicles specifications and improved driver behaviours, fuel consumption and exhaust emissions can be further reduced through route planning/optimization and trip reduction.

Route planning software can be used optimize multi-stop trips. It 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.[33]

Google™ Maps recently announced their mapping/guidance systems will soon feature and advise drivers of the lowest GHG-emission routes to their destinations. By embracing this technology where

[33] Source: https://blog.route4me.com/2020/05/carbon-emissions-reduction-route-optimization-helps-cut-tons-carbon-emissions/

possible/practical in Brampton's fleet, and perhaps combining its use with a corporate policy or directive for employees to minimize their trips where possible, emissions (and costs) could be minimized.

Fuel Switching

E85 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[34].

A higher blend of ethanol, known as E85 (85% ethanol, 15% gas) 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[35]. 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%).

In terms of tailpipe emissions, E85 has a GHG emissions reduction potential of about 30% when compared to the same volume of gasoline[36]. However, E85 contains about 29% less energy than gasoline per unit volume[37]. 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).

Given the significant energy losses per unit volume as compared to gasoline, the lower 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[38].

If E85 is to be considered by the City of Brampton, it may be available at some retail fuel stations and can also potentially be delivered direct-to-vehicle. Alternatively, it could be stored and dispensed

[34] Source: https://afdc.energy.gov/fuels/ethanol_fuel_basics.html
[35] Source: https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-transportation/alternative-fuels/biofuels/ethanol/3493
[36] 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
[37] Source: Department of Energy GREET (Greenhouse gases, Regulated Emissions, and Energy use in Transportation) Model, Jan 20, 2011.
[38] https://afdc.energy.gov/fuels/prices.html

in bulk from an onsite fuelling station, but this would incur additional implementation costs. 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. A pilot-test program is recommended to learn, with certainty, the loss of efficiency impacts of using E85.

Feasibility Considerations

- E85 can be used in flex-fuel ready gasoline vehicles with no further modifications.
- There are no infrastructure costs associated with E85 use if a fuelling station is attended or if E85 is delivered direct-to-vehicle.
- Alternatively, E85 could be stored and dispensed in bulk from an onsite fuelling station, but this would incur additional implementation costs.
- E85 is a cleaner burning fuel than gasoline, thereby reducing air pollution. This can result in cleaner intake valves and fuel injectors, and reduced knocking and pinging[39].
- E85 can improve vehicle performance (acceleration) because of its higher octane content[40].
- 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 offset the higher volume required to achieve the same distance travelled, likely making this solution cost-prohibitive. In-fleet pilot testing is recommended.
- E85 cannot be used in small equipment such as most portable generators and other small engines, so a dedicated fuel tank would be required for exclusive use by flex-fuel capable vehicles only.

Biodiesel

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[41]. Biodiesel is often referred to as fatty acid methyl ester or FAME[42].

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

[39] Source: https://driving.ca/chevrolet/auto-news/news/western-canadas-first-e85-ethanol-gas-station-ready-to-pump
[40] Source: https://www.canadianmanufacturing.com/regulation/ethanol-market-chasing-us-canadas-fueling-options-flatline-142054/
[41] Source: https://www.nrcan.gc.ca/energy/alternative-fuels/resources/nrddi/3669
[42] Source: https://www.neste.com/what-difference-between-renewable-diesel-and-traditional-biodiesel-if-any

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).[43]

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.

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[44]. 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[45]. 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. Using biodiesel can also reduce several other tailpipe emissions including particulates and unburned hydrocarbons[46].

Feasibility Considerations

- Blends of B20 and lower can be used in diesel equipment with no modifications, although certain manufacturers do not extend warranty coverage if equipment is damaged by poor quality fuel in these blends (see details in *Appendix E*).
- Since there are no vehicle conversion or infrastructure costs associated with biodiesel use, biodiesel could be immediately introduced to begin reducing fuel-use and emissions.
- Keeping biodiesel to a lower blend (i.e., B5 or B10) will have better cold weather operability properties than a higher blend (i.e., B20 +) due to thickening at low temperatures.
- Although production is abundant, there are a limited number of biodiesel vendors and distributors.
- Due to thickening at low temperatures, 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.

[43] Source: https://www3.epa.gov/region9/waste/biodiesel/questions.html
[44] Source: https://www.fueleconomy.gov/feg/biodiesel.shtml
[45] Source: Department of Energy GREET (Greenhouse gases, Regulated Emissions, and Energy use in Transportation) Model, Jan 20, 2011.
[46] Source: https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-transportation/alternative-fuels/biofuels/biodiesel/3509

- Biodiesel is as safe in handling and storage as petroleum-based diesel fuel.

Natural Gas

Natural gas (NG), a fossil fuel composed of mostly methane, is one of the cleanest burning alternative fuels. It is also considered 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, buses, 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[47].

CNG has a higher energy content per unit mass than diesel but requires more storage space because it is less dense[48]. Unlike diesel, which is stored in liquid form, CNG is stored as a gas under high pressure. For this reason, the energy density and cost of natural gas is usually provided per unit mass (kg) instead of per unit volume (litres).

To compare energy on an apples-to-apples basis, we must look at the amount of natural gas required to obtain the same energy content as a litre of diesel, also known as the diesel-litre equivalent (DLE). The DLE of one kilogram of natural gas is 1.462 litres[49]. We can also understand this concept through the inverse relationship – 0.684 kg of natural gas are required to get the same energy content as one litre of diesel. However, a natural gas engine uses about 12% more natural gas than a comparably-sized diesel engine[50]. Therefore, the actual amount of natural gas required to obtain the same energy content as one litre of diesel is an estimated 0.77 kg.

Based on the same work performed and confirmed through the above analysis, a CNG vehicle has tailpipe emissions about 20-30% less than a comparable diesel or gasoline vehicle[51,52]. NGVs also

[47] 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.
[48] Source: https://www.eia.gov/todayinenergy/detail.php?id=9991
[49] Source: http://cngva.org/wp-content/uploads/2017/12/Energy-Content-Factsheet-FINAL-EN.pdf
[50] Source: http://cngva.org/wp-content/uploads/2017/12/Energy-Content-Factsheet-FINAL-EN.pdf
[51] Source: https://brc.it/en/categorie_faq/cng/
[52] Source: https://envoyenergy.ca/cng-benefits/#:~:text=Commercial%20fleets%20all%20over%20the,solution%20for%20fuelling%20their%20fleets.

emit up to 95% less nitrogen oxides (NO_x) compared to diesel and gasoline vehicles[53]. Furthermore, CNG vehicles do not emit particulate matter (PM10), a main cause of air pollution[54].

Feasibility Considerations

- New NGVs for Class 5-8 vehicles may cost up to $50,000 ($45,000 modelled in FAR) more than their conventional diesel counterparts; therefore, the payback period may be substantial for lower mileage units.
- New NGVs for light-duty vehicles (LDVs) may cost up to $10,000 ($7,500 modelled in FAR) more than their conventional gasoline counterparts. In this case, depending on kilometres-travelled, the payback period may still be substantial.
- CNG fast-filling station infrastructure costs could run to $1m CAD or much more, ($1.68m modelled in FAR) depending on capacities and complexity, and this may be a conservative estimate. Slow-fill refuellers may be an option, but caution must be exercised to ensure protracted filling time does not create operational challenges.
- An operational concern is that in certain situations, such as a long-duration 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 risk that must be managed.
- Unless subsidies were available to offset the cost, a major investment in an NG fueling system would need to be a long-term capital investment for it to be financially viable.
- CNG is still a non-renewable fossil fuel (albeit a clean-burning one).
- CNG may be a viable short-term solution for GHG reduction while awaiting suitable BEVs to become available. However, a *long-term investment* in very costly CNG fuelling infrastructure to support a *short-term GHG reduction solution* may not be a prudent choice.

Renewable Natural Gas

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 CNG or 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 —

[53] Source: Northwest Gas Association – Natural Gas Facts
[54] Source: https://brc.it/en/categorie_faq/cng/

anything from crop residues and animal manures to municipal organic wastes and food processing by-products.

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; different sources estimate the lifecycle emissions 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[55].

Feasibility Considerations

- Without the commercial availability of RNG, there must be investment in an anaerobic digester to make RNG, adding to the already large cost of $1m or much more to build a CNG fuelling station and the significant additional cost of vehicle retrofits and/or new vehicle upgrades to CNG. Moreover, the quality of the RNG must be ensured to be of high enough standard to be used in natural gas-powered vehicles.

- 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)[56]. Therefore, in many situations the use of RNG may not be a financially viable option. In terms of tailpipe emissions, RNG and NG have the same impacts. *With these facts in mind, we present this solution descriptively, but do not propose to model this solution for the City of Brampton as the implementation of RNG would result in the same tailpipe GHG reduction as NG but cost more than the status quo with gasoline- and diesel-powered units.*

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.

[55] Source: Closing the Loop. Canadian Biogas Association. 2015.
[56] Source: https://www.canadianmanufacturing.com/regulation/ethanol-market-chasing-us-canadas-fueling-options-flatline-142054/

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%[57] 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.

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).

Feasibility Considerations

- Propane vehicle conversions and fueling systems generally cost much less than natural gas systems, modelled at $6,000 and $68,000, respectively, in FAR. Depending on kilometres-travelled, the payback – and the payback period – may still be substantial.

Hybrid-Electric Vehicles

Hybrid Electric Vehicles (HEVs) use two or more distinct types of power, such as an internal combustion engine (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. [58]

Plug-In Hybrid Electric Vehicles (PHEVs) 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 HEVs. 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.[59]

---

[57] Source: Department of Energy GREET (Greenhouse gases, Regulated Emissions, and Energy use in Transportation) Model, Jan 20, 2011.
[58] Source: https://www.autotrader.ca/newsfeatures/20180410/types-of-electric-vehicles-explained/
[59] Source: https://www.autotrader.ca/newsfeatures/20180410/types-of-electric-vehicles-explained/

Feasibility Considerations

- Given the combination of an internal combustion engine (ICE) and a battery-powered electric motor in HEVs, there is little or no preparation required ahead of acquiring these vehicles.

- PHEVs may be plugged into a level one or two charger (120 V outlet or 240 V outlet, respectively), with the later achieving a much faster charging speed. However, if a charger is not readily available, the ICE will allow the vehicles to act as regular hybrids, eliminating any range anxiety.

Battery-Electric Vehicles

Globally, vehicles are steadily moving away from the internal combustion engine toward zero-emission battery-electric vehicles (BEVs) and, potentially, hydrogen fuel cells for some use cases (such as long-haul trucking).

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 fleet. As the world's urban population continues to grow, identifying sustainable, cost-effective transport options is becoming more critical. Battery-electric vehicles (BEVs) are one of the most promising ways of reducing harmful emissions and improving overall air quality in cities.

Fleet managers who operate BEVs will see 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, do not require 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.

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[60].

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.

Upstream Emissions

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 zero emission vehicles (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 > 50% less GHG emissions than their gasoline or diesel counterparts[61], and in some cases emit over 80% less in a grid composed of mostly renewable electricity[62]. 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.

Battery-Electric Light-Duty Vehicles

There are multiple light-duty cars and SUVs currently on the market; current examples include the Nissan Leaf, Chevrolet Bolt, Kia Soul, and the Tesla Model 3. All with sufficient range for fulfilling daily duties, these vehicles have demonstrated that electrification is not only possible, but also convenient and within an acceptable and affordable price range, particularly when considering fuel and maintenance over the vehicle's lifetime.

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

[60] Source: https://www.autotrader.ca/newsfeatures/20180410/types-of-electric-vehicles-explained/
[61] Source: https://www.eei.org/issuesandpolicy/electrictransportation/Pages/default.aspx
[62] Source: https://blog.ucsusa.org/rachael-nealer/gasoline-vs-electric-global-warming-emissions-953

Battery-Electric Trucks

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.

A new study[63] quantified what commercial EV-makers have been saying for years: electric trucks 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 a significant 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 2030 or earlier, electric vehicles will offer a lower total cost of ownership (TCO) for nearly all truck and bus classes, even without incentives.

Medium- and heavy-duty battery-electric trucks are quickly being developed by many manufacturers. BETs offer a multitude of benefits, including:

- Less noise pollution
- Zero tailpipe GHG emissions
- Oil-free operation with very few moving parts
- Simple, low-maintenance electric powertrain with few components
- Longer lasting brakes due to regenerative braking system
- Potential to significantly extend range due to high regenerative braking from carrying heavy loads[64]. The heavier the truck load, the greater the energy produced from regenerative braking.
- Overnight recharging when the vehicle is not in operation and when demand for electricity is lower, which reduces energy costs
- Massive savings potential in total energy costs and service costs

[63] 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/)

[64] Source: https://www.firstpost.com/tech/science/worlds-largest-electric-vehicle-is-a-110-tonne-dump-truck-that-needs-no-charging-7190131.html

- Competitive lifecycle costs over a 10-year operating life and are better suited over gasoline, diesel, or CNG when accounting for future economic trends

Battery-Electric Refuse Trucks

There is an existing and growing market for electric refuse trucks. Several manufacturers have battery-electric refuse trucks on the market (e.g., Volvo, Mack, BYD, Lion Electric), while other companies have converted existing refuse trucks to battery-electric (e.g., Motiv, Emoss). In additional to the benefits previously listed for battery-electric trucks at large, battery-electric refuse trucks offer:

- Range up to and exceeding 200 km[65] for a full day of operation (1,200 homes) on a charge
- Optimal visibility and turning radius
- No hydraulic pumps, valves, tubing, hoses, and fluid
- Arm and body movements powered by battery that drives electric motors for each function
- Savings of up to 80% on total energy costs and up to 60% on service costs

Diesel and CNG refuse trucks require much more input energy to achieve the required outcome relative to electric refuse trucks. Diesel and CNG refuse trucks are approximately 5 and 5.8 times less efficient than battery-electric refuse trucks, respectively, while hydrogen fuel cell electric trucks are approximately 1.8 times less efficient. This is because:

- Internal combustion engines (ICEs) are much less efficient than electric motors in converting input energy to output motion.
- ICEs use energy when the truck is idling, coasting or braking. Electric motors not only don't use energy during these operations, they can act as a generator when coasting or braking, generating energy in a process known as regenerative braking.
- The heavier the refuse truck load, the greater the energy produced from regenerative braking. Depending on the topography of the collection zone, an optimized route can be analysed to further increase the energy efficiency of electric refuse trucks.

