CITY OF BARRIE

ALTERNATIVE FUEL TECHNOLOGY SUMMARY REPORT

TRANSIT

MAY 28, 2021

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TRANSIT

CITY OF BARRIE

FINAL

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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
YOE	Year of Expenditure

EXECUTIVE SUMMARY

Barrie Transit provides key mobility services to residents in the City of Barrie. The transit fleet is currently comprised of 46 buses and 17 specialized vehicles with a daily ridership of 13,000 (pre-COVID) expected to increase to 76,000 by 2041.

In support of climate and environmental goals, and to better serve its residents, the City is exploring different alternative technologies with an aim to reduce emissions.

The City of Barrie retained WSP to conduct a feasibility study to investigate three different technologies – namely battery electric buses (BEB), hydrogen fuel cell buses and Compressed Natural Gas (CNG) buses that operate out of the Maintenance and Storage Facility (MSF) at 133 Welham Road.

An initial high-level analysis was completed and identified BEB and CNG technologies for further study due to their level of maturity and ability to meet the needs of Barrie Transit. Factors that were evaluated and led to this decision included economic, social and environmental. The risks of each technology were carefully assessed, and a total cost of ownership model was constructed to examine the cost of owning each type of vehicle technology. At this initial stage, the cost of the infrastructure upgrades needed was provided at a high level. Based on the initial costing and environmental impact assessment, the two technologies picked to be further analysed were a full fleet conversion to CNG and to BEBs.

Fleet Plan and Growth Analysis

WSP assessed the existing facilities and planned upgrades, and considered fleet use and electrical supply. The current garage is set to have an expansion in 2026 adding capacity for up to 45 vehicles. Beyond that, an additional facility will be required to host the fleet growth in the future. The first alternative technology vehicles were assumed to be adopted starting in 2027, and the fleet growth followed the predictions of the Transit Asset Management Plan.

Operations Analysis

Using Barrie Transit's current schedule and operations data, electric bus performance modeling was conducted using WSP's proprietary tool called BOLT. Each day trip, also known as block, was modelled under different scenarios such as winter and summer and new and aged batteries. The results revealed that 24% of the current day trips could be electrified in the winter with the largest battery pack available in the market without requiring changes to the operations or additional on-route charging. In addition, these results also provided the following takeaways that differentiate electric buses from CNG buses:

- The BEB-to-diesel bus replacement ratio was 1.3 between 2021-2030, and 1.1 beyond 2030 as battery technology improves. This translates into added cost and space requirements for the fleet.
- The charger-to-BEB ratio was calculated to be 3:4 due to the buses operating all day and coming back to charge at night relatively at the same time. This also translated into spatial considerations to fit the chargers within the space.

Peak Demand Analysis and Infrastructure Upgrades Recommendations

Another key output from the modeling was the energy consumption and load profiles at each existing facility in the case of full electrification. A peak load of up to 3.77 MW was calculated when 100% of the current fleet would be electrified, which would then translate into a 8.4MW peak load by 2038 at the existing facility and 4.6 MW at the future facility by 2041. Based on a review of the current facility supply, it is clear that there is not expected to be enough available capacity on-site to electrify Barrie Transit's fleet in the next 10 years.

The local utility confirmed that it would currently be able to supply up to 5MW of power, and beyond that an upgrade to the supply will be needed. The BEB option will require an addition of three substations installed in phases, along with switchgears and charging cabinets. By 2029, 56 chargers will be installed and by 2031, an additional 23 chargers with a total of 102 dispensers that will service both the specialized and transit fleet will be required.

For the CNG option infrastructure upgrades will include adding a compressor and a redundant compressor in 2026 along with a dryer, buffer storage vessel, two dispensers and other related equipment. In addition, the maintenance and storage area needs to be upgraded to CSA codes for handling large amount of CNG safely.

Financial Analysis

Based on the facility phased implementation plan, the CAPEX and the OPEX of the fleet were estimated for the CNG and BEB scenarios. The CNG scenario created a 3.2% savings compared to the BAU case from 2021-2041, compared to a cost increase of 35% for the BEB scenario. When carbon taxes are considered, CNG yields a 4.4% savings and BEB yields a 26% increase.

Based on the completed cost analysis, the transition towards a BEB fleet will require just over twice (2x) the CAPEX (fleet and infrastructure) investment compared to the BAU between 2021-2041. The CNG options requires 1.1x the CAPEX (fleet and infrastructure). The cost analysis assumed that the cost of assets increase with inflation from 2021. In reality, the market predicts that there will be cost reductions in battery electric buses as a result of a reduction in battery costs and economies of scale so it is expected that the business case will improve over time. Analysis showed that BEB reduce OPEX costs by 15% compared to BAU, while the CNG scenario reduces OPEX cost by 12% compared to BAU.

The main advantage of the battery electric bus technology is its emissions reduction potential. In this scenario by the time the whole fleet is converted to electric buses in 2038, yearly emissions are reduced by 80%. Each vehicle would emit about 19.85 tonnes of CO_2e/year, compared to 97 tonnes CO_2e/year for the BAU case. Over the course of the next 20 years, the BEB transition enables GHG emissions reduction of 51%.

The CNG option also has the potential to reduce emissions. However, by 2038, 81 tonnes of CO_2e/vehicles are still being emitted which makes it difficult to reach Canada's net zero emission goal by 2050.

Recommendations

Given the industry trends, potential for future development and governmental support, it is recommended that the City of Barrie implements the adoption of battery electric for it's transit system. High upfront costs of the technology can be mitigated by partnering with manufacturers through lease programs, governmental supports, and potentials to collaborate with local utilities.

Next Steps

The next step is the development of a pilot program. This would include:

- definition of the pilot framework (number of vehicles, length of pilot, scope of pilot services)
- identification of key performance indicators that will measure the success of the project
- identification of funding opportunities
- preparation of pilot requirements and procurement
- identification and updates to infrastructure
- monitoring and reporting on pilot performance

A pilot project would enable Barrie Transit to gain familiarity with the BEB or CNG buses, charging/refueling technology and operational measures before engaging in a full transition program to replace all retiring buses with the alternative technology after the designated adoption start date. It would also enable the collection of critical operational data to update the initial plan, and assist in the negotiation/changes to the P3 Operating Contract.

1 INTRODUCTION

1.1 BACKGROUND

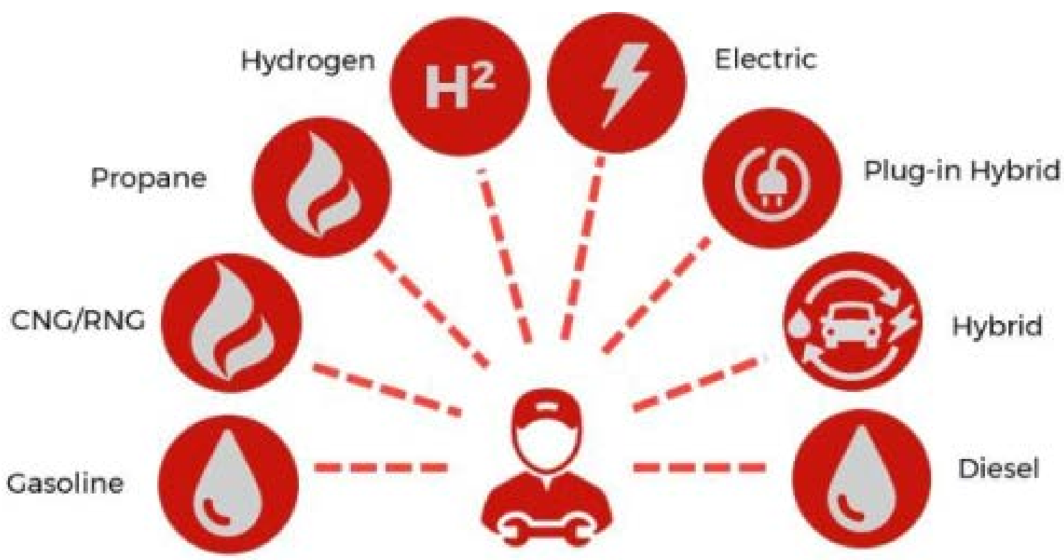
The City of Barrie is located in southern Ontario, on the shores of Kempenfelt Bay, the western portion of Lake Simcoe. The City is a single-tier municipality, and as part of the 2016 census, the City's population was estimated at 141,434. The population is expected to grow to 253,000 by 2041, and the employment within Barrie is expected to increase from the current 74,000 to 129,000 jobs by 2041.

