CITY OF BARRIE

ALTERNATIVE FUEL TECHNOLOGY SUMMARY REPORT

CORPORATE FLEET

MAY 28, 2021

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CORPORATE FLEET

CITY OF BARRIE

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TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

ABBREVIATION LIST

Abbreviation	Definition
A/C	Air Conditioning
AC	Alternating Current
ASTM	American Society for Testing and Materials
BAU	Business as Usual
BEB	Battery Electric Bus
BOLT	Battery Optimization and Lifecycle Tool
BRT	Bus Rapid Transit
CAC	Criteria Air Contaminants
CAPEX	Capital Expenditure
CCS	Combined Charging System
C-rate	Charge rate
CHIC	Canadian Hydrogen Installation Code
CO2e	Carbon dioxide equivalent
CNG	Compressed Natural Gas
DC	Direct Current
DOE	Department of Energy
EAC	Equivalent Annual Cost
ECM	Electronic Control Module
EI	Electrification Index
ESS	Energy Storage System
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FCEV/ FCEB	Fuel Cell Electric Vehicle/ Fuel Cell Electric Bus
GHG	Greenhouse gas

HEV	Hybrid Electric Vehicles
HVAC	Heating Ventilation and Air Conditioning
ICE	Internal Combustion Engine
ITS	Intelligent Transportation Systems
kVA	Kilo Volt Ampere
Kw/ kWh	Kilowatt/ Kilowatt-hours
Lbs.	pounds
LNG	Liquified Natural Gas
NFPA	National Fire Protection Association
NPV	Net Present Value
NREL	National Renewal Energy Laboratory
NRV	Non- Revenue Vehicles
OSHA	Occupational Safety and Health Administration
OEM	Original Equipment Manufacturer
OPEX	Operating Expenditure
P3	Public Private Partnership
PPE	Personal Protective Equipment
RNG	Renewable Natural Gas
SAE	Society of Automotive Engineers
SOC	State of Charge
STM	Société de Transport de Montréal
SV	Salvage value
TA	Transit Authority
TCO	Total Cost of Ownership
TPI	Transit Procurement Initiative
WAVE	Wireless Advanced Vehicle Electrification Inc.
YOE	Year of Expenditure

EXECUTIVE SUMMARY

The City of Barrie is a single-tier municipality situated on the shores of Kempenfelt Bay, the western arm of Lake Simcoe. The City's population was 151,043 in 2020 and that is forecasted to double by 2051. The City is responsible for municipal operations to support it's residents and owns, operates and maintains a mixed fleet consisting of gasoline powered light and medium duty vehicles as well as medium and heavy duty diesel powered vehicles. The City also has diesel powered sander/salter trucks, plows and specialized units such as ice resurfacers.

The City of Barrie wishes to examine the potential of alternative fuel technologies to meet its fleet needs, which will enable a move towards greater sustainability, assist in achieving environmental targets via reduction of GHG (greenhouse gas) emissions and air contaminants, and achieve overall operational efficiencies and modernization. To support this effort, the City retained WSP to conduct a feasibility study to consider alternative fuels such as battery electric, hybrid electric, Compressed Natural Gas (CNG) and biodiesel.

Vehicle operations at four facilities were reviewed as part of this study including the Operation Centre, Fire Station 1, Surface Water Treatment Plant (SWTP) and Wastewater Treatment Plant (WWTF).

A market scan was undertaken to determine what types of alternative fuel vehicles are available in the market. Although there is a wide range of electric light-duty vehicles available for purchase today with ranges that would fit the operational needs of the fleet, the medium and heavy-duty electric vehicle market is still at its infancy. Hydrogen fuel cell technology was also considered for replacement of light-duty vehicles, as some of the more specialized heavy-duty fuel cell vehicles are currently under development. The medium and heavy-duty CNG vehicle market is a lot more mature, and as such was considered as an option to reduce GHG emissions. Each technology was assessed from an economic, social and environmental benefit perspective. The adoption risks of each technology were provided as part of the study, and four potential adoption pathways were developed based on available vehicles today.

In order to narrow down the detailed analysis to one preferred option, a high level total cost of ownership model was constructed to examine the cost of owning each type of vehicle technology. This cost also included high level infrastructure costs. Based on the initial costing, market maturity and environmental impact assessment a decision was made to investigate transitioning light-duty vehicles to battery electric and medium duty vehicles to CNG. The remainder of the fleet, or the heavy duty vehicles remain as diesel or gasoline following the business-as-usual (BAU) approach.

Growth Analysis

As part of the detailed analysis, the existing facilities were assessed to determine their ability to address fleet growth and support the necessary refueling/recharging requirements including the available electrical supply. The fleet growth from 2021-2031 was based on the City's fleet specific projections and beyond 2031 the fleet growth was assumed to follow the population growth projections. This correlates to a vehicle growth from 248 (2021) to 302 (2041). Beginning in 2025, vehicles were transitioned based on a life cycle replacement model. By 2041, 43% of the fleet would be battery electric vehicles while 27% of the fleet would operate with CNG vehicles.

Fuel Consumption Profile and Facility Upgrades

The current average fuel utilization of each vehicle type was assessed to determine range requirements and utilization patterns. This input was used to calculate the number of charging stations required at each facility and the sizing of the CNG refueling station. The following facility modifications are required:

- **For CNG vehicles**: based on the size of the CNG fleet, one refueling station is required outdoors at the Operation Centre. The Operation Center is the central location for all municipal vehicle maintenance and repairs. As such, facility modifications for CNG fuelled vehicles in the maintenance areas would be required as per standard building codes. The refueling station would consist of one dryer, one compressor and a redundant compressor to add systems resiliency.
- **For batter electric vehicles**: Depending on the vehicle energy consumption, the number of chargers per vehicle type varied. Installation of 24 chargers at the Operations Centre and additional electrical supply equipment (such as poles and pad mounted transformer) are required. The other facilities were assumed to have sufficient power supply to the site given future infrastructure upgrades planned by the City, so 4 charging stations were assumed for Station 1, 6 for SWTP and 6 for WWTF.

Financial and Emissions Reduction Analysis

Based on the facility upgrade plan, the CAPEX and the OPEX of the alternative fuel scenario was assessed through a cost-benefit analysis and compared to the BAU. Overall, the alternative fuel scenario saved $3M over the period considered (2021-2041) on OPEX, but resulted in an increase in CAPEX of $12M. This translated to an additional 6-7% total cost over the course of 20 years, or about $2M per Megaton of CO2 equivalent (CO2e) saved.

Transitioning to alternative fuels following the defined approach would reduce total emissions by 13% over the next 20 years compared to BAU. At the end of the 20 years, once the plan is completed, the yearly emissions would be 1,501 tonnes of CO2e, while the BAU's emissions would be 2,016 tonnes of CO2e – a reduction of 25%. Despite having a fleet that is close to 50% electric by 2041, the emission profile remains relatively high because of the lack of maturity in the market of alternative fuel vehicles for heavy-duty vehicles. Canada does have a mandate to achieve carbon neutrality, or "net zero" by 2050 and therefore there is expected to be significant research in this area. Already, there has been significant investment in repowering options and electric vehicle design and market availability would change significantly over the next 10 years.

Recommendations

This study demonstrated the feasibility of transitioning light duty vehicles to electric and medium duty vehicle to CNG and it is recommended that the City move forward with this scenario.

The Operations Centre will be the key facility to host the alternative vehicles and hence, an important place to start the transition. As the Operation Centre undergoes planned infrastructure improvements, it is recommended that upgrades to support electric charging infrastructure is included. In addition, if the City of Barrie considers installing a public charging system network, it is recommended that the Corporate fleet be considered.

It is recommended that the City of Barrie follows a phased approach to electrify its fleet at the Operations Centre as not all charging infrastructure would be required initially, but can be deployed as the gradual transition to battery electric vehicles occurs. At the remaining facilities, the infrastructure could be installed all at once given the size of the upgrades.

Before moving ahead with a CNG refueling station implementation plan, it is recommended that the City waits and reviews how the medium-duty and heavy-duty electric vehicle market matures in the next 2 – 3 years. Many heavy-duty truck models are expected to be available as early as 2021. While CNG is a good option to limit emissions in the short term, it cannot achieve the same level of emissions reduction as electric vehicles.

Next Steps

The City of Barrie is expected to test an electric ice resurfacer in 2021. Piloting alternative fuel technologies for different vehicle classes is an important step that can help staff get familiar with the technology while acquiring data and a good understanding of the operational changes it may cause. There are several funding streams available to support pilot project implementation outlined in this report, including the Federation of Canadian Municipalities (FCM) and Natural Resources Canada. These types of pilot projects would require full-time resources provide project management and to ensure successful implementation and evaluation.

The study identifies the infrastructure needs, high level cots and benefits should the City decide to proceed with a full implementation of this alternative fuel scenario. The earliest that alternate fuel vehicles could be procured is 2025, however it is recommended that this plan be revisited in 3 years prior to making any decisions when more heavy-duty models are available in the market and have a proven efficiency record.

The next steps in the planning of the fleet transition should be integrated with the City's Net Zero Carbon Emissions Strategy and procurement of alternate fuel vehicles with end of life replacement of the fleet should be aligned.

1 INTRODUCTION

1.1 BACKGROUND

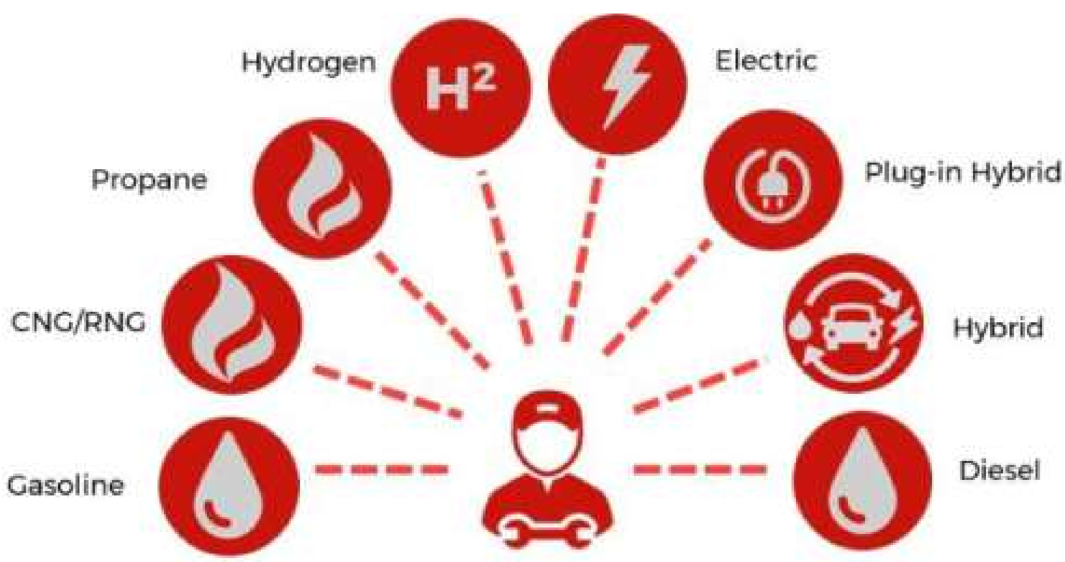
The City of Barrie is located in southern Ontario, on the shores of Kempenfelt Bay, the western portion of Lake Simcoe. The City is a single-tier municipality, with a population of 151,043 for 2020. The City is responsible for municipal operations activities in service of the population, including parks and roads maintenance, maintenance of recreational facilities, fire and emergency services, winter operations and maintenance etc.

In support of its municipal activities, the City of Barrie owns a sizeable fleet of light duty vehicles (consisting of pickup trucks, vans, SUVs (sports utility vehicles), along with medium sized gas and diesel-powered dump trucks. The City also has larger five-ton series fleet of diesel powered units including Sander/salter trucks, plows and specialized units. There are also ice resurfacers – currently operating on compressed natural gas (CNG) – along with larger equipment such as loaders, backhoes and landfill equipment. In order to maintain, refuel and store these vehicles, the City own a 50,000-square foot repair garage, as well as indoor storage garages at its operations building including the Surface Water Treatment Plant, Wastewater Treatment Plant and Landfill site.

The City of Barrie wishes to examine the potential of alternative fuel technologies to meet its fleet needs, which will enable a move towards greater sustainability, assist in achieving environmental targets via reduction of GHG (greenhouse gas) emissions and air contaminants, and achieve overall operational efficiencies and modernization.

1.2 STUDY OBJECTIVES

The objective of this study is to perform an assessment of the available and applicable alternative fuel technologies that are suitable for the City's existing Corporate fleet. The need for alternative technologies is driven by the finite availability of conventional fuels (gasoline and diesel), achieving environmental benefits in preparation of moving towards a carbon neutral future, and identifying opportunities for fleet modernization and operational benefits. As such, this study will support the City's overall strategic direction of a more sustainable and environmentally greener city.



The report will provide an overview of the following:

- Investigation and overview of the alternative fuel technologies currently available in the Canadian market, including a detailed technical and regulatory review for the technologies identified (Battery Electric, Hybrid Electric, Compressed Natural Gas, and Hydrogen Fuel Cells);
- Assessment of the facilities and high-level gap assessment of the adopting different technologies;
- Overview of the various funding opportunities available to the City;
- Identification of potential green fleet scenarios for considerations regarding the City's operational fleet and an assessment of the business case of adopting various different technologies to determine the costs and environmental benefits;
- Identification of risks through an engagement exercise to determine potential risks in adopting alternative fuel technologies, their implications and potential mitigation measures;
- Definition of a potential approach for the City to employ in support of the adoption of alternative fueled vehicles;
- Development of a detailed plan demonstrating the feasibility and preliminary design for converting the light and medium duty vehicles to battery electric and CNG vehicles for the horizon 2021-2041 as described in Scenario 3 of the Task 1 report;
- Assessment of the operational requirements for each technology and provision of an overview of the infrastructure needed to operate the alternative vehicles;
- Provision of a phased implementation strategy whereby 25%, 50% and 100% of fleet replacement is achieved, with a reasonable timeline for when upgrades would be needed;
- Provision of details on the costing (CAPEX and OPEX) for each phased implementation (including assumptions made); and
- Identification of training needs, future trends and stakeholders for future partnerships.

1.3 LIMITATIONS

The findings presented in this study are based on information and data available at the time of writing. It is based on historical and current data provided by the City of Barrie. For certain parameters where data was not available, assumptions were used and validated based on supplementary sources. Examples of supplementary sources include data collected from early adopters, academic journals, desktop research, and consultation with global industry experts. As the electric vehicle technology is ever evolving, the costs estimates provided in this report reflect today's available technology. It is expected that costs will tend to decrease in the future as the technologies and the market matures.

2 CURRENT STATE SUMMARY

2.1 FLEET ASSET INVENTORY

An overview was conducted of the City's current operations asset inventory. The assets were classified into categories based on the class (vehicle class of light duty, medium duty, large medium duty, heavy duty, specialized heavy duty, equipment and trailers). This asset classification system was utilized to form the basis of the business case analysis conducted for examining different alternative green fleet scenarios in the report. It further provides a fleet level assessment of the City's current assets for ease of tracking.

Table 1 provides a summary of the major vehicle assets that were identified from the asset inventory for the four facilities of interest:

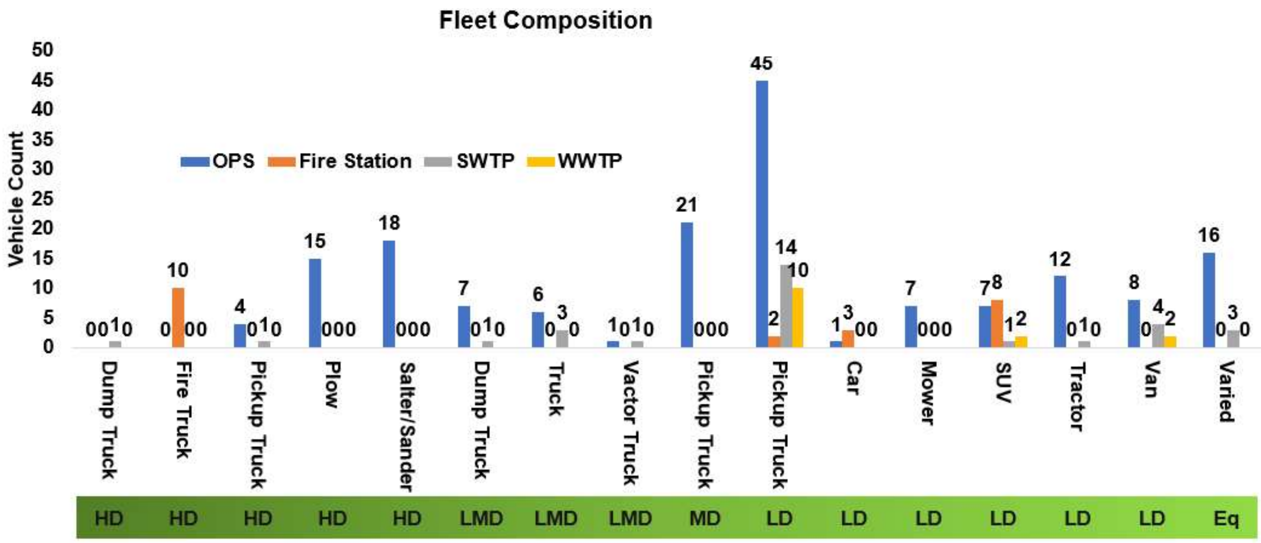
- Operations Centre
- Station 1
- Surface Water Facility (SWTP)
- Wastewater Treatment Facility (WWTP)

Light duty pickup trucks make up the largest category of vehicles currently owned by the fleet, followed by sander/salter vehicles. In addition to these assets, the City also has numerous trailers and equipment that are owned and operated. This information is also summarized in Figure 1.

Table 1 Operations Vehicle Asset Inventory

Vehicle Class	Vehicle Type	Operations Center	Station 1	SWTP	WWTP
Heavy Duty	Dump Truck	0	0	1	0
Heavy Duty	Fire Truck	0	10	0	0
Heavy Duty	Pickup Truck	4	0	1	0
Heavy Duty	Plow	15	0	0	0
Heavy Duty	Salter/Sander	19	0	0	0
Large Medium Duty	Dump Truck	7	0	1	0
Large Medium Duty	Truck	6	0	3	0
Large Medium Duty	Vactor Truck	1	0	1	0
Light Duty	Car	1	3	0	0
Light Duty	Mower	7	0	0	0
Light Duty	Pickup Truck	45	2	14	10
Light Duty	SUV	7	8	1	2
Light Duty	Tractor	12	0	1	0
Light Duty	Van	8	0	4	2
Medium Duty	Pickup Truck	21	0	0	0
Equipment	Varied	16	0	3	0

In 2021, Barrie is expected to pilot an electric ice resurfacer. As this is not part of the current fleet, it was not included in the vehicle asset inventory.



HD = Heavy Duty; LMD = Large Medium Duty; LD= Light Duty; MD = Medium Duty; Eq = Equipment

Figure 1 Fleet Inventory in 2021

2.2 ASSET COSTS AND LIFECYCLE

Table 2 provides an overview of the expected life and acquisition costs of the corporate vehicles identified based on the asset inventory and in discussion with the City. The City currently targets keeping its light duty vehicles for 10 years and its heavier assets 15 years. The City's currently most expensive assets consist of the Fire trucks and specialized heavy-duty stacker for the heavy-duty assets.

Table 2 Corporate Fleet Vehicle Expected Life (years) and acquisition costs

Vehicle Class	Vehicle Type	Acquisition Cost ($)	Life Expectancy (Years)
Heavy Duty	Dump Truck	$250,000	12
Heavy Duty	Fire Truck	$1,000,000	10
Heavy Duty	Pickup Truck	$90,000	10
Heavy Duty	Plow	$350,000	12
Heavy Duty	Salter/Sander	$450,000	12
Large and Small Medium Duty	Dump Truck	$80,000	10
Large Medium Duty	Pickup Truck	$55,000	10
Large Medium Duty	Vactor Truck	$400,000	10
Light Duty	Car	$30,000	10
Light Duty	Mower	$10,000	10
Light Duty	Pickup Truck	$45,000	10
Light Duty	SUV	$35,000	10
Light Duty	Tractor	$35,000	15
Light Duty	Van	$40,000	10

Vehicle Class	Vehicle Type	Acquisition Cost ($)	Life Expectancy (Years)
Medium Duty	Pickup Truck	$50,000	10
Equipment	Ice Resurfacer	$125,000	12
Heavy Duty	Equipment	$30,000	12
Heavy Duty	Trailer	$15,000	15
Light Duty	Equipment	$125,000	12
Equipment	Mower	$100,000	12
Equipment	Plow	$5,000	12
Equipment	Sweeper	$5,000	12
Equipment	Tractor	$100,000	12
Equipment	Utility Vehicle	$12,000	12
Specialized Heavy Duty	Blower	$200,000	15
Specialized Heavy Duty	Dump Truck	$400,000	12
Specialized Heavy Duty	Loader	$350,000	12
Specialized Heavy Duty	Stacker	$1,560,000	15
Specialized Heavy Duty	Sweeper	$400,000	10
Specialized Heavy Duty	Tractor	140,000	12
Trailer	Trailer	$5,000	12

2.3 ALTERNATIVE FUELS EXPERIENCE AND ENVIRONMENTAL INITIATIVES

The City of Barrie's current Corporate fleet is predominantly made up of traditional fuel vehicles (gasoline and diesel). The City has a set of ice resurfacers that are fueled via CNG, thus a subset of operators and mechanics have exposure to this fuel type. Further, the City also has experience with hybrid electric (HEV) cars.

The City of Barrie has developed a Climate Change Adaptation Strategy which aims to increase the sustainability of City operations and provide a guideline to meeting its environmental goals.

As part of Barrie's Climate Change Adaptation Strategy, seven goals were developed to guide the development of the City's actions, together with cross-cutting actions that are applicable across more than one goal.[2] The Cross Cutting Actions include the following:

- "CC.1 Incorporate climate change into the City's Official Plan.
- "CC.2 Integrate climate change considerations into Barrie's existing plans and policies (e.g. Multi-Modal Transportation Plan, Transportation Master Plan, Emergency Management Plan, etc.)

[2] Barrie-Climate-Change-Adaptation-Strategy.pdf

- "CC.3 Develop education initiatives to lead and encourage awareness of climate change for Barrie residents, businesses, and City staff. When possible, integrate these initiatives into existing programs and communications".

The goals most pertinent to adoption of a greener Corporate fleet include the following:

- Maintain Public Health and Safety (via reduction of air emissions)
- Strengthen Infrastructure Resilience
- Protect Biodiversity and Enhance Ecosystem Functions
- Minimize Disruption to Community Services
- Build Community Resilience

2.4 FACILITIES AND INFRASTRUCTURE ANALYSIS

The team visited the City of Barrie's Operations Centre, Satellite Locations and Transit Garage on November 4th, 2020. Information regarding the location, parking, maintenance ability fueling sites, and related observations for each site is summarized below.

Operations Centre (165 Ferndale Dr.)

Figure 2 Operations Centre (165 Ferndale Drive)

Table 3 Operations Centre Site Map Legend

No.	Description
1.0	Employee & Outdoor Fleet Parking
2.0	Greenhouse Building
3.0	Indoor Parking (Traffic)
4.0	Indoor Parking (Parks & Rec)
5.0	Indoor Parking (Municipal Works)
6.0	Fleet Maintenance
7.0	Salt Barn & Indoor Salt/Sander Truck Parking
8.0	Vehicle Wash
9.0	Salt Dome

Site Observations:

- This site is the central location for all municipal vehicle maintenance and repairs except for ambulance and police vehicles.
- Ambulance and police vehicles have their own maintenance repair techs due to demands on turnaround time.
- All vehicles are fueled off-site (previously had gas/diesel fuel pumps but not anymore).
- Protected wetland is present around the site.
- Buildings constructed in 1973, currently working on a reconstruction plan.
- Roof structure would not permit roof mounting of electrical equipment as it was designed for dead load and snow load only.
- Floor space can permit vehicle charging stations with charger cabinets located outside.
- City of Barrie has 1x EV 2016 Ford Focus with Level 2 charge station located inside Traffic Division vehicle storage (Point 3).
- City and contractor plows are parked on-site at the rear of lot toward the salt barn and moved to Municipal Works indoor parking in winter months.
- Municipal Works can park in 6 bays 4x plows deep (priority for winter operations vehicles to be parked indoor during winter months). Vacuum trucks and sweepers are currently parked indoors but are moved to a rented building to make room for plows.
- Salt barn has indoor storage for all salt/sander trucks.
- No staff has High Voltage safety training and no PPE, specialized tools, safety equipment for maintenance of EVs, CNG or hydrogen vehicles on site.
- Shop has 50,000 lbs in-ground hoists (capable of lifting Class 8 fire trucks) and 20,000 lbs portable hoists.
- No major engine/transmission rebuilds are done in-house.
- Automatic drive-through wash on-site. Vehicles are put through air dry and winter operations wash after each deployment.
- City of Barrie has permitted utility to install solar panels on roof of maintenance building and salt barn.
- On-site backup power uses a Detroit Diesel 312 kVA generator.

Figure 3 Municipal Fleet Parking Outdoor (Left) and Indoor (Right)

Figure 4 Vehicles in Repair Shop

Figure 5 Maintenance Shop Inside (Left) and Outside Rear (Right)

Fire Station 1 (155 Dunlop St.)

Figure 6 Fire Station 1 (155 Dunlop Street)

<u>Site Observations</u>:

- Fire Station to dispatch Pump Truck 1, Rescue 1 and Tower Truck 1.
- City of Barrie's service requirement is to deliver 10 firefighters within 10 minutes response time[3].
- Marine 1 hovercraft boat for Lake Simcoe is also located at this station.
- All vehicles fuel off-site at approximately one block away, and all vehicle maintenance are done at 165 Ferndale Operations Centre.
- Vehicles have aux plug to keep vehicle starter battery charged.
- Fire department have 4x Toyota Camry gas-hybrid administrative cars on site.

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[3] Based on site interview

Surface Water Facility (20 Royal Parkside Dr.)

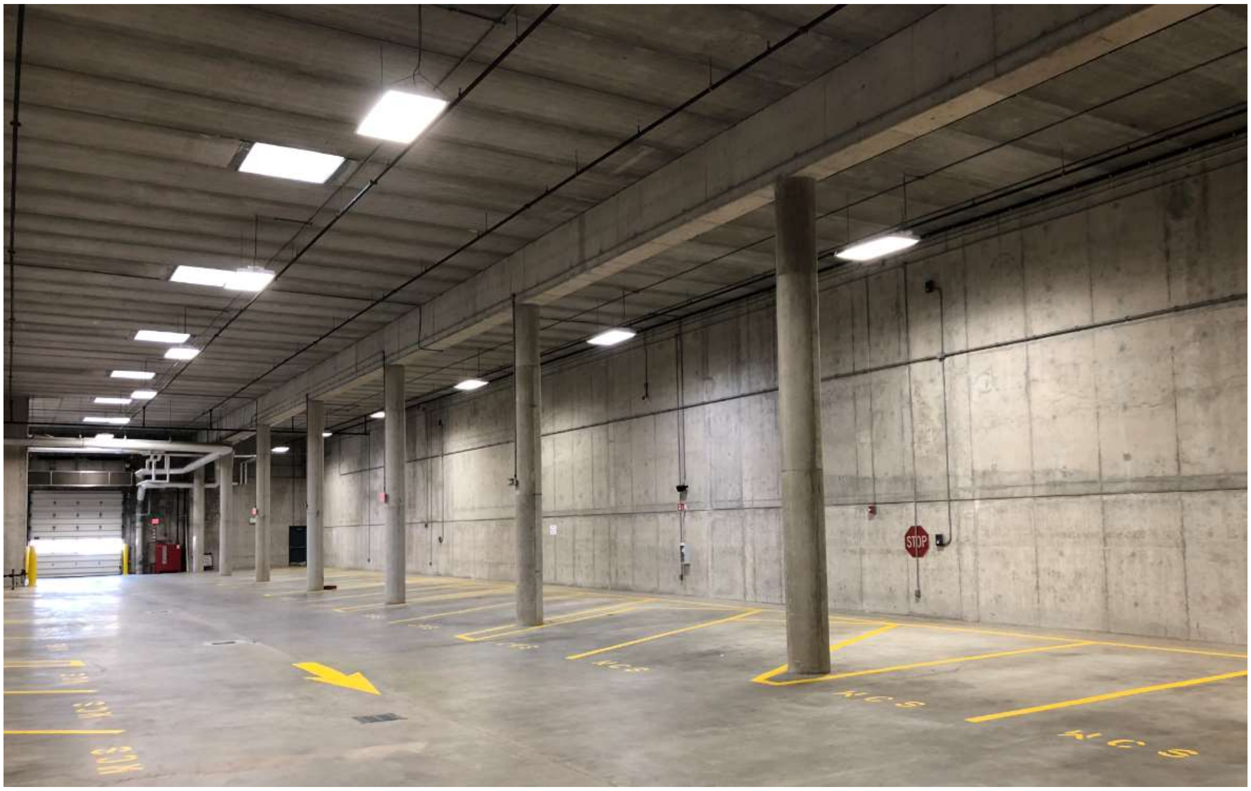

Figure 7 Surface Water (20 Royal Parkside Drive)

Site Observations:

- Approximately 30 vehicles on-site, and all can be parked indoor in heated underground parking garage, but no excess parking capacity for additional vehicles.
- 2x designated parking spots near rear with overhead doors for large diesel vacuum truck and dump truck.
- All vehicles are fueled off-site and all vehicle maintenance are done at 165 Ferndale Operations Centre.
- There is space in the parking garage for installation of EV chargers (in front of parking spots along wall there is 42” between wall, and 30” space between line painting around column supports).

Wastewater Treatment Facility (249 Bradford St.)

Figure 8 Wastewater Treatment Facility (249 Bradford Street)

Site Observations:

- Approximately 30 vehicles are located on-site.
- Most of the parking are outdoor parking combined with employee parking, on a first come first serve basis.
- Fleet at this facility include: Light-duty pickups, vans, 5-ton diesel service truck (1x) and diesel vacuum truck (1x).
- Small garage (left photo above) used to store 2 to 3 plow trucks/sanders in winter months.
- There is an on-going study for the use of methane gas produced on-site. Currently, methane is used to power the two gas engine generators on-site (250 kW each) available for stand-by power.
- All vehicles go to the 165 Ferndale Operations Centre for maintenance and repair.
- There is on-going program for substation upgrade, as power demand is expected to double from the current 1.3 MW demand for wastewater operations. The site power capability is 100% redundant, with 1.5 MW diesel generator on-site for back-up power and redundant transformer.
- Space available in employee parking area for EV chargers.
- All vehicles are fueled off-site.

2.5 UTILITIES ENGAGEMENT

Electricity

The City of Barrie's electrical utility, Alectra, provided the nameplate rating of the existing transformers feeding the fleet facilities. Note that the existing transformer at the Surface Water and Waste Water Treatment Plants are City owned. If replacement transformers are required, it would be at the City's cost.

Alectra also provided daily data points at 60-minute intervals for 2019, for each of the four facilities. These data points were used to calculate average and peak kW loads on an hourly basis.

Averaging this data may not reflect true peak demand loads and additional information would be required to make a more informed assessment.

Natural Gas / Hydrogen

The City of Barrie is uniquely situated on Highway 400, a major corridor to Northern Ontario, and therefore could benefit from a joint venture with a gaseous fuel refuelling partner, where the installation of a public refuelling station adjacent to one of the highway exits would allow for the City's fleet of vehicles, along with other private and commercial vehicles to fuel at a public refuelling station.

A variety of gaseous fuels including Compressed Natural Gas (CNG), Renewable Natural Gas (RNG), Liquified Natural Gas (LNG), Hydrogen and Renewable Hydrogen are possible solutions that would support internal combustion engine vehicles. Alternatively, Hydrogen and Renewable Hydrogen would also support fuel cell electric vehicles. Theses gaseous fuelling solutions offer varying degrees of greenhouse gas emissions reductions.

Gaseous fuels refuelling stations are capital intensive and a joint venture with a gaseous fuel refuelling partner such as Enbridge, would allow the City to benefit from a centrally located refuelling station without having to fund the initial capital cost of a station. The refuelling partner would benefit from an anchor client to help justify the installation of the station, while traffic from other private and commercial fleets grows over time as our society transitions to alternative fuels.

3 ALTERNATIVE TECHNOLOGY OVERVIEW

3.1 TECHNOLOGIES AND TRENDS

The objective of this section is to provide a technical overview of the green vehicle technologies (electric, natural gas, hydrogen electric, high ethanol, renewable diesel, and bio-diesel) for vehicles and equipment that could potentially be adopted by the City.

A detailed summary and comparison table, along with a market analysis of each alternative fuel technology considered has been attached in Appendix B – Alternative Fuel Summary Table.

The International Energy Agency (IEA) published a forecast on the sales volume according to the various propulsion technologies becoming available in the market. This forecast shown in Figure 9 highlights a notable shift towards electric, plug-in electric and hybrid vehicles from 2020 onwards[4].

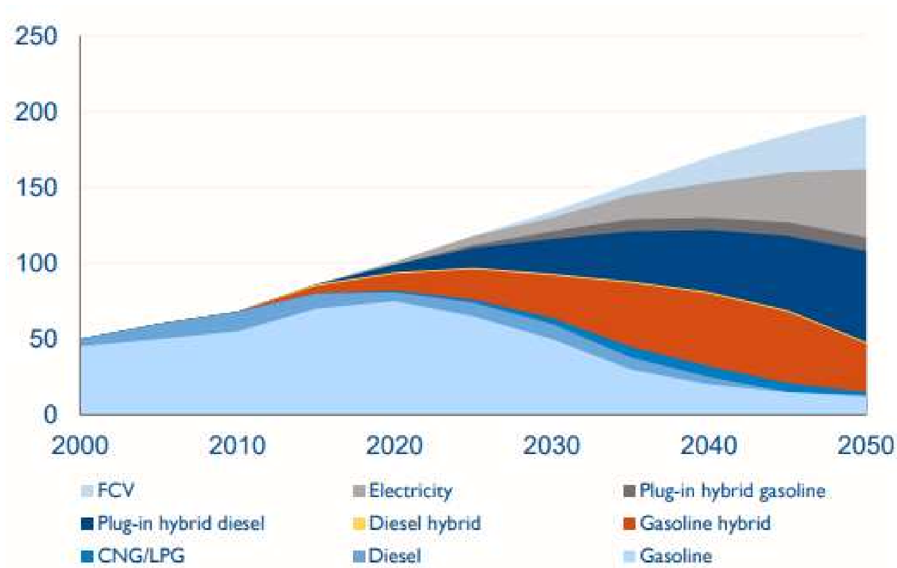

Figure 9 Sales Volume Forecast by Propulsion Technology (millions of units)

Source: A.D. Little

There is an increasing trend for hybrid vehicles with the general population, and light-duty vehicle fleets are also adopting plug-in electricity and hybrid, whereas diesel and gasoline based vehicles are expected to see a dramatic decline in sales in the decades proceeding 2020. This expected change in the automotive market is expected to be catalyzed by several factors including:

- Climate change agreements globally (Paris Agreement) and increasing environmentally sensitive public policy
- Maturing electric and fuel cell technologies
- Increasing widespread electric and hydrogen fuelling infrastructure
- Cost improvements for alternative fuel vehicles

[4] Arthur D Little, 'What's in the future for fuel cell vehicles', 2017. Available at: https://www.adlittle.com/sites/default/files/viewpoints/ADL_Future%20of%20Fuel%20cell%20vehicles.pdf

3.2 BATTERY ELECTRIC

3.2.1 TECHNOLOGY FUNCTIONAL OVERVIEW

A battery electric vehicle (BEV) operates with the same principle as the electric drivetrain components in HEV and PHEVs. A battery powers the electric traction motor which drives the wheels. The vehicle's battery is charged by means of a plug-in coupling and by regenerative braking during operation. The main benefit of a BEV is the removal of the gas drivetrain. As a result, during use this vehicle produces no emission nor requires fuel system components or engine/transmission lubrication systems. This leads to reduced complexity, increased reliability and lower maintenance costs. In addition, there is an overall increased energy efficiency compared to combustion engines due to lower mechanical and thermal energy losses, and high motor efficiency. This ultimately results in lower fuel or energy operational costs of the vehicles[5]. The main components of BEV are illustrated in Figure 10 and Table 4[6].