[65] Source: https://electrek.co/2018/05/09/volvo-all-electric-garbage-truck/

Feasibility Considerations

- DC fast charging installation requires a commercial electrician[66] and costs an estimated $50,000 - $200,000 for equipment and installation[67].
- Overnight charging infrastructure may be more feasible than in-route charging infrastructure if there is limited-service amperage[68].
- Heavy-duty trucks charged in a garage between 50 and 100 kW (equivalent to DC fast charging) would potentially take several hours to charge[69]. Caution must be exercised to ensure longer charging times do not create operational challenges.
- Extreme cold temperatures can significantly reduce range in BEVs due to heating of the cabin and heating of the battery itself[70]. Therefore, it is important account for this when purchasing BEVs to ensure sufficient range is provided to cover a day's worth of routes in the heart of winter.
- Power grid failure or local failure at a garage could pose a significant risk to operations. To mitigate this risk, backup generators can deal with short power outages. For longer outages, larger generators would be needed, but this would come at a very expensive cost. [71]

...

[66] Source: https://calevip.org/electric-vehicle-charging-101
[67] Source: https://www.toronto.ca/wp-content/uploads/2020/02/8c46-City-of-Toronto-Electric-Vehicle-Strategy.pdf
[68] Source: https://www.masstransitmag.com/home/article/12291796/bus-electrification-choosing-the-right-charging-method
[69] Source: https://www.plugincanada.ca/electric-bus-faq/
[70] Source: https://www.geotab.com/blog/ev-range/
[71] Source: https://www.plugincanada.ca/electric-bus-faq/

Section 10.0: Discussion and Next Steps

This Sustainable Fleet Strategy: Baseline Review and Analysis Report, presents:

a) The City of Brampton's near current-day fleet baseline determined by the 2019 review period;
b) Modelling results for long-term capital planning (LTCP) based on optimal replacement cycles and return-on-investment (ROI); and
c) A range of fuel-reduction solutions for the City's future consideration.

This report is intended to support Part Two of the Sustainable Fleet Strategy – Framework and Action Plan Report – in line with the City of Brampton's GHG emissions reduction targets.

Fleet Baseline & Lifecycle Optimization

We have completed the Background Review and Analysis using a specialized software tool that was developed by RSI-FC, which is referred to as the Fleet Analytics Review™ (FAR). Fleet baseline data were analyzed using FAR, and lifecycle analysis (LCA) was performed using a complementary software tool to determine optimal replacement cycles for vehicle categories. Here are the main takeaways for the City of Brampton's consideration:

Baseline Analysis Takeaways

Fleet Services

- Class 3, 5, and 8 units are comparatively older than other classes (as well as municipal peers except for Class 5) and account for a significant proportion of the total fleet; therefore, these classes are potential areas of focus in terms of extending lifecycles where possible and switching to battery-electric in the short- to mid-term as battery-electric vehicle (BEV) and battery-electric truck (BET) replacement models become available.

- Class 8 units have a significantly lower fuel economy, higher emissions intensity, and higher costs per kilometre than Class 8 units from municipal peers, highlighting a potential area of focus for interim solutions such as light-weighting and low-rolling resistance (LRR) tires for appropriate units while awaiting the arrival of BET replacement models.

Fire & EMS

- Class 1 and 2 units comprise the largest portion of the fleet. Class 1 units, which are on average almost two years older than Class 2 units, and all of which are hatchbacks and sedans, are prime candidates for switching to battery-electric when due for replacement in the short-term phase of our proposed low-carbon fleet plan, as these vehicle types are currently available as BEVs.

- Overall, Brampton's Fire & EMS fleet is performing well in comparison to municipal peers with the exception of age; units of classes 3 and up are substantially older than average peer ages, highlighting modernization (i.e. investing in new medium- and heady-duty vehicles) as a potential area of focus.

Transit

- Class 1 units comprise the largest portion of the fleet, and most of these units are sedan rentals. A potential area of focus in the go-forward analysis phase of the Sustainable Fleet Strategy (Part Two: Framework and Action Plan Report) is to determine the cost-effectiveness of replacing these gas-powered rental units by purchasing battery-electric units, as these vehicle types are currently available as BEVs. Given the reduced operating expenses of BEVs and the higher capital costs of rental units, purchasing BEVs may be more cost-effective.

Peer Fleet Comparison

- When compared to benchmark values, the area and population ratios suggest that Brampton's overall fleet (all three fleets combined) is relatively large for its area and population. This result is supported by the relatively low utilization (i.e., km travelled) in much of Brampton's fleet, particularly in Fleet Services. Our recommendation is that the City consider downsizing its fleet by examining underutilized units and stranded assets.

Lifecycle Optimization Takeaways

- Based on business-as-usual (BAU) replacement practices, it was estimated that, in 2021, $28.3 million would be required to replace all due or past-due units with new like-for-like vehicles (no BEVs at this stage). It should be noted that numerous vehicles in the Brampton fleet are beyond the current planned age for replacement – *based on current-day lifecycles, significant "catch-up" would be required to modernize the fleet with like-for-like vehicles.* In ensuing years, far fewer vehicles require replacement, bringing down capital spending to between $3.5 and $4.9 million in the following three fiscal years (2022-2024). However, there is an uneven capital spend projected in following years. In the hypothetical event that all vehicles due for replacement in 2021 are indeed replaced, Opex is estimated to decrease by about $816,000 and GHG emissions are estimated to decrease by about 27 tonnes CO_2e (less than 1% of total emissions) due to the increased fuel efficiency of newer vehicles.

- Based on optimized economic lifecycles, it was estimated that, in 2021, $25.7 million would be required to replace all due or past-due units with new like-for-like vehicles (no BEVs at this stage), which is significantly less than present-day replacement practices. Like BAU, there is an uneven capital spend projected in following years.

- Based on optimized economic lifecycles, we selectively and strategically made 1,103 deferrals over the 15-year budget cycle to maximize Opex benefits, or return-on-investment (ROI). This resulted in a much more balanced Capex over the 15-years than BAU and optimized lifecycle-only scenarios. The annual capital budget ranged from $2.8-11.5 million as compared to the BAU range of $1.9-28.3 million over the budget period, with a lot more clustering around $7-8 million.

Proposed Low-Carbon Fleet Plan

We are proposing a 15-year low-carbon fleet plan for the City of Brampton involving various immediate and/or interim fuel-reduction solutions and a battery-electric vehicle (BEV) phase-in to 2036, as this is the most effective long-term GHG-reduction strategy for a fleet as battery-electric technology continues to advance. Using balanced Capex and optimized lifecycles, our approach is 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.

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 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 outside the scope of this report) are also available for purchase now.

A phased-in approach is recommended for 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 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 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. However, we are proposing to include this option in our modelling in an effort to provide the City of Brampton with a complete analysis of all potential fuel-reduction solutions.

Next Steps

The Background Review and Analysis is Part One of Brampton’s Sustainable Fleet Strategy, setting the foundation for Part Two: Framework and Action Plan Report, for which RSI-FC will model a wide range of fuel-reduction solutions to assist the City in achieving its Corporate GHG-reduction goals.

The data provided by the City of Brampton has been carefully analyzed to inform the baseline and lifecycle analyses. The next steps, involving the development of a green fleet plan, are now underway through RSI-FC’s proposed FAR scenario analyses for various fuel-reduction solutions, with an emphasis on BEV phase-in to achieve deep GHG-emissions reductions.

...

Appendix A: Green Fleet Survey Results

Awareness of Environmental Issues

Figure 8: Views on Brampton's climate change emergency declaration – Fleet Services management

* In June 2020, the City of Brampton declared a climate emergency, joining the Government of Canada and more than 400 other Canadian municipalities that have done the same. Most of these organizations are implementing programs and initiatives to reduce their greenhouse gas (GHG) emissions. Please choose the option below that best reflects your view:

Answer	0% 100%	Number of Response(s)	Response Ratio
I agree there is a climate emergency		5	31.2 %
I support the City of Brampton's climate emergency declaration		8	50.0 %
I do not agree there is a climate emergency		1	6.2 %
I do not support the City of Brampton's climate emergency declaration		1	6.2 %
I need more information about the City of Brampton's climate emergency declaration		1	6.2 %
I am undecided about this matter		0	0.0 %
This issue does not matter to me		0	0.0 %
Other		0	0.0 %
No Response(s)		0	0.0 %
	Totals	16	100%

Figure 9: Views on Brampton's climate change emergency declaration – Fleet Services staff

* In June 2020, the City of Brampton declared a climate emergency, joining the Government of Canada and more than 400 other Canadian municipalities that have done the same. Most of these organizations are implementing programs and initiatives to reduce their greenhouse gas (GHG) emissions. Please choose the option below that best reflects your view:

Answer	0% 100%	Number of Response(s)	Response Ratio
I agree there is a climate emergency		8	29.6 %
I support the City of Brampton's climate emergency declaration		14	51.8 %
I do not agree there is a climate emergency		0	0.0 %
I do not support the City of Brampton's climate emergency declaration		0	0.0 %
I need more information about the City of Brampton's climate emergency declaration		0	0.0 %
I am undecided about this matter		5	18.5 %
This issue does not matter to me		0	0.0 %
Other		0	0.0 %
No Response(s)		0	0.0 %
	Totals	27	100%

Figure 10: Views on Brampton's climate change emergency declaration – Transit management

* In June 2020, the City of Brampton declared a climate emergency, joining the Government of Canada and more than 400 other Canadian municipalities that have done the same. Most of these organizations are implementing programs and initiatives to reduce their greenhouse gas (GHG) emissions. Please choose the option below that best reflects your view:

Answer	0% 100%	Number of Response(s)	Response Ratio
I agree there is a climate emergency		1	16.6 %
I support the City of Brampton's climate emergency declaration		4	66.6 %
I do not agree there is a climate emergency		1	16.6 %
I do not support the City of Brampton's climate emergency declaration		0	0.0 %
I need more information about the City of Brampton's climate emergency declaration		0	0.0 %
I am undecided about this matter		0	0.0 %
This issue does not matter to me		0	0.0 %
Other		0	0.0 %
No Response(s)		0	0.0 %
	Totals	6	100%

Figure 11: Views on Brampton's climate change emergency declaration – Transit staff

* In June 2020, the City of Brampton declared a climate emergency, joining the Government of Canada and more than 400 other Canadian municipalities that have done the same. Most of these organizations are implementing programs and initiatives to reduce their greenhouse gas (GHG) emissions. Please choose the option below that best reflects your view:

Answer	0% 100%	Number of Response(s)	Response Ratio
I agree there is a climate emergency		1	16.6 %
I support the City of Brampton's climate emergency declaration		2	33.3 %
I do not agree there is a climate emergency		0	0.0 %
I do not support the City of Brampton's climate emergency declaration		0	0.0 %
I need more information about the City of Brampton's climate emergency declaration		2	33.3 %
I am undecided about this matter		1	16.6 %
This issue does not matter to me		0	0.0 %
Other		0	0.0 %
No Response(s)		0	0.0 %
	Totals	6	100%

Figure 12: Views on Brampton's climate change emergency declaration – Fire & EMS

* In June 2020, the City of Brampton declared a climate emergency, joining the Government of Canada and more than 400 other Canadian municipalities that have done the same. Most of these organizations are implementing programs and initiatives to reduce their greenhouse gas (GHG) emissions. Please choose the option below that best reflects your view:

Answer	0% – 100%	Number of Response(s)	Response Ratio
I agree there is a climate emergency		2	50.0 %
I support the City of Brampton's climate emergency declaration		1	25.0 %
I do not agree there is a climate emergency		0	0.0 %
I do not support the City of Brampton's climate emergency declaration		0	0.0 %
I need more information about the City of Brampton's climate emergency declaration		0	0.0 %
I am undecided about this matter		1	25.0 %
This issue does not matter to me		0	0.0 %
Other		0	0.0 %
No Response(s)		0	0.0 %
	Totals	4	100%

Figure 13: Ranking of environmental problems – Fleet Services management

* Which of the following do you feel are the biggest problems facing our environment? Please rate the following from 1 (smallest) to 6 (biggest):

1 = Smallest

Answer	1 – 6	Number of Response(s)	Ranking Score*
Toxic waste		16	2.6
Water pollution		16	4.2
Air pollution (ground level smog)		16	4.4
Climate change caused by greenhouse gas emissions		16	4.5
Noise pollution		16	1.7
Loss of biodiversity		16	3.6

*The Ranking Score is the weighted average calculated by dividing the sum of all weighted rankings by the number of total responses.