In support of its current and growing transportation requirements, Barrie Transit provides key mobility services to residents in the City. The City has a conventional fleet of 46 buses (with 35 utilized in service during peak), and 17 specialized vehicles that have an annual ridership of 3.3 million. The city owns a 100,000 square foot transit garage for maintenance and storage of its vehicles, maintains 600+ stops, 350+ bus pads and other assets. Based on a recently completed Transportation Master Plan and Transit Asset Management Plan, the City has identified a mode share target of 7% for transit (total person trips by 2041). Barrie Transit has a P3 (Public Private Partnership) contract with a third-party service provider for operation and maintenance.

In support of its climate and environmental goals, and in order to better serve its residents, the City wishes to explore alternative fuel vehicles. This will enable the City to mitigate and reduce the negative impacts of conventional fuels on human health and the environment, enable the city to move towards greater sustainability, assist in contributing to a reduction in GHG (Greenhouse Gas), 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 transit fleet. The need for alternative technologies is driven by the finite availability of convention fuels (gasoline and diesel), achieving environmental savings and 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 include the following elements:

- A review of the alternative fuel technologies currently available in the Canadian market place, including a detailed technical and regulatory review for the technologies identified for transit vehicles (Battery Electric, Compressed Natural Gas, and Hydrogen Fuel Cells);
- A high-level gap assessment of the different technologies including infrastructure and routing implications for the City, along with information for a potential pilot deployment plan;
- An assessment of the business case of adopting the different technologies to determine costs and environmental benefits associated with each technology, as well as their social impacts;
- A risk identification and engagement summary to highlight potential risks in adopting alternative fuel technologies, their implications and potential mitigation measures for the City to adopt;
- Potential approach for the City to employ in support of the adoption of alternative fueled vehicles;
- A detailed plan demonstrating the feasibility of converting the fleet to 100% CNG or 100% electric vehicles for the horizon 2021-2041;
- Operational requirements for each technology and an overview of the infrastructure need operate the alternative vehicles;
- Provide a phased implementation strategy whereby 25%, 50% and 100% of fleet replacement is achieved, with a reasonable timeline for when upgrades would be required;
- Provide details on the costing (CAPEX and OPEX) or each phased implementation, listing the assumptions;
- Identify future trends and stakeholders for future partnerships.

Note that this version of the document excludes the review the current P3 agreement for confidentiality purposes.

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 the historical data and current data provided from 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 alternative vehicle technologies described in this report are ever evolving, the cost estimates provided in this report reflect today's available technology and may no longer hold true as the market matures.

2 CURRENT STATE SUMMARY

2.1 FLEET ASSET INVENTORY

City of Barrie's current asset inventory consists of 63 vehicles including 46 transit buses, and 17 specialized transit vehicles according to Barrie Transit's fleet inventory. The OEMs (original equipment manufacturer) of City of Barrie's fleet are primarily Nova, Chevrolet, Eldorado, GMC, MOBI, and New Flyer. The breakdown of vehicles by OEM type for each vehicle groups are shown in Figure 1, Figure 2, and Figure 3 below.