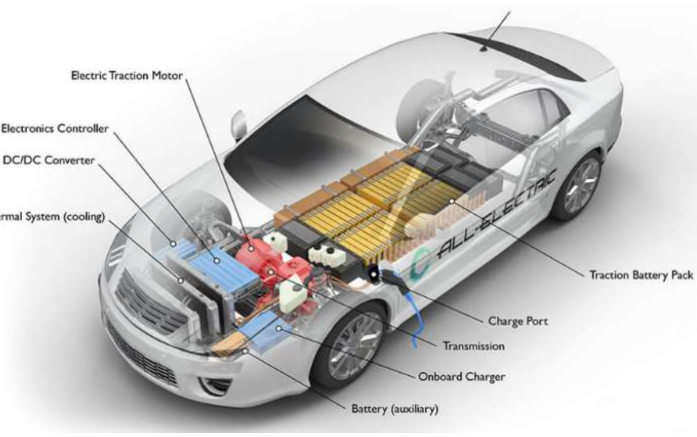

Figure 10 BEV Major Components

Source: Alternative Fuels Data Center

Table 4 BEV Vehicle Components

Component:	Functionality:
Traction battery pack	Vehicle power source, stores electric energy during charging and regenerative braking to power the traction motor, denoted with kWh
Charge port	Access/interface point for external power supply to charge the vehicle battery
Transmission	Transfers electrical power from the traction motor to the wheels, much reduced in complexity compared to ICE (internal combustion engine) vehicles
Onboard charger	Converts external AC power supplied to DC for vehicle charging
Battery (auxiliary)	Low voltage to power auxiliary vehicle electronics (lights, HVAC etc.)
Thermal system	Regulates the temperature of operating electrical components
DC/DC converter	Converts high voltage to low voltage from the traction battery
Power electronics controller	Computer that controls the energy flow from the battery, traction motor speed and torque
Electric traction motor	Drives the vehicles wheels and recharges the battery pack through regenerative braking and reverse power flow

[5] BC Hydro, Power smart, 2021, Available at: https://electricvehicles.bchydro.com/learn/costs-of-electric-vehicles
[6] Alternative Fuels Data Center, 2020, Available at: https://afdc.energy.gov/vehicles/how-do-all-electric-cars-work

Electric Vehicle Charging Stations

Both PHEVs and BEVs are charged by means of a plug-in connector. In North America, the Society of Automotive Engineers (SAE) has established a standard plug-in connector types which ensures the interoperability of charging stations and EVs from different OEMs. This standard is SAE J1772.

As shown in Figure 11 there are two modes of charging, through alternating current (AC) and direct current (DC). The power supply from the electrical grid is in the form of AC and must be passed through a rectifier to be converted to DC.

In addition, there are different charging levels classified by the rate of power transfer for charging the vehicle's battery.

Charging level	AC / DC	Power	km added per hour of charging
Level 1	AC and DC	0-10 kW	50 km
Level 2	AC and DC	10-50 kW	50 – 250 km
Level 3 (Fast charging)	Only DC	> 50 kW (up to 350 kW)	250 – 1750 km

Figure 11 EV Charging Station Specs & Connector Types

Source: ABB

LEVEL 1 AC CHARGING

Level 1 is the slowest form of charging. It uses a plug to connect to the on-board charger and a standard household (120 V) outlet. The on-board charger is the factory-installed charging device that converts AC power from the wall to DC power that charges the vehicle's battery. Charging speeds may vary but the most common chargers are 6.6 kW on battery electric vehicles (BEVs) and 3.3 kW on plug-in hybrid electric vehicles (PHEVs).

LEVEL 2 AC CHARGING

Level 2 uses electric vehicle service equipment (EVSE) as an intermediary between the power source and the vehicle's charging port to provide power at 220 V or 240 V. The EVSE is typically mounted on a wall or a pedestal and is used to relay AC power to the vehicle safely.

LEVEL 3 DC FAST CHARGING

DC Fast charging uses a unit that is roughly the same size as a standard gas pump. This is because this unit takes care of the AC to DC conversion itself, rather than using an on-board charger to accomplish this. DC Power is then relayed via the vehicle's charging port. DC offers the fastest charge rates up to 350 kW.

In North America some of the prominent manufacturers for EV charging stations include ABB, Siemens, Flo and Charge Point. Several of these providers have app based global positioning system (GPS) maps to show the locations of publicly available charging stations.

3.2.2 MARKET OVERVIEW

By 2025, the battery market is expected to over $90 billion, spurred on by investments through companies like Tesla, Dyson, and Daimler AG, along with traditional auto manufacturers pivoting towards electric vehicles[7]. The worldwide market for lithium-ion batteries (the most common battery type used in electric vehicles) is expected to have continually strong growth in the near future. The market for lithium-ion batteries was estimated at $31 billion (USD) in 2019 and is forecasted to reach $80 billion (USD) by 2026, reflecting a 15% compounded annual growth rate (CAGR)[8] from 2020 to 2027. There is even worry amongst analysts that this large investment in lithium-ion batteries may crowd out other technological innovations[9]. The growth in this sector is being fueled by a large spend in research and development, notably in two key areas which will help accelerate the adoption of battery electric vehicles:

- Price Point (Cost per kWh of lithium-ion batteries)
- Energy Density (kWh/kg)

The battery cost trend is presented in Figure 12 which shows a decline of about 20% per year. This graphic is according to a survey conducted by Bloomberg of over 50 companies in the battery manufacturing sector.

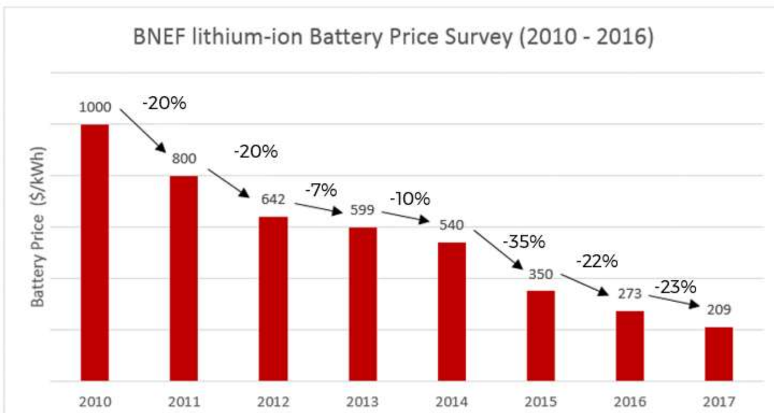

Figure 12 Price Trend of Lithium-Ion Batteries

Source: ABB

Analysts forecast that the key tipping point for electric adoption will be in 2025 when the cost per kWh for lithium-ion batteries is projected to reach $100/kWh[10]. This will put the energy cost and density of battery electric on par with diesel and gasoline. In 2017 the average cost for lithium-ion batteries is at $209/kWh for light-duty vehicles. For heavy-duty vehicles such as Class 8 trucks and highway tractors the cost is around $900/kWh.

In addition, the energy density of batteries has also been improving at a quick pace of approximately 6-8% per year following an exponential trend[11], as show in Figure 13. Due to these two factors electric vehicle OEMs are constantly improving the range on their vehicles.

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[7] Digitaltrends, 'Lithium-ion is just the beginning', 2020, Available at: https://www.digitaltrends.com/features/the-future-of-batteries-energy-storage-technology/

[8] Zion Market Research, Global Lithium Ion Battery Market: Industry Size, Share, Demand, Trends, Growth, Analysis, and Forecasts, 2020–2026, 2020. Available at: https://www.globenewswire.com/news-release/2020/11/10/2123390/0/en/At-15-CAGR-Lithium-Ion-Battery-Market-Share-Will-Reach-USD-80-Billion-By-2026-Facts-Factors

[9] Brookings, 'Investment in lithium-ion batteries may crowd out future innovation', 2016. Available at: https://www.brookings.edu/blog/techtank/2016/10/04/investment-in-lithium-ion-batteries-may-crowd-out-future-innovation/

[10] Bloomberg New Energy Finance survey of 50+ companies

[11] The energy-storage frontier: Lithium-ion batteries and beyond (Crabtree, Kocs and Trahley), 2015

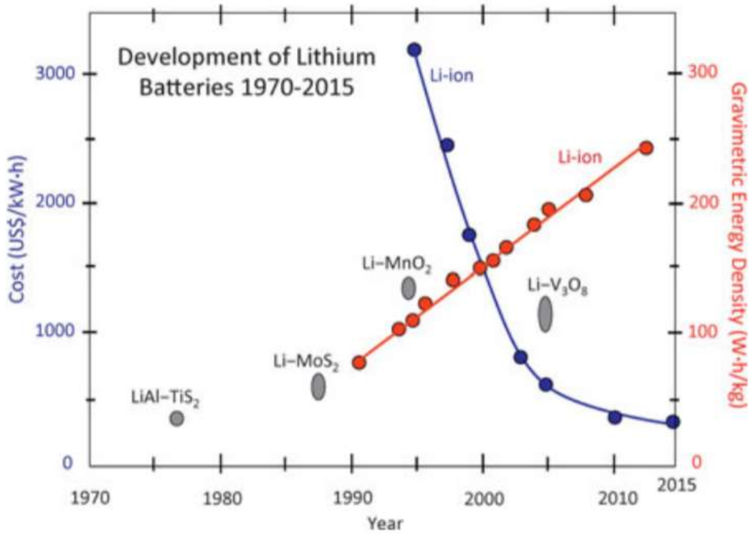


Figure 13 Energy Density Trend of Lithium-Ion Batteries

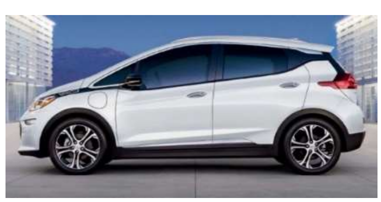
Source: Crabtree Kocks and Trahley

RELEVANT EV MARKET SCAN

The current BEV market has a variety of options for light-duty cars and SUVs available. Some of the most popular OEMs (offering BEVs) include: Tesla, Chevrolet, Hyundai, Nissan, Volkswagen, Kia and Ford. In addition, a few OEMs currently offer light-duty electric pickups: Rivian, Bolinger, Tesla. The current market also has small electric equipment and tools readily available. On the heavy-duty front, battery electric buses are increasingly being deployed for full fleet scale replacements, while electric heavy-duty trucks are still at the pilot projects phase.

In Canada, there has been a proliferation of electric, hybrid and plug-in hybrid vehicle models available on the market for the lighter vehicle classes, with all major auto manufacturers offering electric models or declaring concept electric cars to be released in the near future. The price for these models ranges from $37,000 to $52,000. There are several battery electric car options for the lighter vehicle classes currently available in Canada; six are described below.[12]

Table 5 Popular Light Duty Battery Electric Vehicles in Canadian Market (2020)

Model Name	Image	Description
Chevrolet Bolt		Chevrolet provides customers with an all-electric model called the Bolt. This vehicle is known for its elite all-electric range of 417 km. Other specs and performance measures include a 60-kWh lithium-ion battery, an ability to accelerate from 0 to 96 km/h in under 6.5 seconds and 266 lb ft. of torque

[12] Vehicle specification and data courtesy of vehicle OEMs (obtained publicly)

Hyundai Ioniq Electric		The Hyundai Ioniq all-electric model can travel up to a range of 274 kilometres on a single charge. The car has 134 hp, 218 lb. ft. of torque, a 38.3 kWh lithium-ion battery, and a maximum operation speed of 165 km/h.
Hyundai Kona Electric		The Hyundai Kona electric is a full electric car powered by a 64-kWh lithium-ion battery and 150 kW electric motor. The Kona can run 415 km on a full charge and comes with a regenerative braking system. It also comes with a Level 3 SAE Combo-type charger port. The Kona has a standard onboard 7.2 kW charger (Level 2) that can completely charge the battery in 9 hrs 35 mins while the Level 3, 50 kW quick charge can charge 0 to 80% of the battery in 75 mins.
Nissan Leaf		The Nissan Leaf is one of the world's best-selling electric cars. It has a nominal all-electric range of 363 km, with a 30-min quick charge option, which provides a range of 145 km. Other specs include a 62-kWh lithium-ion battery, 147 hp, as well as 236 lb ft. of torque, and a potential range close to 500 km.
Volkswagen E-Golf		The e-Golf is Volkswagen's first 100% electric vehicle in Canada. The hatchback has a nominal all-electric range of 201 km with a 35.8 kWh lithium-ion battery. The e-Golf has 134 hp with a 214-lb ft. of torque that helps the car travel from 0 to 100 km/h in 9.6 seconds.
Kia Soul EV		The Kia Soul EV is Kia's first battery electric vehicle available in Canada. It has a range of 248 km with a 39.3 kWh lithium-ion polymer battery pack and an exceptional torque rating of 291 ft. lbs.

Tesla Model 3		The Model 3 is Tesla's mass market electric four-door sedan. The Tesla Model 3 is available from $54,600 and has several battery options available. The standard model has up to 400km while the long-range version can deliver up to 518km.
Ford Mustang Mach-E		In 2020, Ford launched their first fully electric model SUV called the Mustang Mach-E. The Mach-E can be specified with either a 77.5 kWh or 98.8 kWh battery pack which tops out at range of about 480km. The Mach-E has an electric motor that delivers 255hp (190 kW) or 459hp (342 kW) based on the purchase specification. Prices range from $40,000 up to $65,000.

BATTERY ELECTRIC TRUCKS

Several start-up companies are approaching the market of electric trucks alongside more established companies like Tesla. Concept cars have also been announced by Chevrolet, GM and Ford. Although information is limited on some of these newer models and concept cars to roll on to the market in the next 5 years, below are examples of vehicles entering the market or under development as early as 2020. For additional information on other types of electric trucks, such as the Havelaar Bison, refer to Appendix A.

Table 6 Battery Electric Trucks in Canadian Market

Model Name	Image	Description
Rivian R1T		Rivian, a start-up automaker, is planning to introduce the R1T pickup for the 2021 model year that enables autonomous driving on the highway. The truck has a quad-motor all-wheel-drive system and will be able to reach 60 mph in just 3 seconds and tow up to 11,000 lbs. There will be three battery size options, with the highest range unit claimed to exceed 400 miles in one charge.
Bollinger B2		Bollinger is another new automaker based in Detroit, which plans to introduce an electric pickup called the B2 in 2021 or 2022 to follow the B1 SUV that is in development for 2020. It features a removable windshield, door panels, roof and rear. With 614 hp, the B2's dual-motor all-wheel-drive system will accelerate from 0 to 60

		mph in four seconds, tow up to 7,500 lbs, and run up to 200 miles on a single charge.
Tesla Cybertruck		Tesla unveiled its Cybertruck in November 2019. The base model is expected to cost $39,900 USD and provide an operating range of 250 miles. The all-wheel drive tri-motor model is priced at $69,900 USD and targets a 500-mile range. The tri-motor model will be able to tow up to 14,000 lbs. Its adaptive air suspension can provide up to 16 inches of ground clearance. Production of the Cybertruck is scheduled to start in 2021.
Havelaar Bison		Havelaar is a Canadian based start-up and has been developing electric powertrain technology (i.e. on-board charging systems, H-150 inverter) to support various electric vehicle developments. In 2017, Havelaar partnered with the University of Toronto's Electric Vehicle Research Centre (UTEV) to launch a prototype electric pickup truck called the Bison. The truck can travel up to 300km on a single charge. It has fully electric all-wheel drive (AWD) and 1.3m^3 (46 ft^3) of bed cargo space.
Ford Electric F150		Ford announced in Fall 2019 that they will be adding a fully electric version of their best selling F150 pickup to their line-up with a launch scheduled for 2021. Ford has developed some early marketing stunts for the F150 including a towing competition versus the Tesla Cybertruck in which the F150 was declared the winner. The electric F150 as demonstrated its high torque by towing over 1 million pounds of freight cars. Ford has not yet published vehicle specifications however it is anticipated to provide at least 300 miles of driving range

BATTERY ELECTRIC VANS

NAVISTAR INC ESTAR™

Navistar Inc. is an American manufacturer of medium- and heavy-duty trucks. The eStar™ is a Class 2 to 3 electric van. It has a range of 160 kilometres (100 miles) per charge and can be fully recharged under 8 hours. It has a lithium-ion battery pack, supplied by A123 Systems, which can be replaced in less than 20 minutes. This model is ideal for on-call operations and services required around the clock. Navistar claims that each eStarTM truck or van can reduce GHG emissions by 10 tonnes annually.

NISSAN E-NV200

Nissan has launched an electric version of their NV200 van, which is a popular vehicle model in municipal fleets. The e-NV200 has a 40-kWh battery which provides a range up to 190km. The e-NV200 has a maximum cargo volume of 3m^3 and is priced around $55,000.

WORKHORSE GROUP: ELECTRIC DELIVERY VAN

Workhorse Group has designed a Class 5 electric van that weighs 5,500 lbs, with 1000 cubic-foot cargo bays. Each van can carry up to 5,000 lbs of payload. The 60 kWh battery packs will have a range of 160 km (100 miles) on a single charge.

ARRIVAL ELECTRIC DELIVERY VAN

Arrival is an electric vehicle start-up based in the UK. The company has launched an electric delivery van and currently has a pilot program with UPS. The Arrival electric van has a lithium-ion battery pack capable of providing up to 160km operating range and the van has a maximum payload capacity of 4,350 kg (9,370 lbs) classifying it in the light-duty category for municipal vehicles. UPS has announced an initial order of 10,000 Arrival vans to be rolled out in their fleet from 2020 to 2024.

BATTERY ELECTRIC TRACTORS

The market for battery electric propelled tractors has been increasing in the past few years, with options available for farming and general utility uses. Solectrac[13] is a firm that specializes in “climate smart electric tractors”. They provide a general purpose electric tractor called “eUtility” that comes with a 26-kWh battery pack (offering 3 to 6 hours of run time), an optional additional battery pack and level 2 fast charging that can recharge 80% of the battery in 3 hours. The battery life is approximately 10 years. eUtility is zero emission and has a lower noise output compared to diesel tractors. Solectrac offers 2WD (wheel drive) and 4WD models (in development). Solectrac claims that eUtility can maintain 24 hp continuously or have a 50 hp peak, and has an expected service life of 80,000 hours.

[13] https://www.solectrac.com/eutility

Fendt e100 Vario electric tractor[14] is another battery powered tractor offered by Fendt, and has a large battery pack size of 100 kWh. The e100 Vario is claimed to be able to provide almost 70 hp and can be sustained for 5 hours under normal conditions. It also offers a "supercharging" options that allows 80% re-charging in approximately 40 minutes. An energy-efficient thermal management system utilizing a heat pump allows for pre-heating and cab-cooling as required for operator comfort, while the tractor is connected to the power supply. The Rigitrac SKE 500 and John Deere SeSAM are other battery electric tractors.

ELECTRIC ICE RESURFACERS

In an effort to reduce emissions, municipalities have been looking for greener ice resurfacer options. In support of this, manufacturers have been developing alternatives to gasoline/ CNG ice resurfacers in the form of Li-ion battery electric ice resurfacers for the market. Zamboni is a renowned manufacturer of ice resurfacers, and they have recently launched their Model 450 Lithium-ion[15], which is designed to meet the industrial requirements. Zamboni states that their electric model can charge quickly between resurfacings, maintaining power and can support a variety of arena schedules. Furthermore, the battery packs require no maintenance, and are completely emission free. Zamboni also offers an optional heavy-duty battery package that supports additional resurfacing for long use periods. The estimated unit price for Model 450 is $125,000. The City of London is in the process of acquiring 14 ice resurfacers from Zamboni for replacement of their existing natural gas fleet, and they estimate this will reduce their GHG emissions by 212 tonnes per year[16].

The OLYMPIA Millennium E is another electric ice resurfacer available on the market for a similar price point as Model 450. OYPMIA claims that the operating expenses of Millennium E is expected to be one tenth the cost of standard propane or natural gas ice resurfacers and the chassis is supposed to last twice as long[17].

The City of Barrie is in the process of replacing one of its existing ice resurfacers with electric as a pilot test (as of writing of this report). The City expects to go to market in early 2021 and receive a unit later in 2021. This presents an excellent opportunity for the City to examine the potential benefits of operating electric, and whether a full transition of its 11 ice resurfacers to electric is feasible.

HEAVY-DUTY ELECTRIC VEHICLES

Build Your Dreams (BYD)

BYD, headquartered in Shenzhen, China, is the largest global manufacturer of electric vehicles and has introduced a Class 6 and a Class 8 truck into its line-up. The Class 6 truck is fully electric with a powertrain powered by the on-board 221 kWh battery pack providing up to 136 km of range. The battery can be slow charged with a 33 kW AC charger in 7 hours or fast charged using a 120 kW DC plug-in charger, which reduces the charging time to 2 hours.

The Class 8 truck has an on-board 435 kWh battery pack can also be charged within 3 hours with AC or in 1.5 hours with DC and can achieve a 200-km operating range. The traction motor has a maximum power of 483 hp.

BYD currently has several of these electric trucks on pilot in North America including in Los Angeles and Palo Alto, California as well as Seattle, Washington.

[14] Future Farming, 'This is the Fendt e100 Vario electric tractor', 2018. Available at: https://www.futurefarming.com/Machinery/Articles/2018/1/This-is-the-Fendt-e100-Vario-electric-tractor-4419WP/
[15] https://zamboni.com/machines/model-450/
[16] City of London, RFP Electric Ice Resurfacers
[17] http://www.resurfice.com/product/millennium-e/

Motive Power Systems

Motive Power Systems in an American OEM of heavy-duty vehicles based in Foster City, California. Motiv's electric truck can be configured with 170 kWh or 212 kWh battery packs providing up to 128 km of operating range with a gross vehicle weight rating of 66,000 lbs. The battery is charged with a 25-kW plug-in system which can recharge back to 50% in 2.5 hours and reach a 100% state-of-charge (SOC) in 8 hours.

Lion Electric Co.

The Lion Electric Co. based in Quebec, Canada is a relatively new OEM starting business back in 2011. They have developed a product line that includes an electric school bus, shuttle bus and Class 8 trucks. The truck has a 480-kWh battery pack capable of providing a maximum operating range of 400 km. The battery can be recharged using either 20 kW or 100 kW plug-in chargers. Lion is fulfilling its first orders for the truck which will supply customers such as CN Rail with operations scheduled to start in late 2019.

Volvo

Volvo is a Swedish manufacturer with a diverse business line including automobiles, transit buses, freight and heavy-duty trucks. Volvo has two electric Class 8 trucks set to be available in North America starting in 2020.

The Volvo FL is the smaller model with a Gross Vehicle Weight Rating (GVWR) of 16,000 kg. It has a maximum operating range of 300 km powered by a battery pack of up to 300 kWh. The Volvo FE is listed with a GVWR of 27,000 kg and will have a higher payload capacity. Also, with battery pack options up to 300 kWh, the operating range is slightly less than the FL model with preliminary specifications stating a 200-km range. Both vehicles can be fully charged in 1 to 2 hours with 150 kW DC fast charging. A slower 22 kW AC charging option will also be available.

Peterbilt

Founded in 1939, Peterbilt has a strong reputation in the brand of heavy-duty diesel trucks but has also identified the opportunity to pursue electric vehicles. The Peterbilt E520EV truck is currently in development. There is limited information available on this highly customizable truck today, but it is expected to be a Class 8 vehicle with a 70-kW charging system capable of reaching a 100% SOC in 2 to 4 hours. The battery size can be inferred to be around 280 kWh. Peterbilt is also developing a Class 6 electric truck called the E220EV. This model is stated to have 148 kWh battery pack providing a range of 160 km and can be fast charged within 1 hour.

Freightliner

Freightliner is another traditional diesel truck OEM transitioning into electric vehicles. Founded in 1942, Freightliner is scheduled to have its Class 6 eM2 106 electric truck available by 2021. Preliminary specifications state a 325-kWh battery size with 370 km maximum operating range. Furthermore, the charging system is stated to fast charge to 80% SOC in 1 hour. This truck has many available features, such as an emergency service application, and supports a wide range of bodies and chassis-mounted equipment.

AUTOMATED VEHICLE FLEET OPPORTUNITIES

Automated vehicles to support City operations are gaining in popularity, many of which are also electric. The following tables summarize a few of the options available.

Table 7 Autonomous fleet vehicles and equipment

Supplier	**Makita** – power tool / equipment provider, leveraging technology to introduce robotic features	**Left Hand Robotics** – provider of industrial robots for turf and snow maintenance operations	**Lumebot** – autonomous street clearing robot for trash, leaves, snow etc.	**Northstar Robotics** – technology platform provider for autonomous industrial vehicles (new build or equipment retrofits) for lawn mowing or snow removal	**Guimi Robot** – R&D company for infrastructure maintenance robot products, specialty in pavement condition assessments
Concepts	Robotic Industrial Vacuum 	RT-1000 Robot Tractor Grass Mover / Snow Clearing 	Next-Generation Smart Machines 	Retrofit existing devices with automation 	Robotic System for Road Disease Detection 
Details	Devices operate within a configured area of operation (defined boundary) and can follow random or defined paths.				
Costs	Variable across providers and according to the leasing / purchasing decision (as well as new equipment versus retrofit).				

3.3 HYBRID ELECTRIC AND PLUG-IN HYBRID

3.3.1 TECHNOLOGY FUNCTIONAL OVERVIEW

Hybrid electric vehicles (HEVs) and plug-in electric vehicles (PHEVs) are very similar. The main difference is the interaction between the electric and gas-powered drivetrains for each vehicle and the ability to charge a PHEV's battery pack directly through its charge port.

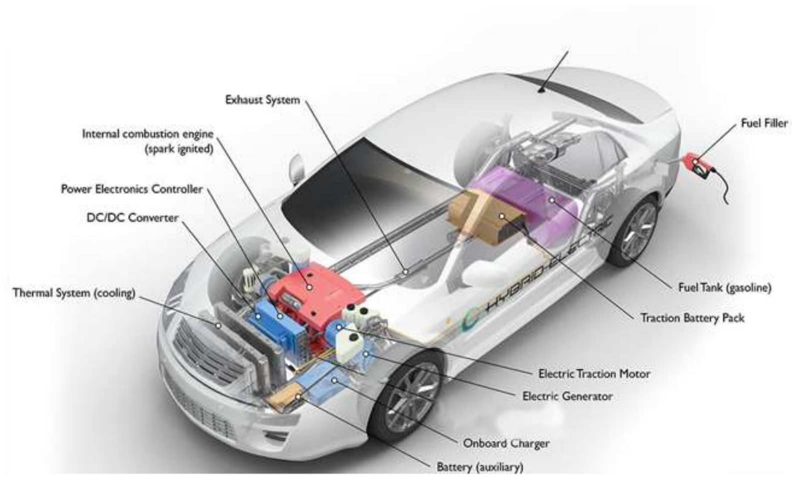


Figure 14 HEV Major Components

A HEV primarily uses its gas-powered engine to generate power. Fuel is supplied from the fuel tank through the fuel system which is injected into the engine and spark ignited to produce power. This vehicle also utilizes an electric drivetrain to aid acceleration and improve fuel economy. The vehicle is equipped with a battery pack which powers an electric traction motor used to drive the wheels. The traction motor is also capable of regenerative braking which recaptures energy during deceleration to charge the vehicle's battery.

PHEVs run on electric energy from its battery pack which powers its electric traction motor. PHEVs also utilize regenerative braking to recharge the vehicle's battery during use. The gas-powered drivetrain can be engaged to run in parallel (same as a HEV) or in series (only after the vehicle's battery pack has been depleted). From that point on, the PHEV operates as a conventional gas vehicle.

Figure 14 and Figure 15[18] show the main components of HEV and PHEV, and Table 8 provides a breakdown of the vehicle components.

The market for HEVs/ PHEVs has been quite matured with most major auto manufacturers offering HEV and PHEV light and medium duty cars, SUVs and pickup trucks. HEVs are also available for some heavy-duty trucks and vans.

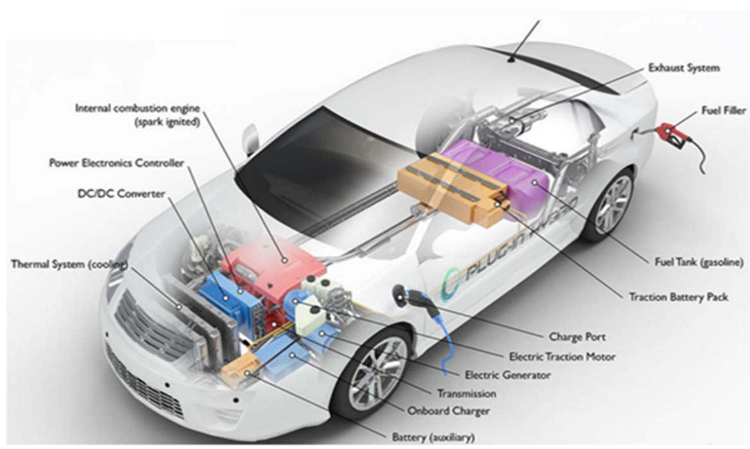


Figure 15 PHEV Major Components

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[18] Alternative Fuels Data Center, 2020, Available at: https://afdc.energy.gov/vehicles/how-do-all-electric-cars-work

Table 8 Hybrid (HEV and PHEV) Vehicle Components

Component:	**Functionality:**
Fuel filler	Access point to replenish fuel stored in the fuel tank
Fuel tank	Stores liquid fuel gasoline (diesel) until release into the fuel system
Fuel line	Transfers fuel from the fuel tank to the engine
Fuel Injection System	Vaporizes fuel that is injected into the engine for ignition
Internal Combustion Engine (ICE)	Produces mechanical power for the vehicle by spark ignition of injected fuel
Transmission	Transfers power produced by the ICE and/or traction motor to drive the wheels
Exhaust System	Channels exhaust gas from the engine out the vehicle tailpipe
Traction battery pack	Stores electric energy during charging and regenerative braking in order to power the traction motor
Electric traction motor	Drives the vehicles wheels and recharges the battery pack through regenerative braking
Electric generator	Generates electrical energy from braking (some traction motors incorporate this function)
Thermal System	Regulates the temperature of operating electrical components
Power electronics controller	Computer that controls the energy flow from the battery, traction motor speed and torque
DC/DC Converter	Converts high voltage from the traction battery pack to low voltage in order to power accessory vehicle electronics
Battery (auxiliary)	Low voltage to power auxiliary vehicle electronics (lights, HVAC etc.)
PHEV Only	
Charge Port	Access/interface point for external power supply in order to charge the vehicle battery
Onboard Charger	Converts external AC power supplied to DC for vehicle charging

3.3.2 MARKET OVERVIEW

The market of hybrid and plug-in hybrid vehicles is quite mature in comparison to the battery electric and hydrogen electric market. As many options are present from most major manufacturers, these include Toyota (Camry, Prius, RAV4 Hybrid, Highlander Hybrid), Kia (Optima Hybrid, Niro), Honda (accord Hybrid, Insight Hybrid), Hyundai (sonata Hybrid), Hyundai (Ioniq hybrid), and Ford (Fusion Hybrid).

3.4 NATURAL GAS (CNG/ RNG)

3.4.1 TECHNOLOGY FUNCTIONAL OVERVIEW

A CNG vehicle has a high degree of part commonality with a gasoline vehicle and both vehicles operate in a similar manner. Both use engines with spark ignition systems to generate power from injected fuel. The main difference is the CNG fuel system. CNG fuel is stored in pressurized tanks which are reduced in pressure through a regulator to an acceptable level for the fuel system. It is then fed through a fuel filter and passed through fuel lines upon being injected into the engine. The mixture of fuel and air is ignited by a spark which releases energy and powers the vehicle. See Figure 16 and Table 9[19] for a breakdown and description of the main components in a CNG powertrain.

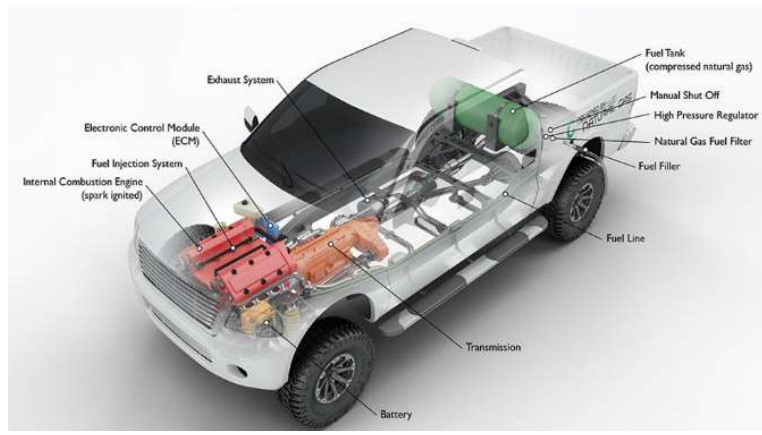

Figure 16 CNG Vehicle Major Components

Table 9 CNG Vehicle Components

Component:	Functionality:
CNG fuel tank	Stores pressurized CNG fuel until release into the fuel system
Manual shut off	Vehicle operator safety mechanism to shut-off the fuel supply
High pressure regulator	Reduces fuel pressure from the CNG tank to an acceptable level for passing through the fuel system
Natural gas fuel filter	Removes particulate, dirt and other contaminants that can harm the engine
Fuel filler	Access point to replenish fuel stored in the fuel tank
Fuel line	Transfers fuel from the fuel tank to the engine
Internal Combustion Engine (ICE)	Produces mechanical power for the vehicle by spark ignition of injected fuel
Fuel Injection System	Vaporizes fuel that is injected into the engine for ignition
Electronic Control Module (ECM)	Engine computer that controls valve timing, fuel injection, monitors engine performance and fuel economy
Transmission	Transfers mechanical power produced by the ICE to drive the wheels
Battery	Powers auxiliary vehicle electronics (lights, HVAC etc.) recharged by an alternator driven off the ICE
Exhaust System	Channels exhaust gas from the engine out the vehicle tailpipe

There are a number of aftermarket vendors that partner with vehicles OEMs to offer certified CNG options for vehicles. Some of the North American vendors include: Alternative Fuel Systems Inc., Frontier CNG Inc., and Landi Renzo Group. Several major medium and heavy-duty truck OEMs offer options to outfit their trucks with a natural gas powertrain, with Cummins Westport the primary OEM manufacturing the natural gas engines. The traditional heavy-duty truck chassis OEMs include Freightliner, Autocar, Mack and Peterbilt.

[19] Alternative Fuels Data Center, 2020, Available at: https://afdc.energy.gov/vehicles/how-do-all-electric-cars-work

3.4.2 MARKET OVERVIEW

Compressed Natural Gas (CNG)

While electric vehicles are popular for light-duty vehicles and advancements in heavy-duty fleets are dominating the news, CNG has a quite mature market in heavy-duty fleets. Natural gas offers a reduction in fuel cost as well as greenhouse gas emissions relative to gasoline or diesel and is also better suited to heavy duty fleet applications than for commuter vehicles. CNG vehicle and refuelling technology is well established in the heavy-duty vehicle market place, with time proven costing and reliability in the Canadian climate. Vehicle refuelling times for natural gas vehicles are similar to refuelling times for diesel or gasoline vehicles.