Figure 14: Ranking of environmental problems – Fleet Services staff

*Which of the following do you feel are the biggest problems facing our environment? Please rate the following from 1 (smallest) to 6 (biggest):

1 = Smallest

Answer	Number of Response(s)	Ranking Score*
Toxic waste	26	3.1
Water pollution	26	4.0
Air pollution (ground level smog)	26	4.2
Climate change caused by greenhouse gas emissions	26	4.2
Noise pollution	26	2.1
Loss of biodiversity	26	3.3

*The Ranking Score is the weighted average calculated by dividing the sum of all weighted rankings by the number of total responses.

Figure 15: Ranking of environmental problems – Transit management

*Which of the following do you feel are the biggest problems facing our environment? Please rank the following from 1 (smallest) to 6 (biggest):

1 = Smallest

Answer	Number of Response(s)	Ranking Score*
Toxic waste	5	3.2
Water pollution	5	4.4
Air pollution (ground level smog)	5	3.4
Climate change caused by greenhouse gas emissions	5	4.0
Noise pollution	5	2.2
Loss of biodiversity	5	3.8

*The Ranking Score is the weighted average calculated by dividing the sum of all weighted rankings by the number of total responses.

Figure 16: Ranking of environmental problems – Transit staff

*Which of the following do you feel are the biggest problems facing our environment? Please rank the following from 1 (smallest) to 6 (biggest):

1 = Smallest

Answer	Number of Response(s)	Ranking Score*
Toxic waste	6	4.0
Water pollution	6	4.0
Air pollution (ground level smog)	6	4.0
Climate change caused by greenhouse gas emissions	6	3.3
Noise pollution	6	3.2
Loss of biodiversity	6	2.5

*The Ranking Score is the weighted average calculated by dividing the sum of all weighted rankings by the number of total responses.

Figure 17: Ranking of environmental problems – Fire & EMS

*Which of the following do you feel are the biggest problems facing our environment? Please rank the following from 1 (smallest) to 6 (biggest):

1 = Smallest

Answer	Number of Response(s)	Ranking Score*
Toxic waste	4	2.2
Water pollution	4	4.5
Air pollution (ground level smog)	4	5.2
Climate change caused by greenhouse gas emissions	4	5.2
Noise pollution	4	1.5
Loss of biodiversity	4	2.2

*The Ranking Score is the weighted average calculated by dividing the sum of all weighted rankings by the number of total responses.

Views on Fleet Pollution Factors

Figure 18: Views on fleet pollution factors – Fleet Services management

*Thinking of pollution caused by fleet vehicles, what are your thoughts on the impacts of each of the following (low to high impact)?

1 = Very low impact, 2 = Low impact, 3 = Unsure/undecided, 4 = Has an impact, 5 = Has a big impact

Answer	Number of Response(s)	Rating Score*
The age of fleet vehicles	16	3.9
The types of fuel used	16	4.1
Maintenance of fleet vehicles	16	3.9
The driving habits of vehicle operators	16	3.8
Fleet vehicles that are over-sized for job requirements	16	3.7
Unnecessary trips in fleet vehicles	16	3.4
Routes that are not planned in a way to reduce distance	16	3.4

*The Rating Score is the weighted average calculated by dividing the sum of all weighted ratings by the number of total responses.

Figure 19: View on fleet pollution factors – Fleet Services staff

*Thinking of pollution caused by fleet vehicles, what are your thoughts on the impacts of each of the following (low to high impact)?

1 = Very low impact, 2 = Low impact, 3 = Unsure/undecided, 4 = Has an impact, 5 = Has a big impact

Answer	Number of Response(s)	Rating Score*
The age of fleet vehicles	27	3.9
The types of fuel used	27	4.2
Maintenance of fleet vehicles	27	3.5
The driving habits of vehicle operators	27	3.6
Fleet vehicles that are over-sized for job requirements	27	3.4
Unnecessary trips in fleet vehicles	27	3.9
Routes that are not planned in a way to reduce distance	27	3.4

*The Rating Score is the weighted average calculated by dividing the sum of all weighted ratings by the number of total responses.

Figure 20: Views on fleet pollution factors – Transit management

*Thinking of pollution caused by fleet vehicles, what are your thoughts on the impacts of each of the following (low to high impact)?

1 = Very low impact, 2 = Low impact, 3 = Unsure/undecided, 4 = Has an impact, 5 = Has a big impact

Answer	Number of Response(s)	Rating Score*
The age of fleet vehicles	5	3.6
The types of fuel used	5	4.0
Maintenance of fleet vehicles	5	3.4
The driving habits of vehicle operators	5	3.4
Fleet vehicles that are over-sized for job requirements	5	3.6
Unnecessary trips in fleet vehicles	5	4.0
Routes that are not planned in a way to reduce distance	5	4.0

*The Rating Score is the weighted average calculated by dividing the sum of all weighted ratings by the number of total responses.

Figure 21: Views on fleet pollution factors – Transit staff

*Thinking of pollution caused by fleet vehicles, what are your thoughts on the impacts of each of the following (low to high impact)?

1 = Very low impact, 2 = Low impact, 3 = Unsure/undecided, 4 = Has an impact, 5 = Has a big impact

Answer	Number of Response(s)	Rating Score*
The age of fleet vehicles	6	3.7
The types of fuel used	6	3.7
Maintenance of fleet vehicles	6	4.0
The driving habits of vehicle operators	6	4.5
Fleet vehicles that are over-sized for job requirements	6	4.2
Unnecessary trips in fleet vehicles	6	4.2
Routes that are not planned in a way to reduce distance	6	3.8

*The Rating Score is the weighted average calculated by dividing the sum of all weighted ratings by the number of total responses.

Figure 22: Views on fleet pollution factors – Fire & EMS

*Thinking of pollution caused by fleet vehicles, what are your thoughts on the impacts of each of the following (low to high impact)?

1 = Very low impact, 2 = Low impact, 3 = Unsure/undecided, 4 = Has an impact, 5 = Has a big impact

Answer	Number of Response(s)	Rating Score*
The age of fleet vehicles	4	4.8
The types of fuel used	4	4.0
Maintenance of fleet vehicles	4	4.0
The driving habits of vehicle operators	4	4.2
Fleet vehicles that are over-sized for job requirements	4	4.0
Unnecessary trips in fleet vehicles	4	4.2
Routes that are not planned in a way to reduce distance	4	4.0

*The Rating Score is the weighted average calculated by dividing the sum of all weighted ratings by the number of total responses.

Views on Alternate Fuels

Figure 23: Views on natural gas- and propane-powered vehicles – Fleet Services management

*Natural gas and propane are gaseous vehicle fuels that produce less GHG emissions than gasoline and diesel. Based on your current knowledge/perspective of vehicles powered by these fuels, please rate your level of agreement on the statements below:

1 = Strongly disagree, 2 = Disagree, 3 = Unsure/undecided, 4 = Agree, 5 = Strongly agree

Answer	Number of Response(s)	Rating Score*
I am familiar with natural gas powered vehicles	16	3.6
I am familiar with propane powered vehicles	16	3.5
Natural gas powered vehicles are more economical to drive	16	3.4
Propane powered vehicles are more economical to drive	16	3.6
Natural gas powered vehicles are reliable	16	3.2
Propane powered vehicles are reliable	16	3.1
Natural gas powered vehicles are safe to drive	16	3.6
Propane powered vehicles are safe to drive	16	3.5

*The Rating Score is the weighted average calculated by dividing the sum of all weighted ratings by the number of total responses.

Figure 24: Views on natural gas- and propane-powered vehicles – Fleet Services staff

*Natural gas and propane are gaseous vehicle fuels that produce less GHG emissions than gasoline and diesel. Based on your current knowledge/perspective of vehicles powered by these fuels, please rate your level of agreement on the statements below:

1 = Strongly disagree, 2 = Disagree, 3 = Unsure/undecided, 4 = Agree, 5 = Strongly agree

Answer	Number of Response(s)	Rating Score*
I am familiar with natural gas powered vehicles	27	3.5
I am familiar with propane powered vehicles	27	3.7
Natural gas powered vehicles are more economical to drive	27	3.4
Propane powered vehicles are more economical to drive	27	3.1
Natural gas powered vehicles are reliable	27	3.1
Propane powered vehicles are reliable	27	3.0
Natural gas powered vehicles are safe to drive	27	3.5
Propane powered vehicles are safe to drive	27	3.4

*The Rating Score is the weighted average calculated by dividing the sum of all weighted ratings by the number of total responses.

Figure 25: Views on natural gas- and propane-powered vehicles – Transit management

* Natural gas and propane are gaseous vehicle fuels that produce less GHG emissions than gasoline and diesel. Based on your current knowledge/perspective of vehicles powered by these fuels, please rate your level of agreement on the statements below:

1 = Strongly disagree, 2 = Disagree, 3 = Unsure/undecided, 4 = Agree, 5 = Strongly agree

Answer	Number of Response(s)	Rating Score*
I am familiar with natural gas powered vehicles	6	3.8
I am familiar with propane powered vehicles	6	3.7
Natural gas powered vehicles are more economical to drive	6	3.3
Propane powered vehicles are more economical to drive	6	2.8
Natural gas powered vehicles are reliable	6	2.8
Propane powered vehicles are reliable	6	2.5
Natural gas powered vehicles are safe to drive	6	3.5
Propane powered vehicles are safe to drive	6	3.3

*The Rating Score is the weighted average calculated by dividing the sum of all weighted ratings by the number of total responses.

Figure 26: Views on natural gas- and propane-powered vehicles – Transit staff

* Natural gas and propane are gaseous vehicle fuels that produce less GHG emissions than gasoline and diesel. Based on your current knowledge/perspective of vehicles powered by these fuels, please rate your level of agreement on the statements below:

1 = Strongly disagree, 2 = Disagree, 3 = Unsure/undecided, 4 = Agree, 5 = Strongly agree

Answer	Number of Response(s)	Rating Score*
I am familiar with natural gas powered vehicles	6	4.0
I am familiar with propane powered vehicles	6	4.3
Natural gas powered vehicles are more economical to drive	6	3.5
Propane powered vehicles are more economical to drive	6	3.3
Natural gas powered vehicles are reliable	6	2.8
Propane powered vehicles are reliable	6	3.3
Natural gas powered vehicles are safe to drive	6	3.2
Propane powered vehicles are safe to drive	6	3.5

*The Rating Score is the weighted average calculated by dividing the sum of all weighted ratings by the number of total responses.

Figure 27: Views on natural gas- and propane-powered vehicles – Fire & EMS

* Natural gas and propane are gaseous vehicle fuels that produce less GHG emissions than gasoline and diesel. Based on your current knowledge/perspective of vehicles powered by these fuels, please rate your level of agreement on the statements below:

1 = Strongly disagree, 2 = Disagree, 3 = Unsure/undecided, 4 = Agree, 5 = Strongly agree

Answer	Number of Response(s)	Rating Score*
I am familiar with natural gas powered vehicles	4	2.8
I am familiar with propane powered vehicles	4	3.0
Natural gas powered vehicles are more economical to drive	4	3.0
Propane powered vehicles are more economical to drive	4	3.0
Natural gas powered vehicles are reliable	4	2.8
Propane powered vehicles are reliable	4	2.8
Natural gas powered vehicles are safe to drive	4	3.0
Propane powered vehicles are safe to drive	4	3.0

*The Rating Score is the weighted average calculated by dividing the sum of all weighted ratings by the number of total responses.

Views on Renewable Fuels

Figure 28: Views on biodiesel and ethanol as fossil-fuel substitutes – Fleet Services management

* Biodiesel is a renewable substitute for standard diesel that is made from plant matter, such as soybeans, as well as waste vegetable oils. It can be used in various blends with standard diesel to reduce GHG emissions. Ethanol is a renewable substitute for standard gasoline that is made from plant matter such as corn. It can be used in various blends with gasoline (up to 85% for some vehicles) to reduce GHG emissions.Based on your current knowledge/perspective of vehicles powered by these fuels, please rate your level of agreement on the statements below:

1 = Strongly disagree, 2 = Disagree, 3 = Unsure/undecided, 4 = Agree, 5 = Strongly agree

Answer	Number of Response(s)	Rating Score*
I am familiar with vehicles powered by biodiesel	16	3.6
I am familiar with vehicles powered by ethanol	16	3.3
Biodiesel is a direct replacement for standard diesel fuel	16	3.0
Ethanol fuel can be used in most modern vehicles	16	3.4
Biodiesel is a safe fuel for use in vehicles	16	3.6
Ethanol is a safe fuel for use in vehicles	16	3.6
Biodiesel makes engines last longer because it provides better lubrication	16	2.8
Using ethanol can result in cleaner intake valves and fuel injectors, and reduced knocking and pinging	16	3.1
I oppose plant-based fuels because they are sometimes made from food crops	16	2.5

*The Rating Score is the weighted average calculated by dividing the sum of all weighted ratings by the number of total responses.