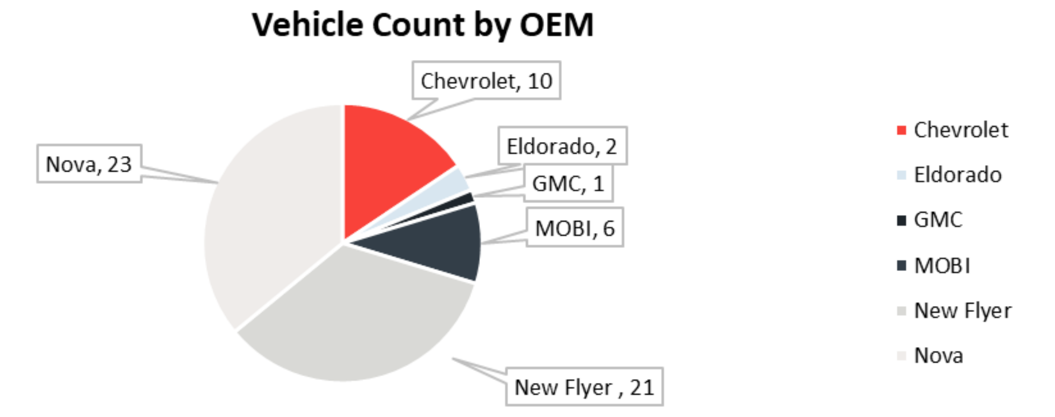


Figure 1 Vehicle Count by OEM

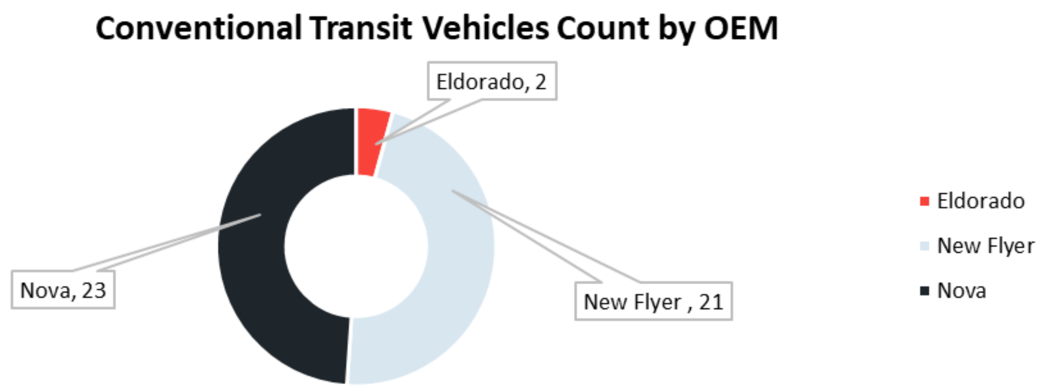


Figure 2 Conventional Transit Vehicles Count by OEM

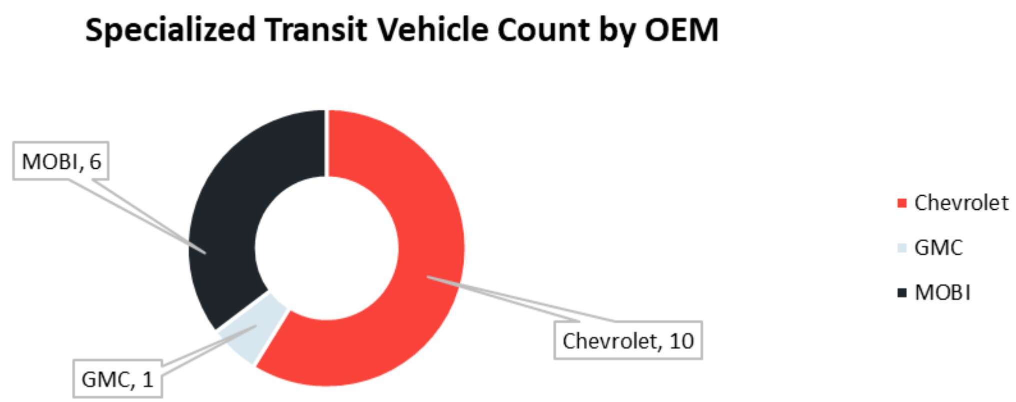
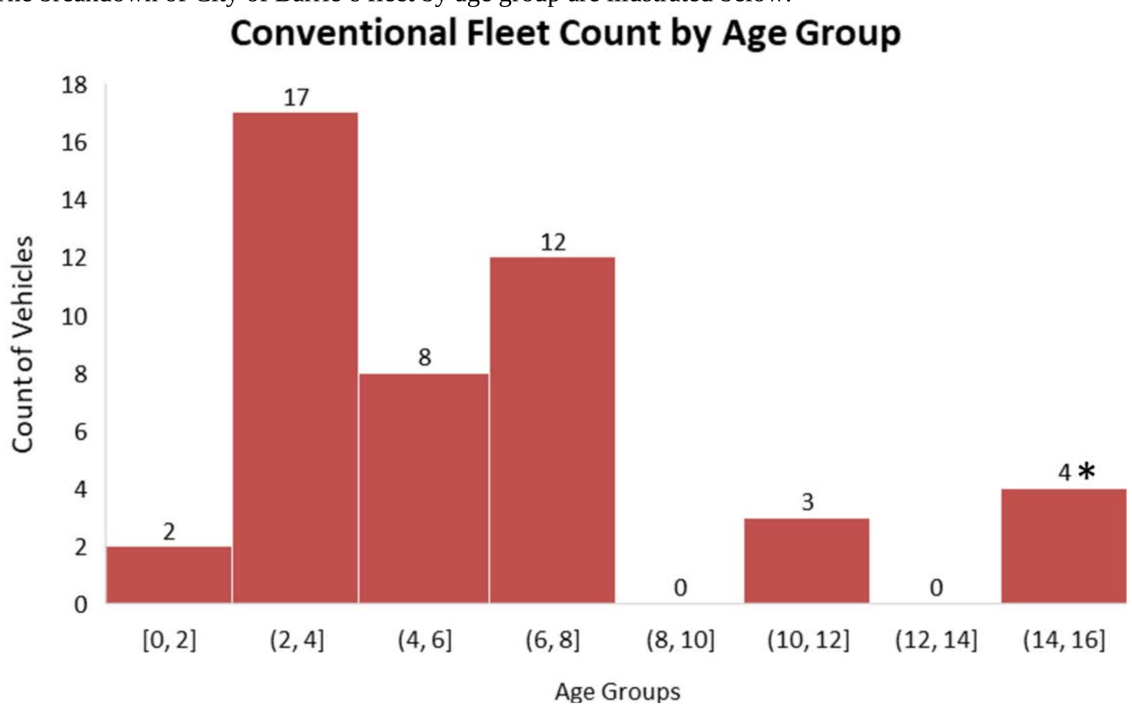
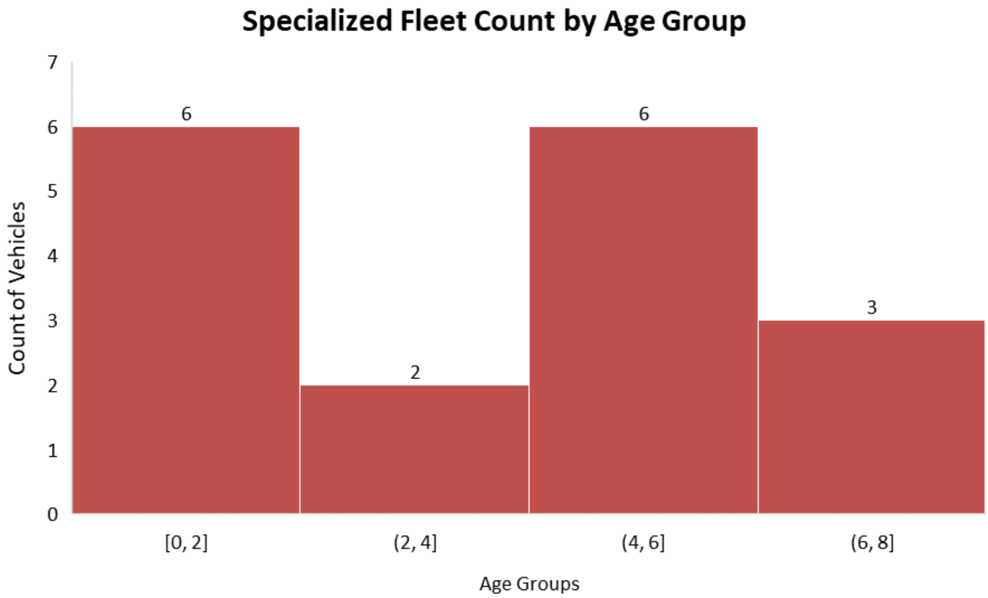


Figure 3 Specialized Transit Vehicle Count by OEM

A majority of City of Barrie's vehicles and conventional transit vehicles are manufactured by Nova and New Flyer and most of the specialized transit vehicles are manufactured by General Motors Company.
The breakdown of City of Barrie's fleet by age group are illustrated below.





*The four vehicles shown with 14-16 years in the conventional fleet received a mid-life refurb that extends their estimated life by 5 years

Figure 4 Fleet Count by Age Group

As illustrated in the figure, Barrie's conventional transit fleet is 6.3 years old on average. This is relatively young compared to the Canadian average of 8.5 years for conventional transit and 7.4 for Ontario, as per CUTA's 2018 Factbook.

2.2 FLEET ASSET MANAGEMENT PLAN

The existing Barrie Transit Asset Management Plan was completed in April 2019 for a 10-year period (2019 to 2028) with a planning timeframe to 2041. The plan achieved the following:

Establishes the state of local infrastructure,

Sets out the proposed level of service,

Determines an asset management strategy to provide the proposed level of service in a sustainable way; and

Develops a financial strategy that supports the strategy.

The fleet asset category consists of three main sub-categories: transit-conventional, transit-specialized, and utility fleet. The useful life of the fleet asset is summarized in the following table.

Table 1 Expected Useful Life

Sub-Category	Useful Life (Years)
Transit- Conventional	12
Transit- Specialized (Cut-away)	7
Transit- Specialized (Mini Van)	5

A conventional bus is estimated to be $650,000. Details on the inventory of the City's conventional buses and the replacement plan are summarized in the next page.

Table 2 Inventory of Conventional Fleet and Replacement Cost (Updated with 2021's Fleet Count)

Make	Model	Quantity	Year in Service	Age	Replacement Cost
New Flyer	D40LF	4[1]	2004	17	$2,600,000
New Flyer	D40LF	3	2009	12	$1,900,000
New Flyer	Xcelsior	6	2012	9	$3,900,000
Eldorado	30 ft.	2	2012	9	$1,300,000
New Flyer	Xcelsior	4	2013	8	$2,600,000
New Flyer	Xcelsior	4	2014	7	$2,600,000
Nova	LFS	4	2015	6	$2,600,000
Nova	LFS	4	2016	5	$2,600,000
Nova	LFS	13	2017	4	$8,450,000
Nova	LFS	2	2020	1	$1,300,000
Total		**46**			**$29,850,000**

1. Four buses were refurbished in 2017 which extended useful life by 5 years to a total of 17 years.

A specialized transit vehicle is estimated to be $185,000. Details on the inventory of the City's specialized transit vehicles and the replacement plan are summarized below:

Table 3 Inventory of Specialized Fleet and Replacement Cost (Updated with 2021's Fleet Count)

Make	Model	Quantity	Year in Service	Age	Replacement Cost
Chevrolet	4500	2	2013	7	$370,000
GMC	3500	1	2013	7	$185,000
MOBI	MV1	6	2015	6	$1,110,000
Chevrolet	4500	1	2016	5	$185,000
Chevrolet	4500	1	2017	4	$185,000
Chevrolet	4500	2	2018	3	$370,000
Chevrolet	4500	4	2020	1	$740,000
Total		**17**			**$3,145,000**

The costs for conventional and specialized fleet from the Barrie Transit AMP completed in April 2019 were taken as BAU (Business as Usual) costs for this analysis.

2.3 FUEL CONSUMPTION PROFILE

The total fuel consumption over the past year was 1,990,511 litres of fuel for all vehicles. Figure 5 shows the total fuel consumption by year for the past 4 years.