Natural Gas Vehicle (NGV) fuel currently has a price advantage over petroleum-based fuels that can help fleet owners reduce fuel costs. With known reserves of natural gas supply now in excess of 100 years, analysts have observed that NGV prices are expected to be predictable and stable for the foreseeable future. Natural gas provides an option that is not only cleaner than conventional petroleum fuels, but is becoming increasingly more economical. In general, CNG decreases vehicle emissions of nitrous oxide, sulphur dioxide and particulate matter in comparison to diesel and gasoline fuels.

In order to be used as a transportation fuel, natural gas must be processed to high pressure. A CNG fuel system contains significantly less energy than diesel fuel on a comparably sized vehicle. The amount of energy will vary by the amount of storage on board and the pressure that the natural gas is compressed to when the fuel system is considered “full”. CNG is therefore often used by short haul, return-to-base fleets. Refuse collection trucks, trucks, school buses and transit buses are appropriate applications for CNG fleets.

Renewable Natural Gas (RNG)

In addition to CNG, there is also the additional option of RNG (renewable natural gas) which can be used for fueling natural gas vehicles. RNG is natural gas that is produced from organic material decay and is carbon neutral as compared to CNG which is sourced from fossil fuels. RNG supply is currently limited and depended on local projects with landfills and other organic material decay sites.

In Ontario, Enbridge recently announced its partnership with the City of Toronto to install new biogas equipment at the Dufferin Facility which can potentially increase the production of RNG in the region. In Nova Scotia, Heritage gas is currently examining the opportunities for developing local sustainable and renewable gas projects.

Renewable Natural Gas (RNG) vehicles operate in the same method as a CNG vehicle. However, the main difference is the sourcing of the natural gas fuel. RNG is produced from biogas decomposing organic waste or bio-mass such as matter found in landfills, farms and other industries. The traditional method of producing natural gas is from underground rock and shale deposits which require a large amount of energy/work to extract and can lead to methane leaks. In contrast, RNG offers a carbon-neutral GHG emissions impact by recycling and repurposing gas which would have been emitted into the atmosphere. Figure 17 illustrates the high-level process of producing RNG proposed for the City of Toronto plan[20].

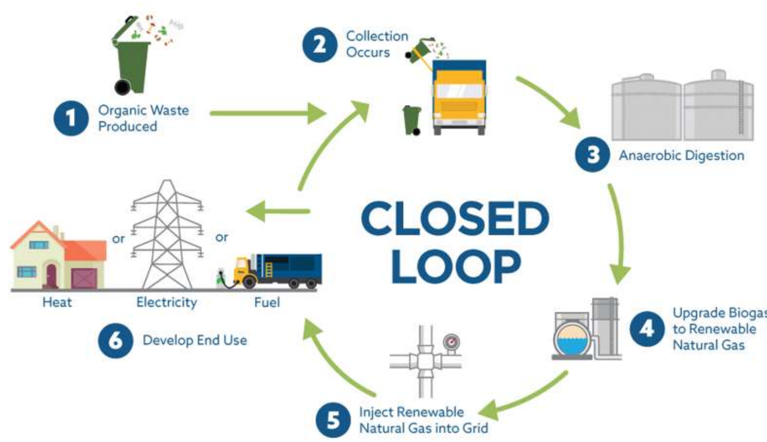

Figure 17 RNG Production Process

[20] City of Toronto, Turning Waste into Renewable Natural Gas, 2020. Available at: https://www.toronto.ca/services-payments/recycling-organics-garbage/renewable-natural-gas/

RNG (biomethane) has significantly lower lifecycle GHG emissions than CNG, and blending RNG with CNG can lead to significant GHG emissions benefits and reduction of fossil fuel consumption. RNG can lead to 80% GHG lifecycle emissions compared to diesel fuel[21].

NATURAL GAS FUELING STATIONS

An overview of the major components in a natural gas fueling station is shown in Figure 18. Natural gas fuel stations operate as natural gas is supplied from a distribution pipeline via a Custody Transfer Station (CTS) that is incorporated into the CNG station footprint. A minimum and maximum contract pressure is set, and the outlet gas pressure at the CTS is regulated to a maximum pressure.

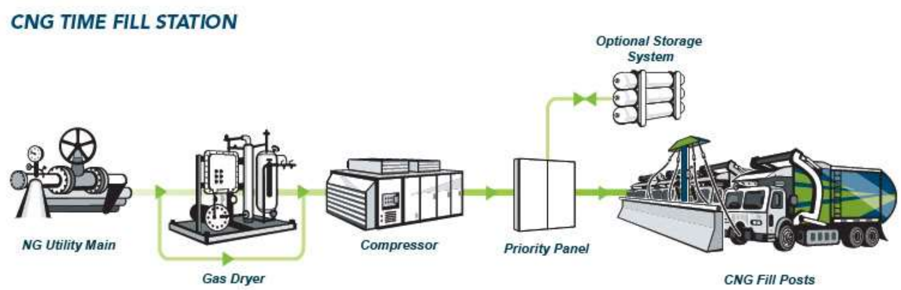

Figure 18 Schematic of CNG Fueling Station Components

The gas supply piping is routed from the CTS to the dryer. The drying of the gas and removal of any particulates provides additional protection to the compressors. The gas is routed through the gas desiccant vessel for drying. The moisture content of the outlet gas is monitored and an alarm is sent to the Master Controller if it exceeds the set point. When an alarm is received, the dryer vessel is taken out of service and regenerated. When regeneration is completed, the dryer is placed back into service.

Gas from the dryer is then sent to the compressors. The Master Controller communicates with the gas control panel and the compressors to direct gas to the buffer storage, or to the time fill posts or the fast fill posts as needed. The service pressure for both the time fill posts and the fast fill posts is typically 3,600 psig (250 barg). The actual target fill pressure depends on the ambient temperature.

Stations are equipped with enough compression to serve the load. The compressor arrangement is designed for a redundancy configuration. For example, with a 1+1 arrangement, one (1) compressor will deliver the required station flows. The second compressor is available on standby in the event of a problem with the on-duty compressor. The control logic will also include a “catch-up” mode whereby both compressors can be operated at the same time. The fill process is then triggered by connecting a “vehicle” to a fill post.

Overall, the cost estimate for a CNG fueling station can vary greatly depending on the availability of connection points to a natural gas utility main at the site, the number of fill posts, as well as the drying and compression requirements.

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[21] World Resources Institute, The production and use of renewable natural gas a s climate strategy in the United Stated, 2020, Available at: https://www.wri.org/publication/renewable-natural-gas

RELEVANT NATURAL GAS MARKET SCAN

The market for light-duty vehicles is typically focused on aftermarket vendors partnering with vehicle OEMs to offer a certified CNG option for their vehicles. Some vendors in North America include:

Figure 19 CNG Ford F150 Pickup

- **Alternative Fuel Systems Inc.** is a subsidiary of Westport Power Inc. who manufactures Cummins Westport CNG engines (including the Cummins ISL-G 280). AFS designs, develops and produces engine control units (ECUs) as well as providing aftermarket fleet conversion in the area of natural gas-powered vehicles.
- **Frontier CNG Inc.** is a company of fleet specialists offering CNG fleet conversions of vehicles from light- to heavy-duty vehicles. They also offer fuel pricing programs and strategies along with installation of CNG fuelling stations. Frontier CNG Inc. has their head office located in Mississauga, ON.
- **Landi Renzo Group** has recently received certification from the environmental protection agency (EPA)[22] for use of their Eco Ready CNG fuel system on Ford F150 pickup trucks. This upgrade can be outfitted through approved regional installers or specified with the truck build at the Ford plant in Kansas City, MI.

To give guidance on the conversion costs of fleet vehicles to natural gas, the following estimates in Table 10 are provided on the associated premium of outfitting different vehicle types with a natural gas option[23].

Table 10 Natural Gas Vehicle Upgrade Premiums

Description	CNG Upgrade Premium
Light-duty cars and SUVs	+$8,000
Light-duty trucks and vans	+$10,000
Heavy-duty public works	+$12,000

Several of the major medium- and heavy-duty truck OEMs offer the option to outfit their trucks with a natural gas powertrain. Cummins Westport is the primary OEM manufacturing natural gas engines for these vehicles. Current models include the Cummins ISX12N which can deliver up to 400 hp and the Cummins L9N with a range of 250 to 350 hp. Traditional heavy-duty truck chassis OEMs include Freightliner, Autocar, Mack and Peterbilt with Class 8 vehicle make/models.

Figure 20 Freightliner 114SD CNG Truck Snow Plow in Oxford County

Several of the major medium and heavy-duty truck OEMs offer the option to outfit their trucks with a natural gas powertrain. Cummins Westport is the primary OEM manufacturing natural gas engines for these vehicles. Current models include the Cummins ISX12N which can deliver up to 400 hp and the Cummins L9N with a range of 250 to 350 hp.

Traditional heavy-duty truck chassis OEMs include Freightliner, Autocar, Mack and Peterbilt with Class 8 vehicle make/models. The notable natural gas trucks available in the market today are mentioned below. Truck chassis OEMs such as Mack and Freightliner typically offer a range of custom options on chassis dimensions that enable capability with various uses of heavy-duty public works fleet vehicles.

[22] Automotive Fleet, EPA Certifies Landi Renzo's CNG F-150, Available at: https://www.automotive-fleet.com/343788/epa-certifies-landi-renzos-cng-f-150

[23] Estimates provided from Change Energy Services

Freightliner

Freightliner in their line-up of diesel trucks has introduced a heavy-duty Class 8 truck chassis. The Freightliner 114SD truck is powered by a Cummins Westport ISX12N CNG engine and can deliver 400 hp. The GVWR is 41,730 kg (92,000 lbs) and the 60-gallon (227 L) CNG tanks can store enough fuel to power over 640 km (400 miles) of driving.

Autocar

Founded in 1897, Autocar is an American manufacturer of Class 7 and 8 type heavy-duty trucks. Autocar has several different options of vehicle chassis dimensions to support a range of payload capacities. As well, Autocar offers the option for CNG powertrains on six of their current truck models (ACMD 4X2, ACMD 4X2, ACMD 6X4, ACX 4X2, ACX 6X4 and ACX 8X4).

These trucks can be built with Cummins L9N (250 to 320 hp) or ISX12N (400 hp) engines. Further details on truck options and subsystems (i.e. axle, transmission) make/models are available in Appendix F.

Mack

Mack has two truck models available with CNG options both Class 8. The Mack TerraPro and LR Model can be built with Cummins L9N engine providing up to 320 hp. These models can then be outfitted for a variety of public works applications.

Peterbilt

Peterbilt has their 520 Model Class 8 truck with several engine options for a natural gas powertrain from Cummins. These include the Cummins Westport ISLG and ISX12G. This truck can also be specified with either pneumatic disc or drum brakes.

3.5 HYDROGEN FUEL CELL

3.5.1 TECHNOLOGY FUNCTIONAL OVERVIEW

In addition to the growth of the Battery Electric Industry, another electric vehicle technology that has been developing concurrently is the hydrogen fuel cell electric vehicles (FCEV). Fuel cell technology is based on an electrochemical reaction involving hydrogen and oxygen that leads to the production of useful electrical energy, and only has water vapour as an emission of the process. The National Renewable Energy Laboratory (NREL) considers Fuel Cell Electric Buses (FCEB) to be on a technology readiness level (TRL) of 7 to 8, which translates to full-scale validation of the technology in a relevant environment (for comparison Diesel is considered TRL 9 Mature technology)[24]. Some major automotive and bus OEMs have invested in developing FCEVs, and the Fuel Cell Vehicle (FCV) market share is expected to continue to grow steadily over the coming decades concurrently with the battery electric vehicles market. The International Energy Agency (IEA) estimates that FCV will have a market share of about 17% by 2050 (35 million annual sales)[25].

The major benefits that are offered by FCVs in comparison to BEVs are a faster charge time (on the order of refueling a gasoline or diesel vehicle), lower weight, greater scalability and larger range abilities. However, they tend to be less energy efficient than BEVs, require a well managed, reliable and safe source of hydrogen which is also not very carbon intensive in production, and require hydrogen fueling infrastructure.

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[24] Fuel Cell Buses in U.S. Transit Fleets: Current Status 2017, (Leslie Eudy and Matthew Post) NREL
[25] What's in the future for fuel cell vehicles?, http://www.adlittle.com/sites/default/files/viewpoints/ADL_Future%20of%20Fuel%20cell%20vehicles.pdf

In addition, the public may also have concerns about the storage of pressurized hydrogen on-board vehicles, as hydrogen is a highly explosive gas that cannot be detected by human senses. However, some observers believe hydrogen is about as safe as gasoline in vehicle fuel tanks, and as hydrogen is lighter than air, its vapors escape instead of pooling on the ground like gasoline. Therefore, in the industry it is determined that doesn't present any higher fire or explosive danger risk[26]. However, as hydrogen as a fuel is still in the early stages of application to transportation, the safety concerns and developments should be followed closely[27].

A hydrogen powered fuel cell electric vehicle (FCEV) operates with the same electrical powertrain principles as the BEV described above. However, the electricity used to power the vehicle is generated through an electrochemical device: a hydrogen fuel cell.

Electrical current is produced, along with heat and liquid water, from the reaction of hydrogen with oxygen in the cell. The fuel cell itself contains no moving components. The on-board fuel tank stores the pressurized hydrogen until it is injected into the fuel cell (similar to a CNG storage tank). These vehicles require refuelling at compressed hydrogen supply stations.

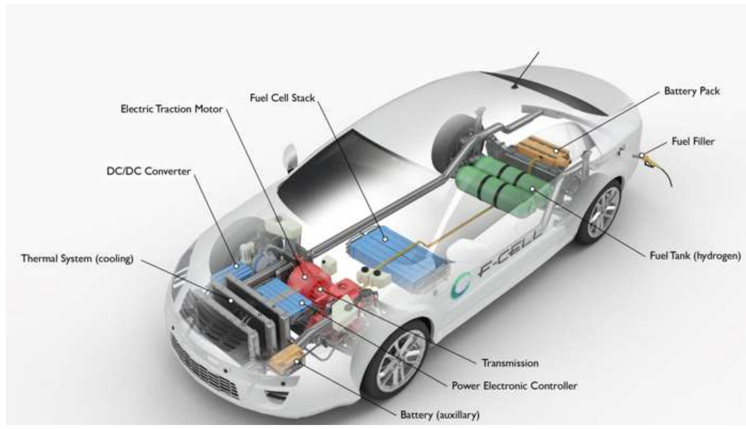

Figure 21 Hydrogen Fuel Cell Vehicle Components

Overall, these vehicles are highly effective in reducing GHG emissions as their only tailpipe by-product is water vapor. The main challenges are the lack of refuelling infrastructure as well as potential safety concerns for carrying pressurized hydrogen tanks on-board. The main components of a fuel cell electric vehicle have been illustrated below[28].

Table 11 Hydrogen Fuel Cell Vehicle Major Components

Component:	Functionality:
Battery pack	Stores electrical energy produced through the fuel cell chemical reaction. Vehicle power source stores electric energy during charging and regenerative braking to power the traction motor
Fuel Filler	Access point to replenish hydrogen stored in the pressurized on-board tanks
Fuel Tank (hydrogen)	Stores the pressurized hydrogen gas to be used in the fuel cell reaction to generate electricity, also termed Compressed Hydrogen Storage System (CHSS)
Fuel Cell Stack	The fuel cell which produces the electrochemical reaction between hydrogen (cathode) and oxygen (anode), results in only water vapour as the product and emission
Transmission	Transfers electrical power from the traction motor to the wheels
Battery (auxiliary)	Low voltage to power auxiliary vehicle electronics (lights, HVAC etc.)
Thermal system	Regulates the temperature of operating electrical components
DC/DC converter	Converts high voltage to low voltage from the traction battery
Power electronics controller	Computer that controls the energy flow from the battery, traction motor speed and torque

[26] https://www.edmunds.com/fuel-economy/8-things-you-need-to-know-about-hydrogen-fuel-cell-cars.
[27] https://dps.mn.gov/divisions/sfm/programs-services/Documents/Responder%20Safety/Alternative%20Fuels/FuelCellHydrogenFuelVehicleSafety.pdf
[28] Alternative Fuels Data Center, 2020, Available at: https://afdc.energy.gov/vehicles/how-do-all-electric-cars-work

Component:	Functionality:
Electric traction motor	Drives the vehicles wheels and recharges the battery pack through regenerative braking

HYDROGEN VEHICLE FUELING STATIONS

Hydrogen fueling stations can operate on the basis of off-site delivery (i.e. hydrogen transported by tanker truck or pipeline to storage tanks located on-site) or on-site generation of hydrogen through a process called electrolysis.

Electrolysis is an electrochemical process, where an electrical current is used to split water into hydrogen and oxygen, from which the hydrogen (H_2) gas is then stored for use in fueling hydrogen fuel cell vehicles. An alternative source of on-site hydrogen generation involves using natural gas conversion to hydrogen. This is completed by reacting natural gas with steam, which produces hydrogen gas and carbon dioxide (termed as the steam – methane reformation reaction).

On-site, a compressor system is used to pressurize the stored hydrogen to reduce volume and achieve the right pressure used for filling vehicle on-board storage tanks. The pressurized hydrogen gas can then be stored in an intermediate stage of storage tanks from which the hydrogen is ready to be dispensed through a filler hose and nozzle.

In some applications, after the compressor stage a chiller can be introduced in a closed-loop system to further chill the hydrogen prior to dispensing. This cooling and reduction off gas volume can enable faster fill times.

The filler nozzles for hydrogen are docked at fill stations similar to diesel, gasoline or natural gas applications. Different receptacle types (i.e. TN1 or TN5 specifically designed for high pressure hydrogen filling with low noise) interface between the fill nozzle and fill receptacle on the vehicle. The hydrogen is then stored in pressurized on-board storage tanks which regulate supply to the fuel cell stack used to propel the vehicle CHSS (Compressed Hydrogen Storage Systems).

In order to have a fully integrated fueling infrastructure regardless of the scale of fuel cell vehicle adoption, the following two primary systems will be required:

1. Hydrogen Generation: A reliable source of hydrogen fuel that is produced off-site for most operations and trucked in for bulk hydrogen storage (either via liquid hydrogen tank or through compressed cylinders). In operations with a large demand (quantity) and lack of near by hydrogen source, an onsite hydrogen generation operation can be considered. Typical solutions for on-site generation include on-site steam methane reformation (can utilize CNG and RNG as source) and on-site electrolysis (electrical conversion of water to hydrogen and oxygen).
2. Compression, Storage and Dispensing (CSD) module: System that is used to transfer/ dispense fuel from its storage cylinders or tanks to the vehicle. This includes compressors, high-pressure storage units and dispensing systems. A hydrogen dispenser is typically positioned on a fueling island similar to conventional fueling infrastructure.

As the specific details of each hydrogen bus fleet situation is unique, there can be different approaches depending on the scale of the planned hydrogen bus fleet. The following describes different phases in adoption from a Demonstration level fleet to full-scale deployment[29].

Phase 1: Demonstration Fleet

This is the preliminary phase in the adoption of electric or fuel cell buses and involves fueling approximately 4 to 5 vehicles. The purpose of this phase is to conduct an initial evaluation of the technology; therefore the required infrastructure must be temporary or scalable with a minimal footprint on the operating environment of the facility. The typical fuel requirements can range from 100 kg to 125 kg of hydrogen fuel per day, and in most cases, the most viable option for this demand is to deliver compressed gas and store it on site in high pressure tube trailers. This also requires a separate CSD module. The costs for this scale of infrastructure is approximately $1 million USD.

[29] Hydrogen Fueling for Fuel Cell Bus Fleets- Flexible fueling solutions for North American Transit Operators, Ballard January 2018

Approximate fuel USD costs per mile are $1.25 – $1.50/ mile (CAD $1.03 -$1.24 /km), and the installation foot print is in the range of 1,800 square feet.

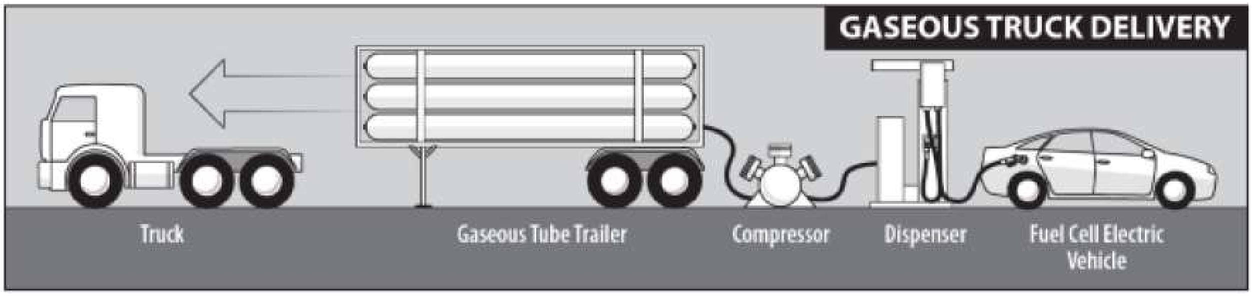

Figure 22 Fueling Process flow for a demonstration fleet, obtained from NREL

Phase 2: Pilot Deployment

The second stage consists of pilot deployment which is in range of five to twenty vehicles (operators are beginning to integrate vehicles into their normal operations). The fuel requirements at this level range from 125 kg to 500 kg of hydrogen per day, with more permanent installation of fueling infrastructure alongside regular fueling operations. Delivered liquid hydrogen storage is the recommended infrastructure mode at this phase, where hydrogen is produced in a large-scale at an off-site industrial facility and delivered via cryogenic transport and stored on-site. This type of infrastructure typically requires an industrial gas provider to install, maintain and operate the fuel storage tank and CSD infrastructure. The costs range from approximately $3-5 million USD (including all major components). Approximate fuel USD costs per mile are $0.75 – $1.13/ mile (CAD $0.62 - $0.93 /km), and the installation foot print is in the range of 1,800 square feet.

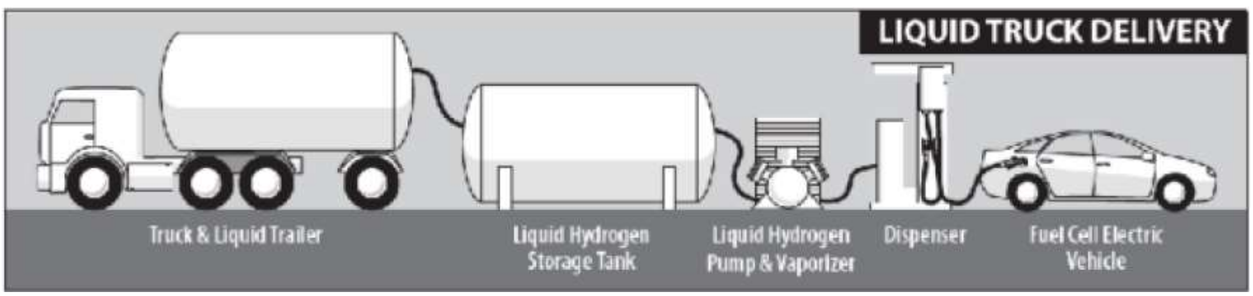

Figure 23 Fueling Process flow for a pilot fleet[36], obtained from NREL

Phase 3: Commercial Deployment

The final stage of adoption is commercial deployment which consists of a fleet greater than twenty vehicles and includes large vehicles including fuel cell electric buses. The two most viable fueling infrastructure pathways are either delivered liquid hydrogen or on-site hydrogen production through steam methane reforming (SMR), along with combinations of these two. This would typically require liquid hydrogen delivery 1to 2 times per week (during off-peak hours) to the facility's hydrogen tank (see process illustrated in Figure 22). The option of utilizing SMR to generate hydrogen requires a reliable source of natural gas to be present. This option is favourable for those fleets that have existing compressed natural gas buses or vehicles. This process has been illustrated[30] in Figure 24.

[30] Linde Group

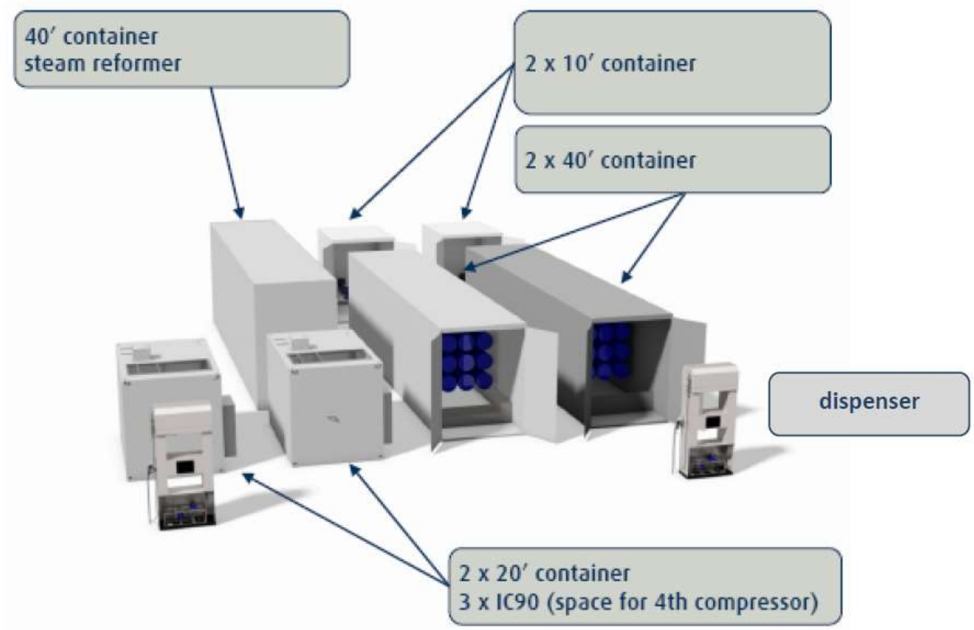

Figure 24 Fueling Process flow for commercial deployment[36] through On-site SMR

The fuel requirements at this level range from 500 – 1,000 kg hydrogen per day, and the associated capital costs for required infrastructure would be $2.5 - $3.5 millions USD for the reformer, and additional equipment costs for $3 – $5 million USD for vaporizer, compressor, high-pressure storage systems and dispensers for the fleet. Approximate USD fuel costs per mile are $0.38 – $0.75/ mile (CAD $0.31 - $0.62 /km), and the installation foot print is in the range of 4,700 square feet.

3.5.2 MARKET OVERVIEW

The market for Hydrogen vehicles is limited with only a few OEMs currently offering Hydrogen vehicle models. This includes Toyota offering the Mirai, Hyundai's Nexo and the upcoming Honda Clarity. Toyota has also announced development of a heavy-duty hydrogen truck, along with other OEMs including Mercedes-Benz, Hyundai and Nikola Corp.

FCEVs currently are more expensive then their BEV counterparts and there is currently a lack of models available on the market for light, medium and heavy-duty vehicles. Similarly, there is a need to develop a fuel distribution system at the provincial level to ease the utilization of these vehicles.

RELEVANT HYDROGEN MARKET SCAN

Hydrogen fuel cell vehicles are not as widely available as electric and natural gas vehicles. There are a limited number of options for hydrogen fuel cell vehicles currently available on the market. Further, the average price of hydrogen fuel cell vehicles is currently higher than $70,000 CAD. The market offerings and prices are expected to improve as there is an increase in available hydrogen light duty vehicle alternatives.

TOYOTA MIRAI

Toyota has produced a fuel cell electric vehicle called Mirai (sedan class), which provides a 500-km driving range nominally, takes approximately 5 minutes to be refueled, and provides 151 hp with 247 lb ft. of torque. In addition, Toyota claims that the Mirai has -30 ^{o}C cold start rating, allowing it to be suitable for even cold environments. The Quebec government has placed an order with Toyota to purchase a fleet of 50 Mirai fuel cell vehicles to add to their fleet[31].

HYUNDAI NEXO

Hyundai is providing a fuel cell SUV option, the Hyundai Nexo, sales started in 2019. The Nexo SUV vehicle will be able to be fuelled in less than 10 minutes and have a range of around 600 km nominally.

3.6 RENEWABLE DIESEL AND BIO-DIESEL

Bio-Diesel

Bio-diesel can be used as an alternative diesel fuel with some improvements in lowering GHG emissions. Bio-diesel is a substitute diesel fuel most often produced from vegetable oils such as soy, corn and animal fats. The production process aims to recycle some of these waste products thereby offering a more sustainable fuel source rather than the conventional diesel fuel derived from crude oil. These products go through a chemical reaction process called transesterification with alcohol and a catalyst in order to produce the fuel[32]. This fuel can then be blended with conventional diesel fuel. The blend is noted by a B-index (i.e. B20 is 20% bio-diesel blend). Biodiesel is utilized in various blends with conventional diesel, where the blends consists of pure biodiesel (termed B100) in a volumetric mixture with diesel fuel. The most common diesel blends consist of B2 (2% B100 and 98% Petroleum diesel), B5 (5% B100 and 95% Petroleum diesel), B10 (10% B100 and 90% Petroleum diesel), and B20 (20% B100 and 80% Petroleum diesel); B100 (pure biodiesel) is rarely utilized in its pure form. Bio-diesels up to a maximum blend of B20 can be used in any standard diesel engine without modifications thereby offering a simple approach to lowering the GHG emissions of fleet vehicles where limited options are available. However, the bio-diesel should come from a reputable source as there is a risk of damage to engine components from particulate matter if not processed at a high standard.

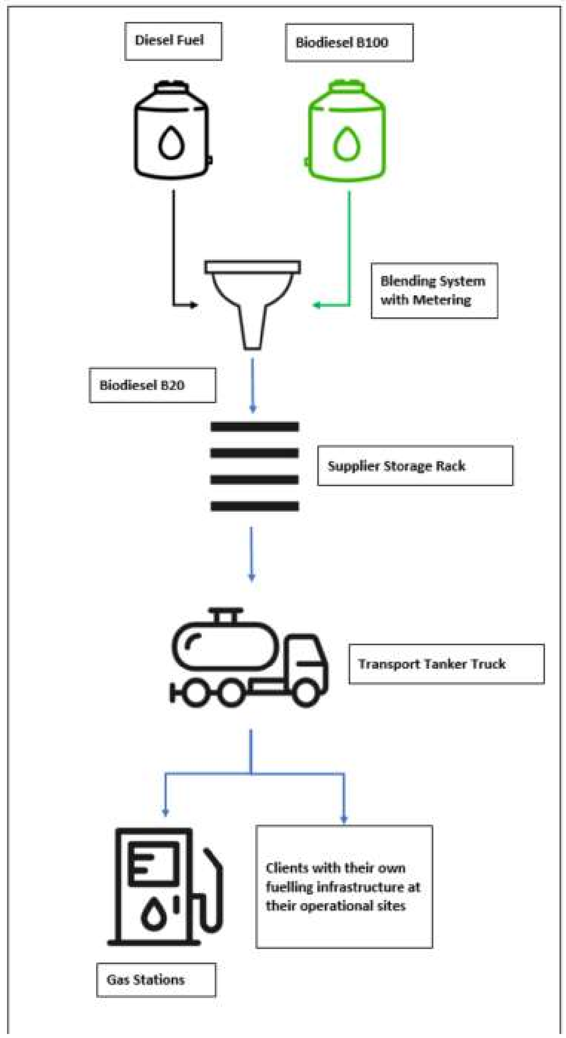

Figure 25 Example of In-line blending process of Biodiesel fuel

Biodiesel in these blends can be used directly with diesel engines with no required modifications and little to no change in the fuelling infrastructure. Figure 25 illustrates an example of an in-line blending process for biodiesel B20 fuel delivery to the end users.

Biodiesel has demonstrated multiple environmental benefits as compared to conventional diesel: renewable feedstock, biodegradable (faster than diesel), GHG reductions,

[31] CBC News, 'Canada's 1st fleet of hydrogen fuel cell vehicles coming to Quebec this year', 2018. Available at: https://www.cbc.ca/news/canada/montreal/75th-annual-montreal-auto-1.4494138
[32] NRCan Biodiesel, 2020. Available at: https://www.nrcan.gc.ca/energy/alternative-fuels/fuel-facts/biodiesel/3509

utilization of organic waste products, reduction in tailpipe emissions of combustion gases, resulting in improved air quality. Biodiesel is also less flammable than conventional diesel and is generally safer to handle. Similar to conventional diesel, biodiesel can form crystals in cold weather which can lead to filter plugging. However, this is impacted in practice by the type of feedstock utilized in the formation of biodiesel, and varies with each fuel supplier. This issue can be mitigated by utilization of additive substances, engine block or fuel filter heaters if necessary, and storing vehicles indoors. The fuel provider must ensure that the right biodiesel formulation is selected and the fuel blend level is correctly adjusted for winter operations; the Canadian General Standards Boards recommends temperature specifications for the season and region of use. This is not a concern when biodiesel is used exclusively in the warmer months.

Biodiesel has the property of acting as a solvent and tends to absorb sediments formed over time in equipment and storage fuel tanks, acting as a cleansing agent, which can result in occasional filter plugging issues. This effect typically occurs in the early stages of switching from petroleum diesel to biodiesel blends and is more prevalent with the use of higher concentration biodiesel blends. It is recommended that potential filter clogging be monitored closely during the transition to minimize the effect on operations.

From a performance perspective, biodiesel has been shown to demonstrate similar torque and horsepower as diesel-powered engines, however pure biodiesel (B100) has approximately 8% lower energy content compared to diesel[33]. This leads to a lower fuel economy; however, this effect is reduced with lower biodiesel blends. Long-term storage along with temperature variations can cause the fuel to degrade, however this can be mitigated by addition of proper additives prior to long-term storage. It should be noted that potential adoption of biodiesel with hybrid powertrains may be possible, however there is currently insufficient information available about combining biodiesel with hybrid engines and its impacts (particularly for heavy-duty engines).

<u>Canadian Biodiesel Market:</u>

- Canada announced a renewable fuels strategy in 2007 with mandated fuel requirements for utilization of bio-based fuels including biodiesel. There was a federal mandate for having a minimum renewable content of 2% of a primary supplier's distillate pool (annual production or imports of diesel fuel)[34], however some provinces require a greater percentage of its fuel to renewable.
- Canadian renewable fuel industry is currently producing over 500 million litres of biodiesel every year. This has assisted in achieving GHG emissions reductions with minimal changes in consumer fuel prices.
- Alberta introduced a Renewable Fuel Standard (RFS) that requires a minimum annual average of 2% bio-based diesel to be blended in diesel fuel sold by all suppliers.
- There has been a chronic problem of diesel shortages in Western Canada each spring and summer, which has resulted in demand outpacing supply (it is estimated that Western Canada imports 40,000 barrels of diesel fuel per day). Having a local Western Canada biodiesel production capacity (approximated at 5,600 barrels) can help to alleviate this problem[35].

<u>Renewable Diesel</u>

Renewable diesel is a biosynthetic replacement for traditional Petroleum diesel and is chemically identical in nature and combustion properties. However, it is produced from 100% renewable feedstock and thereby contains no fossil fuel carbon. Similar to Biodiesel, renewable diesel acts as an interchangeable substitute for diesel and does not require any modifications to existing diesel vehicles. Renewable diesel can be stored, transported, and dispensed in the existing infrastructure for diesel fuel and undergo combustion in a typical diesel engine[36].

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[33] Ibid.
[34] Government of Canada, Federal Renewable Fuels Regulation, Available at: https://www.ec.gc.ca/lcpe-cepa/documents/consultations/cr_rf/overview-eng.pdf
[35] Advanced Biofuels Canada, Available at: https://advancedbiofuels.ca/advanced-biofuels/
[36] Gladstein, 'The Potential – and Challenges – of Renewable Diesel Fuel for Vehicles', 2020, available at: https://www.gladstein.org/the-potential-and-challenges-of-renewable-diesel-fuel-for-heavy-duty-vehicles/

Renewable Diesel (RD, also referred as hydrogenation derived renewable diesel HDRD) is different from biodiesel discussed previously, despite both fuels being obtained from organic biomass and similar feedstocks. High-quality renewable diesel is produced from hydrotreated vegetable oils, fats or esters, and is a colorless and odorless fuel with the identical chemical composition of petroleum diesel. Renewable diesel does not have any blending requirements as opposed to biodiesel and can be used with 100% concentration in diesel engines (Neste – Neste Oil, is currently the world's largest producer of renewable diesel)[37]. RD is free of the ester compounds found in biodiesel and has a lower aromatic content. On the other hand, as discussed previously, biodiesel is obtained from the esterification process of vegetable oils and fats, which limits its quality and imposes blending requirements with typical diesel fuel. RD does not cause any potential fuel filter blocking and is also more stable for long-term storage as compared to biodiesel.