Figure 29: Views on biodiesel and ethanol as fossil-fuel substitutes – Fleet Services staff

* Biodiesel is a renewable substitute for standard diesel that is made from plant matter, such as soybeans, as well as waste vegetable oils. It can be used in various blends with standard diesel to reduce GHG emissions. Ethanol is a renewable substitute for standard gasoline that is made from plant matter such as corn. It can be used in various blends with gasoline (up to 85% for some vehicles) to reduce GHG emissions.Based on your current knowledge/perspective of vehicles powered by these fuels, please rate your level of agreement on the statements below:

1 = Strongly disagree, 2 = Disagree, 3 = Unsure/undecided, 4 = Agree, 5 = Strongly agree

Answer	Number of Response(s)	Rating Score*
I am familiar with vehicles powered by biodiesel	27	4.1
I am familiar with vehicles powered by ethanol	27	3.6
Biodiesel is a direct replacement for standard diesel fuel	27	3.7
Ethanol fuel can be used in most modern vehicles	27	3.4
Biodiesel is a safe fuel for use in vehicles	27	3.8
Ethanol is a safe fuel for use in vehicles	27	3.4
Biodiesel makes engines last longer because it provides better lubrication	27	2.9
Using ethanol can result in cleaner intake valves and fuel injectors, and reduced knocking and pinging	27	3.3
I oppose plant-based fuels because they are sometimes made from food crops	27	3.1

*The Rating Score is the weighted average calculated by dividing the sum of all weighted ratings by the number of total responses.

Figure 30: Views on biodiesel and ethanol as fossil-fuel substitutes – Transit management

* Biodiesel is a renewable substitute for standard diesel that is made from plant matter, such as soybeans, as well as waste vegetable oils. It can be used in various blends with standard diesel to reduce GHG emissions. Ethanol is a renewable substitute for standard gasoline that is made from plant matter such as corn. It can be used in various blends with gasoline (up to 85% for some vehicles) to reduce GHG emissions.Based on your current knowledge/perspective of vehicles powered by these fuels, please rate your level of agreement on the statements below:

1 = Strongly disagree, 2 = Disagree, 3 = Unsure/undecided, 4 = Agree, 5 = Strongly agree

Answer	Number of Response(s)	Rating Score*
I am familiar with vehicles powered by biodiesel	5	3.6
I am familiar with vehicles powered by ethanol	5	3.0
Biodiesel is a direct replacement for standard diesel fuel	5	2.8
Ethanol fuel can be used in most modern vehicles	5	3.4
Biodiesel is a safe fuel for use in vehicles	5	3.2
Ethanol is a safe fuel for use in vehicles	5	3.4
Biodiesel makes engines last longer because it provides better lubrication	5	3.2
Using ethanol can result in cleaner intake valves and fuel injectors, and reduced knocking and pinging	5	3.2
I oppose plant-based fuels because they are sometimes made from food crops	5	2.2

*The Rating Score is the weighted average calculated by dividing the sum of all weighted ratings by the number of total responses.

Figure 31: Views on biodiesel and ethanol as fossil-fuel substitutes – Transit staff

*Biodiesel is a renewable substitute for standard diesel that is made from plant matter, such as soybeans, as well as waste vegetable oils. It can be used in various blends with standard diesel to reduce GHG emissions. Ethanol is a renewable substitute for standard gasoline that is made from plant matter such as corn. It can be used in various blends with gasoline (up to 85% for some vehicles) to reduce GHG emissions.Based on your current knowledge/perspective of vehicles powered by these fuels, please rate your level of agreement on the statements below:

1 = Strongly disagree, 2 = Disagree, 3 = Unsure/undecided, 4 = Agree, 5 = Strongly agree

Answer	Number of Response(s)	Rating Score*
I am familiar with vehicles powered by biodiesel	6	4.3
I am familiar with vehicles powered by ethanol	6	3.5
Biodiesel is a direct replacement for standard diesel fuel	6	2.2
Ethanol fuel can be used in most modern vehicles	6	2.7
Biodiesel is a safe fuel for use in vehicles	6	2.5
Ethanol is a safe fuel for use in vehicles	6	3.0
Biodiesel makes engines last longer because it provides better lubrication	6	1.8
Using ethanol can result in cleaner intake valves and fuel injectors, and reduced knocking and pinging	6	2.3
I oppose plant-based fuels because they are sometimes made from food crops	6	1.8

*The Rating Score is the weighted average calculated by dividing the sum of all weighted ratings by the number of total responses.

Figure 32: Views on biodiesel and ethanol as fossil-fuel substitutes – Fire & EMS

*Biodiesel is a renewable substitute for standard diesel that is made from plant matter, such as soybeans, as well as waste vegetable oils. It can be used in various blends with standard diesel to reduce GHG emissions. Ethanol is a renewable substitute for standard gasoline that is made from plant matter such as corn. It can be used in various blends with gasoline (up to 85% for some vehicles) to reduce GHG emissions.Based on your current knowledge/perspective of vehicles powered by these fuels, please rate your level of agreement on the statements below:

1 = Strongly disagree, 2 = Disagree, 3 = Unsure/undecided, 4 = Agree, 5 = Strongly agree

Answer	Number of Response(s)	Rating Score*
I am familiar with vehicles powered by biodiesel	4	3.5
I am familiar with vehicles powered by ethanol	4	3.8
Biodiesel is a direct replacement for standard diesel fuel	4	3.0
Ethanol fuel can be used in most modern vehicles	4	3.5
Biodiesel is a safe fuel for use in vehicles	4	3.0
Ethanol is a safe fuel for use in vehicles	4	3.0
Biodiesel makes engines last longer because it provides better lubrication	4	2.8
Using ethanol can result in cleaner intake valves and fuel injectors, and reduced knocking and pinging	4	2.8
I oppose plant-based fuels because they are sometimes made from food crops	4	3.2

*The Rating Score is the weighted average calculated by dividing the sum of all weighted ratings by the number of total responses.

Views on Battery-Electric Vehicles

Figure 33: Views on BEVs – Fleet Services management

There has a been a lot of news lately about zero-emission, battery-electric vehicles. Light-duty electric cars and SUVs, as well as electric buses and refuse trucks, are available now. Light-, medium-, and heavy-duty electric trucks are coming soon. Based on your current knowledge/perspective of electric vehicles, please rate your level of agreement on the statements below: *

1 = Strongly disagree, 2 = Disagree, 3 = Unsure/undecided, 4 = Agree, 5 = Strongly agree

Answer	Number of Response(s)	Rating Score*
Electric vehicles can travel far enough to meet my daily needs and fulfil my job duties	16	4.0
Electric vehicles are powerful enough for my job duties	16	4.1
Electric vehicles are sufficiently warm in the winter and cool in the summer for comfort	16	3.8
Electric vehicles are safe	16	4.1
Electric vehicles cost less to operate and will save money for the City of Brampton	16	3.6
Electric vehicles cause less pollution than standard gas or diesel vehicles	16	3.8
Electric vehicles of the type the City of Brampton requires are available now or in the near future	16	3.5

*The Rating Score is the weighted average calculated by dividing the sum of all weighted ratings by the number of total responses.

Figure 34: Views on BEVs – Fleet Services staff

There has a been a lot of news lately about zero-emission, battery-electric vehicles. Light-duty electric cars and SUVs, as well as electric buses and refuse trucks, are available now. Light-, medium-, and heavy-duty electric trucks are coming soon. Based on your current knowledge/perspective of electric vehicles, please rate your level of agreement on the statements below: *

1 = Strongly disagree, 2 = Disagree, 3 = Unsure/undecided, 4 = Agree, 5 = Strongly agree

Answer	Number of Response(s)	Rating Score*
Electric vehicles can travel far enough to meet my daily needs and fulfil my job duties	27	3.8
Electric vehicles are powerful enough for my job duties	27	3.9
Electric vehicles are sufficiently warm in the winter and cool in the summer for comfort	27	3.7
Electric vehicles are safe	27	4.1
Electric vehicles cost less to operate and will save money for the City of Brampton	27	3.6
Electric vehicles cause less pollution than standard gas or diesel vehicles	27	4.2
Electric vehicles of the type the City of Brampton requires are available now or in the near future	27	4.0

*The Rating Score is the weighted average calculated by dividing the sum of all weighted ratings by the number of total responses.

Figure 35: Views on BEVs – Transit management

* There has a been a lot of news lately about zero-emission, battery-electric vehicles. Light-duty electric cars and SUVs, as well as electric buses and refuse trucks, are available now. Light-, medium-, and heavy-duty electric trucks are coming soon. Based on your current knowledge/perspective of electric vehicles, please rate your level of agreement on the statements below:

1 = Strongly disagree, 2 = Disagree, 3 = Unsure/undecided, 4 = Agree, 5 = Strongly agree

Answer	Number of Response(s)	Rating Score*
Electric vehicles can travel far enough to meet my daily needs and fulfil my job duties	6	3.8
Electric vehicles are powerful enough for my job duties	6	3.7
Electric vehicles are sufficiently warm in the winter and cool in the summer for comfort	6	3.7
Electric vehicles are safe	6	4.0
Electric vehicles cost less to operate and will save money for the City of Brampton	6	4.2
Electric vehicles cause less pollution than standard gas or diesel vehicles	6	4.5
Electric vehicles of the type the City of Brampton requires are available now or in the near future	6	4.2

*The Rating Score is the weighted average calculated by dividing the sum of all weighted ratings by the number of total responses.

Figure 36: Views on BEVs – Transit staff

* There has a been a lot of news lately about zero-emission, battery-electric vehicles. Light-duty electric cars and SUVs, as well as electric buses and refuse trucks, are available now. Light-, medium-, and heavy-duty electric trucks are coming soon. Based on your current knowledge/perspective of electric vehicles, please rate your level of agreement on the statements below:

1 = Strongly disagree, 2 = Disagree, 3 = Unsure/undecided, 4 = Agree, 5 = Strongly agree

Answer	Number of Response(s)	Rating Score*
Electric vehicles can travel far enough to meet my daily needs and fulfil my job duties	6	3.7
Electric vehicles are powerful enough for my job duties	6	3.7
Electric vehicles are sufficiently warm in the winter and cool in the summer for comfort	6	3.3
Electric vehicles are safe	6	3.3
Electric vehicles cost less to operate and will save money for the City of Brampton	6	2.2
Electric vehicles cause less pollution than standard gas or diesel vehicles	6	2.8
Electric vehicles of the type the City of Brampton requires are available now or in the near future	6	3.3

*The Rating Score is the weighted average calculated by dividing the sum of all weighted ratings by the number of total responses.

Figure 37: Views on BEVs – Fire & EMS

* There has a been a lot of news lately about zero-emission, battery-electric vehicles. Light-duty electric cars and SUVs, as well as electric buses and refuse trucks, are available now. Light-, medium-, and heavy-duty electric trucks are coming soon. Based on your current knowledge/perspective of electric vehicles, please rate your level of agreement on the statements below:

1 = Strongly disagree, 2 = Disagree, 3 = Unsure/undecided, 4 = Agree, 5 = Strongly agree

Answer	Number of Response(s)	Rating Score*
Electric vehicles can travel far enough to meet my daily needs and fulfil my job duties	4	2.2
Electric vehicles are powerful enough for my job duties	4	2.2
Electric vehicles are sufficiently warm in the winter and cool in the summer for comfort	4	3.0
Electric vehicles are safe	4	3.2
Electric vehicles cost less to operate and will save money for the City of Brampton	4	3.0
Electric vehicles cause less pollution than standard gas or diesel vehicles	4	4.0
Electric vehicles of the type the City of Brampton requires are available now or in the near future	4	3.5

*The Rating Score is the weighted average calculated by dividing the sum of all weighted ratings by the number of total responses.

Views on Actions to Reduce Fleet GHGs

Figure 38: Views on actions to reduce fleet GHG emissions – Fleet Services management

* In 2018, the transportation sector accounted for about 25% of Canada's GHG emissions, second only to the oil and gas sector. GHG emissions are responsible for human-caused climate change, which is manifesting as overall global warming and more extreme weather events.As a result of this reality, vehicle fleets everywhere, including the City of Brampton, are taking action to reduce their GHG emissions. How do you feel about the following options for the City of Brampton's fleet? We invite your ideas and comments or explanations about your responses in the text box below.

1 = Really bad idea, 2 = Bad idea, 3 = Unsure/undecided, 4 = Good idea!, 5 = Really good idea!!

Answer	Number of Response(s)	Rating Score*
Have a "younger," more modern, and more fuel-efficient fleet	16	4.1
Downsize vehicles to the minimum required for the job	16	3.8
Reduce unnecessary engine idling	16	4.5
Switch some vehicles to natural gas or propane fuels	16	3.4
Switch vehicles to renewable fuels (biodiesel and ethanol)	16	3.3
Switch some vehicles to hybrid (gas/electric)	16	4.1
Switch some vehicles to all-electric (battery power only)	16	4.2
Use GPS devices to reduce trip distances	16	3.6
Use virtual meetings and video methods to avoid vehicle trips	16	4.1

*The Rating Score is the weighted average calculated by dividing the sum of all weighted ratings by the number of total responses.