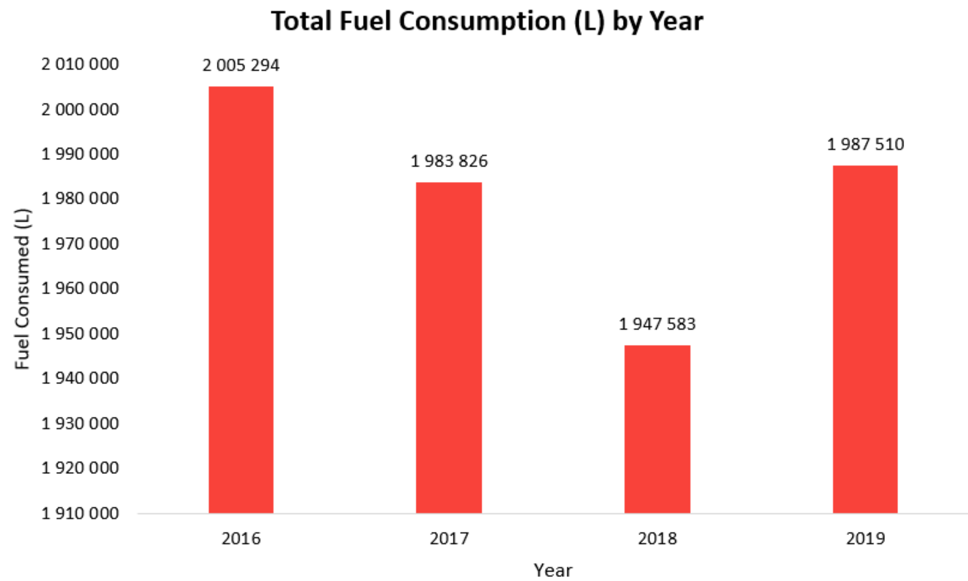


Figure 5 Total Fuel Consumption (L) by Year

2.4 ALTERNATIVE FUELS EXPERIENCE & ENVIRONMENTAL INITIATIVES

The City of Barrie’s current transit fleet is made up of traditional fuel vehicles (gasoline and diesel). 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, along 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.)
- “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 operations fleet include the following:

- Maintain Public Health and Safety (via reduction of air emissions)
- Strengthen Infrastructure Resilience

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

- Protect Biodiversity and Enhance Ecosystem Functions
- Minimize Disruption to Community Services
- Build Community Resilience
- Help Local Business and the Tourism Industry adapt to Changing Conditions

2.5 FACILITIES AND INFRASTRUCTURE ANALYSIS

The team visited City of Barrie's Transit Garage on November 4th, 2020. Information regarding the location, parking, maintenance ability fueling sites, etc. for the transit site is summarized below.

Barrie Transit Garage (133 Welham Rd.)

Figure 6 Barrie Transit Garage (133 Welham Road)

Table 4 Transit Garage Site Map Legend

Area	Description
1	Indoor Bus Storage
2	Maintenance Repair Bays
3	Service Line (Fuel + Wash)
4	Available Land for Site Expansion
5	Employee Parking

- The Barrie Transit garage construction was completed in 2015 as part of a P3 contract (DBFOM), Kenaiden Construction Company and IBI Group were the consultants and contractors for the Design-Build.
- The facility is approximately 108,000 sq. ft. in size.
- The roof does not have excess capacity for mounting of electrical chargers/equipment as it was designed for only dead load and snow load. City of Barrie previously investigated rooftop mounted solar panels.
- In 2015, MVT Canadian Bus was awarded the contract for fleet operations and maintenance for 20 years.

- Indoor storage is provided for all of the City of Barrie's specialized transit, 30ft and 40ft transit buses. Indoor storage currently is beginning to approach capacity and City of Barrie has plans for future expansion in the south for more indoor storage (Area 4).
- The facility contains 15 lanes for 6x 40ft buses parked deep for an estimated total capacity of 90x 40ft buses.
- The Transit fleet contains all diesel buses, with a mix of gasoline and diesel specialized vehicles. Currently:
  - 46x transit buses, 17x para-transit vehicles (including vans and cutaways)
- Two service lines are available for daily refueling and wash of fleet (Area 5), but currently only 1 service line is used. Buses are fetched from indoor parking (Area 1) and put through the service line at the end of day and re-parked.
- Low point to bottom of overhead HVAC ducting is approximately 13ft, and 16ft to overhead steel web joists (OSWJs).
- Bus parking lane width = 122", Walkway width = 52", Column line painting width = 25"

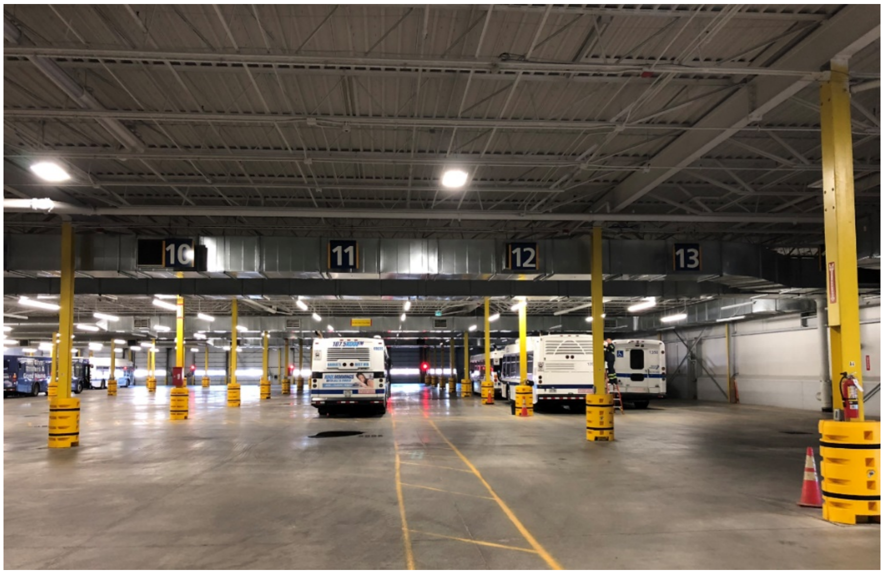


Figure 7 Parking Lanes

- Parking Lane 1 is dedicated to non-revenue vehicles, Parking Lanes 2 and 3 are dedicated for specialized transit vehicles (cutaways, vans).
- Parking Lanes 4 to 9 are dedicated for operational transit buses, and Parking Lane 10 is reserved for GO bus parking (agreement with Metrolinx).
- Parking Lanes 11 to 13 are dedicated for buses needing scheduled maintenance or repair
- Buses returning from road call/tow call are parked outside on the west side of building (maintenance bay entrances).
- 5x maintenance bays and 2x bays for tire/degrease and detailing work.

Figure 8 Maintenance Bays

- Mostly portable hoists are used, each one has a 18,500 lbs lifting capacity (per wheel).
- Limited floor space available for couple portable chargers in the maintenance area (Heliox model portable charger).
- On-site generator is located outside (south of service line entrance) and has capacity for running all facility power except for A/C.
- No concern for any height clearance issues in the maintenance bays (interior roof height is more than suitable).
- Overhead HVAC ducting is a possible concern in bus storage area and roof structure cannot support roof hanging pantographs or charging cabinets. However, there is floor space available and a possibility to reinforce overhead beams/support columns for pantographs (around 265 lbs per pantograph).
- Modifications may be required to accommodate taller electric and / or CNG vehicles for the following infrastructure:
  - Upgraded electrical service including transformer and switchgear as required for electric vehicle charging.
  - Overhead clearance to the diesel exhaust hoods in the fuelling bays.
  - Overhead clearance to the vehicle wash equipment.
  - Overhead clearance to the lighting fixtures.
  - Overhead clearance to the HVAC duct work, fans and equipment.
  - Overhead clearance to the door openings

2.6 UTILITIES ENGAGEMENT

Electricity

The City of Barrie's electrical utility, Alectra, provided the nameplate rating of the existing transformer feeding the facility at 1000 kVA. Note that the existing transformer is customer owned. If a replacement transformer is required, it would be at the customer's cost.