Renewable diesel can contribute major reductions in GHG emissions when combusted in diesel engines, as compared to diesel emissions. As per the California Air Resources Board (CARB), the carbon intensity of renewable diesel ranges from 50% to 85% lower than baseline diesel. Carbon intensity is the weighted potency of GHG emissions that are emitted when a diesel engine burns renewable diesel instead of regular fossil diesel. The choice of feedstock utilized in the production of renewable diesel has a big impact on carbon intensity and GHG emissions reductions from renewable diesel. In addition, renewable diesel also leads to a reduction in the CACs (Criteria Air Contaminants) emissions, which includes fine particulates, nitrogen oxides, hydrocarbons, carbon monoxide, and polyaromatic hydrocarbons. As more suppliers begin to offer RD as a fuel option, its market share in diesel fuel consumption is expected to increase to align with increasing carbon emission reduction targets.

3.6.1.1 *CODES AND STANDARDS, TRAINING AND SAFETY IMPLICATIONS*

In general terms, renewable diesel and biodiesel may be handled in a similar manner to conventional diesel. Generally, biodiesel introduces material compatibility issues that differ from conventional diesel and must be addressed. For addition information regarding the requirements for working with biodiesel, refer to the US Department of Energy's publication: Biodiesel Handling and Use Guide (Fifth Edition) DOE/GO-102016-4875 November 2016.

3.7 RECOMMENDED TECHNOLOGIES AND SCENARIO FOR THE FEASIBILITY STUDY

An initial high-level analysis was performed to assess which technology should be considered for further analysis as part of Barrie Corporate Fleet's transition. The modelled scenarios consisted of the current fleet for a baseline comparison (BAU: Business-As-Usual), and four (4) additional scenarios detailed below:

i. Scenario 1: This scenario is targeted towards minimal transition of the fleet with the addition of hybrid and plug-in hybrid (HEV) vehicles to light duty fleet vehicles (pickup trucks, cars, vans and SUVs).

ii. Scenario 2: This scenario considered an increase in fleet electrification with battery electric vehicles (BEVs) for light duty cars/ SUVs, and CNG for vans and pickups (light and medium duty).

iii. Scenario 3: This scenario considered BEVs for applicable light duty vehicles, representing increased electrification compared to Scenarios 1 and 2. Further it considers CNG for the compatible heavy-duty pickups and dump trucks

iv. Scenario 4: The fourth scenario considered the case of maximum electrification of the fleet, along with CNG for all applicable heavy-duty assets, and biodiesel for all others. It represents the potential for maximum environmental benefits.

[37] Neste, 2016, Available at: https://www.neste.com/what-difference-between-renewable-diesel-and-traditional-biodiesel-if-any

These scenarios were determined in consultation with the City of Barrie; a cost analysis and GHG emission analysis was provided to assess the benefits of each scenario and compare them. The following conclusions can be made from the cost and GHG emission analysis:

- All scenarios present higher CAPEX and OPEX compared to the BAU due to additional infrastructure requirements;
- Scenario 3 and 4 show the greatest environmental benefits, leading to similar GHG emissions reduction impacts; and
- Scenario 3 and 4 show the greatest OPEX reduction of approximately 17% compared to BAU but overall Scenario 4 was more expensive due to increase infrastructure costs (more CNG vehicles and more electric vehicles).

From these results, the City of Barrie decided to investigate Scenario 3, with a slight change in that all heavy-duty vehicles should remain diesel vehicles. Table 12 shows the breakdown of the technology chosen for each vehicle type in Scenario 3 compared to BAU.

Table 12 Fleet Allocation for Scenario 3

Vehicle Class	Vehicle Type	BAU	Scenario 3
Heavy Duty	Dump Truck	Diesel	Diesel
Heavy Duty	Fire Truck	Diesel	Diesel
Heavy Duty	Pickup Truck	Diesel	Diesel
Heavy Duty	Plow	Diesel	Diesel
Heavy Duty	Salter/Sander	Diesel	Diesel
Large Medium Duty	Dump Truck	Diesel	Diesel
Large Medium Duty	Pickup Truck	Diesel	Diesel
Large Medium Duty	Vactor Truck	Diesel	Diesel
Light Duty	Car	Gasoline	BEV
Light Duty	Mower	Gasoline	BEV
Light Duty	Pickup Truck	Gasoline	BEV
Light Duty	SUV	Gasoline	BEV
Light Duty	Tractor	Diesel	Diesel
Light Duty	Van	Gasoline	BEV
Medium Duty	Pickup Truck	Gasoline	CNG
Equipment	Ice Resurfacer	CNG	CNG

4 PEER REVIEW

As part of the alternative fuel engagement, WSP engaged a number of peers to gather feedback with regards to experience with alternative fueled vehicle and technologies. Results from Toronto Transit Commission (TTC), the City of Calgary and City of Abbottsford were collected. This section provides an overview of the experience of the City of Abbotsford and TTC which had the most pertinent information with regards to operational fleet vehicles. WSP also engaged with Metrolinx, who informed that they haven't currently not considering electric vehicle specifications for fleet vehicles.

City of Abbotsford

The City of Abbotsford has one facility that supports the entire fleet and follows the following guidelines when it comes to replacement of vehicles. The table below highlights the replacement guidelines for the vehicles in Abbotsford's inventory.

Table 13 Replacement Guidelines

Type of Vehicle	Replacement Guidelines
Cars	12 years or 150,000 km
Pickup Truck - Light	12 years or 150,000 km
Vans	12 years or 150,000 km
Trucks - 1 Ton and Larger	12 years or 200, 000km
Backhoes, Dozers, Graders, loaders, Forklifts	10 years or 10,000 hours
Tandems, sweepers, ice makers	10 years or 10,000 hours
Garbage Truck	7 years or 7,000 hours
Police Cars - Patrol	5 years or 150,000 km
Fire Engines	20-25 years or 5,000 hours

Abbotsford is focusing on prioritizing electric and using renewable fuels wherever electric cannot meet the needs or is too expensive to consider. Tandem Trucks and other heavy-duty equipment cannot be converted to electric yet, so they will be switched to renewable fuel. For Police patrol vehicles, Ford Escape Hybrids were purchased and are being monitored for success rate. It was determined that CNG is not an economical option for Abbotsford as it needs capital investment in infrastructure upgrades (facility and fueling station) and does not reduce GHG emissions to the same levels as renewable fuel. If money were to be invested into CNG now, it means Abbotsford may not have sufficient funds to move to electric as soon as possible. Renewable diesel is a more economical option that can assist with short term goals and Abbotsford is currently in process of getting council approval.

In the City of Abbotsford's opinion, electric vehicle cost less to operate and maintain and do not have adverse environmental impact. The charging infrastructure is easy to setup and the electric cars in the fleet have had very little maintenance requirements. However, the main issue with electric is range. In addition, Abbotsford is concerned about electrified heavy-duty fleet availability: thus, renewable diesel will be used instead.

The Green Fleet Strategy was prepared and adopted by council in 2019. Currently Abbotsford is trying to switch diesel fleet on renewable diesel. Abbotsford looks for alternate fuel for all new procurements and new cars and SUV purchased in 2020 onwards will be BEV. The City of Abbotsford has also completed a study to upgrade their electrical service to the yard to support the transition to battery electric vehicles in the next 20 years. Abbotsford wants to meet the council target of 20% reduction in GHG emission by 2025. They will not conduct any pilot programs, they will directly change their light duty fleet to electric and heavy duty to renewable fuel, where possible. Over the next 20 years, the City will be purchasing small amount of new alternative fuel fleet at a time.

Toronto Transit Commission (TTC)

The TTC has a fleet of approximately 457 light, medium, and heavy-duty vehicles that are non-revenue and support their operations. In addition, the TTC also has 536 on-licenced tractors and equipment. The table below summarizes the vehicle lifecycle and replacement guidelines for TTC's major operational vehicle assets.

Table 14 TTC Vehicle Replacement Guidelines

Type of Vehicle	Replacement Guidelines
Cars	6 years or 200,000 km
Pickup Truck - Light	8 years or 175,000 km
Vans	7 years or 175,000 km
Tractors/Forklifts	15 years
Heavy-Duty Speciality Truck (>9,500 kg)	12 years or 200,000 km
Medium-duty Speciality Truck (4,500 kg <, <9,500 kg)	12 years or 200,000 km

The TTC has two garages dedicated to NRV (Non-revenue vehicles) and equipment: 1810 Markham Rd (16,500 sq. ft., ~330 light-duty vehicles) and Lakeshore (58,000 sq. ft. ~250 Wheel-Trans and 200 NRVs). TTC has engaged its NRV user groups with regards to adoption of alternative and electric vehicles, and noted the following concerns and feedback:

- Range anxiety and availability of charging/fueling stations due to work at remote site locations is a concern.
- Power draw of accessory electronics on battery electric vehicles which would be required for vehicles to function as mobile workstations.
- Overall technological maturity and reliability needs to be a priority.
- Limited or no market of alternate vehicle options for specialized vehicles makes transition of those vehicles very difficult.

The TTC's current plans for moving towards alternative fuel vehicles can be summarized as follows:

- Currently own 6 2008 Prius hybrid vehicles, which have demonstrated decent performance with few issues, small battery, 4-5 vehicles still running for runaround pool vehicles (attending meetings etc.).
- 40 Ford Explorer hybrids are in the process of being procured this year; 15-20 in service already, small issues with learning curve of new technology, they have demonstrated fine performance and power, more coming in the future, however they do not have much mileage or experience as of yet.
- Forklifts, sweepers are planned to be all electric to eliminate safety concern of gas leak/detection in confined workspace.
- Don't want CNG from infrastructure view, long term just want electric to be the dominant propulsion type.
- Strategy with hybrid is a cultural change, getting proper training, get proper behaviour for plug in charging; Auxiliary power pack on explorers that helps with idling, ex. using lights on at site, this allows for lower engine idling and hence fuel savings.
- TTC is introducing auxiliary lithium-ion power pack on-board vehicles to reduce idling (i.e. transit control vehicles, power packs to power lights) can power lights for up to 4 days versus idling engine for 40min/4hours.

- Looking at PHEVs for light duty, this gives time for getting electrical infrastructure to be installed, and staff to be used to the new technology.
- Looking at full electric mid-size SUV and minivans and cargo vans for the future.
- Looking to move electric for Class 6 -7, working with OEMs for electric options.
- Heavy duty trucks, class 5-6 Kenworth electric options are best working as payload delivery (regular loads) zero accessory loads, dump trucks not viable for electric as it kills batteries, electric technology doesn’t work with snow ploughs either as of yet.
- TTC send high voltage repairs to dealer, want staff to be aware of risk/safety on high voltage components but assign repair expertise to dealers to for best practices.

Based on the peer reviews conducted, the common strategy towards transitioning to a greener fleet between both City of Abbotsford and TTC is obtaining electric vehicles (plug-in hybrids and battery electric) for their light duty fleet vehicles and tools, while tracking developments of electric vehicles for the heavier duty or class of vehicles and equipment. The justification for this strategy has been that electrification of fleet is viewed as the long term solution to having increased sustainability, and investing in interim solutions would only be a stop gap for the time being.

5 REGULATION, CODES AND STANDARDS

5.1 BATTERY ELECTRIC

Conversion to alternative propulsion technologies requires consideration of the appropriate codes and standards. The regulatory instruments governing the use of electric vehicles include:

- CSA C22.1 – Canadian Electrical Code
    - Section 86 – Electric Vehicle Charging Systems
- NFPA 70-2017 – National Electrical Code
    - Article 625 – Electric Vehicle Charging Systems

In addition to these instruments, there are several different standards that dictate vehicle charger interface standards, including:

- SAE J1772 – North American Standard for Electric Connectors for Electric Vehicles, as maintained by SAE International

Finally, there are several standards development organizations (SDOs) that are working to develop the required codes and standards as this technology becomes more widely adopted. These organizations include:

- Institute of Electrical and Electronics Engineers, Inc.;
- National Fire Protection Agency;
- Society of Automotive Engineers;
- Underwriters Laboratory; and
- International Code Council.
- CSA Group (Canadian Standards Association)

With regards to training requirements, OEMs typically provide training to their clients as part of the vehicle purchase price or pilot program along with including all related operating and maintenance manuals. Training requirements can be specified in the procurement process and contract negotiations. If additional training is necessary, it can be provided through a third-party institution.

Maintenance training shall focus primarily on the electrical systems of the vehicle, as most non-electrical components are similar to those on a diesel vehicle. While the amount of necessary training will depend on the particular vehicle and OEM it should cover the basics of working with electric propulsion (traction motors), inverters and batteries. In the case of electric vehicles operating on a fuel cell (hydrogen), it should also cover the safe refuelling practices and maintenance around the fuel cell and storage tanks. Training should also include the required safety procedures for working with high voltage electrical components, correct usage of personal protective equipment (PPE) and specialized tools. Once a primary group of personnel have been trained, they can train additional mechanics and operators.

New standardized maintenance procedures will be needed regarding the lockout/tagout procedure for battery removal and other high voltage components along with putting a dedicated service line in place. Process flow maps need to be developed clearly illustrating the differences in maintenance practices between electric and diesel vehicles. In addition, similar standardized operating procedures and training need to be developed for charging infrastructure at depots and on-route working with respective OEMs.

Furthermore, organizations such as the Society of Automotive Engineering (SAE) offer courses such as “High Voltage Vehicle Safety Systems and PPE”, which is a one-day program focusing on the safety aspects of maintenance technicians working on electric and hybrid vehicles. It also covers electrical circuit design/diagnosis and isolation measures on DC and AC detection systems through high voltage controllers to mitigate the possibility of electrocution between a maintenance technician and the vehicle body/chassis.

New standard operating procedures around lock-out/lock-in procedure, removing batteries and service line would need to be developed. Process flow maps of current processes would need to be developed, highlighting the difference between electric vehicle processes versus diesel or diesel-hybrids. Moreover, a similar standard operating procedures and training would need to be developed for charging/refuelling infrastructure at depots and on-route working with respective OEMs.

Lastly, training should be provided for emergency responders and utility workers such that in the event of an accident involving an electric vehicle, these personnel are aware of the potential high voltage and chemical hazards associated with electrical vehicles. They should have mitigation strategies and a safe response procedure in place.

OEMs have been working with the National Fire Protection Association (NFPA) to provide safety plans on how to respond to incidents involving their trucks. Schematics show the location of high voltage cables and how to disconnect the power supply. It is recommended to request a detailed safety response plan in the procurement package of refuse trucks for the fleet or for initiating a pilot program.

5.2 NATURAL GAS (CNG/RNG)

Conversion and installation of facilities for the use of natural gas requires consideration of the following primary codes and standards, each of which references several other applicable codes and standards:

- CAN/CSA B108-18 – Natural Gas Fuelling Stations Installation Code, A National Standard of Canada
    - Note: An updated version of CSA B108 will be issued in 2021.
- CSA B401-18 – Vehicle Maintenance Facilities Code, First Edition
    - Note: An updated version of CSA B401 will be issued in 2021. The new edition will include requirements for Parking Structures.
- NFPA 88A-2019 – Standard for Parking Structures (see note above re CSA B401)
- In addition, there are many standards for specific components (such as hoses, nozzles, receptacles, etc.) identified and required by the design codes.

CSA B108 sets out the requirements for vehicle refuelling stations for vehicles powered by CNG or LNG.

CSA B401 was published in November of 2018 and is the first ever version of the Code. It sets out the requirements for existing and new vehicle maintenance facilities that “host” CNG and LNG vehicles for maintenance and repair.

NFPA 88A sets out the requirements for vehicle parking structures for vehicles of all fuel types. It is an American publication and has no official status in Canada. However, in the absence of a Canadian code/standard, it is used as reference material.

The following guideline should also be referenced:

- Technical Guideline for the Design and Operation of Facilities Used for Indoor Repair, Storage and Cargo Handling for Vehicles Fuelled by Compressed Natural Gas and Liquefied Natural Gas (a Best Practices guideline)

This technical guideline aids fleet facility owners, architectural / engineering firms and building contractors in determining the requirements for existing or planned new facilities, to ensure they are safe for CNG vehicles maintenance, repair, storage, or cargo handling.

With regards to training, vehicle OEMs producing CNG models commonly provide standard training, operating, and maintenance manuals with the purchase of their vehicles or with vehicle retrofits. For a CNG vehicle, most of the vehicle maintenance activities will be similar to that of an equivalent diesel vehicle. However, there are notable differences regarding the fuel system.

Training should focus on the safe handling of pressurized gas tanks and inspection, as well as monitoring safe level of gas exposure with proper detection equipment. Necessary training can also include working at heights with lifts, scaffolding, and the use of fall arrest equipment in order to service CNG tanks which are commonly located on the roof or box collection/compaction body of a refuse truck, for example. Maintenance technicians servicing pressurized gas components onboard the vehicles will also require an appropriate gas fitters’ certification. Furthermore, workers should be aware and service CNG vehicles in a facility equipped with proper ventilation and meeting applicable codes and standards.

In addition, emergency responders should have familiarity training with CNG so that they are aware of the potential hazards and have a mitigation plan in the event of responding to an incident involving a CNG vehicle.

CNG is becoming a widely adopted fuel alternative in transportation. As such, there are several institutions with specific training programs for maintenance workers. This includes The National Institute for Automotive Service Excellence (ASE) Certification for Light-/Medium-Duty CNG training program available in Canada and other programs offered by CNG engine OEMs such as Cummins Natural Gas Academy.

6 TECHNOLOGY RISK ASSESSMENT

As part of this assessment, WSP completed a comprehensive risk workshop with the City of Barrie to identify potential risks and their associated mitigation measures for adoption of alternative fueled technologies. The risk workshops looked at potential risks pertaining to Technical Specification, Installation, Funding/ Regulations, Operations, Preventative and Corrective Maintenance, Third Party Maintenance and Removal/ Disposal of the assets. A 5-point rating scale of (very low, low, medium, high and very high) was utilized to quantify the risk probability and impact ratings.

For the Corporate fleet, a total of 15 general risks (common to all alternative propulsion types) and 18 technology specific risks were identified, assessed and their associated mitigation actions were developed. The fully completed risk register has been provided to the City, and should be used as a reference point and working document moving forward for the City' transition towards alternative vehicles. The risk register also allows tracking of the risk owners and those responsible for monitoring and managing the risks. The completed register has also been attached as part of Appendix A.

For the General Risks assessed, six (6) risks were assessed as having High impact. They have been outlined below:

- Technical Specifications: Due to failure to obtain input from users in spec development, there is a risk of reduced asset quality which could lead to cost overruns and level of service impacts.

  Mitigation Method: Prepare a detailed plan for having important stakeholders and user engagement and buy in early in the procurement and specifications development cycle

- Technology Evolution: Due to technological advancement there is the risk that new/unproven technology could result in additional in-service vehicle failures and/or the need for vehicle recalls thereby increasing maintenance/operational costs.

  Mitigation Method: Procure from vehicle OEMs with reputable operations and the ability to support new technology repairs. Pilot new technology in phases, gradually expanding viable technology into the fleet.

- Funding/regulatory: Local provincial and/or federal government mandate can change favourability towards adoption of new vehicle/propulsion technology. This can impact funding programs, regulations, infrastructure changes and the overall viability of a new technology.

  Mitigation Method: Engage with local political representatives to communicate the benefits/drawbacks of new vehicle/technology options and how this aligns with the Barrie's objectives.

- Diagnosis of Maintenance Needs: Due to lack of historic data, mechanic is unable to properly use historical diagnostic to make decision to go forward.

  Mitigation Method: Connect with peer agencies and industry organizations to gain insight into any maintenance issues that arise

- Supply Chain Part Lead Times: Due to uniqueness of propulsion technology and limited vendors long lead times for replacement components can occur. This can result in higher costs and schedule delays.

  Mitigation Method: Conduct an assessment of expected lead times of critical components and parts for each technology adopted in consultation with OEMs

- Premature Failure (Operations): Due to the technological maturity level (i.e. lack of demonstrated complete lifecycle operations) there is a risk of premature failure of the asset or unfavorable economics that cause early retirement/disposal thereby impacting capital costs and service availability of the fleet.

  Mitigation Method: Review existing pilot operations of peer agencies, conduct limited pilots to gather primary operational performance data.

7 FLEET AND FACILITY REQUIREMENTS

7.1 UTILIZATION AND FUEL CONSUMPTION PROFILE

Table 15 provides a summary of the average utilization of the vehicle assets (in KM), the average fuel economies, and the expected annual fuel consumption. These values have been provided for the vehicles that have been considered for the alternative propulsion scenarios as described in Section 2.1. This assessment provides a baseline for comparison and development of the business case for different green fleet scenarios. The vehicles with the highest annual vehicle kilometers are the large medium duty dump trucks and the light duty pickup trucks. The analysis also demonstrates that the heavy-duty plow vehicles and Vactor trucks have the highest expected fuel consumption on L/km basis.

It can be observed that SUVs and cars demonstrate the most fuel-efficient operations out of all fleet vehicles, with a noticeable improvement in comparison to pick-up trucks.

Table 15 Fleet Vehicle Average Utilization and Annual Fuel Consumption summary

Vehicle Class	Vehicle Type	Vehicle Annual km	Fuel Type	Average Fuel Economy (L/km)	Annual Fuel Consumption (L) per Vehicle	Alt. Fuel and consumption (dLe/km or kWh/km)
Heavy Duty	Dump Truck	6,442	Diesel	0.67	4,316	Diesel - same
Heavy Duty	Fire Truck	5,441	Diesel	0.67	3,645	Diesel – same
Heavy Duty	Pickup Truck	5,999	Diesel	0.67	4,019	Diesel – same
Heavy Duty	Plow	2,295	Diesel	1.49	3,419	Diesel – same
Heavy Duty	Salter/Sander	3,369	Diesel	0.93	3,133	Diesel – same
Large Medium Duty	Dump Truck	11,488	Diesel	0.67	7,697	CNG – 0.67 DLE/km
Large Medium Duty	Pickup Truck	9,632	Diesel	0.67	6,453	CNG – 0.67 DLE/km
Large Medium Duty	Vactor Truck	2,193	Diesel	1.69	3,706	Diesel – same
Light Duty	Car	4,940	Gasoline	0.10	494	EV - 0.16 kWh/km
Light Duty	Mower	500	Gasoline	0.47	235	EV - 0.4 kWh/km
Light Duty	Pickup Truck	8,517	Gasoline	0.20	1,661	EV - 0.26 kWh/km
Light Duty	SUV	7,834	Gasoline	0.12	909	EV- 0.19 kWh/km
Light Duty	Tractor	400	Diesel	0.47	188	Diesel-same
Light Duty	Van	6,253	Gasoline	0.20	1,219	EV - 0.26 kWh/km
Medium Duty	Pickup Truck	8,208	Gasoline	0.57	4,679	CNG – 0.57 DLE/km
Equipment	Ice Resurfacer	400	CNG	0.47	188	CNG – 0.47 DLE/km

7.2 FACILITIES AND INFRASTRUCTURE CONSIDERATION

Facilities storing and maintaining electric vehicles require additional considerations compared to typical facilities housing diesel or gasoline vehicles to ensure safe and successful operations. A number of considerations are discussed in the following sections.

7.2.1 CHARGING INFRASTRUCTURE

As electrification increases in popularity, there is a rise in third-party charging station product offerings. This allows the ultimate product(s) selected for installation to be dependant on the level of charging required to maintain typical operations for the electrified fleet.

A brief process description has been provided below for the classifications of charging level available. A summary of notes on charging infrastructure is provided in Table 16.

LEVEL 1 - AC CHARGING

Level 1 is the slowest form of charging. It uses a plug to connect to the on-board charger and a standard household (120 V) outlet. The on-board charger is the factory-installed charging device that converts AC power from the wall to DC power that charges the vehicle's battery. Charging speeds may vary but the most common chargers are 6.6 kW on battery electric vehicles (BEVs) and 3.3 kW on plug-in hybrid electric vehicles (PHEVs). Level 1 chargers are fitted with a SAE J1772 standard connector.

LEVEL 2 - AC CHARGING

Level 2 uses Electric Vehicle Service Equipment (EVSE) as an intermediary between the power source and the vehicle's charging port to provide power at 220 V or 240 V. The EVSE is typically mounted on a wall or a pedestal and is used to relay AC power to the vehicle safely, which converts the power to DC. Level 2 chargers are fitted with a SAE J1772 standard connector. Level 2 chargers may be in the form of a wallbox, bollard base, or larger wall-mount installation.

Level 3 - DC FAST CHARGING

DC Fast charging uses a unit that is roughly the same size as a standard gas pump to complete the AC to DC conversion itself, rather than using an on-board charger to accomplish this. DC Power is then relayed via the vehicle's charging port. There are three types of DC fast charge systems: SAE Combined Charging System (CCS), CHAdeMO, or Tesla. Level 3 chargers typically come as an in-ground installation due to the larger electrical infrastructure requirements.

MOBILE CHARGING UNITS

A number of OEMs carry DC Fast charging mobile units, providing flexibility to clients where major infrastructure upgrades are not feasible or to supplement existing charging infrastructure configurations. This may help avoid costs relating to grid distribution upgrades and installation of permanent charging solutions. Manufacturers such as Blink, SparkCharge, and Heliox have a variety of mobile units available on the market. For example, Heliox provides Level 3 units ranging from 25 kW - 50 kW. Mobile charging units are currently a small portion of the greater EV charger market, but it is expected to grow from $16 billion in 2020 to over $60 billion by 2030.[38]

PHYSICAL SPACE OF CHARGERS

Level 1, Level 2, and Level 3 chargers come in a variety of configurations as discussed above, these configurations are shown in Figure 26. When possible, wall mounting is preferred as they often require the least infrastructure to support the charger (i.e. smaller foundation) and are the most cost-effective solution. Consideration should be given to charger configuration, size, and space available. Proposed charger locations should have sufficient space for vehicle parking and charger operations (i.e. sufficient flush space between the installation location and proposed parking locations or other operational areas in the facility). It is recommended that visible markings identify the charger operational areas within the facility. Typically, chargers are installed in locations that provide two parking areas – along a wall with access to two parking spots or placed in an open area with two designated parking spots. Charging stations should be installed such that they (or the vehicles they charge) do not pose as an obstacle for vehicle maneuvering or operations within the facility. Collision protection items such as bumper buffs or bollards should be installed to protect the charger and cabling ducts.

[38] Mobile EV chargers and vans get ready for prime time - https://electrek.co/2020/05/06/mobile-ev-chargers-and-vans-get-ready-for-prime-time/

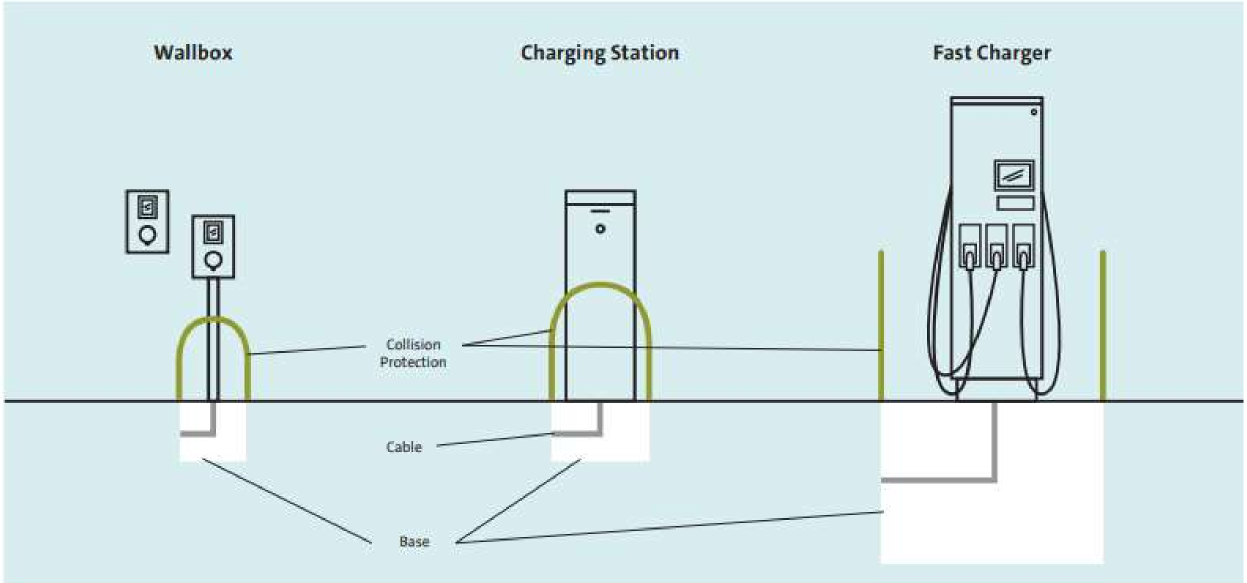


Figure 26 Typical Charger Configurations and Infrastructure Requirements

Table 16 Notes on Electrical Charging Infrastructure

Charging Unit	Level 1 AC	Level 2 AC	Level 3 DC Fast
Power Rating	1.4 kW to 2.4 kW	2.8 kW to 19.2 kW	44 kW to 63 kW
Current Rating	12+ A	12 A to 40 A	120 A to 125 A
Added Range per hour of charging	3 to 5 km	16 to 40 km	Provides approx. 80% charge in half an hour of charging.
Hardware Costs	Ranges from $500 to $1,000.	Ranges from $500 to $7,000. Dependent upon complexity of the equipment (i.e. billing/tracking capabilities, network communications, smart grid capabilities, etc.).	Ranges from $12,000 to $35,000. Dependent upon complexity of the equipment as well.
Installation Costs	Dependent upon a number of factors, including distance to the electrical panel, whether or not lighting and shelter is required, and whether or not landscaping is required. Installation costs are known to vary considerably – employers are encouraged to gather several quotes before making a decision.	Dependent upon a number of factors, including distance to the electrical panel, whether or not lighting and shelter is required, whether or not landscaping is required, and whether or not upgrades to the existing electrical equipment are necessary. Installation costs are known to vary considerably – employers are encouraged to gather several quotes before making a decision.	See Level 2 AC.
Physical Dimensions (WxDxH)	Dependant on supplier, worst case: 7.7” x 5.6” x 12.6”	Dependant on supplier, worst case found: 13.7” x 19” x 95.5”	Dependant on supplier, worst case found: 46.3” x 17.4” x 88.2”

CHARGING LEVEL RECOMMENDATION

Level 1, Level 2, and Level 3 chargers will likely be compatible with a variety of vehicle types. Ultimately, the charger product(s) selected for installation depends on the typical operations for the electric fleet and how sensitive to change the operations are. Table 17 showcases the impact power rating and choice in charger can have on a typical light duty vehicle, in this case a Chevrolet Bolt with a 60 kWh battery pack.

Table 17 Impacts of Charging Infrastructure of Chevrolet Bolt (60 kWh battery)

Charging Unit	Level 1 AC	Level 2 AC	Level 3 DC Fast
Power Rating	1.0 kW	7.2 kW	48 kW
Full-charge time	60 hours	8.33 hours	2 hours
Added Range per hour of charging	9 km	41 km	340 km

As shown in Table 17 above, a Level 1 charger would have significant impacts on the availability of high-use operational fleet vehicles as the vehicles will require a significant amount of time to fully charge. Use of only Level 1 chargers would likely require a greater investment in fleet vehicles to ensure sufficient vehicles are available and fully charged to compensate for longer charging times. Level 1 chargers also provide meager added range per hour of charging as compared to Level 2 and 3, making Level 1 charging inefficient for battery top-up midday or between vehicle use.

Level 2 provides a more reasonable full-charge time which can likely be accommodated overnight. It also provides a more significant added range per hour of charging, making it more suitable for battery top-up midday or between vehicle use.

Level 3 provides a fast-full charge time and provides significant added range per hour of charging. In combination with Level 2 chargers, a minimal number of Level 3 chargers would be required at facilities as the batteries available for light-duty electric vehicles are relatively small and a single Level 3 charger could charge/top-up multiple vehicles per day. It is also possible to use mobile fast charging units in place of traditionally installed Level 3 chargers or as redundancy for peak charging times, as dictated by operations.

7.2.2 CHARGER COMPATIBILITY

As discussed for Level 3 chargers, there are three types of charging systems.

CCS

Combined Charging System (CCS) is a connector type used in rapid-charging and growing in popularity across North America due to it being an open international standard. A CCS connector is based on the SAE J1772 standard connection interface with two additional DC power lines that allow for higher voltages compared to the J1772 connector. This is illustrated in Figure 27 the similar layout in the top portion of the CCS charge port allows for EV owners to use Level 1, Level 2 or Level 3 chargers for the same vehicle. Choosing or mandating a CCS connection when electrifying a fleet allows for greater selection of third-party charging systems and compatibility across a wide range of vehicle manufacturers, charging equipment OEMs, and charger types (i.e. Level 1, Level 2, Level 3). CCS is used by most American automakers.

Figure 27 CCS Charge Port (left) and J1772 Charge Port (right)

CHAdeMO

CHAdeMO is a common connector type and typically offered due to it's popularity in Asian vehicle models. CHAdeMO connectors are only available for Level 3 chargers.

TESLA

Tesla charge port, shown in Figure 29, is a modified Type 2 plug that Tesla uses in its Supercharger quick-charging charging stations. Only Tesla vehicles can be charged with direct current using these plugs; the unique charge port and connector works for all charging levels including Tesla's Supercharger. Tesla vehicles are not compatible J1772 and CHAdeMO charge ports, but adapters for the two systems are available.

Figure 28 CHAdeMO Charge Port

7.2.3 INFRASTRUCTURE UPGRADES

It is important that operational pathways (entry, park, and exit), vertical surfaces, protected areas, and locations of existing electrical equipment be considered and assessed when planning infrastructure electrification upgrades. Electric Vehicle Supply Equipment (EVSE) may be mounted on walls, light posts, and other vertical structures provided that adjacent space is available for vehicle parking. Relying on existing surfaces may reduce capital costs by eradicating the needs for dedicated posts and in-ground wiring. Careful consideration should be given to ensure EVSE cords do not create safety hazards by obstructing safe walkways within facilities or forcing new walkways through more exposed parts of the facility.

Figure 29 Tesla Supercharger North American Charge Port

As part of the facility electrical feasibility assessment, careful consideration of selected charger locations will include minimizing length of wired connections as construction will be costly and disruptive. EVSE selected to meet operational requirements may require installation of a new meter, electrical panels, switchgears, or other electrical infrastructure upgrades. Minimizing the path from the transformer to the chargers will help lower costs. If long distances cannot be avoided, sub distribution may be required. As such, planning for electrification should consider EVSE footprint, safe-distance requirements, allowable/recommended cable lengths, worker access and facility operational processes, and required infrastructure upgrades.

Infrastructure upgrades such a subpanel upgrade (200A, 120/240 VAC single phase) and/or a utility transformer upgrade may be required to support a larger electrical fleet. These requirements should be flagged and discussed with Alectra to determine a suitable plan that balances electrical requirements, electrification goals, and overall project cost. A discussion on the likely electrical infrastructure requirements as part of the electrification of Barrie's operational fleet is discussed further in Section 4.2.

A charging station should not only provide power, but also be able to communicate to report on load management, monitoring, and/or for billing. A Wi-Fi connection also provides advantages such as software updates for the vehicle/charger and allows employees to use the internet connection while waiting for charging/top-up.