Figure 39: Views on actions to reduce fleet GHG emissions – Fleet Services staff

In 2018, the transportation sector accounted for about 25% of Canada's GHG emissions, second only to the oil and gas sector. GHG emissions are responsible for human-caused climate change, which is manifesting as overall global warming and more extreme weather events.As a result of this reality, vehicle fleets everywhere, including the City of Brampton, are taking action to reduce their GHG emissions. How do you feel about the following options for the City of Brampton's fleet? We invite your *ideas and comments or explanations about your responses in the text box below.

1 = Really bad idea, 2 = Bad idea, 3 = Unsure/undecided, 4 = Good idea!, 5 = Really good idea!!

Answer	Number of Response(s)	Rating Score*
Have a "younger," more modern, and more fuel-efficient fleet	27	4.4
Downsize vehicles to the minimum required for the job	27	3.8
Reduce unnecessary engine idling	27	4.3
Switch some vehicles to natural gas or propane fuels	27	3.5
Switch vehicles to renewable fuels (biodiesel and ethanol)	27	3.6
Switch some vehicles to hybrid (gas/electric)	27	4.0
Switch some vehicles to all-electric (battery power only)	27	4.0
Use GPS devices to reduce trip distances	27	3.7
Use virtual meetings and video methods to avoid vehicle trips	27	4.0

*The Rating Score is the weighted average calculated by dividing the sum of all weighted ratings by the number of total responses.

Figure 40: Views on actions to reduce fleet GHG emissions – Transit management

In 2020, the transportation sector accounted for about 25% of Canada's GHG emissions, second only to the oil and gas sector. GHG emissions are responsible for human-caused climate change, which is manifesting as overall global warming and more extreme weather events.As a result of this reality, vehicle fleets everywhere, including the City of Brampton, are taking action to reduce their GHG emissions. How do you feel about the following options for the City of Brampton's fleet? We invite your *ideas and comments or explanations about your responses in the text box below.

1 = Really bad idea, 2 = Bad idea, 3 = Unsure/undecided, 4 = Good idea!, 5 = Really good idea!!

Answer	Number of Response(s)	Rating Score*
Have a "younger," more modern, and more fuel-efficient fleet	6	3.8
Downsize vehicles to the minimum required for the job	6	3.7
Reduce unnecessary engine idling	6	4.5
Switch some vehicles to natural gas or propane fuels	6	3.2
Switch vehicles to renewable fuels (biodiesel and ethanol)	6	3.3
Switch some vehicles to hybrid (gas/electric)	6	3.8
Switch some vehicles to all-electric (battery-power only)	6	4.2
Use GPS devices to reduce trip distances	6	4.2
Use virtual meetings and video methods to avoid vehicle trips	6	4.5

*The Rating Score is the weighted average calculated by dividing the sum of all weighted ratings by the number of total responses.

Figure 41: Views on actions to reduce fleet GHG emissions – Transit staff

In 2020, the transportation sector accounted for about 25% of Canada's GHG emissions, second only to the oil and gas sector. GHG emissions are responsible for human-caused climate change, which is manifesting as overall global warming and more extreme weather events.As a result of this reality, vehicle fleets everywhere, including the City of Brampton, are taking action to reduce their GHG emissions. How do you feel about the following options for the City of Brampton's fleet? We invite your *ideas and comments or explanations about your responses in the text box below.

1 = Really bad idea, 2 = Bad idea, 3 = Unsure/undecided, 4 = Good idea!, 5 = Really good idea!!

Answer	Number of Response(s)	Rating Score*
Have a "younger," more modern, and more fuel-efficient fleet	6	4.0
Downsize vehicles to the minimum required for the job	6	3.3
Reduce unnecessary engine idling	6	4.0
Switch some vehicles to natural gas or propane fuels	6	3.0
Switch vehicles to renewable fuels (biodiesel and ethanol)	6	3.0
Switch some vehicles to hybrid (gas/electric)	6	3.5
Switch some vehicles to all-electric (battery-power only)	6	3.5
Use GPS devices to reduce trip distances	6	3.5
Use virtual meetings and video methods to avoid vehicle trips	6	4.0

*The Rating Score is the weighted average calculated by dividing the sum of all weighted ratings by the number of total responses.

Figure 42: Views on actions to reduce fleet GHG emissions – Fire & EMS

In 2020, the transportation sector accounted for about 25% of Canada's GHG emissions, second only to the oil and gas sector. GHG emissions are responsible for human-caused climate change, which is manifesting as overall global warming and more extreme weather events.As a result of this reality, vehicle fleets everywhere, including the City of Brampton, are taking action to reduce their GHG emissions. How do you feel about the following options for the City of Brampton's fleet? We invite your *ideas and comments or explanations about your responses in the text box below.

1 = Really bad idea, 2 = Bad idea, 3 = Unsure/undecided, 4 = Good idea!, 5 = Really good idea!!

Answer	Number of Response(s)	Rating Score*
Have a "younger," more modern, and more fuel-efficient fleet	4	4.0
Downsize vehicles to the minimum required for the job	4	3.5
Reduce unnecessary engine idling	4	4.0
Switch some vehicles to natural gas or propane fuels	4	2.5
Switch vehicles to renewable fuels (biodiesel and ethanol)	4	3.0
Switch some vehicles to hybrid (gas/electric)	4	3.8
Switch some vehicles to all-electric (battery-power only)	4	3.5
Use GPS devices to reduce trip distances	4	3.5
Use virtual meetings and video methods to avoid vehicle trips	4	4.2

*The Rating Score is the weighted average calculated by dividing the sum of all weighted ratings by the number of total responses.

Appendix B: 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:

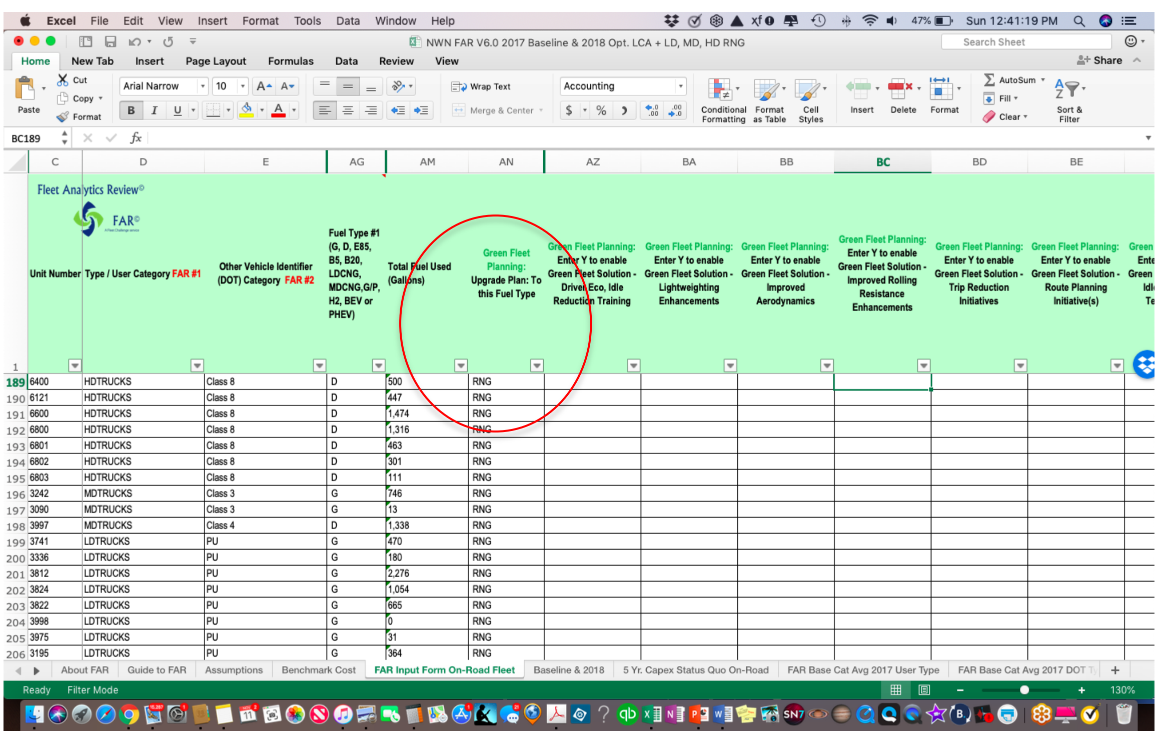
- The fuel usage and cost differential (+ or -) for the fuel type selected vs the current type (if applicable)
- The energy-efficiency difference

- 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 43 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 43: 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
6400	HDTRUCKS	Class 8	D	500	RNG
6121	HDTRUCKS	Class 8	D	447	RNG
6600	HDTRUCKS	Class 8	D	1,474	RNG
6800	HDTRUCKS	Class 8	D	1,316	RNG
6801	HDTRUCKS	Class 8	D	463	RNG
6802	HDTRUCKS	Class 8	D	301	RNG
6803	HDTRUCKS	Class 8	D	111	RNG
3242	MDTRUCKS	Class 3	G	746	RNG
3090	MDTRUCKS	Class 3	G	13	RNG
3997	MDTRUCKS	Class 4	D	1,338	RNG
3741	LDTRUCKS	PU	G	470	RNG
3336	LDTRUCKS	PU	G	180	RNG
3812	LDTRUCKS	PU	G	2,276	RNG
3824	LDTRUCKS	PU	G	1,054	RNG
3822	LDTRUCKS	PU	G	665	RNG
3998	LDTRUCKS	PU	G	0	RNG
3975	LDTRUCKS	PU	G	31	RNG
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 C: Lifecycle Analysis Charts