Alectra also provided 49 data points from 2016 10 to 2020 11. These monthly values of both actual readings and estimates provided the monthly consumption and the average kilowatt hours per day (based on monthly consumption divided by number of days listed in that billing period). Alectra also provided a detailed load consumption of the facility with data points provided every 5 min. The peak load of the facility approximates 191 kW.

Natural Gas

The local natural gas utility was contacted as part of the project and didn't disclose details on the availability of natural gas distribution through the existing pipeline network at the site vicinity. Given the dense distribution of natural gas in the area, it is unlikely that availability of natural gas at the required pressure will cause issues in the project. Should Barrie Transit decide to pursue the option of deploying CNG buses, it is recommended to engage in further discussions with Enbridge to obtain a clearer picture on the cost of fuel supply and natural gas availability.

Hydrogen

Today, in Ontario, liquified hydrogen pipelines are unavailable and the distribution system is limited. For this reason, utility engagement isn't required to assess fuel availability or fuel supply, but rather to ensure that the necessary power can be delivered to the site to operate hydrogen refueling stations and auxiliary equipment. That said, utilities such as OPG and gas companies such as Enbridge could be interested to discuss options for Hydrogen use from Barrie Transit. Other liquified hydrogen suppliers in Ontario such as Air Product in Sarnia can also be contacted to review supply availability.

3 ALTERNATIVE TECHNOLOGY OVERVIEW

3.1 BATTERY ELECTRIC

3.1.1 TECHNOLOGY FUNCTIONAL OVERVIEW

3.1.1.1 VEHICLE TECHNOLOGY

An BEB or Battery Electric Bus (BEB) is propelled through an electric traction motor, which draws its power from an on-board battery. The motor powers the drive axle, wheels and the battery also powers auxiliary loads such as heating and cooling, vehicle lighting systems, opening and closing of doors etc. One of the advantages of an electric motor is that is can also be used as a generator, thus enabling the recuperation of energy through regenerative braking when the vehicle decelerates. There are variants of BEBs available that utilize diesel heaters to warm the internal bus climate for cold weather operations, which enables the vehicle's operational range to not be overly affected.

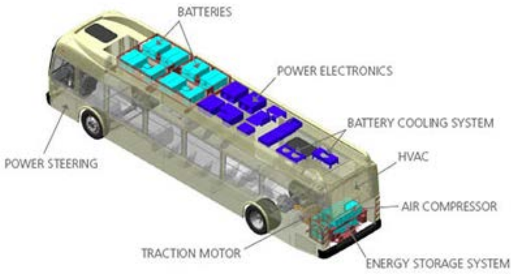


Figure 9 Major BEB Systems

The energy distribution from the battery pack to the traction motor is controlled by a power electronics system and other high-voltage electrical systems while also enabling regenerative braking for energy recapture. The BEB can be charged via several options, including on-route charging through overhead pantograph chargers, also called opportunity charging at the terminal stations, or at the depot through plug-in or depot charging.

The market for BEBs has been rapidly evolving over the past decade. With continuous research, the battery technology has seen important improvements in terms of energy storage/density (kWh per kilogram) as well as reducing battery cost ($/kWh). According to the BloombergNEF Electric Vehicle Outlook 2020, BEBs are projected to comprise over 67% of the global bus fleet in 2040[3]. Further, the average battery density is expected to continue to rise at 4-5% per year with new and improved chemistries hitting the market. From 2010 – 2019 the average lithium-ion battery price ($/ kWh) fell by 87%, and this trend of falling prices is expected to continue into the next decade[4].

As of 2020, the average price of lithium ion battery is close to $137/kWh (USD)[5]. It is expected that by 2023, average prices will be reach $100/kWh making the energy cost and density of batteries on par with diesel and gasoline for conventional light-duty engines. That price is widely cited in the industry as a tipping point to reach price parity where electric vehicles options won't be seen as the pricier option. Figure 10 provides an outlook of the cost of lithium ion battery costs over the next 10 years.

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[3] https://about.bnef.com/electric-vehicle-outlook/

[4] Ibid.

5 https://www.statista.com/chart/23807/lithium-ion-battery-prices/#:~:text=According%20to%20data%20collected%20by,%241%2C191%20just%2010%20years%20ago.

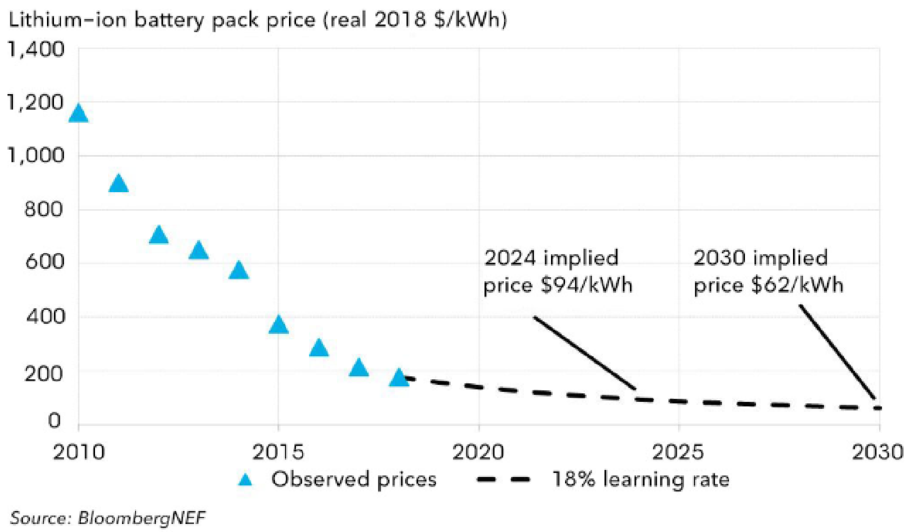

Figure 10 Lithium-ion battery price outlook

For heavy-duty applications such as BEBs, batteries tend to have a higher capital cost because the battery packs are larger and require a more robust assembly. Therefore, the forecasted price parity year of 2024 may not align directly for this application. Figure 11 shows the battery cost over time for two scenarios in the case of a high demand for heavy-duty batteries and in the case of low demand[6]. The costs are initially reported in €/kWh and converted to CAD$/kWh in this figure. The price parity of USD $100/kWh, or CAD$140/kWh, will be reached closer to 2030 according to these predictions.

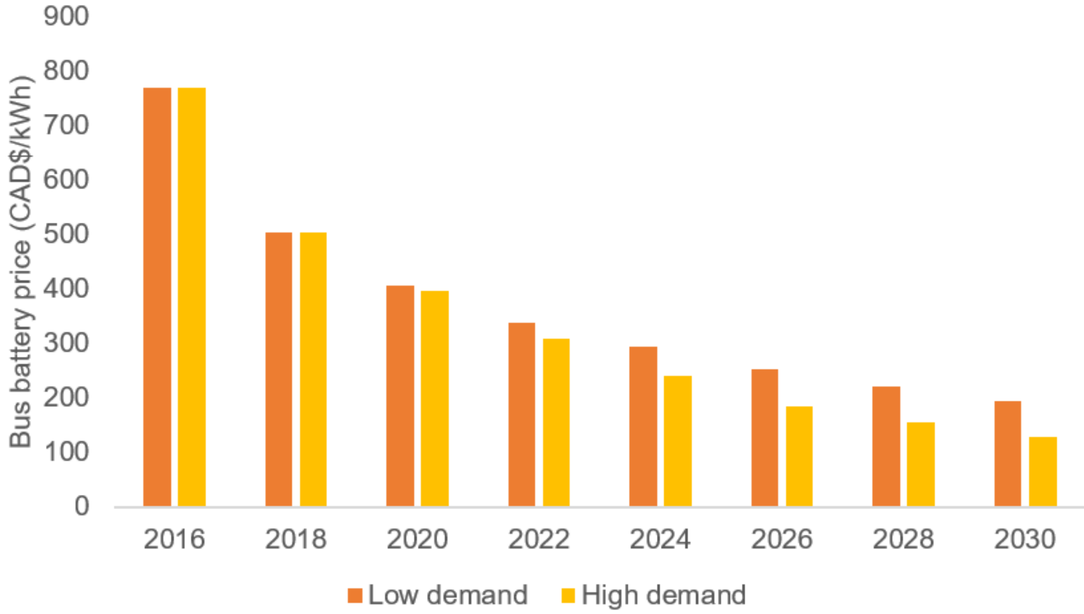

Figure 11 Heavy-Duty Battery Price Predictions in the Next 10 Years[7]