Infrastructure upgrade and construction costs will greatly depend on the charging technology required and on-site conditions. Consideration should be given to sizing charging equipment appropriately for fleet operations and analyzing proposed charger locations to minimize new cable duct installation and expensive infrastructure upgrades in order to minimize overall project costs.

8 FLEET GROWTH PLAN

8.1 FLEET GROWTH

The identified fleet growth included equipment, which is out of the scope of this study, as well as different classes of vehicles. As the host facility wasn't indicated for the growth asset it was assumed that the growth inventory was added to the Operations Centre to remain conservative in the fuel consumption assumptions. Table 18 below shows the breakdown of the vehicles that were progressively added to the fleet.

Table 18 Growth Vehicles Added to the Operations Centre Fleet

Vehicle Type	2021	2023	2025	2027	2029
300 series	2	1	2	2	2
Half Ton Pickup Truck	1	1	-	1	1
Total	**13**				

Beyond 2031, the City didn't have available prediction for fleet growth. As a result, a generic percentage increase of 1.9% annually was assumed for the fleet following Barrie's population growth prediction of 1.9% annually between 2031 and 2041 (210,000 in 2031 and 253,000 in 2041). Table 19 provides the total fleet growth for the four facilities.

Table 19 Growth Vehicle Added to the Four Facilities Between 2032-2041

Vehicle Class	Vehicle Type	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
Heavy Duty	Dump Truck	0	0	0	0	0	0	0	0	0	0
Heavy Duty	Fire Truck	0	0	0	0	1	0	0	0	1	0
Heavy Duty	Pickup Truck	0	0	0	0	0	0	0	0	0	0
Heavy Duty	Plow	0	0	1	0	0	1	0	0	1	0
Heavy Duty	Salter/Sander	0	1	0	0	1	0	0	1	0	1
Large Medium Duty	Dump Truck	0	0	0	0	0	0	1	0	0	0
Large Medium Duty	Pickup Truck	0	0	0	0	1	0	0	0	0	1
Large Medium Duty	Vactor Truck	0	0	0	0	0	0	0	0	0	0
Light Duty	Car	0	0	0	0	0	0	0	0	0	0
Light Duty	Mower	0	0	0	0	0	0	1	0	0	0

Vehicle Class	Vehicle Type	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
Light Duty	Pickup Truck	1	1	2	1	2	1	2	1	2	2
Light Duty	SUV	0	0	0	0	0	1	1	0	0	0
Light Duty	Tractor	0	0	0	1	0	0	0	1	0	0
Light Duty	Van	0	0	0	0	0	1	0	0	0	0
Medium Duty	Pickup Truck	1	0	1	1	0	1	1	0	1	1
Equipment	Varied	0	0	1	0	0	1	0	0	1	0

8.2 ALTERNATIVE FUEL FLEET PLAN

This section provides an overview of the fleet distribution through the horizon 2021-2041 with the adoption of the new technology as per Scenario 3. The key assumptions for creating the fleet plan for each facility was as follows:

- To provide sufficient time to install the required infrastructure and secure funding, it was assumed that the earliest the alternative technology would be implemented was 2025.
- About 30% of the fleet currently operates at an age greater than its life cycle. As an example, there are heavy duty dump trucks, and light duty pickup trucks that have been in operations from 2000. It was therefore assumed that these vehicles would be retired in 2021, and later be replaced by CNG or electric vehicles according to the scenario of interest once they reach their end of useful life (10 to 12 years depending on the asset type).

Figure 30 through Figure 33 provide graphical representations of the proposed fleet distribution by technology under scenario 3, to each of the in-scope facilities.

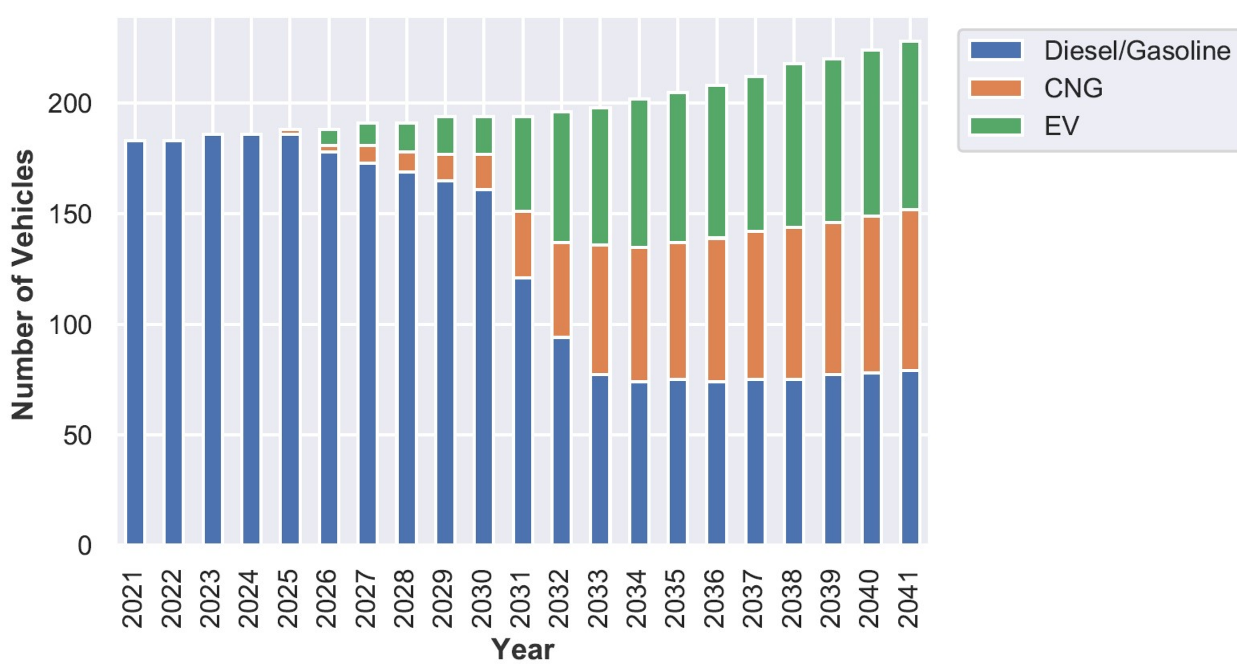


Figure 30 Operations Centre Fleet Distribution (2021-2041)

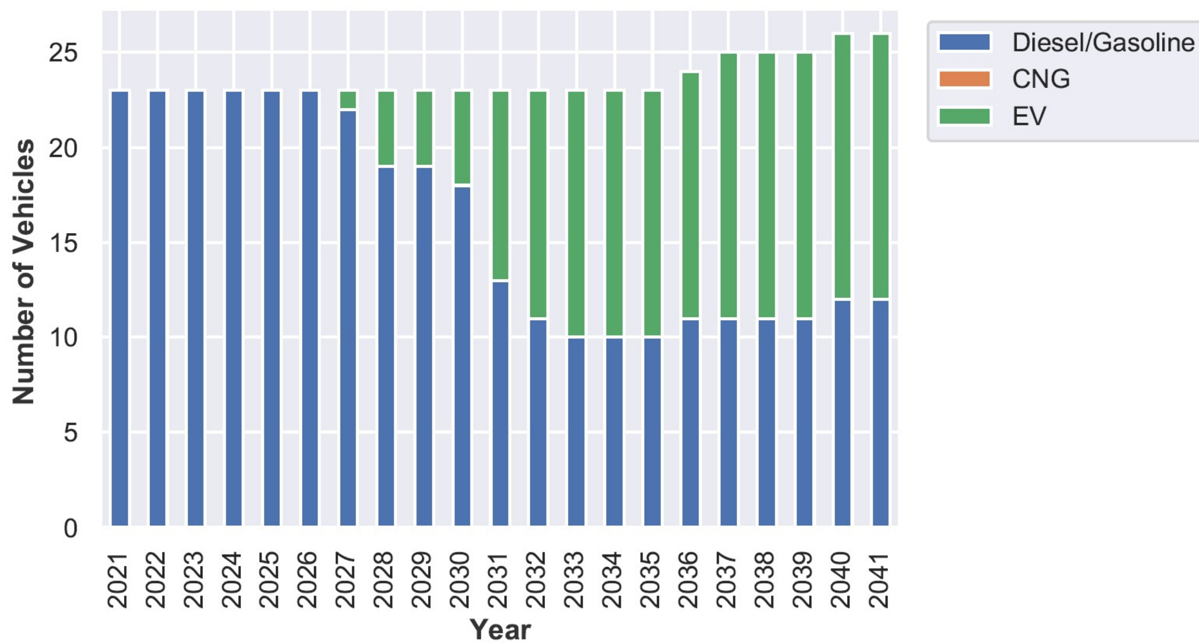


Figure 31 Station 1 Fleet Distribution (2021-2041)

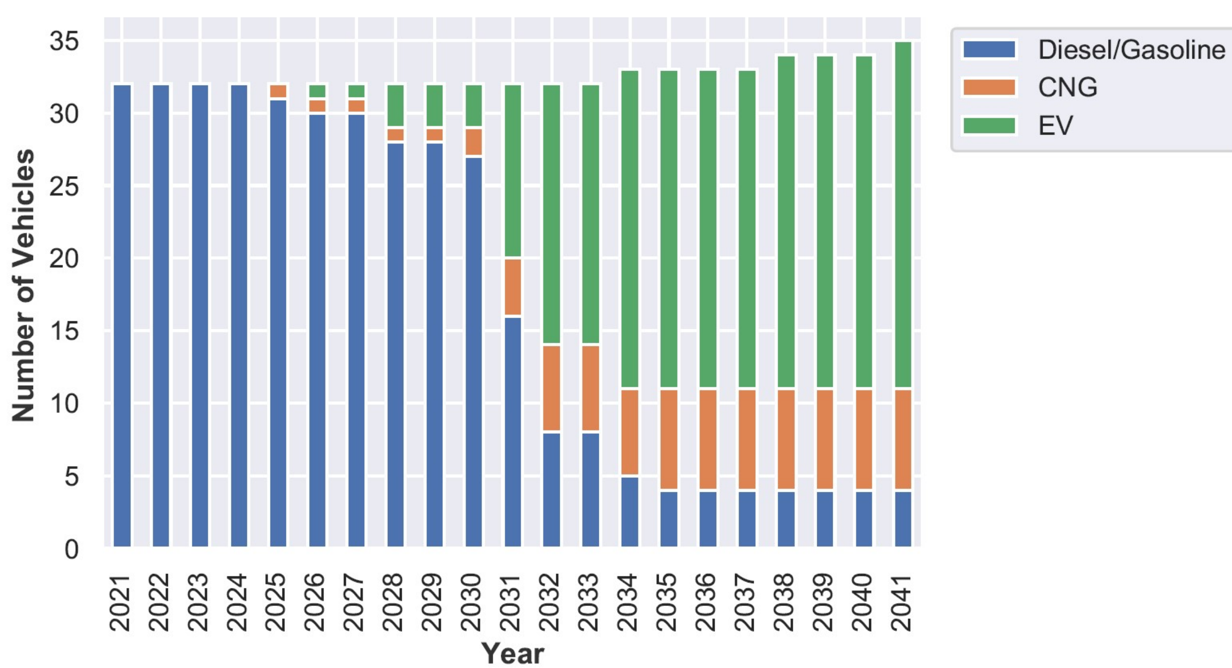


Figure 32 SWTP Fleet Distribution (2021-2041)

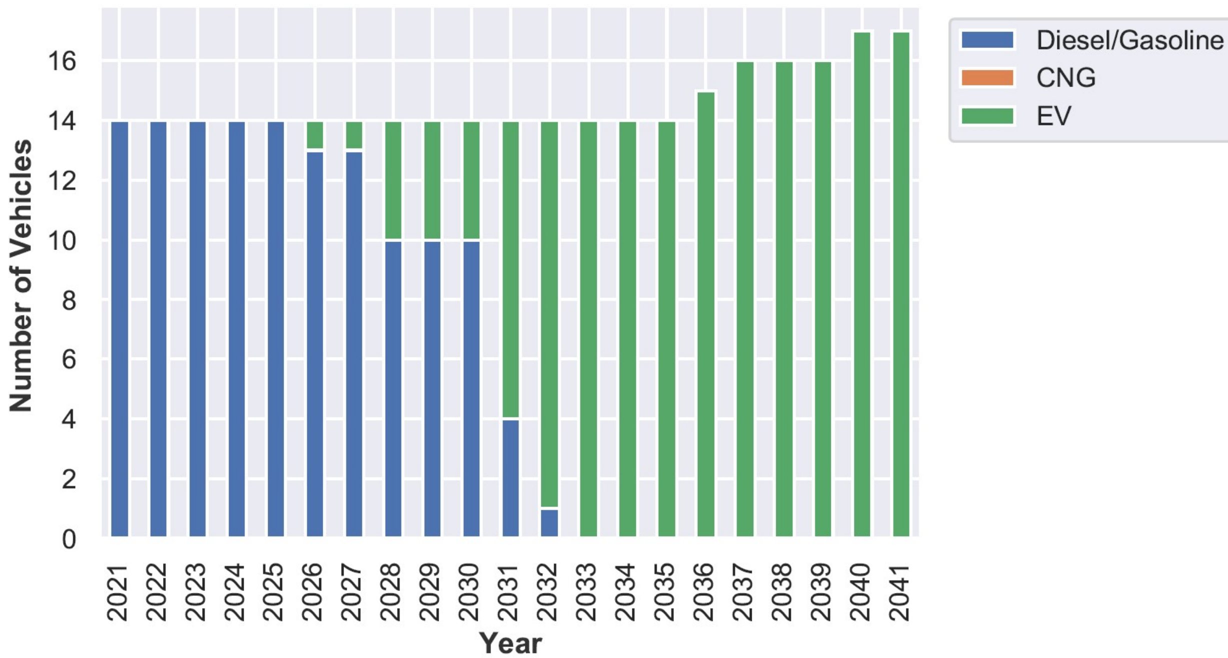


Figure 33 WWTF Fleet Distribution (2021-2041)

The following conclusions can be made from the above figures:

- The Operations Centre fleet size increases with time as more vehicles are added to the fleet
- The Operations Centre hosts the largest CNG and EV fleet compared to the other facilities
- By 2041, 34% of the Operations Centre fleet will rely on diesel and gasoline fuels, 32% on CNG (73 vehicles) and 34% will be converted to electric vehicles (76 vehicles)
- By 2041, 46% of the Station 1 fleet will rely on diesel and gasoline fuels, and 54% will be converted to electric vehicles (14 vehicles in total)
- By 2041, 12% of the SWTP fleet will rely on diesel and gasoline fuels, 20% (7 vehicles) on CNG and 68% will be converted to electric vehicles (24 vehicles in total)
- By 2041, 100% of the WWTF fleet will be converted to electric vehicles (17 vehicles)

9 FACILITY UPGRADES PLAN

This section provides a review of the proposed adoption plan based on the current state of the facilities. It should be noted that the Operations Centre and WWTF are planned to undergo facility upgrades, expansion and retrofit in the future. Any changes resulting from the ongoing capital program will need to be reflected and updated based on the finding of this report.

9.1 CNG VEHICLE ADOPTION PLAN

Based on the fleet plan described in the previous section, it is recommended the City of Barrie proceeds with installing only one CNG refueling station and that it be at the Operations Centre. In fact, the number of CNG vehicles to justify the capital expenditure and recurrent maintenance costs of a CNG station is usually between 20 – 30 vehicles depending a number of factors (such as the mileage and fuel economy, the price of diesel, fuel availability etc.). As a result, adding a CNG refueling station at the Station 1 Facility and the SWTP are not economically justifiable and the CNG vehicles parked at those facilities will need to refuel at the Operations Centre.

The Operations Centre CNG refueling station was therefore sized to serve a fleet of mixed vehicles (total of 80 vehicles by 2041). The daily site consumption value is based on the average fuel consumption of each operations vehicle type considered. This consumption is then rounded to the nearest hundred and a redundancy adjustment of 10% is added to ensure that each station has adequate capacity. The refueling station includes one dryer and one compressor that have been sized to provide a total of 1,100 m^3/day on an assumed suction pressure of 60 psig and discharge pressure of 4,500 psig. A redundant compressor unit should also be included in the plan to add systems resiliency. Phasing of this station has not been recommended, as multiple units of the major equipment are not required (i.e., when the station is fully built out, only one (1) dryer tower and one (1) compressor unit are required). Should the City decide to proceed with conversion of fleet to CNG following Scenario 3, the station should be built and ready to operate by 2031 when the larger fleet of natural gas vehicles starts their operations. Approximately 775 m3 of ground storage has been included at the facility and was sized based on a fast cascade fill system.

The Operations Centre is the central location for all municipal vehicle maintenance and repairs except for ambulance and police vehicles. As such, facility modifications for CNG fuelled vehicles in the maintenance areas will be required as per the CSA B401. This code applies to the maintenance facility where natural-gas-fuelled vehicles are maintained, repaired, or stored during maintenance or repair. The facility should also be modified to follow best practice approach for CNG vehicle storage and fueling stations.

In terms of timelines, major equipment procurement lead times are typically the critical item. For example, the compressors are typically 18 to 24 weeks from the receipt of a purchased order, depending on the equipment manufacturers production orders and factory capacity. The detailed design and approvals process can proceed in parallel with the equipment procurement, after the initial design phase where equipment sizing specifications have been established.

Typical design build life cycles for CNG refuelling stations can vary between a few months to a year depending on size of the station, the availability of design resources, Authority Having Jurisdiction (AHJ) approvals (including municipality zoning, first responder reviews, and Technical Standards and Safety Authority (TSSA) approvals), equipment lead times and construction resources available and site conditions.

The Operations Centre is being redeveloped as part of a current capital project outlined in the Operations Master Plan Project. Should the City decide to proceed with the inclusion of a CNG refueling station, it is important that the current redevelopment considers requirements for operating and maintaining CNG vehicles.

CNG is an explosive gas when combined with oxygen with an upper explosive limit of 15% (volume of gas in air) and a lower explosive limit of 5% (volume of gas in air). It is also flammable in the presence of an ignition source. For these reasons, it is crucial to install a warning system of active alarms that shuts down the fuelling process when the gas concentrations approach the lower explosive limit. As a result, handling large amounts of CNG indoors comes with significant infrastructure upgrades to get the rooms rated against explosions. This would add a significant cost to the budget.

For this reason, it is recommended that the CNG refuelling occurs outdoors. The drawing of the proposed refueling solution at the Operations Centre is shown in Appendix A, while Figure 34 illustrates the principles of the proposed solution explained above. This drawing is based on current configuration of the Operations Centre and any modifications to the building will need to be considered and may impact costing presented in this report.

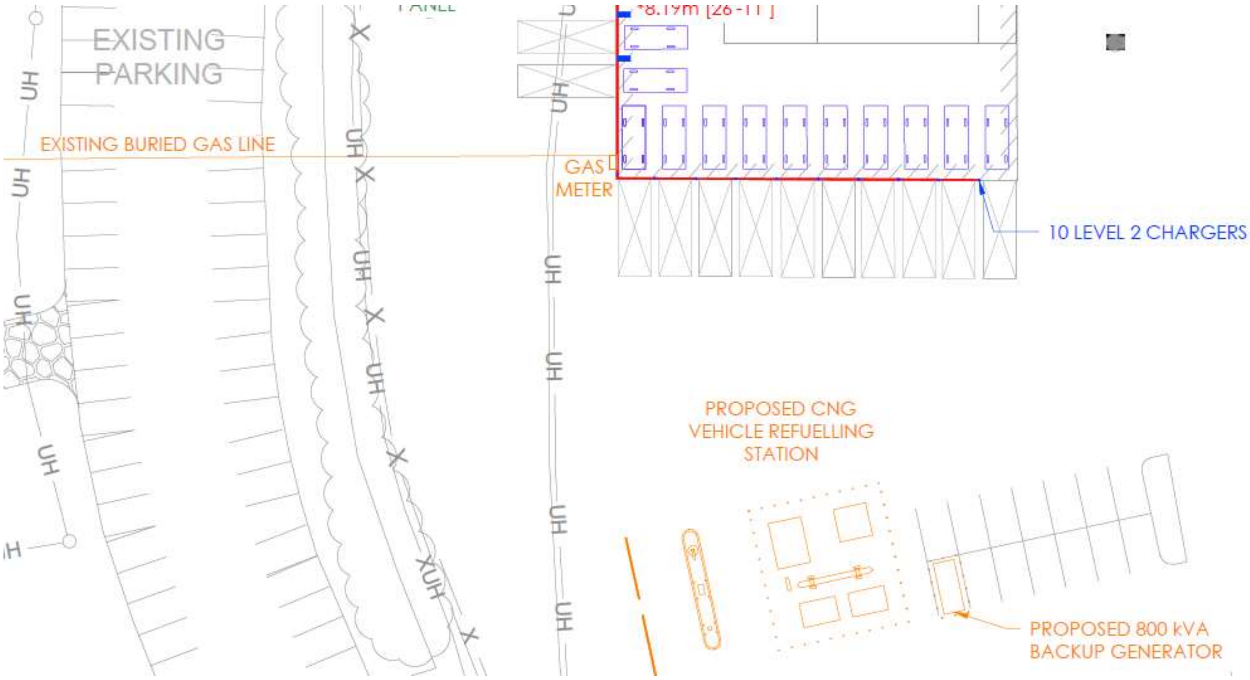


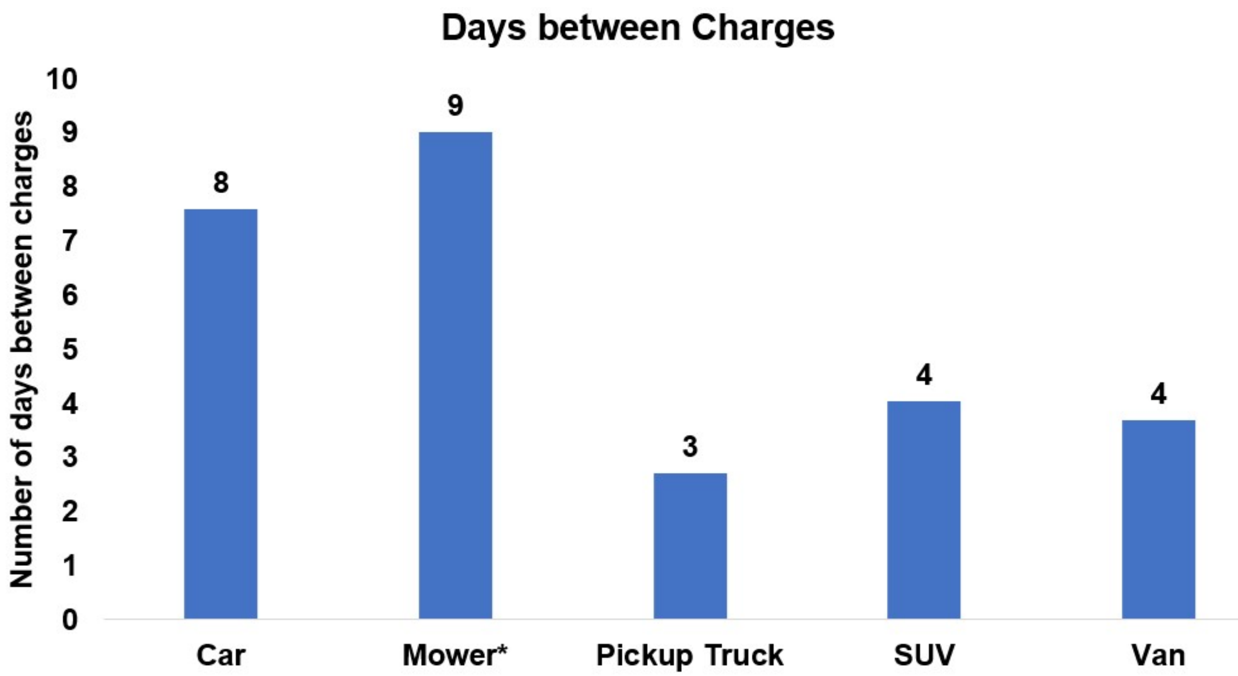
Figure 34 Concept Design for the CNG Station

Note that based on previous experience, an environmental assessment hasn't been required prior to installation of CNG refuelling infrastructure, as long as this infrastructure is built in an existing yard that already sees traffic.

9.2 ELECTRIC VEHICLE ADOPTION PLAN

To determine the minimum infrastructure required to recharge the electric vehicle fleet, it was crucial to first assess the fleet energy consumption. The total kWh consumed per year for the fleet was calculated using the average yearly km travelled and average fuel consumption shown in Table 15.

The charging frequency was then calculated assuming each vehicle type has a 20-kWh battery pack on-board; this is on the smaller side for vehicle battery packs and results in conservative assumption for charging frequency. The daily travel requirements were calculated assuming the vehicles operated 300 days per year and used to estimate the number of days between charges for each vehicle type. Figure 35 shows the results of this analysis.



*The Movers were assumed to only operate 3 months per year

Figure 35 Light Duty Vehicles: Number of Days Between Each Charge

It was then assumed that the charging needs should be served primarily by Level 2 chargers (80%) and by a smaller fraction of Level 3 chargers (20%). Based on the EV deployment fleet plan and the numbers of days required between each charge, the number of chargers required to serve the needs of the fleet was estimated as shown in Figure 36. The final ratio of charger-to-vehicle is 1:33 for the Operations Centre, 1:4.6 for Station 1, and 1:3.2 for the SWTP and WWTF facilities.

Best practises may indicate to install more chargers, so that there is up to 1 charger per vehicle to ease operations and charge management. This comes with the drawback that the fleet peak demand will be increased, and as such more electrical infrastructure and higher CAPEX investments will be required. The methodology developed in this section provides the minimal number of chargers that can be installed to operate the electrical vehicle fleet. It will be critical that the City of Barrie leads internal discussions with the various operations group to understand the level of acceptable disruption to typical operations and prioritize adding more chargers or adapting the operations.

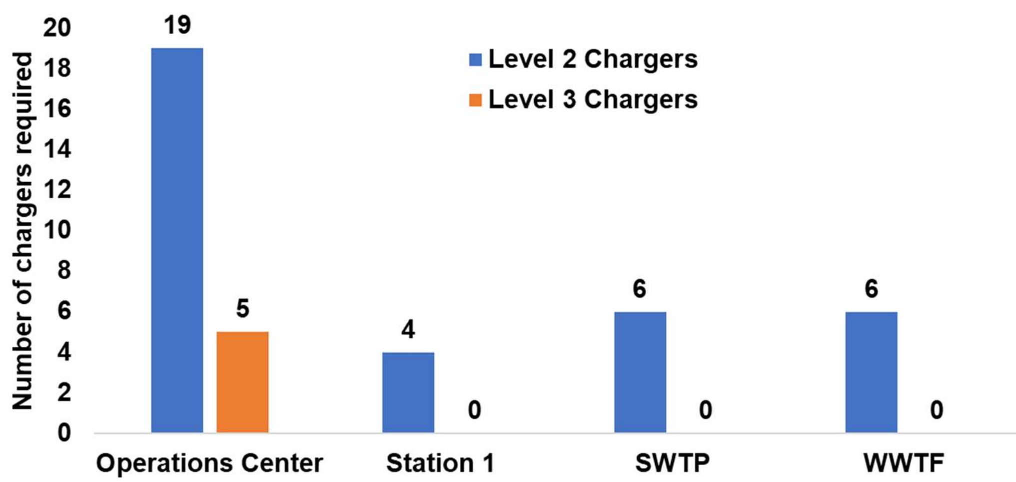


Figure 36 Charging Ports Requirements at Each Facility

The additional peak demand required to supply the load to the equipment was also calculated assuming that Level 2 chargers would deliver up to 19 kW of power and Level 3 chargers up to 50 kW. Information on existing name plate rated transformer capacity at each facility was also collected to assess the electrical infrastructure upgrade requirements. Table 20 shows the breakdown of the additional power supply that needs to be installed on-site to meet the charging load.

Table 20 Required Charging Power to Meet the Charging Load

Facility	Peak Demand from Charging	Power Supply at the Facility Today	Available Capacity (Considering Facility Peak Demand)	Required Additional Power Supply to Meet Charging Load
Operations Centre	611 kW	425 kW	211 kW	750 kVA
Station 1	76 kW	255 kW	132 kW	No upgrades needed
SWTP	114 kW	3000/4000KVA*	Enough available capacity for EV charging	No upgrades needed
WWTF	114 kW	1275 kW to be increased **	Enough available capacity for EV charging	No upgrades needed

*As provided by the City of Barrie, a 44KV – 3000/4000 kVA transformer feeds the SWTP feed

**a new 44kV electrical substation is proposed to the WWTF to provide peak power demand for the 76MLD MBR retrofit solution, with enough spare capacity for future power requirements that are expected within the equipment rated life expectancy (30-40 years), and provide partial redundancy with one transformer off-line for the majority of the power demands, taking into consideration the limitations of the commercially available 600V switchgear. As a results, this study assumes that the electric vehicles requiring a charge will be able to use that load.

From this analysis, the following electrical upgrades are required at each site:

Operations Centre

Assuming the facility is directly connected to the grid through a 27.6 kVa connection, a 750-kVA pad mounted transformer will be installed and connected to four switchgears / distribution panels supplying 1x 800 amps, 2x 250 amps and 1x 600 amps to the chargers. A detailed drawing of the Operations Centre showing the proposed charger, transformers and distribution panels arrangement is shown in Appendix B while Figure 37Figure 34 provides an overview.

It is recommended that the installation is phased in as follows:

- **Phase I (2026):** install one of the 250 amp switchgear, along with 4 x Level 2 chargers and 2 x Level 3 chargers
- **Phase II (2030):** Install one of the 600 amp switchgear, along with 10x Level 2 chargers and 3 x Level 3 chargers
- **Phase III (2031):** Install the last 250 amp switchgear, along with the 5x Level 2 chargers

Note that the increased capacity installed on-site will enable some flexibility to install up to two additional Level 2 chargers or 1 Level 3 charger for employees use. The cost of this equipment was excluded from this analysis, but could be considered by the City of Barrie as an increasing number of electric cars are being sold to the public in North America.

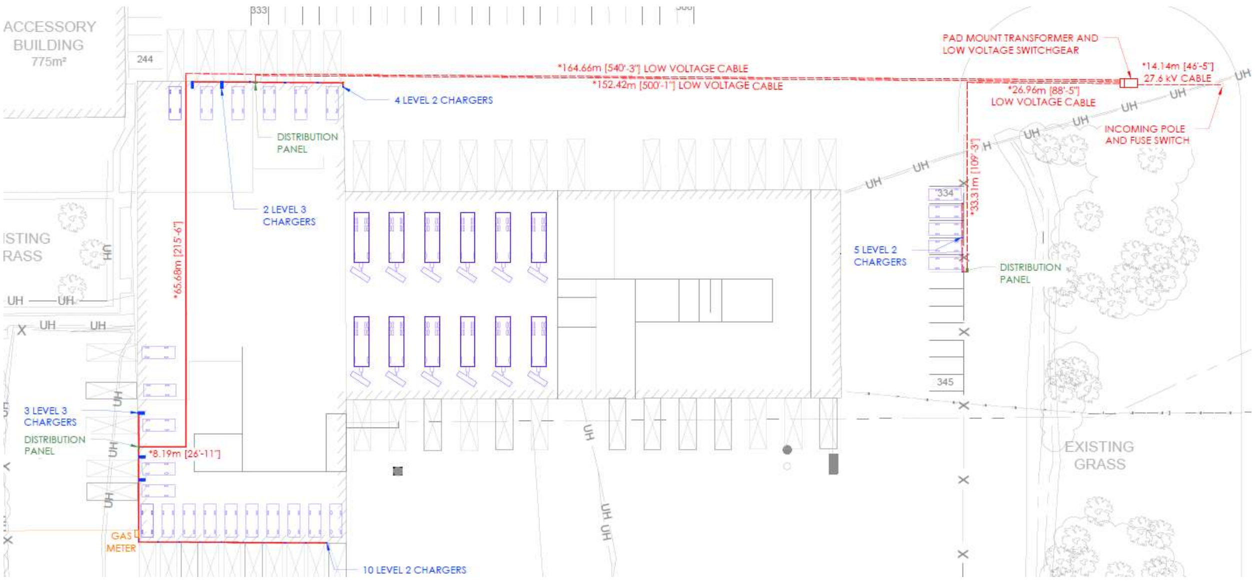


Figure 37 Operations Center Concept Design (Charging)

Station 1

As shown in Table 20, enough capacity exists to install the four Level 2 chargers without the need for an additional transformer or increased supply. Figure 38 shows a concept of where each of the chargers could be installed within the facility.

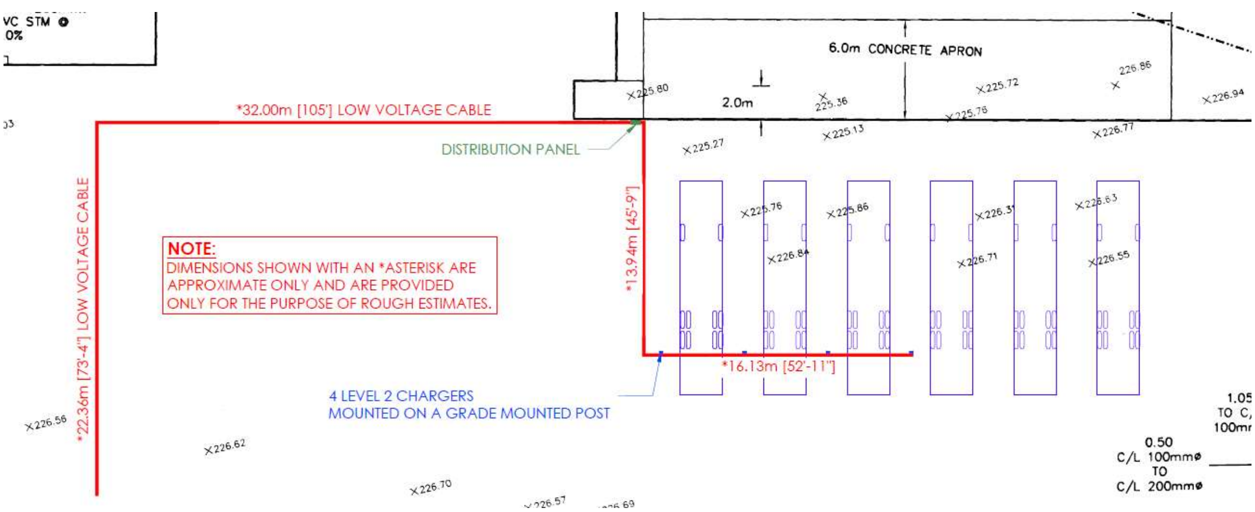


Figure 38 Station 1 Concept Design

SWTP

It was determined that the SWTP facility will have enough existing capacity to accommodate the addition of electric charging stations. Detailed drawings of the SWTP facilities showing the proposed charger and distribution panels arrangement is shown in Appendix C while Figure 39 provide overviews. It is recommended that the installation of the equipment is not phased but completed in one phase given the scale of the upgrades, although the chargers can be installed gradually as demand increased.