Table 14: LCA for Class 1 – car using Brampton fleet data

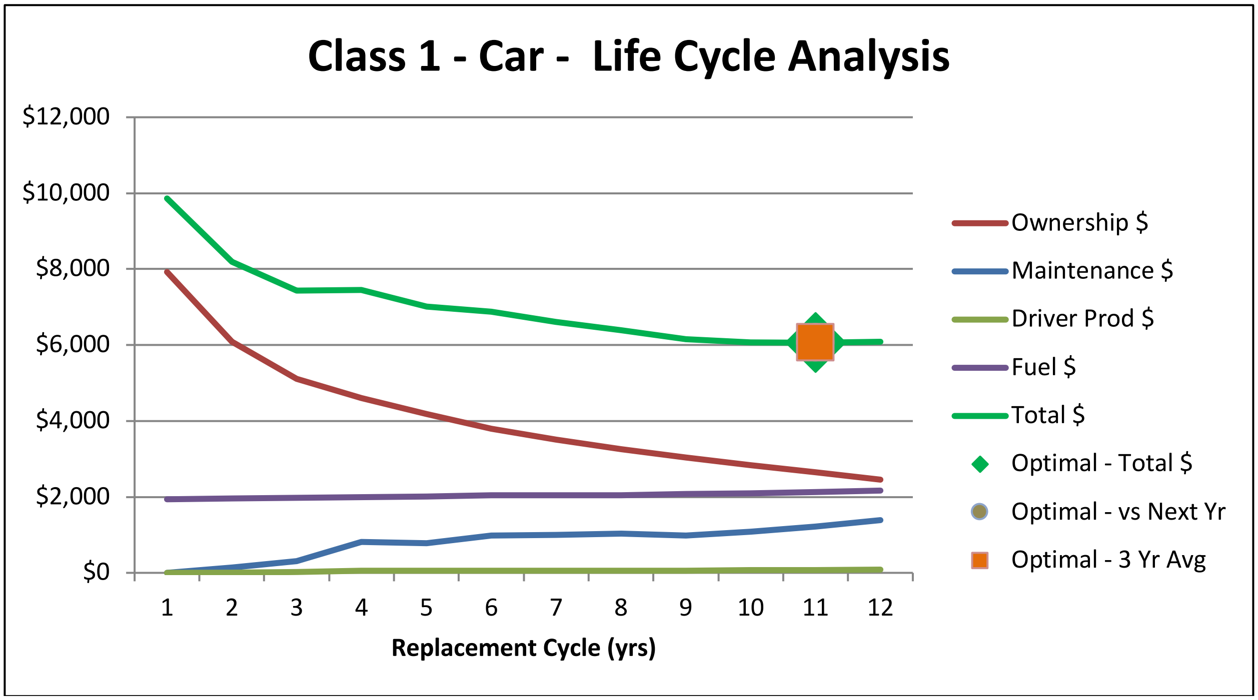


Table 15: LCA for Class 1 – pickup, van using Brampton fleet data

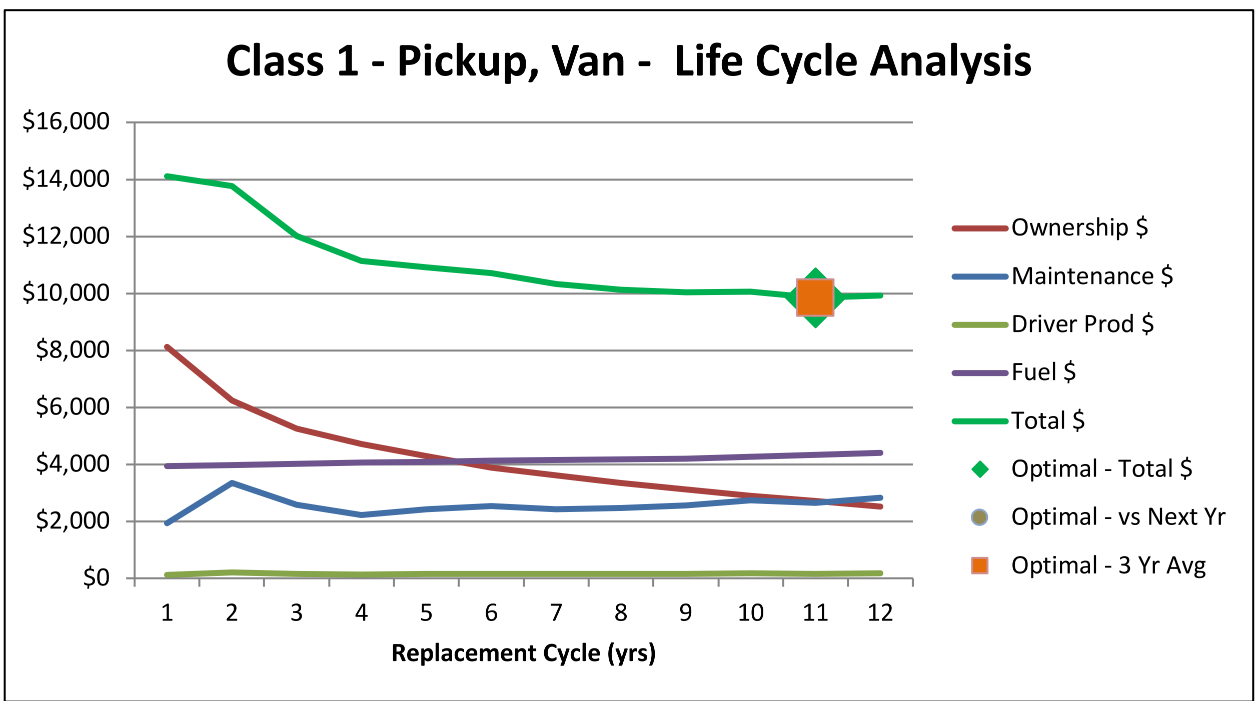


Table 16: LCA for Class 1 – SUV, wagon using Brampton fleet data

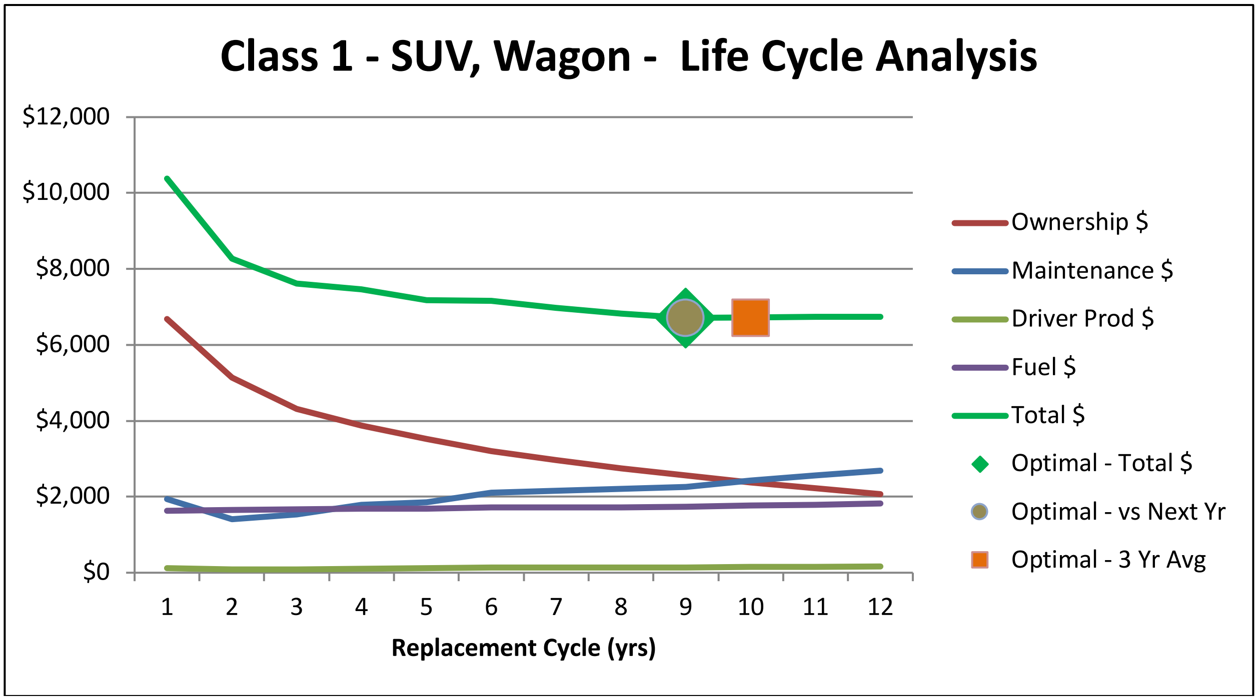


Table 17: LCA for Class 2 – pickup using Brampton fleet data

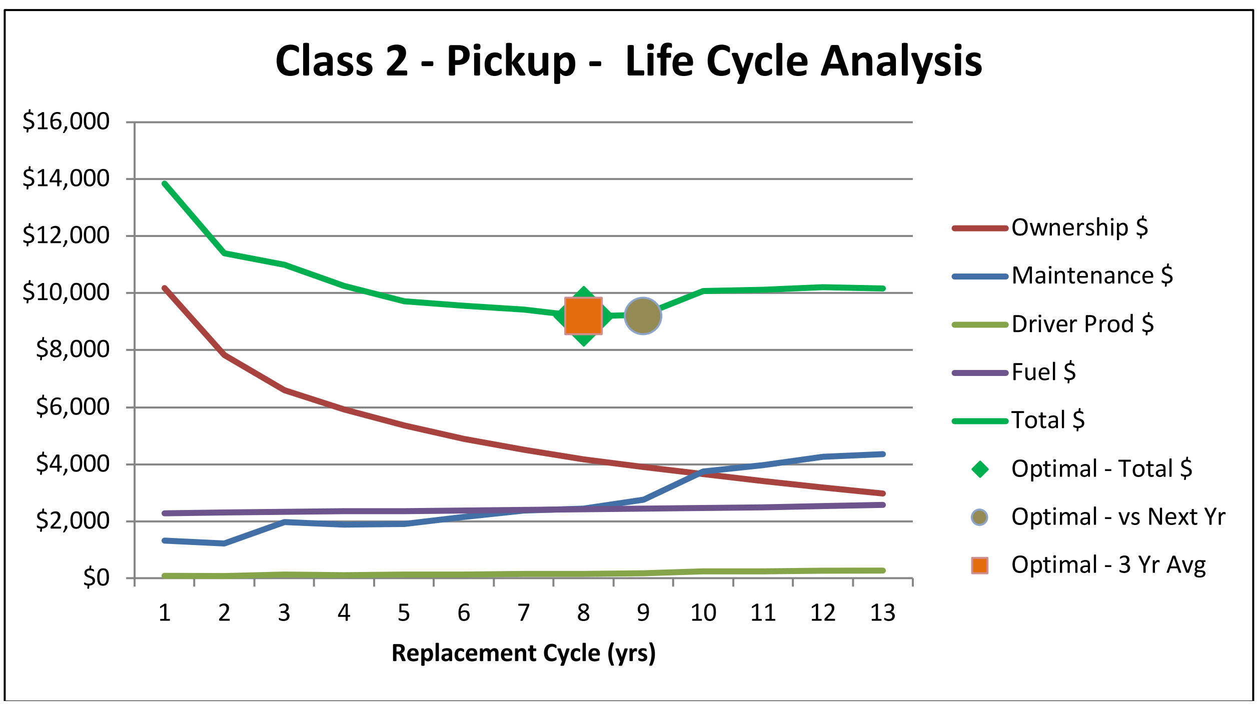


Table 18: LCA for Class 2 – van using Brampton fleet data

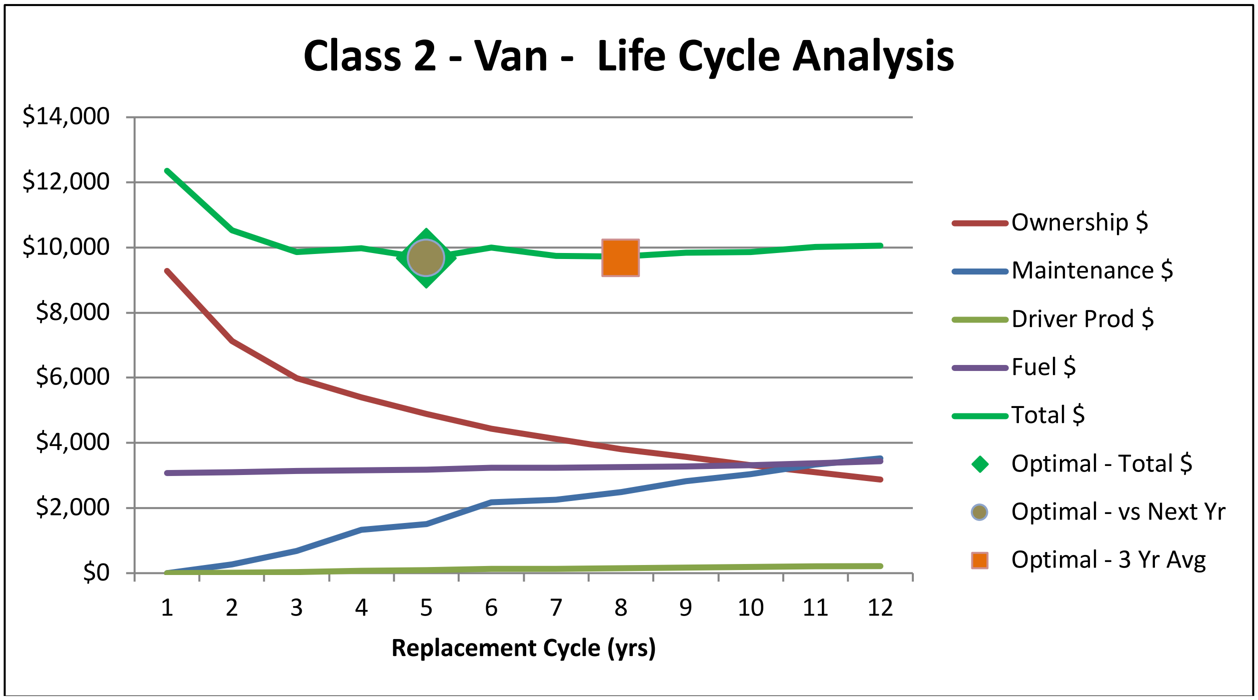


Table 19: : LCA for Class 3 – pickup, cargo van using Brampton fleet data

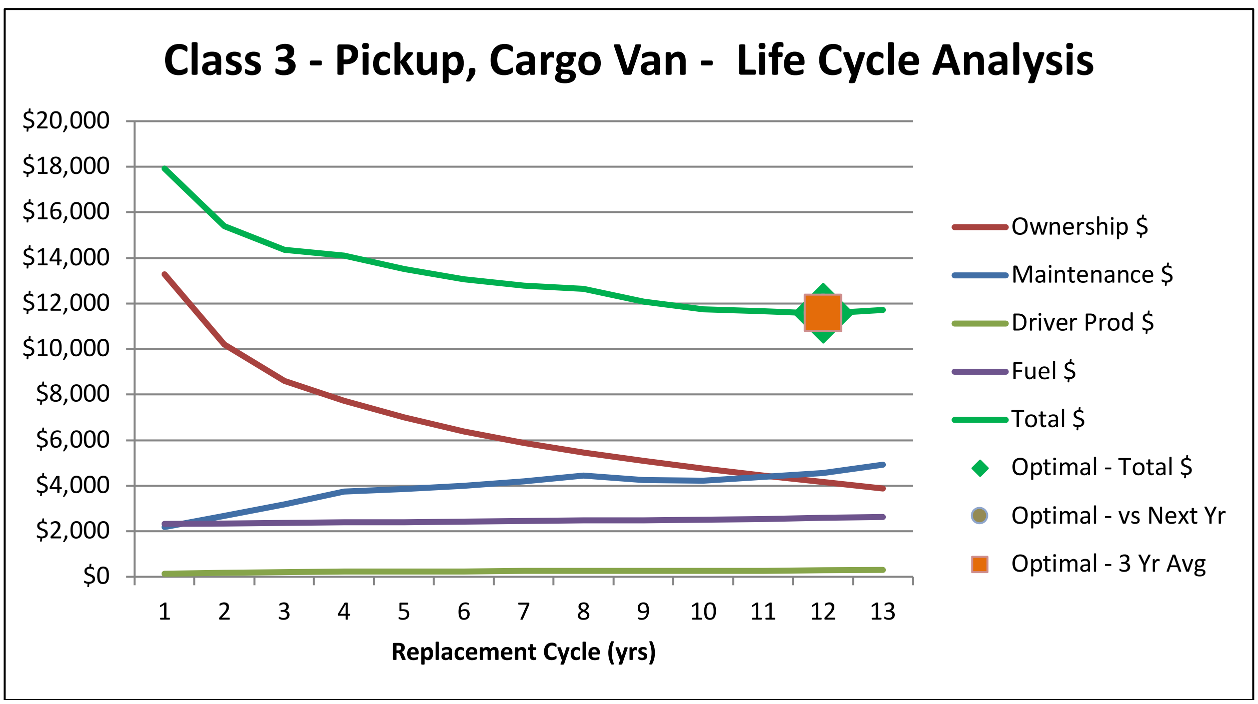


Table 20: LCA for Class 5 - truck using Brampton fleet data

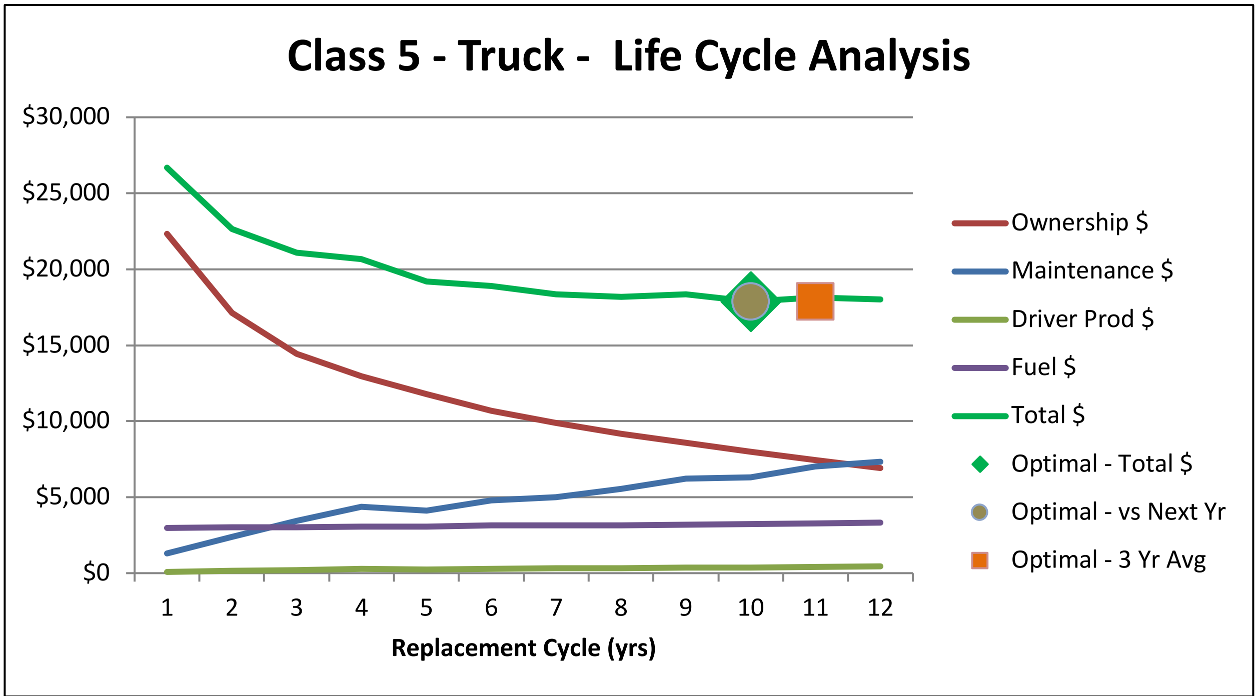
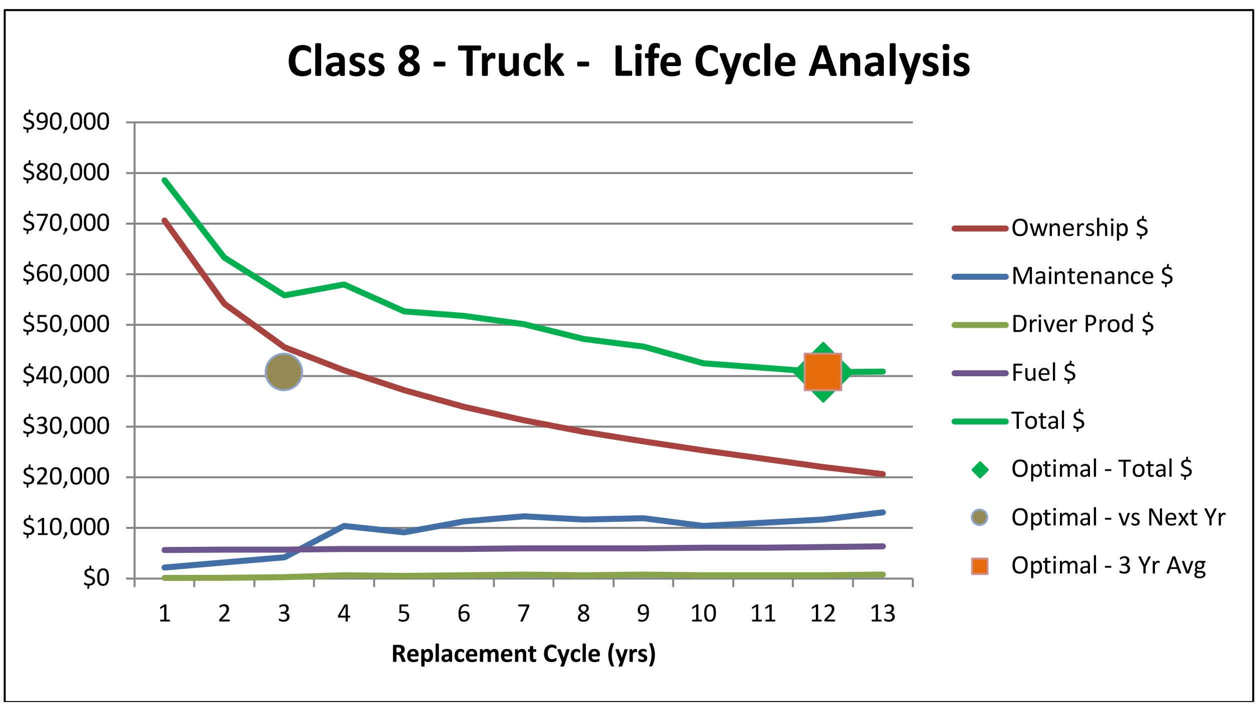


Table 21: LCA for Class 8 - truck using Brampton fleet data



Appendix D: 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 are considered as potential new, 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 22* lists sample vehicle specifications and their respective impacts.

Table 22: 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[72]. 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.

[72] 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[73]. 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 44*.

Figure 44: 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[74]
- Increased tires tread life by up to 30 percent, improving the tire's life and its grip to the road[75]
- Reduced fuel consumption by up to 6%[76]

---