[6] https://www.transportenvironment.org/sites/te/files/publications/Electric%20buses%20arrive%20on%20time.pdf
[7] https://www.transportenvironment.org/sites/te/files/publications/Electric%20buses%20arrive%20on%20time.pdf

Most early implementations of battery electric buses used relatively small batteries with limited range. As a result, on-route charging systems were relied upon where buses were charged before each round trip. This allowed buses to provide service all day long with a relatively small lighter-weight battery. For cost and operational reasons, however, most agencies would prefer battery electric buses that could operate all daylong without the need to stop and charge during the day. Today, as BEBs can travel longer distances with a single charge, the bus industry continues to focus on the more affordable depot charging, while leaving the option of opportunity charging for specific scenarios. Furthermore, these on-route charging stations have a high capital cost (est. $1 million) which risks becoming obsolete infrastructure as battery technology continues to improve.

BEBs share some common elements and build platforms with diesel buses. However, there are vehicle systems impacted from the use of an electrical power train and energy storage system which differ from a conventional transit bus. Table 5 provides a comparison between the major subsystems in a diesel bus versus an BEB.

Table 5 System Changes from Diesel Bus to BEB

System	Diesel	Change to Electric Bus
Propulsion	Internal combustion engine, transmission, fuel system and exhaust after treatment.	Electronic traction motor, battery with energy storage system.
Windows, Structure & Exterior Body	Chassis, roof & side structures, undercarriage, windows.	More robust structure to support battery weight, roof structure, low centre of gravity (with floor-mounted battery packs).
Electrical	Low voltage system to power auxiliary components, interior lighting, headlights, starter motors, etc.	Additional high voltage power electronics to manage battery charging, regenerative braking and traction motor operation
Steering	Hydraulic power steering.	Electrical power steering system.
Brakes, Pneumatic & ABS Sensors	Friction braking system with brake callipers.	Regenerative braking system, partially recharges batteries during deceleration.
Wheels, Axles, Suspension & Differential	Pneumatic suspension front & rear, rear differential, standard wheel & tire size.	Rear axle to be compatible with regenerative braking, higher axle & suspension rating to support battery weight.
HVAC	Diesel-powered heater.	Diesel heater or electric heater (to reach zero tailpipe emissions).
Farebox & ITS	Fare payment equipment, communications and destination signs.	No significant changes, varied design depending on the model.
Doors & Ramps	Bifold doors front & rear, manual or powered ramp deployment.	No significant changes, varied design depending on model.
Interior	Passenger seating, stanchions, stop request, signals, etc.	Optimized weight of interior components to compensate for additional battery weight (i.e. plastic seats, plastic stanchions).

Generally, the battery packs are roof mounted to optimize interior cabin space for seated and standee passengers. However, battery packs may be stored in different locations depending on the manufacturer's design.

Battery electric buses provide an option that enables dramatic reduction in the GHG (Greenhouse gases) and CACs (Criteria Air Contaminants) emissions of the fleet, as it has zero tailpipe emissions (excluding any auxiliary diesel heater options added), and its carbon footprint is directly proportional to the electrical grid it is connected to. Furthermore, as electric systems and power flow through a battery, it has much higher efficiency as compared to the diesel internal combustion engine, and leads to better net utilization of energy. As the electrical energy sources and grids migrate to more renewable and carbon neutral options in the future, this leads the possibility of very minimal to zero upstream carbon emissions.

Electric buses are expected to have lower routine maintenance costs in comparison to diesel buses. Electric buses have fewer components and less moving components than a diesel bus. This is the primary advantage that will result in reduced maintenance and part costs, although there is a risk of a higher overall lifecycle costs if major systems fail and require an overhaul. These benefits may be further capitalized upon once the familiarization with new electrical systems is reached by mechanics. However, this is unproven at this time as no electric bus has been in operation for a complete lifecycle in North America.

3.1.1.2 *CHARGING TECHNOLOGY*

This section provides an overview of the key charging technology that is utilized for charging BEBs. Three types of chargers are commonly used by BEB fleets: plug-in, inductive and pantograph chargers.

Plug-in Charging

Direct plug-in charger is the most broadly implemented and cheaper charger type. They are considered safe, easy to use and efficient. The charging time depends on the limitation on the battery C-rate, which is limited to prevent battery degradation. It also depends on the charge level of the battery or state-of-charge (SOC). Current manufacturers of plug-in charging stations include ABB and Siemens with input power on the charging station models ranging from 50 kW up to 350 kW (currently under development)[8, 9]. Chargers supplying 200 kW and over require split cabling or the need for liquid cooling to avoid overheating from power transfer during charging. This adds weight to the charging cables and can make them more difficult for operators to handle. This additional weight needs to be considered for installation at the garages. The most common connection standard in North America for this technology is SAE J1772, while BYD follows the Guobiao Standard (GB-T) standard used primarily in China.

Figure 12 CCS Type Connectors SAE J1772

Inductive Charging

Inductive charging uses induction power transmitters in the floor slab or roadway to transfer power to a vehicle parked above, as shown in Figure 14. With this system, the bus does not require a physical contact with the charger to receive power. Reported charging rates using inductive charging are akin to those achieved using wired connections. Currently, inductive on-route charging is not that appealing due to the need for road excavation to install the charging infrastructure under the road surface. This can disrupt traffic flow, transit lines and requires coordination with the city on the location and possible relocation of underground utilities.

Currently, there is not an adopted standard in the industry for this technology, however one is being developed by the Society of Automotive Engineers (SAE) - the J-2954/2[10] - which will define criteria for interoperability.

Figure 13 Inductive Charging Concept

[8] https://new.abb.com/ev-charging/products/car-charging/high-power-charging

[9] https://assets.new.siemens.com/siemens/assets/api/uuid:1fa0520c-3842-428e-b4e1-84faa37c6801/broschuere-sicharge-uc-v12-en.pdf

[10] https://www.sae.org/standards/content/j2954/2/

There are several manufacturers of this type of technology in North America. WAVE (Wireless Advanced Vehicle Electrification Inc.) is a manufacturer that develops high power wireless charging stations that can transfer power at rates of 50 kW and 250 kW. Momentum Dynamics is another manufacturer that has deployed three wireless inductors on the BRT Red line of Indianapolis's public transport system, IndyGO. The pads are set to deliver 300 kW of power. Inductive charging solutions are still in the early stages of commercial development and implementation. It also carries significant capital costs and requires the demolition and rebuild of the route pavements.

Pantograph Charging

The last option is pantograph charging. Electric vehicles are connected via automated pantograph to a high-voltage power source to reduce charging time, using charging stations with power supply ranging from 150 kW to 600 kW. The pantograph can be mounted on board the bus or on the charger (inverted pantograph).

The advantage of on-board pantograph is that it simplifies the charging infrastructure. The pantograph is one of the charger components that is most susceptible to wear and tear. Thus, if the pantograph is mounted on overhead infrastructure (rather than on-board) and needs repair, the entire fleet operations will be impacted instead of just one bus.

On the contrary, the inverted pantograph simplifies the bus system by making it lighter. Some pantograph manufacturers in North America include ABB, Siemens and Heliox. The connection standard for this technology is the SAE J3105[11], published in 2019.