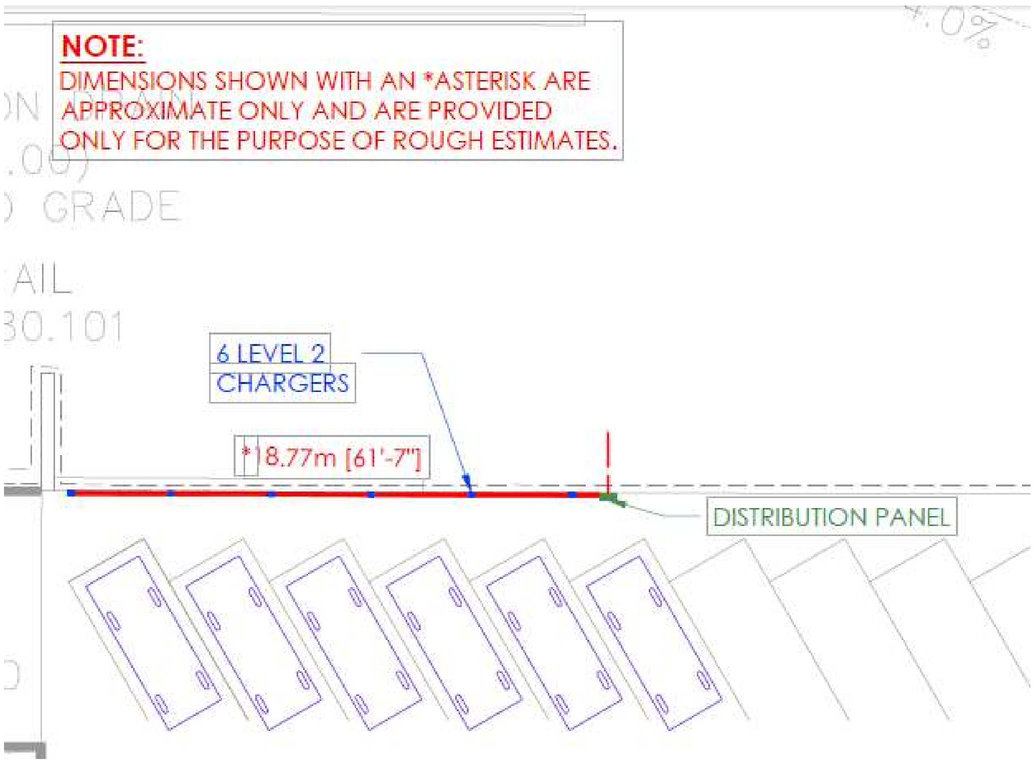


Figure 39 SWTP Concept Design

WWTF

An extensive program of work is planned at the WwTF over the next 10-15 years, to upgrade to membrane technology and expand the plant capacity. Therefore, the electrical system of the WWTF facility is expected to evolve in the future with the addition of the 44-kVA substation. As a result, the drawings provided for the WWTF only include charging location and an example of where the control panels could be located. This is subject to change as the design of the new substation gets finalized.

It should be noted that the larger work program at the plant will impact the ability to implement the infrastructure needs identified herein. A comprehensive site strategy plan will be developed and will consider the infrastructure requirements identified in this report, to support fleet charging. A drawing of the solution proposed at the WWTF facility showing the proposed charger and distribution panels arrangement is shown in Appendix D while Figure 39 provide a screenshot of the solution.

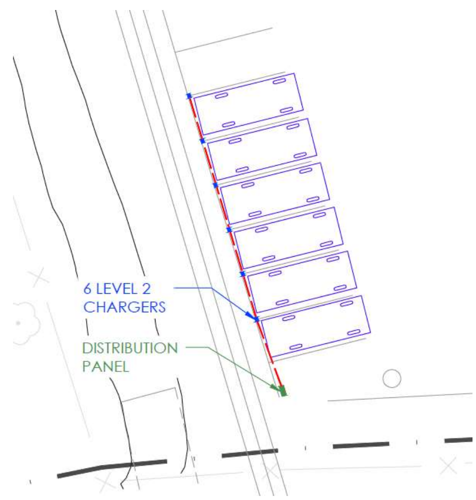


Figure 40 WWTP Concept Design

10 TRIPLE BOTTOM LINE ANALYSIS

10.1 COST ANALYSIS

This section provides a review of the key assumptions and results of the cost analysis for each technology reviewed, following the fleet conversion plan outlined in the previous section. The risks and limitations of the assumptions are also provided for consideration and follow-up studies.

10.1.1 DETAILED ASSUMPTIONS

CAPITAL COSTS OF THE CNG STATION

The following assumptions went into the costing of the CNG station at the Operations Centre:

- The total station cost provided in this report considers a central refuelling station that would be located at the City of Barrie's Operations Centre, since it is expected to house the most CNG vehicles
- The total station cost provided in this report includes the cost of all equipment, installation, commissioning, training, project management, engineering services, general contractor fees, approvals, and a contingency fund. The cost modelling results presented in the report assume 3% for auxiliary equipment, 35% for installation, 7% for general contractor fees, 0% for owner oversight and administrative fees, and 10% for contingencies. The allowance for CATS, training, project management, and engineering is calculated based on the preliminary equipment total – in these scenarios, is calculated at 8%.
- The daily site consumption value is based on the average fuel consumption of each operations vehicle type considered, which was provided by the City of Barrie. This consumption is then rounded to the nearest hundred and a redundancy adjustment of 10% is added to ensure that each station has adequate capacity.
- The cost estimate includes one (1) dryer tower that has been sized to provide a total of 1,100 m^3/day.
- The cost estimate includes one (1) compressor unit that has been sized to provide a total of 1,100 m^3/day, based on an assumed suction pressure of 60 psig and an assumed discharge pressure of 4,500 psig.
- One (1) redundant compressor unit has been included in the cost estimate, in addition to the aforementioned compressor(s) and is available on standby in the event of a problem with the on-duty compressor(s).
- The total site power includes compression and an additional 10% for ancillaries.
- This scenario does not consider slow filling any vehicles and therefore, slow fill posts have not been included in the cost estimate. Slow filling can be a good option for fleets whose vehicles routinely return to a "home base" for an extended period of time, however given the nature of the operations for the Corporate Fleet, there are not considered in this report.
- The cost estimate includes two (2) fast fill dispensers that are capable of handling the station's daily refuelling events.
- Cost estimates for all major equipment are based on catalogue pricing received from equipment manufacturers and/or quotes from past projects.
- An allowance of $1,000,000 has been included in the cost estimate to account for building modifications in the maintenance area (i.e., "CNG proofing"). Note that this is an estimation based on WSP's past project and required a stronger investigation of the current state of the facility to be refined.
- An allowance of 60,000 has been added for additional civil costs (i.e., fences and gates, jersey barriers and guardrails, site preparation, paving and landing strips, and surface treatment other than paving), considered to be conservative.

- An allowance of 4% has been included to account for commissioning, acceptance, testing, and start-up activities, training, and third-party engineering. The general contractor fee is a placeholder value for cases where we are not sure how the project will be organized. This is intended to cover off any third-party supervision fees over and above the cost of installation.
- An allowance of $10,000 has been included to account for the approvals process which include approvals from ESA and TSSA, and any other municipal approval.
- The cost of backup power generators is based on past projects and assumes a unit cost of $643/kW and a requirement of 700 kW (for the EV system and the CNG station)
- Added a person full-time for six years (2025-2032) to manage the fleet transition (EV and CNG) and installation builds at $150,000 per annum.

Table 21 below shows the equipment and installation CAPEX for the proposed solution.

Table 21 CNG Station CAPEX

Station Component	Operation Centre Facility w/ Redundant Compressor
Equipment	
Dryer	$31,000
Compressor	$431,000
Ground Storage	$134,000
Priority Panel	$22,000
Fast Dispenser	$120,000
Slow Dispenser	$-
PCC Panel	$30,000
Building Modifications	$1,000,000
Auxiliary Equipment (3%)	$55,000
Diesel Generator	$450,100
Civil Installation	
Installation Budget (35%)	$532,000
Site Preparation, Fences and Gates, Paving and Surface Treatment	$60,000
Design & Execution Allowances	
Gas Service	$0
Electrical Service	$0
CATS, Training, Project Management & Engineering (4%)	$71,000
Approvals	$10,000
General Contractor Fee (7%)	$124,000
Contingency (15%)	$266,000
Owner Oversight & Administrative Fees	$900,000
Total	**$3,786,000**
Total with Diesel Generator	**$4,236,100**

CAPITAL COSTS OF THE ELECTRIC VEHICLE UPGRADES

The following assumptions went into the costing of the EV charging stations at each facility:

- Assumed that the incoming power line at each facility was 27.6 kV
- The Operations Centre required one (1) 750 KVA pad-mounted transformer
- The SWTP and the WWTF both require one (1) 150 KVA pole mounted transformer
- 19 Level 2 chargers (20 kW) and 5 Level 3 chargers (50 kW) are installed at the Operations Centre over the course of 8 years
- 4 Level 2 chargers are installed at the Station 1 (one in 2026, one in 2027, one in 2030 and the last one in 2032)
- 6 Level 2 chargers are installed at the WWTF (one in 2025, one in 2027, 2 in 2030 and the remaining in 2032)
- 6 Level 2 chargers are installed at the SWTP (one in 2025, two in 2030, two in 2031, the last one in 2033)
- An allowance of $250,000 was added for the civil work requirements for the Operations Centre, and $100,000 for the remaining facilities (trenching, signage, foundations, concrete etc.)

Table 22 below provides an overview of the CAPEX (including equipment and installation cost) at each facility to replace the fleet of light duty vehicles with EVs.

Table 22 EV Systems Costing*

Station Component	Operations Centre	Station 1	SWTP	WWTF
Equipment				
27.6 kV Pole	$4,000	-		
27.6 kV Fuse Switch	$7,000	-		
27.6 kV Cable	$6,800	-		
750 KVA Pad Mounter Transformer	$80,000	-		
600 V Switchgear - 800 A	$20,000	-		
600 V Switchgear - 250 A	$3,000	$1,500	$3,000	$1,500
600 V Switchgear - 600 A	$5,000	-	-	-
1000 V Cable- 1x500 kcmil	$30,000	-	-	-
1000 V Cable- 1x250 kcmil	$9,600	$2,250	$750	$750
1000 V Cable- 3x#6	$4,000	$1,500	$1,200	$2,500
Grounding	$10,000	$4,000	$4,000	$4,000
Level 2 chargers	$133,000	$28,000	$42,000	$28,000
Level 3 chargers	$185,000	$-	$-	$-
Design & Execution Allowances				
Installation Budget (35%)	$174,500	$13,500	$18 000	$13,000
Civil Work Improvement	$250,000	$100,000	$100,000	$100,000
CATS, Training, Project Management & Engineering (4%)	$ 20,000	$1,500	$ 2,500	$1,500
Approvals	$10,000	$10,000	$10,000	$10,000
General Contractor Fee (8%)	$ 35,000	$3,000	$4,000	$3,000
Contingency (15%)	$ 75,000	$ 6,000	$8,000	$6,000
Total	**$1,061,900**	**$171,250**	**$193,450**	**$170,250**

*This is based on a conceptual electrical design; this estimate is subject to changes provided additional engineering efforts and supporting civil infrastructure refined cost analysis

FLEET OPERATING COSTS

The assumptions related to the operating costs of each technology is shown in Table 23.

Table 23 Key Input Parameters and Assumptions of CBA

Input Parameter	Value	Notes
Fleet Asset Inventory and Vehicle Expected Life	Dependent on Asset	Counts
Vehicle Acquisition Prices	Dependent on Asset	$
Vehicle Fuel Consumption	Dependent on Asset	$
Vehicle Annual Mileage	Dependent on Asset	km
Model Time Horizon	Dependent on Asset	Years
Asset Salvage Value	5%	% of procurement cost
Federal Zero Emissions Vehicle Program Rebate	BEV - $5,000 HEV/PHEV - $2,500	$/vehicle, to a max claim of 10 vehicles per year
Gasoline Fuel Price	$0.90 /L in 2021, then a 2.1% increase per year	$/L, City historic average
Diesel Fuel Price	$0.80/L in 2021, then a 2.1% increase per year	$/L, City historic average
CNG Fuel Price	0.5 $/m^3 in 2021, then a 2.1% increase per year	Past projects
Electricity Price	Administrative fee: 150.84$/month Electricity cost (including GA): 0.125$/kWh Demand cost: 8.9887 $/kW in 2021, then a 2.1% increase per year	Large Customer Rates (50-4999 kV), Alectra, 2021
Maintenance Savings	BEV – 70% CNG – 95% HEV – 105%	% savings assumed from BAU costs
GHG Emission Factors (CO_2 / kg) for all Fuel Types	Dependent on Fuel Type: gasoline, diesel, electric, CNG, biodiesel Emissions from grid varying from 0.031 kgCO2e/kWh in 2021 to 0.098 kgCO2e/kWh in 2041	CO_2/unit fuel (sourced from GHGenius tool) Tailpipe emissions only IESO's 2020 Annual Planning Outlook

FLEET CAPEX

The table below provides an overview of the acquisition cost for the different technologies.

Table 24 Acquisition Cost for Different Vehicle Types

Vehicle Class	Vehicle Type	Acquisition Vehicle Cost ($)	Alternative Fuel Vehicle Cost ($)*
Heavy Duty	Dump Truck	$250,000	-
Heavy Duty	Fire Truck	$1,000,000	-
Heavy Duty	Pickup Truck	$90,000	-
Heavy Duty	Plow	$350,000	-
Heavy Duty	Salter/Sander	$450,000	-
Large Medium Duty	Dump Truck	$80,000	(CNG) $92,000
Large Medium Duty	Pickup Truck	$55,000	(CNG) $67,000
Large Medium Duty	Vactor Truck	$400,000	-
Light Duty	Car	$30,000	(EV) $45,000
Light Duty	Mower	$10,000	(EV) $16,600
Light Duty	Pickup Truck	$45,000	(EV) $63,160
Light Duty	SUV	$35,000	(EV) $48,000
Light Duty	Tractor	$35,000	-
Light Duty	Van	$40,000	(EV) $63,160
Medium Duty	Pickup Truck	$50,000	(CNG) $60,000
Equipment	Varies	$125,000	(CNG) $125,000

*Note that the alternative vehicle lifecycles are assumed to be the same as their conventional fuel counterpart

EQUIPMENT OPERATING COSTS

- A 1% of the CAPEX allowance was included as part of the analysis to account for maintenance cost of the equipment (CNG refueling stations and charging stations). The typical lifecycle of these equipment was assumed to be greater than 15 years and weren't replaced in this analysis.

10.1.2 RESULTS

This section presents a review of the cost analysis results for each facility, including fleet growth.

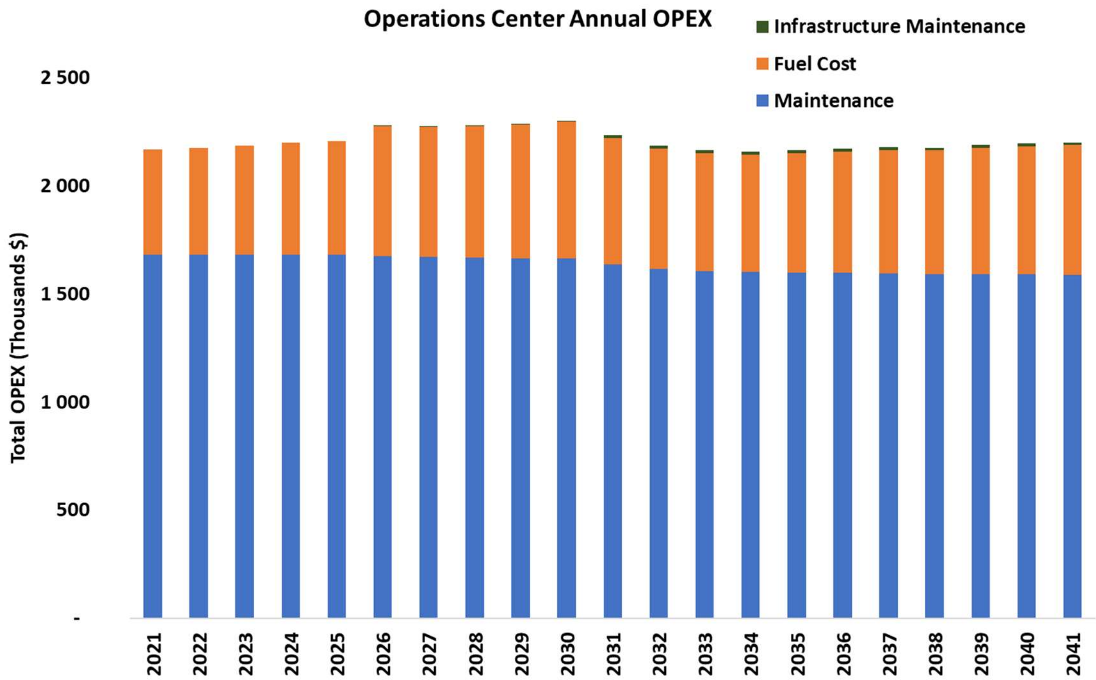


Figure 41 Annual OPEX - Operations Centre

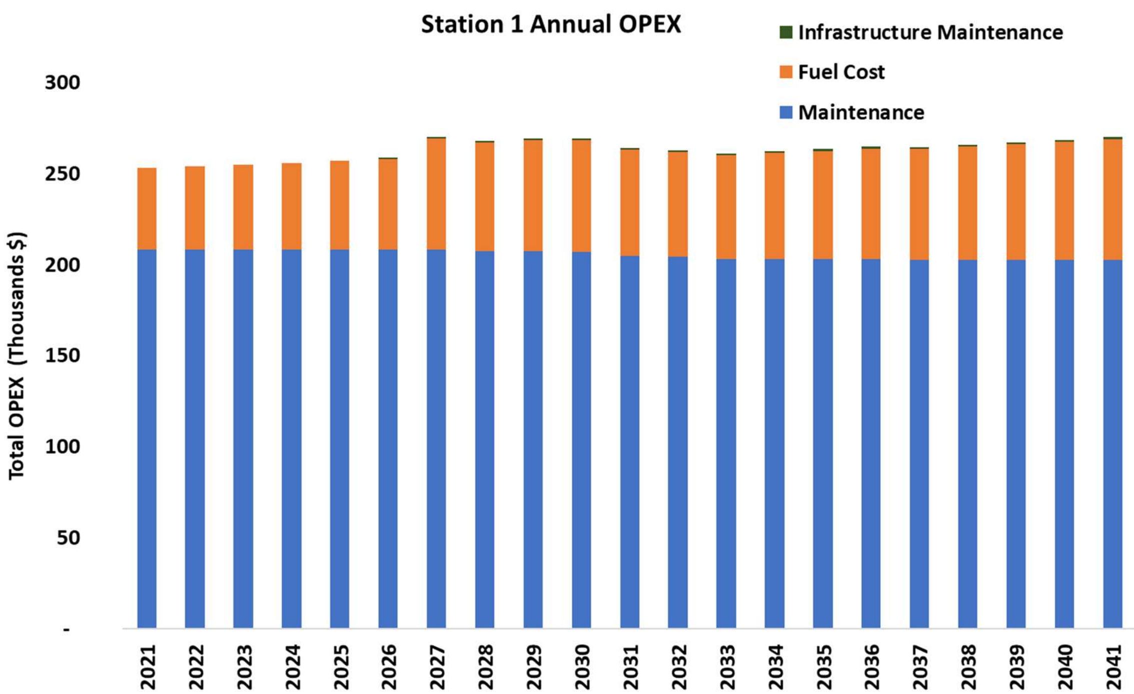


Figure 42 Annual OPEX - Station 1

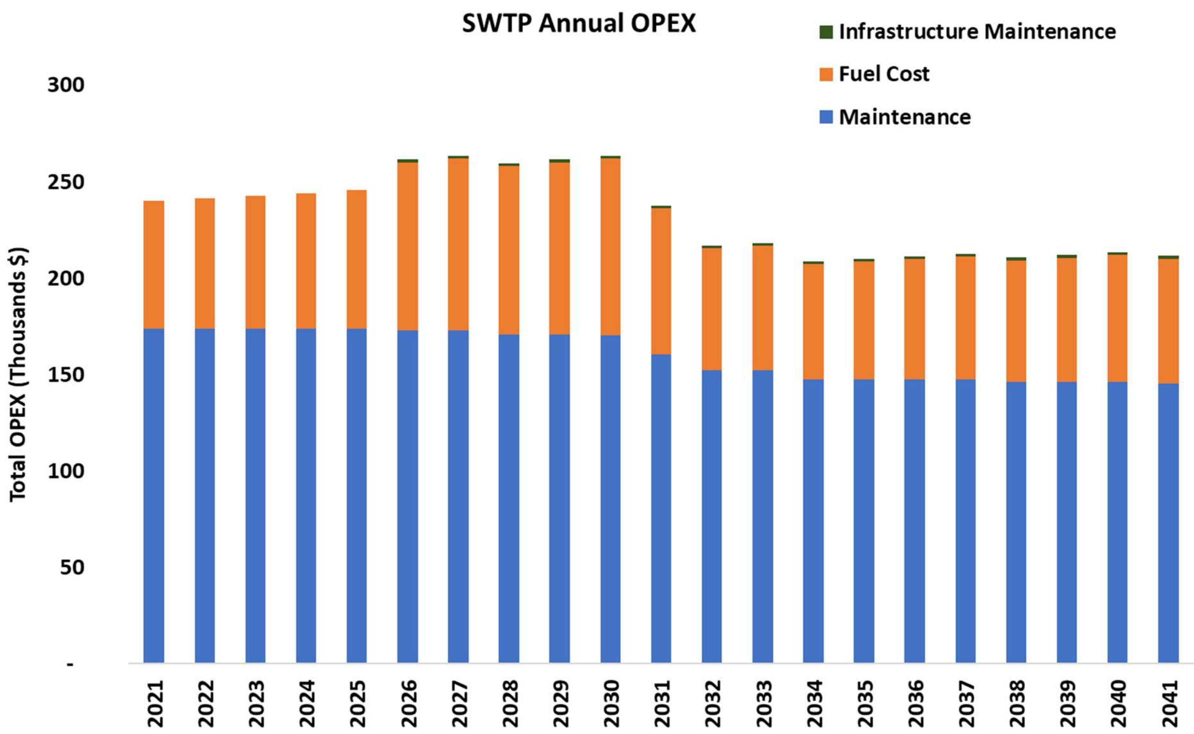


Figure 43 Annual OPEX - SWTP

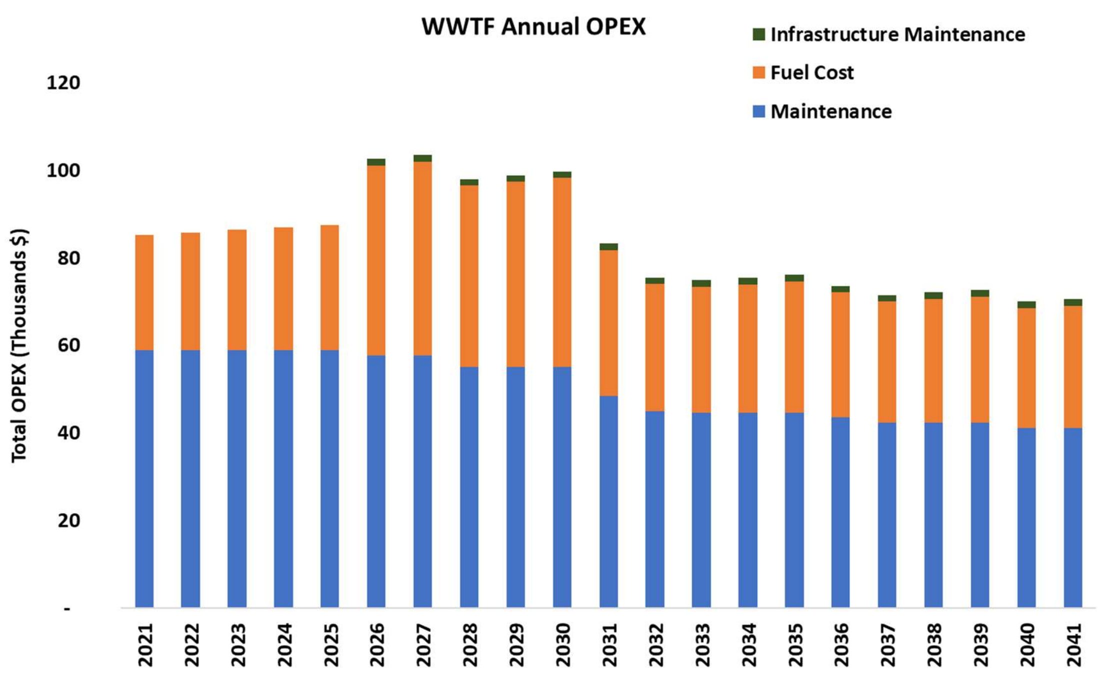
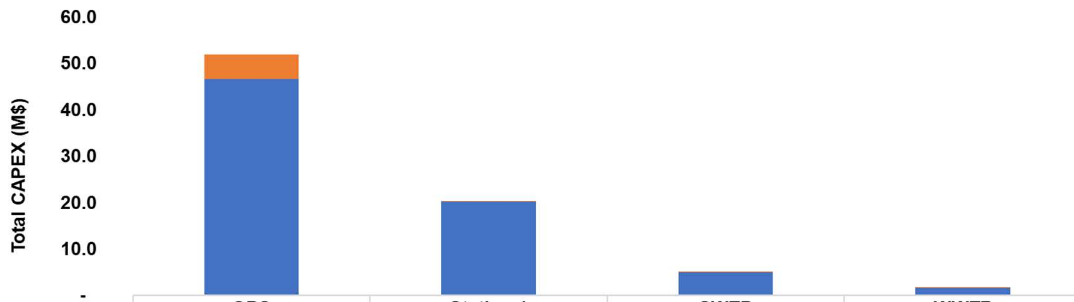


Figure 44 Annual OPEX - WWTF

Figure 41 through Figure 44 presents the evolution of the OPEX (fleet maintenance, fuel cost and infrastructure maintenance) as the technology transitions. As shown in this graph, throughout time, the total OPEX are either kept at a similar level or decreasing over time. Figure 45 presents the CAPEX analysis based on the transition plan outlined in Section 4. The largest CAPEX investment required is at the Operations Centre, and facility upgrades in this facility account for about 10% of the total CAPEX expenditure required between 2021-2041. The larger portion of the investment is reserved for the rolling stock. Note that the total fleet procurement includes the salvage value of the vehicles as well.

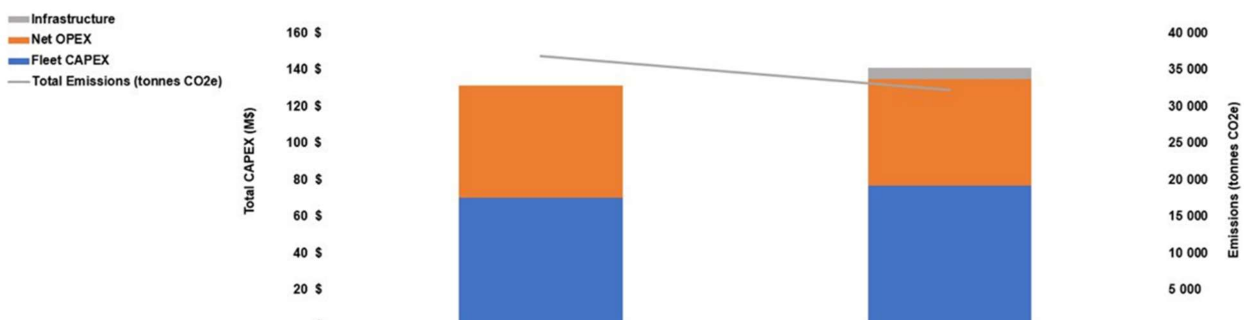


	OPS	Station 1	SWTP	WWTF
Total CAPEX	5.3	0.2	0.2	0.2
Total Fleet Procurement	46.6	20.2	4.9	1.6

Figure 45 CAPEX for the Four Facilities (2021-2041) (in million $)

10.1.3 COMPARISON WITH BUSINESS-AS-USUAL

The following Table 25 and Figure 46 present a cost comparison of the business-as-usual (BAU) and transition Scenario 3 as described in this report.



	BAU (2021-2041)	Alternative Fuel Transition Plan (2021-2041)
Infrastructure	0	5.8 $
Net OPEX	61 $	58 $
Fleet CAPEX	70 $	77 $
Total Emissions (tonnes CO2e)	36 925	32 266

Figure 46 Cost Comparison Between the Two Scenarios Over 20 Years

Table 25 Cost Comparison Between the Two Scenarios (in million $)

	BAU (2021-2041)	Alternative Fuel Transition Plan (2021-2041)
CAPEX		
Infrastructure	N/A	$ 5.8
Fleet Procurements	$70	$77
Salvage Value (SV)	($4)	($4)
Net CAPEX	**$67**	**$79**
OPEX		
Fleet Maintenance	$45	$43
Fuel/CNG/Electricity	$17	$15
Net OPEX	**$61**	**$58**
Fleet Emissions		
Total Emissions (tonnes CO2e)	36 925	32 266
Total (CAPEX + OPEX)	**$127.7**	**$137.4**
Carbon Tax	**$7**	**$5.8**
Total (with carbon tax)	**$134.7**	**$143.2**
M$/MtCO2e saved	**-**	**2.0**

Following the alternative fuel scenario would increase overall cost by 7% compared to the BAU over the next 20 years. It is important to note that the operating costs tend to decline overall as the new technologies are implemented. Furthermore, this model assumes a constant procurement cost throughout time for the alternative technology, though this cost is expected to decrease compared to diesel and gasoline vehicles as the technology matures.

One of the key takeaways from these results is that infrastructure upgrades represent a small portion of the overall CAPEX for the projects. The key elements driving costs are the fleet procurement and the operations. While the alternative fuel transition scenario provides 4.6% of operating cost savings compared to the BAU scenario over the 20 years period, it also comes with an increased CAPEX of 18.1%. The table below presents a comparison of the yearly OPEX between the BAU case and the alternative scenario:

Table 26 Decrease in Yearly OPEX (between BAU and Alternative Scenario at year 2041)

	Operations Centre	Station 1	SWTP	WWTF
Decrease in yearly maintenance costs (%)	-6%	-3%	-16%	-30%
Decrease in total fuel cost (%)	-21%	-7%	-34%	-19%

As shown in this table, net savings are made over time at each facility. The percentage of savings depends on the fleet composition, with greater savings shown when most of the vehicles operating from the facility are electric vehicles. For instance, the SWTP facility will reach 68% of electrification for its fleet by 2041. Similarly, the WWTF facility shows higher returns as 100% of its fleet operates electric vehicles. Despite operating over 50% of electric vehicles, the savings at the Station 1 are low due to the fact that the most expensive vehicles to maintain and fuel are heavy duty vehicles.

Another important figure that can be drawn from this analysis is that following this scenario, it will cost the City $2M per Mt of CO2e saved to reduce its emissions over the next 20 years.

In 2019, Canada passed the Greenhouse Gas Pollution Pricing Act, or carbon tax, in an effort to cut Canada's carbon pollution by 30% below 2005 levels by 2030. The carbon tax was initially set at $20 per tonne of CO_2. In December 2020, the government announced a gradual hike of this carbon tax to reach $170 per tonne by 2030.

Assuming a linear growth between $30 and the target 2030 price, and assuming a constant growth thereafter, it is possible to assess the potential benefits from switching to an alternative fuel source for Barrie's fleet[39]. This would decrease the additional CAPEX and OPEX investment required for the alternative fuels scenario down to 2%.

10.1.4 FUNDINGS AND AVAILABLE GRANTS

FEDERATION OF CANADIAN MUNICIPALITIES (FCM)

The Green Municipal Fund (GMF), offered by the Federation of Canadian Municipalities (FCM), aims to build better lives for Canadians through helping municipalities and municipal partners implement sustainability projects. Since 2000, FCM has financed more than 1,300 municipal sustainability initiatives and throughout the process GMF projects have cut 2.6 million tonnes of greenhouse gas (GHG) emissions. The Green Municipal Fund offers grants and loans in three categories:

1. Reducing fossil fuel use in fleets;
2. Signature initiatives that are transformative, highly innovative and impactful; and
3. Transportation networks and commuting options that encourage people to switch to less polluting transportation.

The first category is most applicable in exploring green fleet options for the municipal service vehicles managed and maintained by the City of Barrie. Examples of projects eligible to study, pilot or implement include vehicle procurement and fleet optimization, alternative fueling infrastructure for vehicles (i.e. fast charging stations), or alternate fuels and technology to reduce fuel consumption. The FCM funds feasibility studies, pilot projects, and capital projects; the details of each project funds are discussed below in further detail.

REDUCING FOSSIL FUEL USE IN FLEETS (STUDY)

The FCM funds feasibility studies and pilot projects, as well as provides a combination of loans and grant funding for capital projects that reduce or avoid the use of fossil fuels in vehicles that deliver municipal services. The purpose of this funding is to help Canadian cities and communities pursue projects that minimize energy consumption and GHGs, as well as improve their air quality. The target of the project must be a reduction of GHG emissions by 20%, compared to an established baseline. The feasibility study grant offers up to 50% of eligible costs to a maximum of $175,000.

PILOT PROJECT FUNDING

Pilot projects examine potential solutions in real-life conditions. The pilot project can examine the financial and/or environmental performance of a new or proven initiative and the associated social benefits of the project. To apply, municipalities must review the prerequisites and required supporting documentation, complete the project workbook, confirm that other funding sources for the project are being secured, and complete the application form. Applications are accepted year-round until all the funding has been allocated. The pilot project grant offers up to 50% of eligible costs to a maximum of $350,000.

CAPITAL PROJECT FUNDING

The Green Municipal Fund offers a combined loan and grant for capital funding that reduce or avoid the use of fossil fuel in a municipal fleet. There are two types of fund combinations, which can cover up to 80% of eligible costs. The first category is classified as a regular loan and grant. This includes a low-interest loan of up to $5 million and a grant worth up to 15% of the loan. The second category is classified as a high-ranking project loan and grant, which includes a low-interest loan of up to $10 million and a grant worth up to 15% of the loan.

[39] https://www.canadadrives.ca/blog/news/carbon-taxes-and-carbon-tax-rebates-in-canada-explained

To apply, municipalities must review the prerequisites, required supporting documentation and the criteria table that outlines eligible and ineligible costs. A detailed project budget must be developed, followed by confirming that other funding sources for the project are secured. Once the initial steps are completed, a two stages application process must be followed. The initial review form can be submitted year-round. Eligible recipients will then be provided an application form to submit.

NATURAL RESOURCES CANADA

The Federal Government of Canada is investing to support the establishment of a charging network for electric vehicles, natural gas and hydrogen refueling stations. The Electric Vehicle and Alternative Fuel Deployment Initiative offers repayable contributions limited to a maximum of $5 million per project. For electric vehicle fast chargers, the program will pay up to 50% of the total project cost to a maximum of $50,000 per charging unit. Similarly, the program will pay up to 50% of the total project costs for natural gas and hydrogen refuelling stations, to a maximum of $1 million per refueling station.

Table 27 Summary of NRCan Incentives for Charging & Fueling Stations

Category	NRCan Repayable Incentives
EV Charging Stations	50% (up to $50,000 per charging unit)
CNG and Hydrogen Fueling Stations	50% (up to $1 million per refueling station)

Municipal governments are eligible to apply. Some eligibility requirements include that the project must be a permanent installation located in Canada and it must be within the eligible technology constraint. Furthermore, the project should be completed 18 months after the receipt of the Letter of Conditional Approval for EV fast chargers or 2 years after the receipt of the Letter of Conditional Approval for natural gas and hydrogen refueling stations.

A demonstration of due diligence is required at the proposal stage, which includes proof of 50% secured funding of the project costs, proof of engagement with the energy supplier and ownership or proof of eligibility to access the project site for at least 10 years. Applicants must submit a single copy of the complete application with additional supporting documentation required by the Program to fully assess the project in electronic format.

TRANSPORT CANADA

As of May 2019, the Canadian Federal Government via Transport Canada announced incentives for purchasing and leasing of hybrid, battery electric and fuel cell vehicles in order to help promote the transition to more environmentally sustainable vehicles.

These incentives are applicable at the point of sale and cover the following categories listed in Table 28. To qualify the MSRP for vehicles with six seats or fewer must be less than $45,000 (exclusive of freight, delivery and other fees). Vehicles with seven seats or greater and a MSRP up to $60,000 can also qualify for purchase incentives. The Government of Canada webpage can be referenced for further details[40].