[73] Source: https://nacfe.org
[74] Source: http://www.gonitrotire.com
[75] Source: http://www.gonitrotire.com
[76] 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[77]. 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[78]. 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.

[77] Source: NHTSA Report, 2009: https://one.nhtsa.gov/DOT/NHTSA/NRD/Multimedia/PDFs/.../2009/811094.pdf
[78] 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 23.* To reap the most benefits any idling-reduction technology, installation should always be accompanied by behavioural solutions of driver training and motivation.

Table 23: 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.)[79].

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.[80]

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.[81]

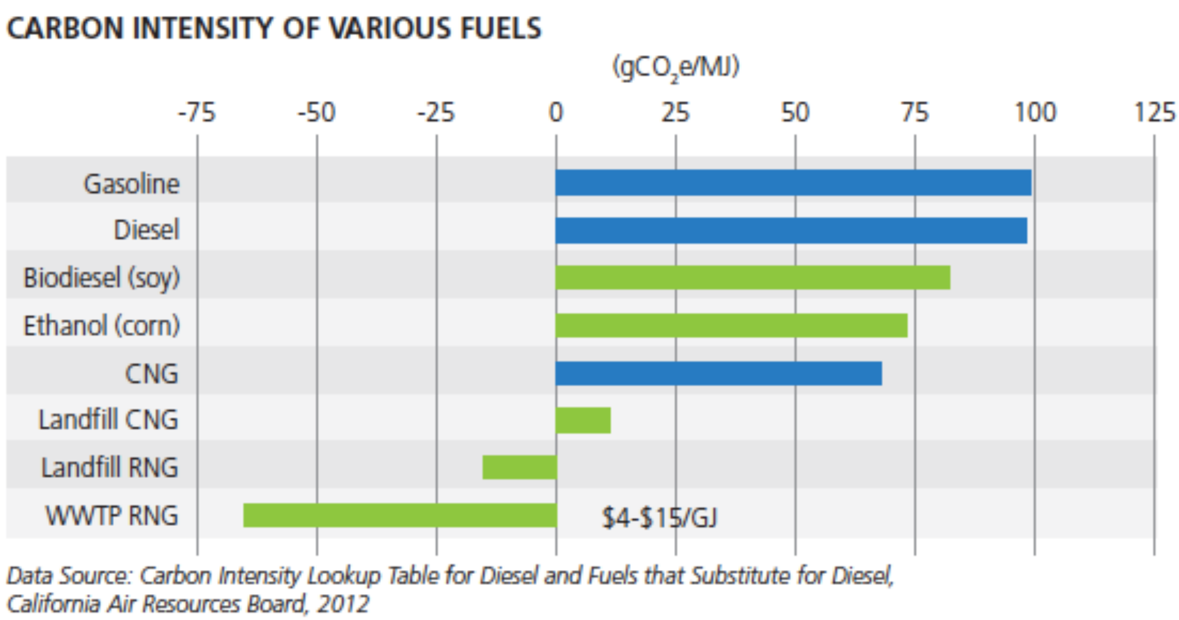
[79] Source: https://www.capterra.com/route-planning-software/
[80] Source: https://blog.route4me.com/2020/05/carbon-emissions-reduction-route-optimization-helps-cut-tons-carbon-emissions/
[81] Source: https://blog.route4me.com/2020/05/carbon-emissions-reduction-route-optimization-helps-cut-tons-carbon-emissions/

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

Figure 45: Carbon Intensity of Various Fuels

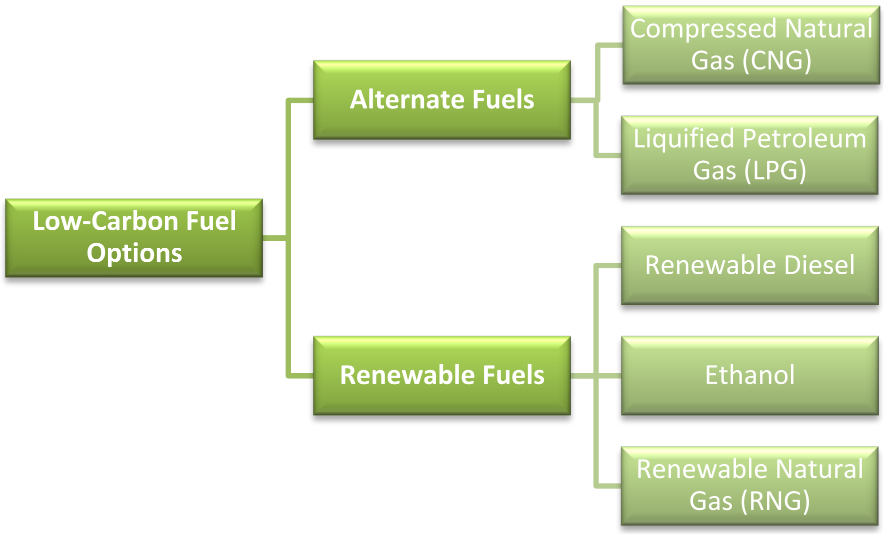


No Pain, No Gain!

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

Figure 46: 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."

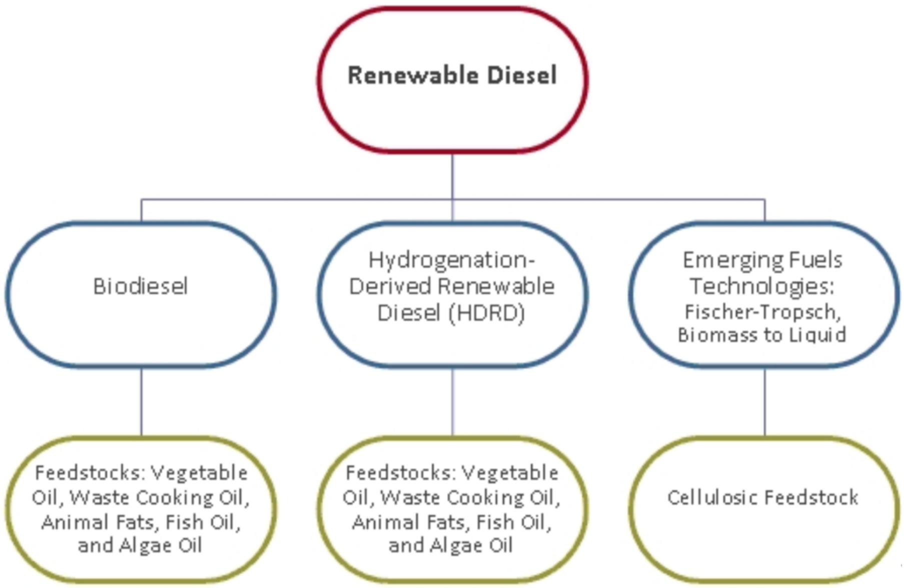
Renewable Diesel

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[82]."