Figure 14 Onboard Pantograph (Left) and Inverted Pantograph (Right) Examples[12]

3.1.2 MARKET OVERVIEW

In North America, there are five electric bus Original Equipment Manufacturers (OEMs) offering 40-foot electric transit buses (BYD, Green Power, New Flyer, Nova Bus and Proterra) with a sixth transit bus manufacturer (Gillig) set to partner with Cummins Inc to integrate new battery electric technology offered by Cummins with Gillig's zero-emissions transit buses.

[11] https://www.sae.org/news/2020/02/sae-j3105-promotes-safe-charging-for-buses-and-heavy-duty-vehicles

[12] Fundamentals of Electric Bus Charging (ABB Domestic Sales 05/2016 J Mäkinen)

3.1.2.1 *40FT BUS TRANSIT REVIEW*

NEW FLYER

New Flyer is a Canadian bus manufacturer based in Winnipeg, MB, and has a long history supplying vehicles for the diesel, compressed natural gas (CNG), hybrid, trolley, and battery electric bus markets in North America. Currently, all of New Flyer's electric buses are built on their Xcelsior base model, which is widely used for their diesel, trolley and CNG fleet offerings. The New Flyer Xcelsior (XE40) is the 40ft (12m) conventional bus and comes available with options for seven different battery configurations to cater to short duration routes with on-route charging up to larger battery capacities for primarily depot charging:

- **Rapid Charge:** 160 kWh, 213 kWh, 267 kWh, 320 kWh
- **Long Range:** 311 kWh, 388 kWh and 466 kWh[13]

The XE40 uses lithium-ion battery packs manufactured by XALT Energy and has a Siemens ELFA2 Electric Drive System capable of delivering 160 kW (1,400 Nm) of output power and torque.

The XE40 vehicle dimensions are 40.2 ft. (12.5 m) long by 102 in (2.6 m) wide with a roof height of 130 in (3.3 m). Note the electric version of the Xcelsior has a higher roof and requires greater clearance inside transit facilities due to roof mounted battery packs and power electronics.

The XE40 capacity is 40 seated passengers and up to 42 standing passengers, for a maximum passenger capacity of 82 passengers, dependent on the battery configuration.

New Flyer also has a 60ft (18m) articulated model of the Xcelsior (XE60) which can seat up to 52 passengers and accommodate an additional 73 standees for a total of 125 passengers, dependent on battery capacity. Similar to the XE40 there are different battery configurations:

- **Rapid Charge:** 213 kWh, 267 kWh, 320 kWh
- **Long Range:** 466 kWh

The XE60 also has a Siemens ELFA2 Electric Drive System and a ZF AVE 130 in-wheel motor drive for the centre axle. This powertrain can deliver 210 kW and up to 2,000 Nm of torque. The XE60 has designed two locations for wheelchairs (in the front and rear), but other seat configurations and accessibility options are available. New Flyer also offers a stainless-steel chassis option on both the XE40 and XE60.

Charging options:

Two charging options are available to recharge the Xcelsior, depending on the preferred battery size and type (power battery versus energy battery). The plug-in charger uses CCS Type 1 connection following the SAE Standard SAE J1772. The overhead fast charging system follows the SAE J3105-1 standard.

NOVA BUS

Nova Bus is a Canadian subsidiary of the Volvo Group which has supplied diesel, CNG, hybrid, and battery-electric buses to the North American market for nearly 40 years. Based in Montreal, QC, Nova Bus has the engineering support of Volvo Group, which has extensive experience in electric bus deployment in European cities and has pioneered the development of the OppCharge standard protocol.

The Nova Bus electric model, the LFSe, comes with a standard 76 kWh battery. By reducing the on-board weight, coupled with frequent charging stations, Nova Bus aims to better align the LFSe with on-route charging applications. This BEB has a TM4 Sumo HD Electric powertrain with a maximum output of 230 kW (2,700 Nm).

[13] https://www.newflyer.com/buses/xcelsior-family/

The vehicle is 40 ft. (12.2 m) long by 102 in (2.6 m) wide with a roof height of 130 in (3.3 m). The vehicle has capacity for 41 seated and 34 standing passengers, for a loading capacity of 75 passengers. This BEB debuted on the Société de Transport de Montreal (STM) in 2016.

In 2019, Nova Bus announced a partnership with BAE Systems to release the LFSe+ which has a total battery capacity of 594 kWh and offers a dual charging system, namely the overhead pantograph and the plug-in charging options[14]. The BAE Systems HDS200 powertrain can deliver 200 kW (5,200 Nm). The LFSe+ has passenger capacity for 41 seated and up to 27 standees for a total of 68 passengers. Figure 15 shows a schematic of the LFSe platform.

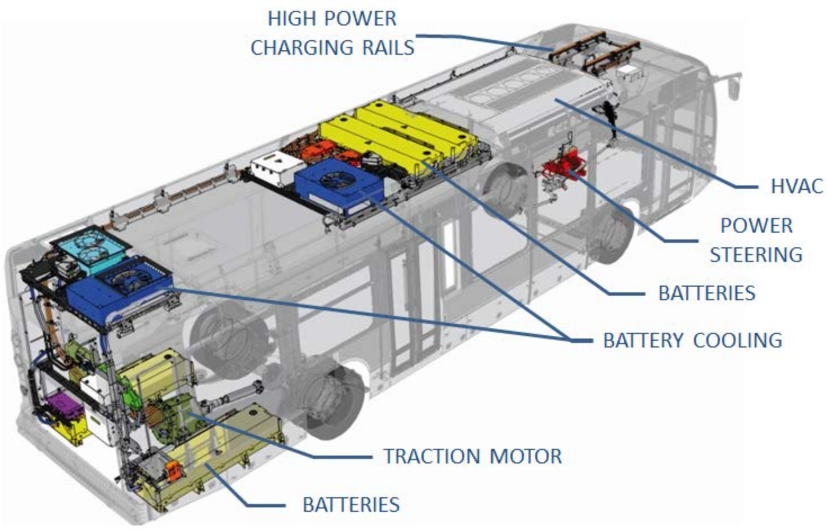

Figure 15 Nova LFSe Schematic

Charging options:

Two charging options are available to recharge the LFSe: the plug-in charger uses CCS Type 1 connection that follows the SAE Standard SAE J1772. The overhead fast charging system follows the SAE J3105-1 standard.

BYD

BYD is one of the world's largest electric vehicle manufacturers with over 200,000 electric vehicles in operation around the world. Headquartered in China, BYD currently offers BEB and eCoach models ranging from 30ft to 60ft in North America. To be most applicable to Barrie Transit's current fleet the scope will focus on presenting BYD's 40ft (12m) and 60ft (18m) BEB models.

The BYD K9 is the 40ft (12m) BEB model, CMVSS (Canadian Motor Vehicle Safety Standards)-certified in Canada and manufactured at the BYD Factory in California. The BYD K9 model comes with a 324-kWh lithium iron-phosphate battery pack. Vehicle dimensions are 40.2 ft. (12.3 m) long by 101.6 in (2.6 m) wide with a roof height of 134 in (3.4 m). The drive motor is a proprietary AC synchronous (TYC-150A) with dual in-wheel motors each providing 150 kW (550 Nm) for a total power and torque output of 300 kW and 1,100 Nm respectively.

[14] https://www.newswire.ca/news-releases/nova-bus-introduces-the-lfse-a-new-long-range-electric-bus-with-dual-charging-options-856225784.html.

The vehicle has a capacity of 38 seated passengers and up to 39 standing passengers, for a maximum passenger capacity of 77 passengers. Figure 16 shows the schematic layout of electric drive components on the BYD electric bus.