Table 28 Federal EV Purchase and Lease Incentives

Vehicle Category	Incentive
Long Range Plug-in Hybrids, Battery Electric and Fuel Cell	$5,000
Short Range Plug-in Hybrids	$2,500

[40] Transport Canada, Zero-emission vehicles, Available at: https://tc.canada.ca/en/road-transportation/innovative-technologies/zero-emission-vehicles

10.2 ENVIRONMENTAL AND SOCIAL IMPACTS

10.2.1 EMISSIONS REDUCTION POTENTIAL

The vehicle emissions were calculated based on the fleet fuel/energy utilization profiles using the average energy efficiency and fuel economy listed in Table 15. Figure 47 demonstrates the potential of adopting electric vehicles in reducing yearly emissions. Transitioning to alternative fuels following the plan outlined in this report would reduce emissions by 13% over the next 20 years compared to BAU.

At the end of the 20 years, once the plan is completed, the yearly emissions are 1,501 tonnes of CO_2e, while the BAU's emissions would be 2,016 tonnes of CO2e – a reduction of 26%. It should be noted that Canada's mandate is to achieve carbon neutrality, or "net zero" by 2050 and it is likely that more policies and measures will be implemented going forwards to advance this goal. By adopting Scenario 3 and the plan outlined in the report, the City of Barrie would still need to reduce its emissions substantially to reach carbon neutrality.

Although there are avenues to reduce GHG emissions for natural gas vehicles by replacing the CNG with renewable natural gas (RNG), the province of Ontario currently lacks a clear path towards deploying RNG at a large scale; rather, the province of Ontario currently relies on a clean electricity grid.

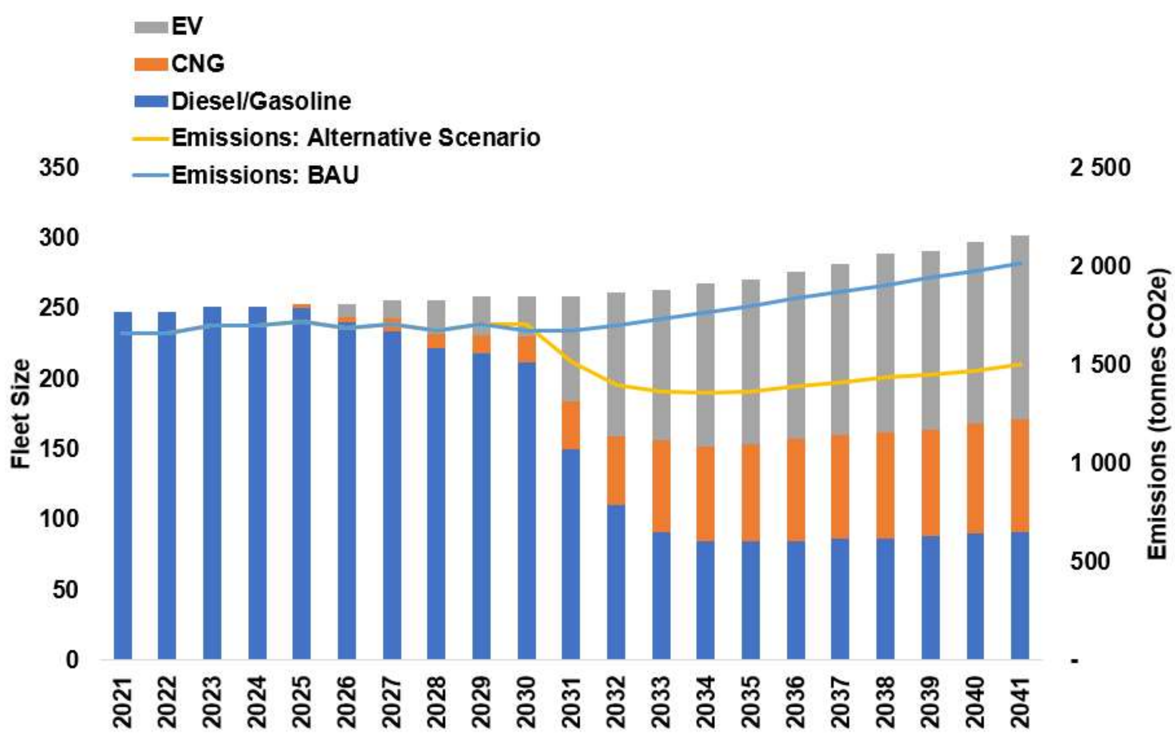


Figure 47 Emissions Profiles for the Alternative Fuel Scenario

It is recommended that an Environmental Impact Assessment (EIA) be conducted comparing the environmental impacts of the Scenario 3 Corporate fleet adoption. The study itself may take as little as 6 months depending on the complexity, and will help characterize the true benefits of the scenario envisioned. It is typically expected Criteria Air Contaminants (CAC) emissions differ by propulsion technology, with EVs having the least emissions of CACs followed by CNG. All expected EV emissions are upstream emissions, as BEVs have zero tailpipe emissions, making them the best option for improving air quality locally. However, CNG technology also demonstrates improvements for some of air pollution emissions as compared to the conventional fuels, overall improving air quality. An EIA will analyze the environmental impacts of the selected fleet scenario.

10.2.2 NOISE CONSIDERATIONS

The adoption of alternative fuel vehicles can have an impact on traffic-related noise levels. This is a component that is often overlooked when purchasing vehicles, however it may have a significant impact on the health of people being exposed to the noise produced by the vehicle (i.e. employees, operators, passengers, and local community). It is particularly significant for heavy duty vehicles, although light- and medium-duty vehicles also experience an impact.

Aside from the benefit of not having to deal with loud traffic-related noises, there are measured societal benefits of quiet buses including health benefits and cost. For reference, there has been studies conducted in Europe that depicts how impactful traffic noise can be. It is estimated that nearly 120 million people in the European Union (EU), which is about a third of the total population, are exposed to unhealthy traffic-related noises. The World Health Organization reports that over 1 million healthy life years are lost annually from traffic-related noise in the western European countries. Sleep disturbance and annoyance resulting from traffic-related noise makes up most of the lost healthy life years[41]. The magnitude of the health effects of road traffic noise is most likely to be similar in Canada.

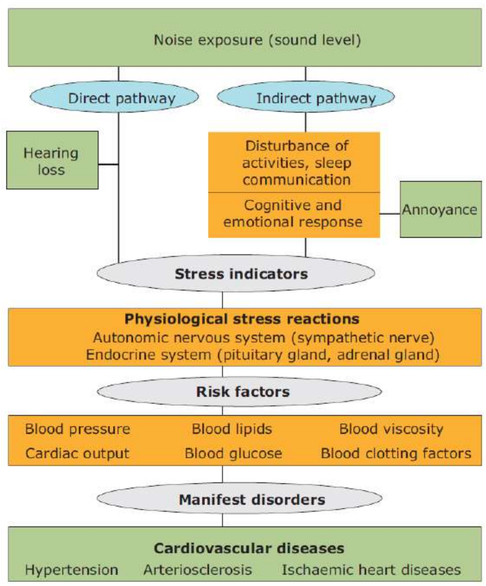


Figure 48 Effects of Noise Exposure

There is also a socio-economic cost aspect that must be considered when considering traffic-related noise levels. This would include some increase health-related costs due to long-term noise exposure and real-estate cost. In general, the quieter nature of electric vehicles has been appreciated by operators, in addition to the broader public affected at large. Aside from reductions in GHG emissions, potential benefits related to traffic-related noise should also be considered when purchasing alternative propulsion vehicles.

[41] https://www.volvobuses.com/en-wa/news/2019/sep/electric-buses-can-address-noise-pollution.html

10.2.3 PUBLIC PERCEPTION & SAFETY

Another important aspect to be considered when adopting alternative fueled propulsion systems is the public perception of the fuel/ technology and its associated infrastructure. Natural gas is a mature technology that has been present as a fuel for decades, however its public perception has been mixed. Safety of natural gas vehicles has been among the top concern from all stakeholders, including fleet managers and the general public. This is due to the perception that natural gas vehicles pose more explosive and combustion risks and are dangerous in accident situations[42].

However, there have been multiple safety tests around the world on natural gas vehicles and storage cylinders, which have demonstrated that the technology is as safe as gasoline/ diesel vehicles. Majority of incidents involving CNG failures and explosive accidents are due to improper installation and not due to the systems designs. Furthermore, in the event of a leakage, CNG fuel evaporates and disperses quickly into the surrounding environment, as opposed to diesel and gasoline fuel which tends to pool on the surface (Figure 49). In addition, CNG fuel has a higher ignition temperature compared to the other fuels, and a flammability rating of approximately 5% to 15% gas in air, reducing the risk of combustion if a leak occurs43.

Property	Natural Gas	Gasoline	Diesel
Physical State	Vapor	Liquid	Liquid
Ignition Temperature	1,080 °F	540 °F	410 °F
Density	22 Grams/Cubic Foot (Lighter Than Air)	2,800 Grams/Gallon (lighter than water)	3,200 Grams/Gallon (lighter than water)
Spill Behavior	Evaporates and Disperses	Pools on Surface	Pools on Surface
Storage Temperature	CNG: Ambient Temperature LNG: Below –200 °F	Ambient Temperature	Ambient Temperature
Strong Pressure	CNG: 3,000–3,600 psi LNG: Varies	Ambient Pressure	Ambient Pressure

Figure 49 Properties of Natural Gas Fuel Compared with Gasoline and Diesel

Despite the lingering safety concerns that may be present with regards to CNG fuel, the public also perceives these vehicles as more environmentally friendly and cost effective. The cleaner-burning nature of CNG has been presented well in public information campaigns by suppliers and vehicle manufacturers. CNG fuelled vehicles produce 80% less carbon monoxide then gasoline vehicles, reducing the chance of carbon monoxide poisoning. As such, CNG fueling is viewed as more favourable from a human health perspective.

Public perceptions towards safety of electric vehicles has been positive, and there haven't been many notable concerns regarding the operation of electric vehicles. Batteries are typically placed at the bottom of the vehicles, which provides a lower centre of gravity, and more design freedom for having less dangerous collisions (less chance of roll-over, more crumple space for dissipating kinetic energy safely, etc.)[44]. The greatest aspect of perception of electric vehicles is range anxiety, and potential battery performance issues due to calendar and cyclical ageing. However, these perceptions can be dispelled by the choice of a battery size of sufficient capacity to meet operational needs, and through pilot programs demonstrating the operational viability of these vehicles.

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[42] CNG & LNG Safety: Perceptions & Reality, Clean Fuels Consulting https://www.unece.org/fileadmin/DAM/energy/se/pp/geg/geg2_jan2015/ai9_4_Seisler.pdf

[43] https://www.cngunited.com/why-is-cng-better-than-other-fuels/

[44] https://cleantechnica.com/2018/04/01/do-electric-vehicles-have-better-overall-safety-part-2/

Recent research indicates potential safety concerns may exist with electric vehicles being too quiet. Advocacy groups have raised pedestrian safety concerns since EV motors quieter than internal combustion engines (ICEs) and do not emit the familiar warning sounds non-motorists rely on. This was found to have an impact on pedestrians, cyclists, and particularly people with a range of vision impairments who heavily rely on noise cues to navigate. A study conducted by the USDOT National Highway Traffic Safety Administration (NHTSA) in 2011 analyzed data back to 2000 and concluded that the odds of any hybrid electric vehicle being in a passenger crash was 22 percent greater than the odds of an ICE passenger vehicle.[45] The industry is adapting by adding back minimal noise and specific warning systems into electric vehicles to aid non-motorists.

Electric vehicles are generally viewed as green technology by the public due to zero tail pipe emissions, and majority of the municipalities and transit agencies that have adopted them have reported a positive sentiment from the public regarding them.

10.2.4 COMMERCIAL INDUSTRY IMPACT

Adoption of alternative fuel vehicles will necessitate not only a demand in the associated fuel and its infrastructure, but also an increase in the skills and knowledge required by the workforce. The demand for CNG that will be required, would support in growing the commercial natural gas industry in Ontario, which can be leveraged for any future projects. Further, the skills required in operating and maintaining these vehicles and facilities, would require the existing workforce to be retrained and supplemented by existing experts. Similarly, adoption of electric vehicles will necessitate an increase in the sophistication and capacity of the local electrical grids, which would be beneficial for ensuring grid reliability and pre-emptive planning of wider adoption of electric vehicles by the public.

The new skills and knowledge required by the mechanics will require some time to transition to new processes and requirements, however it would also position the staff to be prepared to handle these technologies in the future better, as well as increase their employment opportunities and strengthen their career position.

45 Incidence Rates of Pedestrian and Bicyclist Crashes by Hybrid Electric Passenger Vehicles: An Update (2011) - https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811526

11 DEPLOYMENT CONSIDERATIONS

11.1 TRAINING REQUIREMENTS

11.1.1 ELECTRIC VEHICLE TRAINING REQUIREMENTS

Maintenance training shall focus primarily on the electrical systems of the vehicle, as most non-electrical components are similar to those on a diesel or gasoline vehicle. While the amount of necessary training will depend on the particular vehicle and OEM, it should cover the basics of working with electric propulsion (traction motors), inverters and batteries. Training should include the required safety procedures for working with high voltage electrical components, correct usage of personal protective equipment (PPE) and specialized tools. Once a primary group of personnel have been trained, they can train additional mechanics and operators as needed.

Electric vehicles will introduce many changes in operations for the City of Barrie that does not currently have EV's in their operational fleet. As a result, new standard operating procedures around lock-out/lock-in procedure, removing batteries and other high voltage components along with putting a dedicated service line in place would need to be developed. Process flow maps of current processes would need to be developed by the City, highlighting the difference between electric vehicle processes vs. diesel or gasoline. Moreover, a similar standard operating procedures and training would need to be developed for charging/refuelling infrastructure at depots with respective OEMs.

In Canada, the voltage threshold of 30V mandates maintenance personnel to have a high voltage qualified training for working on electrical components and circuitry and for using specific PPE. For reference, several OEMs use different battery pack voltages such as the Tesla 400V DC battery and the Toyota Pirus 201.6V DC.

Furthermore, organizations such as the Society of Automotive Engineering (SAE) offer courses such as "High Voltage Vehicle Safety Systems and PPE" which is a one-day program focusing on the safety aspects of maintenance technicians working on electric and hybrid vehicles. It also covers electrical circuit design/diagnosis and isolation measures on DC and AC detection systems through high voltage controllers to mitigate the possibility of electrocution between a maintenance technician and the vehicle body/chassis.

Maintenance of electric vehicles can require specialized tools in order to service the more complex and high voltage electrical systems not present on diesel or gasoline vehicles. These systems included battery packs, inverters and electric motors (traction motors). Some specialized tools include:

- High impedance multi-meters, diagnostic cable equipment, electrical safety equipment, battery protection tools, insulated screwdrivers etc.
- Special tools for electric accessories, which will be based on the specific bus model and OEM

ASTM Labeling Chart
Natural Rubber Electrical Insulating Gloves

Class Color	Proof Test Voltage AC/DC	Max. Use Voltage AC/DC	Insulating Rubber Glove Label
00 Beige	2,500 / 10,000	500 / 750	10 ASTM D120 CLASS 00 MAX USE VOLT 500V AC EN60903 TYPE I
0 Red	5,000 / 20,000	1,000 / 1,500	10 ASTM D120 [illegible]
1 White	10,000 / 40,000	7,500 / 11,250	10 ASTM D120 CLASS 1 MAX USE VOLT 7500V AC EN60903 TYPE I
2 Yellow	20,000 / 50,000	17,000 / 25,500	10 ASTM D120 CLASS 2 MAX USE VOLT 17000V AC EN60903 TYPE I
3 Green	30,000 / 60,000	26,500 / 39,750	10 ASTM D120 [illegible]
4 Orange	40,000 / 70,000	36,000 / 54,000	10 ASTM D120 CLASS 4 MAX USE VOLT 36000V AC EN60903 TYPE I

Figure 50 ASTM Isolation Gloves According to Voltage Level

Furthermore, personal protective equipment (PPE) is a requirement for technicians working on electric vehicles. The American Society for Testing and Materials (ASTM) has published PPE usage specs for items such as the required insulated glove class for safe use according to voltage level.

Some of the common maintenance tools needed to service electric vehicles are given further description below:

High Impedance Multimeter: Used to measure the voltage and current across two points in an electrical circuit. Impedance is the amount of electrical resistance in the tool which governs the voltage limit in the circuit it can be applied to. Voltage/Multimeters are used to help troubleshoot electrical circuits and identify the power supply has been safely disconnected for further work. Most high impedance multimeters now have an electrical resistance greater than 1 megaohm (MΩ) and can cost upwards of $1,300.

Static-Free Tools: Electrostatic discharge (ESD) safe tools are required to safely dissipate the static electricity charge that people can build-up naturally and then can be released through touching a conductive material (ex. metallic vehicle frame). This discharge can also damage electrical circuits such as when working on sensitive components in a computer. Static-free tools are made from non-conductive materials or have protective coatings which mitigate this electrical discharge. Furthermore, anti-static wrist straps and floor mats can also be used as part of PPE for safety working on electrical components.

Specialized Electric Vehicle Tools: Any OEM specific tools required to service and maintain the electric vehicles (ex. for the traction motor or battery pack installation/removal) can be specified and included as part of the procurement process.

In addition to these instruments, there are several standards development organizations (SDOs) that are working to develop the required codes and standards as this technology becomes more widely adopted. These organizations include:

- Institute of Electrical and Electronics Engineers, Inc.;
- National Fire Protection Agency;
- Society of Automotive Engineers (specifically SAE J1772);
- Underwriters Laboratory;
- International Code Council; and
- CSA Group.

With regards to training requirements, OEMs typically provide training to their clients as part of the vehicle purchase price or pilot program along with including all related operating and maintenance manuals. Training requirements can be specified in the procurement process and contract negotiations. If additional training is necessary, it can be provided through a third-party institution.

Lastly, training should be provided for emergency responders and utility workers such that in the event of a collision involving an electric fleet these personnel are aware of the potential high voltage and chemical hazards. They should have mitigation strategies and a safe response procedure in place. OEMs have been working with the National Fire Protection Association (NFPA) to provide safety plans on how to respond to incidents involving their trucks. Schematics show the location of high voltage cables and how to disconnect the power supply. It is recommended to request a detailed safety response plan in the procurement package of refuse trucks for the fleet or for initiating a pilot program.

11.1.2 CNG VEHICLES TRAINING AND SAFETY

Although there is a large degree of part commonality with a diesel vehicle, some specialized tools are required for the servicing and maintenance of a CNG vehicle. These tools are primarily related to the pressurized fuel system and CNG tanks. Some specialized tools include:

- Gas leak detector worn by maintenance workers to monitor any gas leakage that could become a safety concern to workers and potential fire hazard.
- Tools for the removal and inspection of CNG tanks (gas extractor, torque wrenches and tensioner straps).

Figure 51 shows some of these tools (clockwise from top left: gas detector, gas injector/extractor, and torque wrench).

Figure 51 CNG Special Tools

Training should focus on the safe handling of pressurized gas tanks and inspection as well as monitoring safe level of gas exposure with proper detection equipment. Furthermore, workers should be aware and service CNG vehicles in a facility equipped with proper ventilation and meeting applicable codes and standards.

In addition, emergency responders should have familiarity training with CNG so that they are aware of the potential hazards and have a mitigation plan in the event of responding to an incident involving a CNG bus or vehicle.

CNG is becoming a widely adopted fuel alternative in transportation. As such there are several institutions with specific training programs for maintenance workers. This includes The National Institute for Automotive Service Excellence (ASE) Certification for Light/Medium Duty CNG training program available in Canada. ASE tests can cost anywhere from $36 to $129, and the cost of training will depend on the level of skill of the participant being tested. CNG engine OEMs offer other programs as well, much like the Cummins Natural Gas Academy. Those interested in the Cummins Natural Gas Academy are encouraged to contact their local Cummins distributor for more detail, including pricing information.

11.2 FUTURE TRENDS

The industry is seeing rapid expansion of commercial electric vehicle deployments and with that comes innovation and constant technology development, some future trends are discussed below.

VEHICLE INNOVATIONS

A lot of research and development is undertaken to develop the next generation of lithium-ion battery technology and related materials. According to Bloomberg New Energy Finance, the average global cost for lithium-ion batteries in 2018 was about $175 per kWh and is expected to reach $62 per kWh by 2030 [46]. In addition, automotive lithium-ion battery energy density (kWh/kg) is expected to improve by 25-35% by 2030 [47] depending on the chemistry. This will possibly improve both the battery electric bus market and the hydrogen fuel cell bus market, which also uses smaller sized batteries to propel its electric motor(s). Increased vehicle range comes with simplified operations planning as the light duty vehicles will require less frequent charging. Some estimations show that by the year 2025, most electric vehicles and hybrid cars will account for almost 30% of cars on sale.

With this new market sector, another key innovation often cited lists autonomous and connected driving that usually comes with electric vehicles. Autonomous driving is characterized by different levels:

- SAE level 0: no automation
- SAE level 1: driver assistance
- SAE level 2: partial driving automation

[46] https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/
[47] https://www.woodmac.com/press-releases/global-battery-electric-vehicle-sales-to-surge-in-2020s/#:~:text=According%20to%20Wood%20Mackenzie%2C%20the,state%20and%20lithium%2Dsulphur%20batteries.

- SAE level 3: conditional automation
- SAE level 4 and 5: high to full driving automation.

Vehicles capable of SAE Levels 1 and 2 autonomies represent the two largest area of autonomous growth which receive a lot of attention. It is expected that vehicles with some degree of automation will represent 50% of all vehicles produced by 2024[48]. Hence, should the City of Barrie decide to start its transition past 2025, it is likely that the vehicles purchased will have some level of automation.

There is also innovation occurring for vehicle performance data (telematics) tracking. It is possible to install on-board data loggers on the vehicles once they are procured to more accurately track their utilization and as such, their efficiency and emissions. The data can be collected in real-time and accessed by fleet managers, who will then be able to adapt their plans and operations according to the data gathered. Natural Resources Canada (NRCan) received resources to support the installation of data loggers in fleets and could support the City of Barrie with the funding and installation of these loggers [49].

Another innovation to note is the option of retrofiting existing heavy-duty powertrains to CNG or electric powertrains. Companies such as XL Fleet specializes in these types of retrofit that can support emission reduction and increased efficiency. Another option is to install an electrical Power Take-Off (PTO) shaft such as the ones provided by Effency to eliminate the need to run engines when trucks are stationary. This could be an interesting solution to implement for Barrie's vehicles that report high idling time, which could save fuel and reduce emissions.

CHARGING SYSTEMS INNOVATIONS

Another key trend in the industry is the development of turnkey and integrated charging solutions that provide a plug-and-play equipment for fleet electrification. Examples of such suppliers in Canada include Hitachi, Siemens and Proterra. A recent technology development introduced by Hitachi called "Grid-eMotion Fleet" provides a scalable AC/DC rectification from a single unit to supply chargers between 50 to 600 kW[50]. This solution will reduce space requirements and cabling, result in shorter delivery time, and integrate with SCADA and other energy management systems. Similarly, ABB developed its EcoFlex product line which is an enclosure enabling EV charging shown in Figure 52 and can provide an output power of up to 4000 kVA. These systems, which look similar to a standard shipping container, are scalable and enable space savings[51]. These technologies have been introduced to the market in 2020 and 2017 respectively, and as a result are new in their deployment North American manufacturers are developing charging solutions that are both easy to integrate and scalable with a limited footprint in mind.

If the City follows the plan outlined in this report, by 2039 there will be 117 electric vehicles operating from the four different faculties. This increases complexity as their charging requirements are different than typical fueling requirements and increases the level of planning required. One way to streamline this process is to install a cloud-based system with which the fleet manager can access real-life data from the vehicles and supporting infrastructure, an example of such a system is show in Figure 53. These types of application monitor charging activity and can send alerts in case of failure of either a vehicle or a charging system.

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48 ttps://www.idc.com/getdoc.jsp?containerId=prUS46887020#:~:text=According%20to%20a%20new%20forecast,(CAGR)%20of%2011.5%25.

49 https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/transportation/NRCan_GreeningGovFleets_e.pdf

50 https://www.hitachiabb-powergrids.com/ca/en/offering/product-and-system/substations/railway-and-urban-transport-electrification/grid-emotion-charging-solutions-for-e-mobility/grid-emotion-fleet

51 https://www.proterra.com/wp-content/uploads/2020/10/SPEC_CHG-SYS_1.5M_V8_10.26.20.pdf

Figure 52 ABB's EcoFlex eHouse [52]

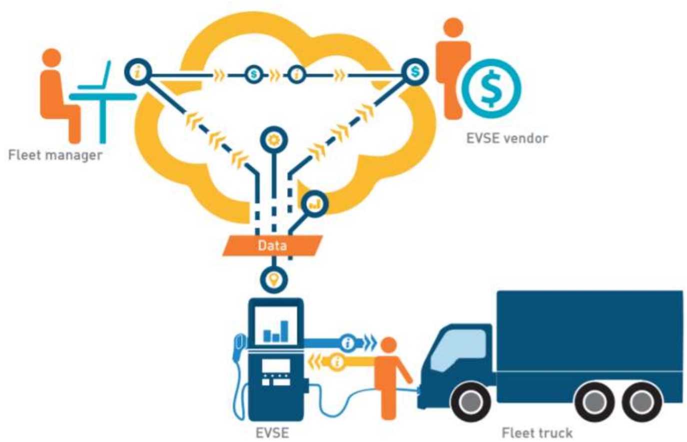

Figure 53 Illustration of a Cloud-Based Connected System to Access Data in Real-Time (from PGE[53])

MICRO-GRID AND ENERGY STORAGE

Another trend observed in the industry is the notion of micro-grid or "vehicle-to-grid" capabilities for electric vehicle systems. In fact, fleet operators introduce new load that the electrical grid must accommodate. As a result, costly electrical upgrades may be required to provide the required peak load to each facility.

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[52] https://search.abb.com/library/Download.aspx?DocumentID=1VPD110001A0461&LanguageCode=en&DocumentPartId=&Action=Launch
[53] https://www.pge.com/pge_global/common/pdfs/solar-and-vehicles/your-options/clean-vehicles/charging-stations/ev-fleet-program/PGE_EV-Fleet-Guidebook.pdf

Therefore, an opportunity exists for the end-users to become active consumers of energy to limit their dependence on local grids. Solutions such as installing an Energy Storage Systems (ESS) in the form of batteries and the adding solar photovoltaic (PV) arrays both help mitigate peak demand and increase resilience. Figure 54 illustrates different elements of a micro-grid that can be applied to a facility implementing battery electric vehicles to increase resilience.

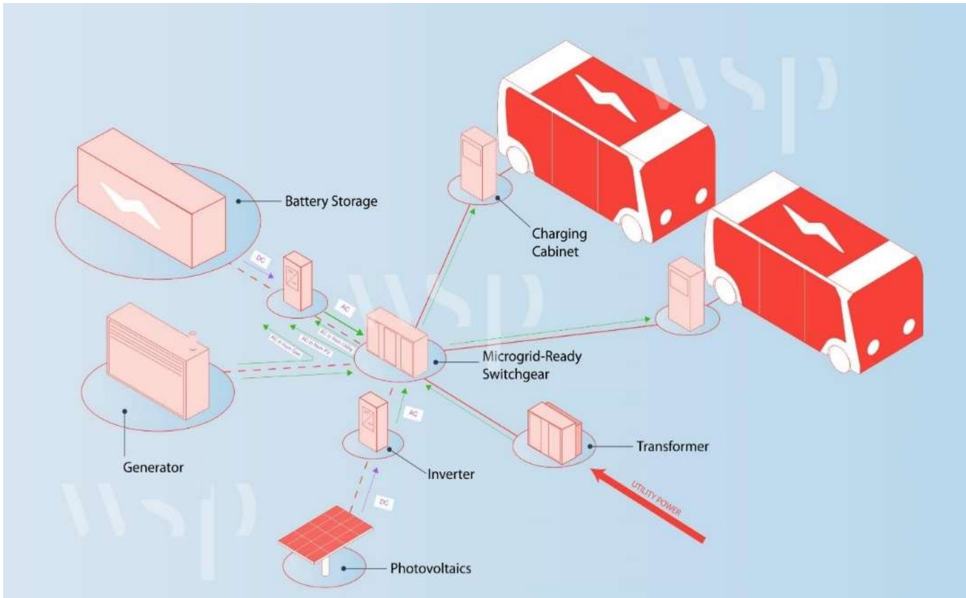

Figure 54 Illustration of a Local Micro-Grid System to Power an eBus Fleet

MANUFACTURING CAPACITY, SUPPLY CHAINS AND TRAINING

Ontario has a strong vehicle supply chain that fosters 100,000+ jobs across the province. It is the only province in Canada that builds cars and trucks. Québec for instance is more specialized in raw material and parts/tier 2 manufacturing than building the vehicles. Additionally, there are 24 colleges in Ontario that offer auto-related research initiative and training programs[54].

As a result, companies including Toyota, Honda, GM, Ford and Fiat invest heavily in the province and the manufacturing capacity of alternative propulsion systems is getting stronger over time. In October 2020, the provincial and federal government announced their commitment to Ford Motor Company of Canada's investment in its Oakville Assembly complex, which include a repurposed battery-electric vehicle production plant[55]. Recycling or repurposing batteries once they reach their end-of-life is a critical innovation in the industry as batteries in electric vehicles age with their utilisation.

That said, availability of EVs is limited in most of Canada's car dealerships and supply is inadequate to meet demand. A recent study commissioned by Transport Canada showed that only 1 in 3 Canadian car dealers had one electric vehicle in stock, and 60% of dealerships surveyed had a three to six months wait time for buying an electric car [56]. This issue should be taken into account by the City of Barrie and planned for early on in the process of procuring these new vehicles. Though it is likely that the production of electric vehicles in Canada will continue to increase with time, it is also important to regularly check with local dealership to understand wait times to remain within the proposed transition schedule.

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54 https://files.ontario.ca/auto-strategy-en.pdf
55 https://www.newswire.ca/news-releases/new-commitment-to-battery-electric-vehicle-manufacturing-in-ontario-833966689.html
56 https://electricautonomy.ca/2020/09/10/plug-in-electric-vehicle-supply-canada/

11.3 CONSIDERATIONS FOR FUTURE PARTNERSHIPS

UTILITY AND TURKNEY SOLUTIONS PARTNERSHIPS

The City of Barrie can look for potential partnerships with utilities that have a proven record of operating and maintaining complex electrical infrastructure assets (i.e. fueling stations and electrical equipment).

One recent example of this type of partnership is from the TTC's fleet electrification program. In October 2020, the TTC announced they have been working in partnership with Toronto Hydro and Ontario Power Generation (OPG). In this agreement Toronto Hydro would deliver increased electrical service capacity to each of the TTC bus garages and OPG will design, build, operate and maintain (DBOM) all on-site electrical charging infrastructure. These include services for 8 garages (2,000 buses), 10 MW+ of power demand per site, integration of battery storage and power generation and $500 million investment in electrical infrastructure.

The City of Barrie could to explore a similar arrangement with OPG and/or Alectra for the addition of its electrical infrastructure.

Partnerships with Enbridge will also be beneficial, especially regarding options for renewable natural gas supply. In 2020, Enbridge announced a partnership with Walker Industries and Comcor Environmental to build Ontario's largest RNG plant in Niagara Falls – a $42 million project[57]. Though the supply from this plant will be limited, Enbridge might consider the option of supplying RNG to the City of Barrie as a customer. Despite this advancement, it should be noted that RNG supply is limited in the province and that there currently is not a clear path forward yet on how to scale up RNG production in the medium to long term.

The City of Barrie is uniquely situated on Highway 400, a major corridor to Northern Ontario, and therefore could benefit from a joint venture with a gaseous fuel refuelling partner, where the installation of a public refuelling station adjacent to one of the highway exits would allow for the City's fleet of vehicles, along with other private and commercial vehicles to fuel at a public refuelling station. A variety of gaseous fuels including Compressed Natural Gas (CNG), Renewable Natural Gas (RNG), Liquified Natural Gas (LNG), Hydrogen and Renewable Hydrogen are possible solutions that would support internal combustion engine vehicles.

Gaseous fuels refuelling stations are capital intensive and a joint venture with a gaseous fuel refuelling partner such as Enbridge, would allow the City to benefit from a centrally located refuelling station without having to fund the initial capital cost of a station. The refuelling partner would benefit from an anchor client to help justify the installation of the station, while traffic from other private and commercial fleets grows over time as our society transitions to alternative fuels.

The reference the map below illustrates the City of Barrie's four Corporate fleet facilities and their proximity to a possible gaseous fuel refuelling station located central to the facilities and in close proximity to Highway 400. The Transit garage is also shown for context.

[57] https://www.enbridge.com/stories/2020/october/enbridge-and-partners-break-ground-ontarios-largest-rng-plant

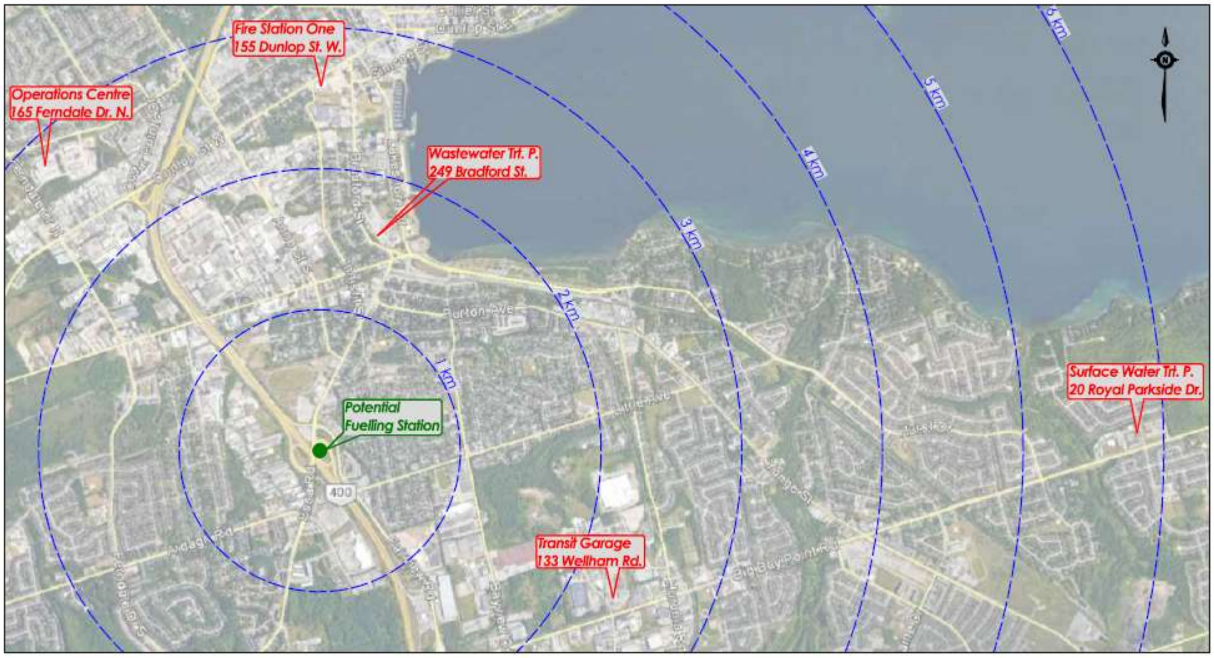


Figure 55 Potential Locations for Joint Refueling Stations

In additions to utilities, other private companies can support the City as they specialise in the installation of turnkey EV charging solutions to deploy customized EV charging programs. They also specialize in the development of energy management software to minimize electrical bills and reduce the need for additional infrastructure upgrades to the sites.

AGENCIES & ASSOCIATIONS

Networking with peer transit municipalities and industry associations such as Electric Mobility Canada (EMC) can be valuable to discuss lessons learned from deployments of alternative fleet technology and infrastructure projects.