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 47)*[83]. All diesel fuel sold in Canada contains a percentage of renewable diesel owing to a renewable fuels standard.

82 Source: https://www.nrcan.gc.ca/energy/alternative-fuels/resources/nrddi/3669
83 Source: https://www.nrcan.gc.ca/energy/alternative-fuels/resources/nrddi/3669

Figure 47: 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[84]. 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[85].

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).[86]

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

[84] Source: https://www.nrcan.gc.ca/energy/alternative-fuels/resources/nrddi/3669
[85] Source: https://www.neste.com/what-difference-between-renewable-diesel-and-traditional-biodiesel-if-any
[86] 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[87].

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[88]. 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[89].

---

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

Biodiesel At a Glance

Table 24: 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[90,91,92] 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[93]. 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[94]. Taking into account this energy loss, using blends ranging from B5 to B20,

[90] 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.
[91] Source: http://biodiesel.org/using-biodiesel/oem-information
[92] Source: https://www.afdc.energy.gov/fuels/biodiesel_blends.html
[93] Source: https://www.fueleconomy.gov/feg/biodiesel.shtml
[94] 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[95]. Moreover, the lifecycle CO_2 emissions can be significantly lower for biodiesel than for conventional diesel[96].

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.

[95] Source: https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-transportation/alternative-fuels/biofuels/biodiesel/3509
[96] 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. [97]

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*[98] 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

[97] Source: https://www.afdc.energy.gov/uploads/publication/biodiesel_handling_use_guide.pdf
[98] 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[99]:

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

[99] 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[100]. Most North American engine manufacturers now offer full support using biodiesel blends up to a B20 with no vehicle modifications required[101].

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).

[100]http://www.truckandenginemanufacturers.org/file.asp?A=Y&F=7036%2Epdf&N=7036%2Epdf&C=documents
[101] 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[102].

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[103]. 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[104].

[102] Source: https://afdc.energy.gov/fuels/ethanol_fuel_basics.html
[103] Source: https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-transportation/alternative-fuels/biofuels/ethanol/3493
[104] 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.[105]

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

[105] 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. [106]

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[107]. Corn-based E85 is estimated to reduce lifecycle GHG emissions by 25-50% compared to gasoline[108]. 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[109].

In terms of tailpipe emissions, E85 has a GHG emissions reduction potential of about 30% when compared to the same volume of gasoline[110]. However, E85 contains about 29% less energy than gasoline per unit volume[111]. 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[112].

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

[106] Source: https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-transportation/alternative-fuels/biofuels/ethanol/3493
[107] Source: https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-transportation/alternative-fuels/biofuels/ethanol/3493
[108] Source: https://www.tandfonline.com/doi/pdf/10.3155/1047-3289.59.8.912
[109] Source: https://afdc.energy.gov/fuels/ethanol_benefits.html
[110] 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
[111] Source: Department of Energy GREET (Greenhouse gases, Regulated Emissions, and Energy use in Transportation) Model, Jan 20, 2011.
[112] 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[113].

In Canada, business case modelling[114] 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[115], 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 25: 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[116,117] 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

[113] 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.
[114] Source: Natural Gas Use in the Medium and Heavy-Duty Vehicle Transportation Sectorin Roadmap 2.0 June 2019
[115] Source: https://cutaactu.ca/en/news-media/natural-gas-buses-cost-operational-and-environmental-alternative
[116] Source: https://brc.it/en/categorie_faq/cng/
[117] 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[118] 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

[118] 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[119,120]. NGVs also emit up to 95% less nitrogen oxides (NO_x) compared to diesel and gasoline vehicles[121]. Furthermore, CNG vehicles do not emit particulate matter (PM10), a main cause of air pollution[122].

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)[123,124]. New CNG buses can cost $120,000 more than conventional diesel buses[125,126], 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.

[119] Source: https://brc.it/en/categorie_faq/cng/
[120] Source: https://envoyenergy.ca/cng-benefits/#:~:text=Commercial%20fleets%20all%20over%20the,solution%20for%20fuelling%20their%20fleets.
[121] Source: Northwest Gas Association – Natural Gas Facts
[122] Source: https://brc.it/en/categorie_faq/cng/
[123] Source: Closing the Loop. Canadian Biogas Association. 2015.
[124] Source: Consultations with Change Energy
[125] This value represents the additional cost, in CAD, of a CNG transit bus over a traditional diesel bus.
[126] 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.[127]

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.

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

RNG at a Glance

Table 26: 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[128].

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

[128] 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)[129]. 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%[130] 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.

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

Emissions Reduction Potential

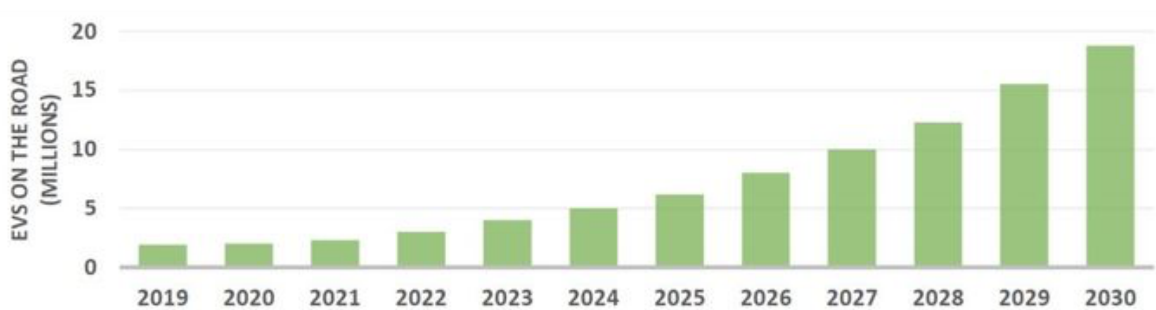
In terms of tailpipe emissions, propane has a GHG emissions reduction potential of about 33% when compared to the same volume of gasoline based on GHGenius version 5.01a. However, as mentioned, propane contains about 27% less energy than gasoline per unit volume. Given this energy loss, about 37% more 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 48* for the United States.

Figure 48: 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. [131]

- **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. [132]

- **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.[133]

- **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[134]. Examples of BEVs include the Nissan Leaf, Chevrolet Bolt, Kia Soul, and Tesla Model 3.

[131] Source: https://www.autotrader.ca/newsfeatures/20180410/types-of-electric-vehicles-explained/
[132] Source: https://www.autotrader.ca/newsfeatures/20180410/types-of-electric-vehicles-explained/
[133] Source: https://www.autotrader.ca/newsfeatures/20180410/types-of-electric-vehicles-explained/
[134] 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[135], 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[136], while the 2020 Chevrolet Bolt has an EPA-estimated range of 417 km[137].

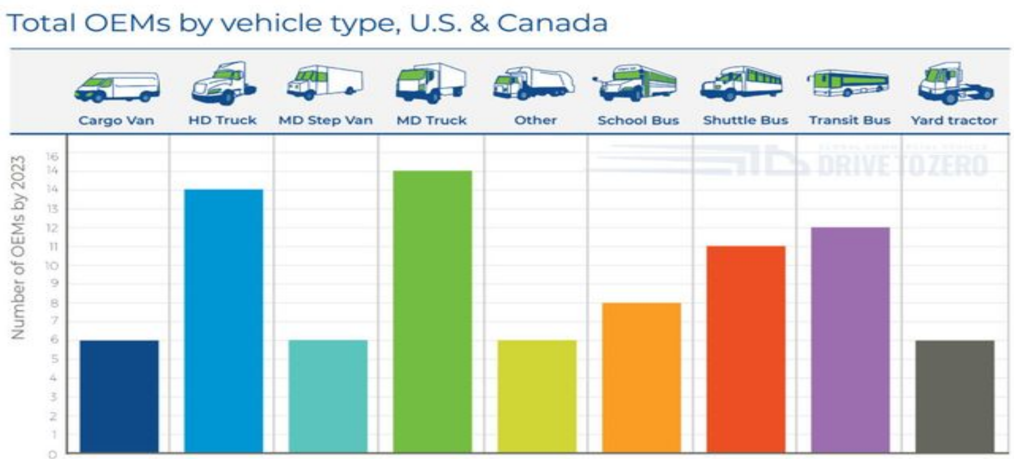
There has also been significant expansion in charging infrastructure through publicly available charging stations. As of early 2020, there were nearly 5,000 charging outlets across Canada, and Natural Resources Canada is investing $130 million from 2019-2024 to further expand the country's charging network,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

[135] Source: https://www.mrmoneymustache.com/the-nissan-leaf-experiment/
[136] Source: https://www.tesla.com/en_ca/model3
[137] 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 49*, 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 49: 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[138] 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

[138] 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 27: 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[139]. 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.

[139] 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[140], and in some cases emit over 80% less in a grid composed of mostly renewable electricity[141]. 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 28*[142]:

Table 28: 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

140 Source: https://www.eei.org/issuesandpolicy/electrictransportation/Pages/default.aspx
141 Source: https://blog.ucsusa.org/rachael-nealer/gasoline-vs-electric-global-warming-emissions-953
142 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.

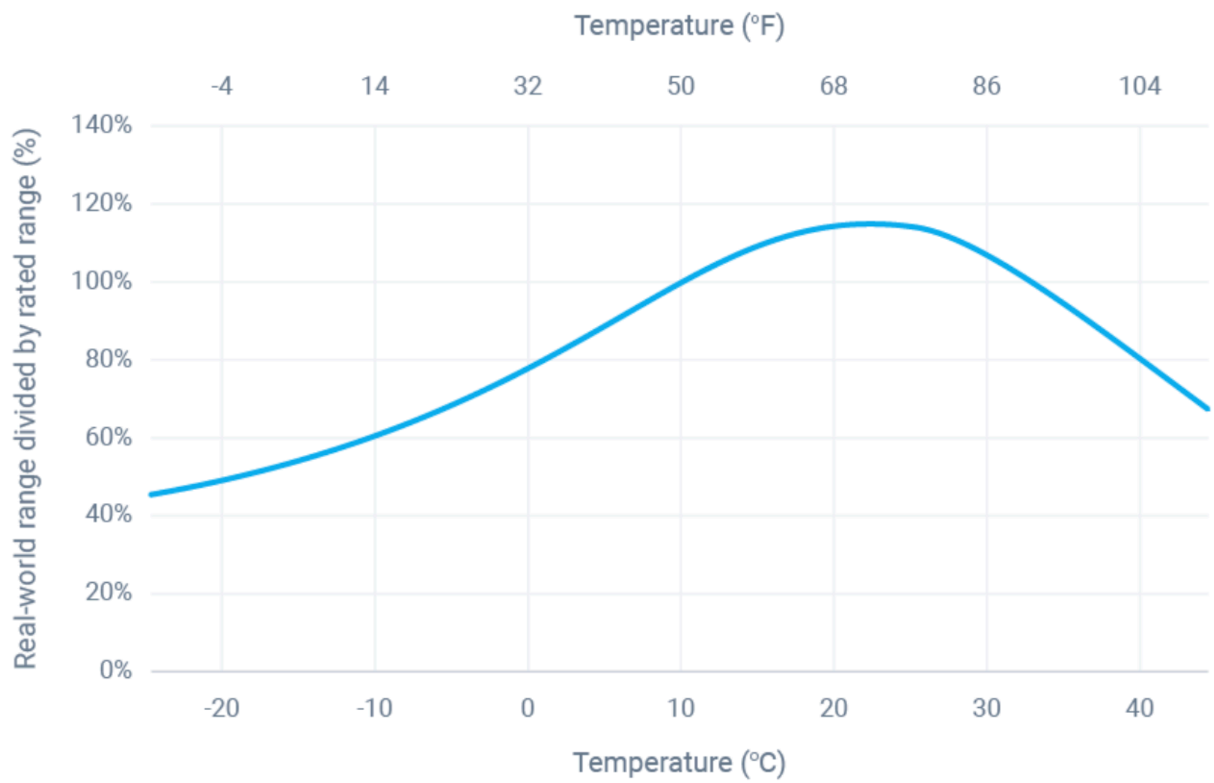
Level 3, or direct current fast chargers (DCFCs), requiring inputs of 480+ volts and 100+ amps (50-60 kW)[143], are specialized systems designed to quickly charge vehicles and provide flexibility to owners travelling longer distances or in need to partial quick charge. For a light-duty BEV with a range 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[144]. 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[145].

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 50*, 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.[146]

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

Figure 50: 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 will be available to the public soon[147].

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[148]. 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[149].

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

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

voltage in any format, including BEVs, should be provided guidance on applying Occupational Health & Safety Management System fundamentals. This includes a "plan, do, check, and act" philosophy while working with energized electrical equipment[150]. 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.

[150] 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 51* (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 51: 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[151]. 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

[151] 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[152]:

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[153]. 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.

---

[152] Source: http://www.gladstein.org/hydrogen-fuel-cell-trucks/?elqTrackId=6a5315625a44431c811600250fbe96e3&elq=f9398669248a444fa236415f8ae2dde6&elqaid=1302&elqat=1&elqCampaignId=700
[153] 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.

...