There are multiple municipalities that have been piloting alternative fuels or that completed studies such as this one that Barrie could learn from. As an example, the City of Abbotsford has one facility that supports the entire fleet of light, medium and heavy-duty vehicles. The City is focusing on prioritizing electric and using renewable fuels wherever electric cannot meet the needs or is too expensive to consider. Tandem Trucks and other heavy-duty equipment cannot be converted to electric yet, so they will be switched to renewable fuel. For Police patrol vehicles, Ford Escape Hybrids were purchased and are being monitored for success rate.

In the City of Abbotsford's opinion, electric vehicle costs less to operate and maintain and do not have adverse environmental impact. The charging infrastructure is easy to setup and the electric cars in the fleet have had very little maintenance requirements. However, the main issue with electric is range. In addition, the City of Abbotsford is concerned about electrified heavy-duty fleet availability: thus, renewable diesel is being used in the transition instead.

LOCAL CAR DEALERSHIPS AND PUBLIC CHARGING STATIONS

The City of Barrie has 109 public charging stations, 70% of the ports are Level 2 charging and 60% of the ports offer free charges for electric vehicles. The City may assess the option of prioritizing charging for its own Corporate fleets using the public charging station, instead of solely relying on facility recharge.

In addition, there are a few vehicle dealerships in Barrie which could become direct providers of alternative technology. It is recommended that the City approaches these local dealerships to discuss long-term partnerships, as working with them directly would promote local economy.

LOCAL COLLEGES AND TRAINING CENTRES

The City should consider approaching local colleges and training Centres in Ontario, as maintaining alternative fuel technology requires new sets of skills and training. CNG is an explosive gas, and batteries operate at high voltage. The CNG and EV powertrains are sources of hazard if not handled properly. Colleges are also noticing the trend towards electrification and starting to develop tailored training programs for the next generation of mechanics, but also for experienced mechanics who need to learn how to operate the new technology.

Georgian College, Barrie's local college, offers many training and apprenticeship programs. Though none of the programs are currently specifically designed for battery electric vehicles repairs, they offer apprenticeship programs for electricians, machinists and a program in automotive product designs. It might be worth engaging with them to discuss the possibility of designing programs that will teach critical skills in support of Barrie's fleet transition.

12 RECOMMENDATIONS AND CONCLUSIONS

The key findings of this report have helped bring into focus that transitioning light duty vehicles to electric and medium duty vehicles to CNG is feasible for the City of Barrie from a technical standpoint.

The Operations Centre would be the key facility to host the alternative vehicles. A CNG refueling station would serve the CNG vehicles operating from the nearby facilities as well. Since most of the repair and maintenance is done at the Operations Centre, it would be necessary to upgrade the maintenance area to meet CSA's codes to maintain CNG vehicles. This CNG station alone would be able to support the CNG vehicles up to 2041, but it also means that operators would need to drive the vehicles all the way to the Operations Centre for refueling; increasing the mileage of the vehicles. To facilitate the operations of the CNG fleet, Barrie could consider partnering with other private or public entities on a joint venture to create a public refueling station adjacent to one of the highway exits.

Electric vehicles offer more flexibility as they use electricity as a source of energy and hence can be charged at any facility provided sufficient upgrades. Based on the analysis conducted in this report it was calculated that the Operations Centre would need an increased capacity of 611 kW to operate its chargers, while the other facilities have enough electrical supply on-site to support the EV adoption. The sizing requirement of the electrical infrastructure, such as additional transformers, was provided in detail in Section 4.

Overall, it is recommended that the City of Barrie follows a phased approach to electrify its fleet at the Operations Centre. At the remaining facilities, the infrastructure could be installed all at once given the size of the upgrades.

Comparing the cost of this implementation scenario with the BAU, it was found that adopting the newer technology would results in additional 6-7% total cost over the course of 20 years. At the end of the 20-year period, the alternative fleet would decrease maintenance cost between 3-30% and 7-34% for fuel costs depending on the facility. As a result, transitioning to an alternative fuel following the results of Scenario 3 does not lead to significant cost increases based on the assumptions cited in Section 5.1.1.

From an environmental perspective, the adopting of alternative fuel could reduce emissions by 13% over the next 20 years compared to BAU. At the end of the 20 years, once the alternative vehicles are in operations, emissions would be reduced by 26% compared to 2021's levels.

Though this potential emissions reduction is encouraging, it likely is not sufficient to meet Canada's mandate is to achieve carbon neutrality, or "net zero" by 2050. That said, the heavy-duty electric vehicle technology is ever-evolving, and new vehicle models are released each year. As the technology matures, it is fair to assume that an increasing number of manufacturers would propose electric vehicle models as part of their catalogues. This study was completed by analysing the technology available today, and as a result the 26% emissions reduction is a base case that is likely to improve as the alternative fuel market matures. An emerging trend is the aftermarket modification to create a plug-in hybrid heavy duty vehicles. Depending on the use case, and in situations where there is currently a lot of idling, savings of 30% of emissions have been recognized with a return on investment of 5-7 years.

As a result, this study should be treated as a starting point to prepare the required infrastructure before alternative vehicles are procured in 2025. It is recommended that this plan and study be revisited in 3 years before the first vehicle is procured, when more heavy-duty models are available in the market and have a proven efficiency record.

APPENDIX

A RISK REGISTER

City of Barrie - Alternative Fuels Study - Operations Fleet Risk Register

Date: November 18, 2020

Participants:

		1	2	3	4	5
Rating Guide						
		Very Low	Low	Medium	High	Very High
Probability		1%-15%	16%-30%	31%-65%	66%-80%	81%-100%
Cost Impact		Less than 1% increase	2% to 10% increase	11% to 25% increase	26% to 50% increase	Greater than 50% increase
Schedule Impact		Insignificant slippage	<1 month slippage	1-3 months slippage	3-6 months slippage	>6 months slippage
Quality		No impact	Partial/ small impact on requirements	Deviation from requirements, mostly	Deviation from requirements,	Can't meet requirements

Risk Register - General Risks

No.	Risk	Description	Mitigation Method	Applicability		Risk Assessment		
				Operations	Risk Owner	Risk Probability Rating	Risk Impact Rating	Comments
1.0	Technical Specifications	Due to failure to obtain input from users in spec development, there is a risk of reduced asset quality which could lead to cost overruns and level of service impacts.	Prepare a detailed plan for having important stakeholders and user engagement and buy in early in the procurement and specifications development cycle	Y	Ops -Fleet Supervisor	3 - Moderate	4 - High	- Confidence in EVs limited, and not sure about technology maturity - Lack of knowledge of technologies, limits the buy in towards spec developments from users - Spec requirements to meet address variable weather issues
2.0	Technical Specifications	Due to delays in preparing tender documentation, there is a risk of reduced asset performance which could impact level of service	This risk can be mitigated by ensuring that sufficient technical information is gathered before tender process starting, which can then be fed into the specifications and ensure limited delays in timeline	Y	Ops -Fleet Supervisor	3 - Moderate	3 - Moderate	- Procurement process likely to take longer due to new tech, probability likely higher, impact low as continuity of business will be managed through pilots or limited initial adoption of vehicles (could be mitigated) - No firm deadlines at the moment from Transit side, so limited impact - Risk of Metrolinx TPI causing delays to the tender documentation - Ops: getting the proper info in specifications
3.0	Technology Evolution	Due to technological advancement there is the risk that new/unproven technology could result in additional in-service vehicle failures and/or the need for vehicle recalls thereby increasing maintenance/operational costs.	Procure from vehicle OEMs with reputable operations and the ability to support new technology repairs. Pilot new technology in phases, gradually expanding viable technology into the fleet.	Y	Ops -Fleet Supervisor	4 - High	4 - High	
4.0	Legislation/Politics	Due to evolving legislative requirements and new demands from various user groups pushing early adoption, there is a risk of adopting not sufficiently matured technology, which would reduced asset quality leading to cost overruns and level of service impacts.	Ensure adequate time for adoption of new technologies and consider pilots to gather data prior to larger adoption.	Y	Ops -Fleet Supervisor	3 - Moderate	3 - Moderate	- Require adequate funding and time for moving to new technology and adopting
5.0	Funding/Regulatory Risk	Local provincial and/or federal government mandate can change favourability towards adoption of new vehicle/propulsion technology. This can impact funding programs, regulations, infrastructure changes and the overall viability of a new technology	Engage with local political representatives to communicate the benefits/drawbacks of new vehicle/technology options and how this aligns with the Barrie's objectives.	Y	Ops -Fleet Supervisor	3 - Moderate	4 - High	- Likely mandate from government for support of new technology, likely high impact for funding from higher level government (federal), business case/ viability of purchasing relies on funding heavily
6.0	Vehicle Production QA	Due to inadequate QA of asset on production line, there is a risk of reduced asset quality which could lead to cost overruns and level of service impacts	Have QA checks of vehicles delivered to operations fleet, and monitor performance of new assets by OEMs as they are slowly integrated in to the traditional fleet.	Y	Ops -Fleet Supervisor	3 - Moderate	3 - Moderate	- Operations, likely variance in terms of QA of difference types of vehicles, example of NG garbage trucks not having sufficient power for delivery, not meeting quality requirements - Probability lower due to qualified QA staff that should be able to adopt, however due to mass purchase of TAs can QA inspection can suffer if many orders placed
7.0a	Resistance to Change (Ops)	Experienced fleet maintenance staff are reluctant to change in order to service new propulsion types/technology. This change would require attending additional training and certifications.	Engage all stakeholders including fleet maintenance staff throughout the process of considering new fleet technology/propulsion types. Encourage productive dialogue to consider all stakeholder perspectives. Incentivise attendance to new training and certification programs.	Y	Ops -Fleet Supervisor	2 - Low	2 - Low	- Operations, likely low probability as staff is good at embracing new technologies
8.0	Diagnosis of Maintenance Needs	Due to lack of historic data, mechanic is unable to properly use historical diagnostic to make decision to go forward.	Connect with peer agencies and industry organizations to gain insight into any maintenance issues that arise	Y	Ops -Fleet Supervisor	3 - Moderate	4 - High	- Lack of senior knowledge on maintenance will have large - Connect with other peers to share solutions to maintenance problem - Updated risk
9.0	Supply Chain Part Lead Times	Due to uniqueness of propulsion technology and limited vendors long lead times for replacement components can occur. This can result in higher costs and schedule delays.	Conduct an assessment of expected lead times of critical components and parts for each technology adopted in consultation with OEMs	Y	Ops -Fleet Supervisor	4 - High	4 - High	
10.0	Disposal Cost	New technology could incur additional and unforeseen disposal costs for components	**Mitigation Method TBD**	Y	Ops -Fleet Supervisor	3 - Moderate	2 - Low	- Best practice for disposing? - Recycling programs for batteries and other electrical components, fuel cell recycling?
11.0	Salvage Value	Due to ineffective cannibalizing of the asset, there is a risk that asset components could be undervalued thereby impacting the revenue that could be generated on the salvage value	Risk is avoided as no cannibalizing of assets occur, utilize direct auction system	Y	Ops -Fleet Supervisor	2 - Low	2 - Low	- Operations auctions vehicles with no cannibalizing - No more cannibalizing for transit end of life

12a	Premature Failure (Operations)	Due to the technological maturity level (i.e. lack of demonstrated complete lifecycle operations) there is a risk of premature failure of the asset or unfavorable economics that cause early retirement/disposal thereby impacting capital costs and service availability of the fleet	**Mitigation Method TBD**	Y	**Ops -Fleet Supervisor**	**3 - Moderate**	**4 - High**	- Lot of different vehicle lifecycles and consequently higher probability, high impact on business case if vehicles can't make full lifecycle, lots of new vehicles types in development with variance in expected life
13.0	Utility/ Stakeholders	If the city opts to have offsite fuelling/ charging stations for their operations fleet which is shared with the public (thereby offsetting capital investment costs), coordination will be required to for land use and for ensuring availability	Establish engagement with Utility and stakeholders early and ensure that a process is put in place to ensure availability of fuelling stations/ chargers prioritizing City vehicles	Y	**Ops -Fleet Supervisor**	**2 - Low**	**3 - Moderate**	-Not applicable for electrical for transit - Fuelling on site for transit most likely, NG and Hydrogen limited opportunity for shared fuelling/charging - Operations, not likely to share charging infrastructure
14a	Indoor Storage Capacity (Operations)	The City currently parks vehicles indoors, if charging stations/ fuelling stations are installed, there is a risk that occupied floor space could reduce indoor storage capacity especially for winter operation vehicles.	Risk is avoided as fuelling and charging will be outdoors	Y	**Ops -Fleet Supervisor**	**2 - Low**	**2 - Low**	- Operations, fuelling and charging will be outdoors and not impact
15.0	Facility/ Site retrofits	Due to changing legislative/ regulatory requirements and technological changes of fuelling and maintenance equipment, the site locations will require continuous retrofitting and modifications	Create an assessment of expected facility retrofits and changes required for short, medium and long term time horizons of alternative fuel adoption	Y	**Ops -Fleet Supervisor**	**3 - Moderate**	**3 - Moderate**	

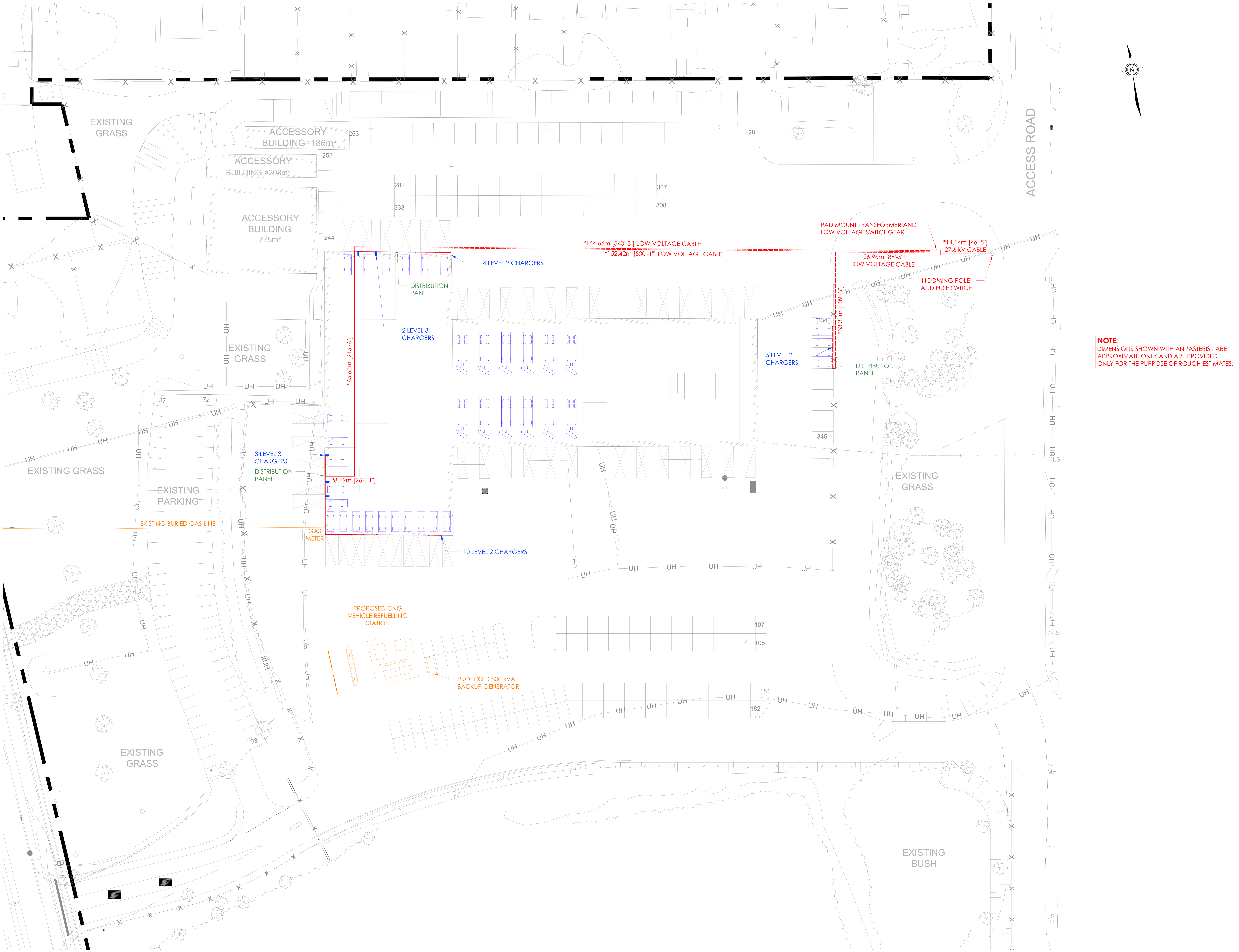
Risk Register - Technology Specific						Risk Probability Rating			Risk Impact Rating			
No.	Risk	Description	Mitigation Method	Applicability		Hydrogen	Battery Electric	Natural Gas	Hydrogen	Battery Electric	Natural Gas	Comments
Lifecycle Category: Procurement				Operations	Risk Owner							
1.0	Technical Specifications	Due to incorrect specification, there is a risk of reduced asset quality which could lead to cost overruns and level of service impacts	Have multiple specifications preparation cycles, try to acquire buy in from other peer agency/ expert experience with vehicle specification, leverage shared procurement initiatives such as Metrolinx TPI as applicable	Y	**Ops - Fleet Supervisor**	4 - High	3 - Moderate	2 - Low	4 - High	3 - Moderate	2 - Low	
2.0	Technology Evolution	Vehicle technology is rapidly evolves thereby rendering previous vehicle models less efficient or less cost effective	Phase in new vehicles in order to capitalize on technology improvements and implement a staged procurement cycle.	Y	**Ops - Fleet Supervisor**	3 - Moderate	3 - Moderate	3 - Moderate	3 - Moderate	3 - Moderate	2 - Low	
3.0	Marketplace Competitiveness	Due to a lack of OEMs offering similar vehicle/propulsion types this could result in a lack of competitive bids or purchase prices available for vehicles	Procure vehicle/propulsion types with several reputable OEMs having similar offerings.	Y	**Ops - Fleet Supervisor**	3 - Moderate	3 - Moderate	3 - Moderate	3 - Moderate	3 - Moderate	2 - Low	
4.0	Infrastructure Needs	Infrastructure needed to support vehicle operation is not currently available or has limited availability. This can include fueling stations, specialized servicing equipment for maintenance, etc.	Conduct infrastructure planning and select vehicle propulsion technology compatible with long-term viability and the broader direction of the industry.	Y	**Ops - Fleet Supervisor**	4 - High	2 - Low	2 - Low	3 - Moderate	2 - Low	2 - Low	
Lifecycle Category: Operations												
5.0	Operating Range	Vehicle technology is insufficient to meet the service demand on daily travel/usage due to range limitations; can be due to operational requirements, weather events (snow and extreme cold)	Leverage peer experience with vehicle technologies to shape performance expectations. Procure vehicles with range limitations by incorporating a safety level on range expectations. Consider a pilot program before large scale implementation of technology.	Y	**Ops - Fleet Supervisor**	4 - High	3 - Moderate	2 - Low	3 - Moderate	3 - Moderate	2 - Low	
6.0	Fuel Supply	The fuel source needed for vehicle operations is not currently available or has limited supply thereby running the risk of fuel shortages and/or volatile fuel prices	Select propulsion technologies compatible with local energy production and fuel sources. Engage in long-term fuel/power purchase agreements if necessary to mitigate price volatility.	Y	**Ops - Fleet Supervisor**	4 - High	2 - Low	2 - Low	3 - Moderate	2 - Low	2 - Low	
7.0	Vehicle Operations/Drivers	Due to improper operation of the asset or human error, there is a risk of unreliable asset performance which could impact level of service	Plan driver education and training program to minimize occurrence of human errors, and to maximize benefits of asset operations.	Y	**Ops - Fleet Supervisor**	3 - Moderate	3 - Moderate	3 - Moderate	3 - Moderate	3 - Moderate	4 - High	
8.0	Vehicle Operations/Drivers	Drivers are opposed to the new technology and initiate requests to change vehicle allocation, thereby disrupting service and schedule	Engage all stakeholders including operators/drivers to acquire feedback during the decision making stage to incorporate new vehicles/technology, get stakeholder buy-in. Provide education on the benefits/drawbacks of new vehicle/technology options.	Y	**Ops - Fleet Supervisor**	4 - High	2 - Low	2 - Low	3 - Moderate	2 - Low	2 - Low	
9.0	Public/User Perception	The general public/users reject new vehicles/propulsion technology on the basis of quality, safety, price, environmental perspective.	Engage all stakeholders including the general public to acquire feedback during the decision making stage to incorporate new vehicles/technology. Provide education on the benefits/drawbacks of new vehicle/technology options.	Y	**Ops - Fleet Supervisor**	3 - Moderate	2 - Low	2 - Low	3 - Moderate	2 - Low	2 - Low	
10.0	Infrastructure Needs	Due to the reliance on supporting infrastructure for fleet operations (i.e. fuel/charging stations) infrastructure repair needs or poor reliability consequently impact fleet operations	**Mitigation Method TBD**	Y	**Ops - Fleet Supervisor**							
Lifecycle Category: Maintenance												
11.0	Specialized Skills/Knowledge Gap	Current fleet maintenance staff would have a knowledge gap required to properly maintain new technology.	Incentivise and arrange for attendance to new training and certification programs. Partner with local colleges and institutes to encourage/recruit new graduates for mechanics/tradesperson positions.	Y	**Ops - Fleet Supervisor**	4 - High	4 - High	4 - High	3 - Moderate	4 - High	3 - Moderate	- Senior mechanics will have lower knowledge of newer tech, staff will need to know for multiple technologies simultaneously
12.0	Supply Chain Part Lead Times/Obsolescence	Due to uniqueness of propulsion technology and limited vendors long lead times for replacement components can occur. In some cases technological obsolescence can limit the availability of replacement components or result in high cost.	Procure vehicle/propulsion types with several reputable OEMs having similar offerings. Establish minimum terms of ensured spare part supply in the procurement contract.	Y	**Ops - Fleet Supervisor**	3 - Moderate	3 - Moderate	3 - Moderate	3 - Moderate	3 - Moderate	3 - Moderate	Typically manufacturers will stock parts for ten years
13.0	Asset Availability	Due to disruption in asset availability, there is a risk of causing bottlenecks to other business operations which could lead to cost overruns and level of service impacts.	Determine period of high asset utilization, and ensure that all required maintenance checks are planned to be conducted in advance, along with ensuring proper spare parts supply is present in inventory	Y	**Ops - Fleet Supervisor**	3 - Moderate	3 - Moderate	4 - High	3 - Moderate	3 - Moderate	4 - High	Heavy equipment with CNG could be affected due to parts issues during a snow event
14.0	Tooling & Equipment Availability	Due to unavailability of required equipment and tools, there is a risk of unreliable asset performance which could impact level of service	Ensure that there is a budget request for acquiring new tools and equipment, conduct scan of required additional specialized tools required prior to adoption of technologies.	Y	**Ops - Fleet Supervisor**	3 - Moderate	3 - Moderate	3 - Moderate	3 - Moderate	3 - Moderate	3 - Moderate	Budget request for new fuel or electric vehicles will include training and equipment
Category: Overhaul												

Risk Register - Technology Specific						Risk Probability Rating			Risk Impact Rating			
No.	Risk	Description	Mitigation Method	Applicability		Hydrogen	Battery Electric	Natural Gas	Hydrogen	Battery Electric	Natural Gas	Comments
15.0	Overhaul Program Cost	Due to the technological maturity level there is a lack of reliable benchmarks on fleet overhaul needs, best practices and associated costs	Ensure proper technician training is conducted to mitigate risk	Y	**Ops - Fleet Supervisor**	**3 - Moderate**	**3 - Moderate**	**3 - Moderate**	**3 - Moderate**	**3 - Moderate**	**3 - Moderate**	Proper training should mitigate most of the issues
16.0	Tooling & Equipment Availability	Due to unavailability of required equipment, tools and lack of experience with overhaul activity needs there is the risk for prolonged out-of-service time for the asset during the overhaul program	Ensure that there is a budget request for acquiring new tools and equipment, conduct scan of required additional specialized tools required prior to adoption of technologies.	Y	**Ops - Fleet Supervisor**	**3 - Moderate**	**3 - Moderate**	**3 - Moderate**	**3 - Moderate**	**3 - Moderate**	**3 - Moderate**	Budget approval tor vehicles will be tied to tools and training
Category: Safety												
17.0	Fuel Leak/Fire Hazard	Improper handling of fuel, vehicle accident, use of tooling and/or proper facility design (i.e. ventilation) results in fuel leak. Pooled fuel liquid or gaseous in a concentrated area poses a fire hazard for risk of ignition.	Ensure facility & fueling station design in compliance with all applicable codes & standards relevant to the fuel in use. Provide staff training and Standard Operating Procedures (SOPs) for maintenance and fueling. Provide a well documented fuel spill response/clean up plan. Coordinate training with local emergency response services for developing a response plan in case of a vehicle accident. Best practices include installation of gas detection and ventilation in indoor storage facilities.	Y	**Ops - Fleet Supervisor**	**1 - Very Low**	**1 - Very Low**	**3 - Moderate**	**1 - Very Low**	**1 - Very Low**	**3 - Moderate**	Combustible fuels are already used within shop with the exception of CNG being compressed the hazards are the same
18.0	High Voltage Arc Flash Hazard	Electrical hazard resulting from a high voltage electrical discharge between conductors bridged by an air gap. This jump of electrical current at high voltage creates a large release of energy both thermal and as a light flash in the form of an electrical explosion which can be very dangerous.	Ensure all proper Arc Flash safety Personal Protective Equipment (PPE) is provided to all maintenance staff. Arrange for training programs to be conducted for all staff on high voltage safety. Develop SOPs for repair on/around high voltage sources/components and ensure all access areas to high voltage components are properly labeled and ensure a working perimeter is established with a mandatory PPE zone.	Y	**Ops - Fleet Supervisor**	**3 - Moderate**	**3 - Moderate**	**1 - Very Low**	**3 - Moderate**	**3 - Moderate**	**1 - Very Low**	Proper training should mitigate any potential electrical safety issues

APPENDIX

B

OPERATIONS CENTRE DRAWING



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CONCEPTUAL

rev	description	by	m.d.y
1b	for team review	CR	03.04.2021
1a	for team review	CR	03.03.2021
1	FOR SUMMARY REPORT	CR	12.30.2020
0	INITIAL ISSUE	CR	12.11.2020

CHANGE energy services
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www.changeenergy.ca PH: (905) 829-5756

City of Barrie
Alternative Fuels Study
Operations Centre
165 Ferndale Drive North, Barrie, Ontario

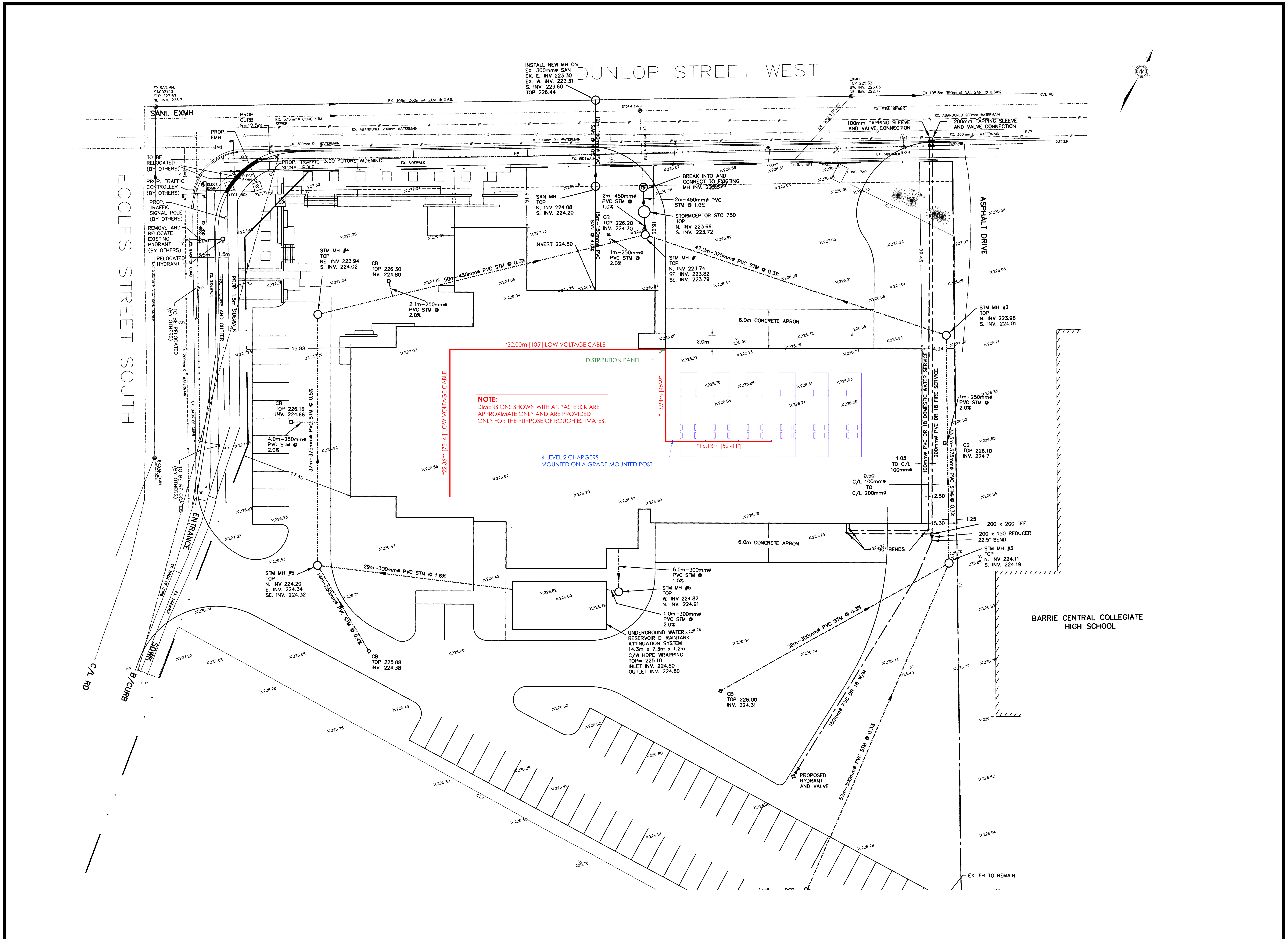
scale [D size]	1:500
designed	G. STEPHANIAN
drawn	C. ROBINSON
checked	G. STEPHANIAN
approved	G. STEPHANIAN date

OPERATIONS CENTRE
Proposed Electric Vehicle Storage and Charging

CES project number	sheet number
D20.011.05	G-200.2

APPENDIX

C STATION 1 DRAWING



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0	INITIAL ISSUE	CR	12.11.2020

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City of Barrie
Alternative Fuels Study
Fire Station One
155 Dunlop Street West, Barrie, Ontario

The City of BARRIE
wsp

scale [D size]	1:250
designed	G. STEPHANIAN
drawn	C. ROBINSON
checked	G. STEPHANIAN
approved	G. STEPHANIAN date

FIRE STATION ONE
Proposed Electric Vehicle Storage and Charging

CES project number	sheet number
D20.011.05	G-200.1

APPENDIX

D SWTP DRAWING

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CHANGE energy 2 services
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City of Barrie
Alternative Fuels Study
Surface Water Treatment Plant
20 Royal Parkside Drive, Barrie, Ontario

scale [D size]	1:250
designed	G. STEPHANIAN
drawn	C. ROBINSON
checked	G. STEPHANIAN
approved	G. STEPHANIAN date

SURFACE WATER TRT. PLANT
Proposed Electric Vehicle Storage and Charging

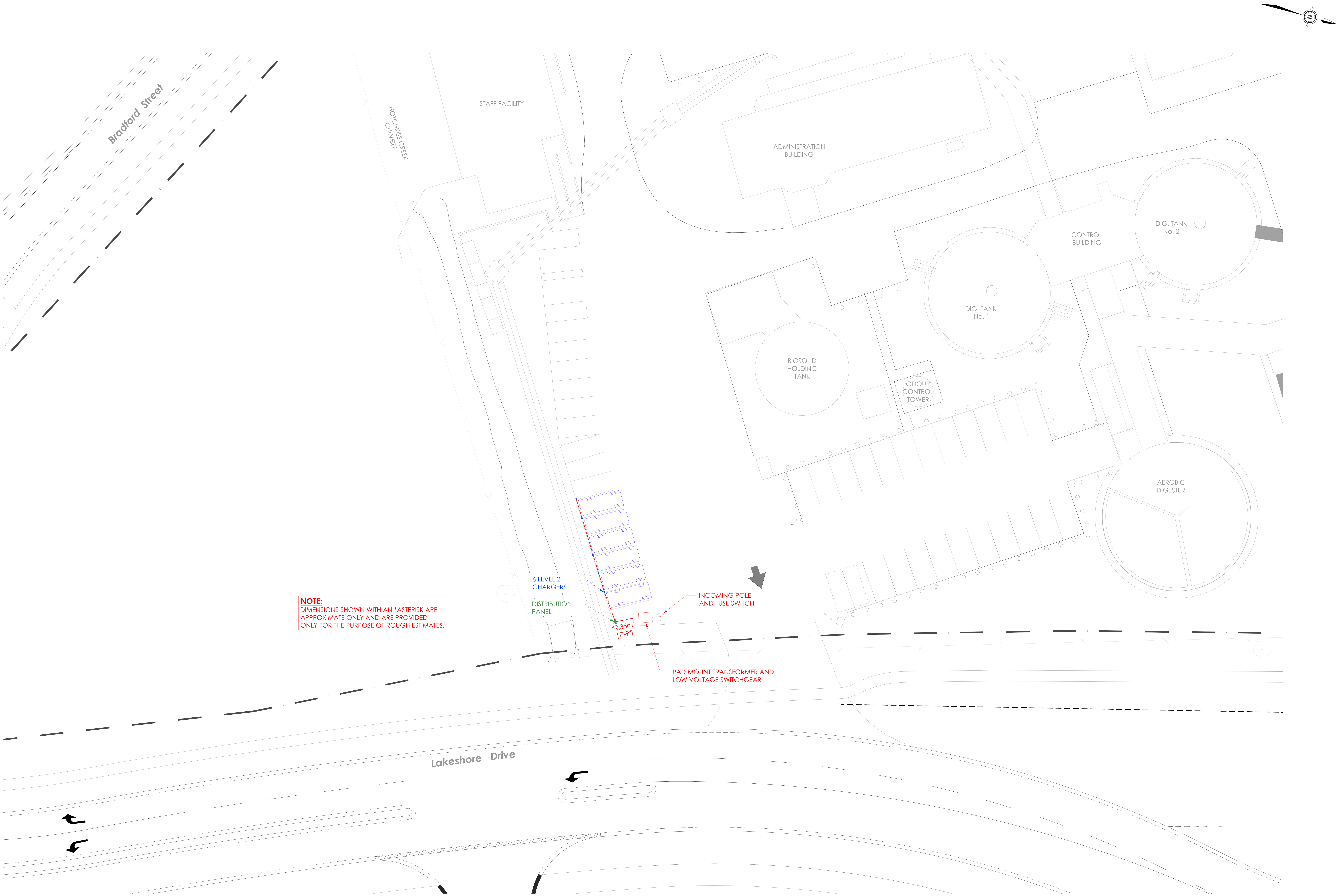
CES project number	sheet number
D20.011.05	G-200.5

APPENDIX

E

WWTP DRAWING

"Controlled document is electronic file on CES server. Verify latest version."



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City of Barrie
Alternative Fuels Study
Wastewater Treatment Plant
249 Bradford Street, Barrie, Ontario

scale [D size]	1:250
designed	G. STEPHANIAN
drawn	C. ROBINSON
checked	G. STEPHANIAN
approved	G. STEPHANIAN date

WASTEWATER TRT. PLANT
Proposed Electric Vehicle Storage and Charging

CES project number	sheet number
D20.011.05	G-200.3