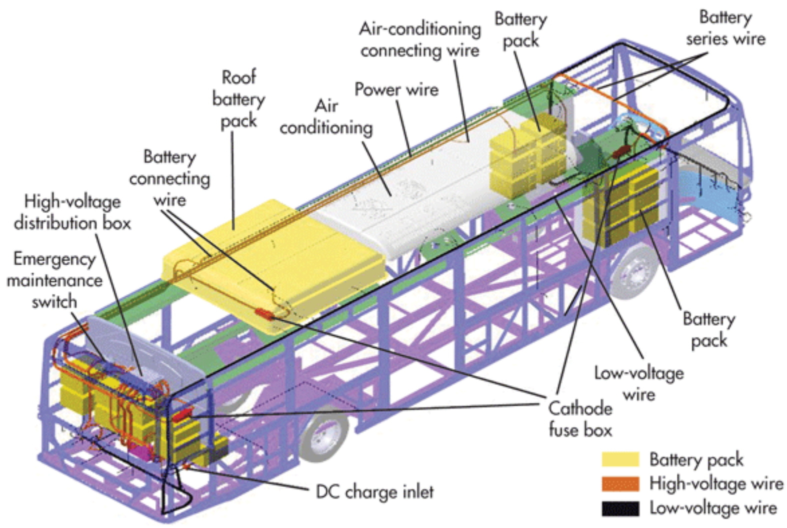

Figure 16 BYD K9 Electric Bus Diagram

BYD also has a 60ft (18m) BEB model called the K11. This model first entered service with the Antelope Valley Transit Agency (AVTA) in 2017. The K11 has a battery capacity of 578 kWh and AC synchronous (TYC-180A) dual in-wheel traction motors each providing 180 kW power output and 1,500 Nm torque for a total of 360 kW (3,000 Nm).

The BYD K11 measures 60.7 ft. (18.5m) long by 101.6 in (2.6m) wide and has a maximum roof height of 134 in (3.4m). This BEB can accommodate up to 55 seated and 55 standee passengers for a total up to 102 people on-board.

Charging options:

The BYD plug-in charge system is unique as it is AC power with the power AC to DC inverter installed on-board the BEB. BYD has dual plug-in connectors according to the Guobiao Standard (GB-T) standard used primarily in China with each charger providing 40kW for a total of 80kW plug-in power. This AC charger also enables vehicle-to-grid power transfer.

BYD recently introduced the ability to use a wireless inductive charging system, making it the first BEB OEM in North America with this technology. This charging system being tested in Wenatchee, Washington[15], on the Red BRT Line of Indianapolis and has yet to enter mass production.

PROTERRA

Founded in 2004, Proterra has been an exclusive manufacturer of BEBs since its inception. Proterra has collected over 2.5 million miles of service with their 35ft and 40ft BEB offerings since entering the market in 2008.

PROTERRA

[15] http://www.linktransit.com/news_detail_T2_R28.php.

Proterra's currently available BEB platform, the 40ft Catalyst model, comes in various battery configurations ranging from 79 kWh to 660 kWh. This provides transit agencies with the flexibility to choose on-route charging or endpoint depot charging strategies. The vehicles are 42.5 ft. (12.9 m) long and 102 in (2.6 m) wide with a roof height of 135.5 in (3.4 m). Proterra also manufactures their own drive trains. One option is the ProDrive with 200 kW power output while the DuoPower system uses dual in-wheel 190 kW motors for a total of 380 kW drive power.

The passenger capacity is 40 seated passengers and up to 38 standing passengers, for a potential maximum passenger capacity of 80 passengers. The Proterra Catalyst has the largest passenger capacity of all 40ft models. Proterra vehicles have been operating in various climates, with the first Catalyst being deployed into service in 2016. In 2017, Proterra set a new world record by driving 1,102 miles on a single charge, with a 660-kWh battery pack. This was the longest distance ever driven by an electric vehicle[16].

Proterra has developed its proprietary charging system for on-route charging of the vehicles, and has created a subsidiary branch called Proterra Energy Fleet Solutions to support the integration of Proterra BEB and chargers in fleets. Figure 17 shows a Proterra 40ft Catalyst schematic of major subsystems and components. Proterra has recently introduced a modular battery pack option with the objective to enable future battery pack upgrades for additional kWh capacity.

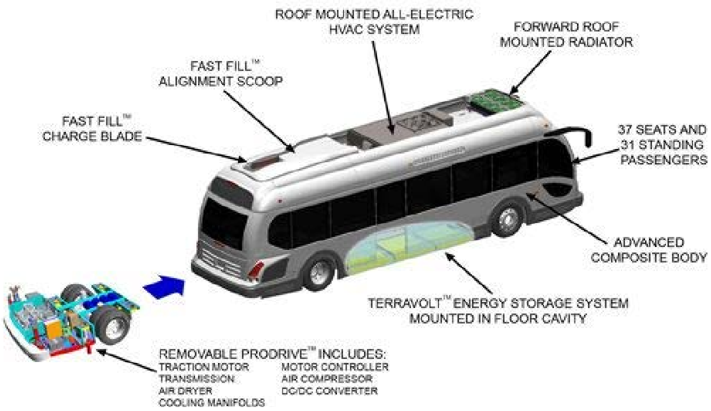

Figure 17 Proterra 40ft Catalyst electric bus schematic

Charging options:

Two charging options are available to recharge the Proterra buses: the plug-in charger uses CCS Type 1 connection that follows the SAE Standard SAE J1772. The overhead fast charging system follows the SAE J3105-1 standard.

[16] https://www.proterra.com/press-release/proterra-catalyst-e2-max-sets-world-record-and-drives-1101-2-miles-on-a-single-charge/

GREENPOWER

GreenPower Bus is a Canadian company based in Vancouver, BC offering electric buses to the North American market. Founded in 2011, the company presented their first vehicle, a 40ft low floor transit bus in 2014. Ever since, they have expanded their product line offerings which includes 30ft to 45ft all-electric transit buses, 45ft double-decker bus, school buses, and shuttle buses.

The GreenPower 40ft BEB model EV350 has a battery capacity of 430 kWh and a stated nominal operating range up to 320 km. GreenPower uses Siemens ELFA dual in-wheel motors each providing 85 kW for a total power output of 170 kW.

The vehicle is 40ft (12.2m) long by 102 in (2.6m) wide with a roof height of 126 in (3.2m). The bus has capacity for 40 seated plus additional standing passengers.

GreenPower has recently started construction of its manufacturing facility in Porterville, CA. The GreenPower EV350 has yet to complete the Altoona Test program which is standard in North America for validating transit buses to a 12-year lifecycle.

Charging options:

GreenPower follows the SAE J1772[17] standard for plug-in charging.

INDUSTRY TRENDS

There are a large number of BEB pilots and fleet procurements on-going across North America and worldwide backed by Federal government incentives to help lower the GHG emissions of public transit. This section provides and overview of the electric bus programs in various parts of Canada.

STM and STL, Quebec

The Société de Transport de Montreal (STM) and Société de Transport de Laval (STL) awarded contracts for electric buses at $43.2 million CAD in 2018 with New Flyer set to deliver 40 of their electric Xcelsior (XE40) buses by end of 2021. From the contract 30 buses will operate on the STM transit network out of their Stinson bus garage and 10 buses will operate for the STL. STM is one of the first transit agencies in Canada to install indoor pantograph chargers. Currently, the STM has three Nova LFSe buses that run along route 36 with on-route charging. The STM is committed to only purchasing electric buses by 2025 while the STL is committed to a slightly later date of 2030[18].

Figure 18 Nova LFSe On-route Charging STM

TransLink, British Columbia

In the west, TransLink in Vancouver, BC is just starting a 2.5-year electric bus pilot program led by the Canadian Urban Transit Research and Innovation Consortium (CUTRIC). TransLink has been piloting since late 2019, two Nova LFSe buses and two New Flyer XE40 buses along their Route 100 between the 22nd street station and Marpole Loop[19].

[17] https://www.greenpowerbus.com/about-us/
[18] https://www.cbc.ca/news/canada/montreal/stm-stl-montreal-laval-electric-bus-purchase-1.4792790
[19] https://www.translink.ca/About-Us/Media/2018/April/TransLink-launches-new-electric-bus-trial.aspx

Overhead catenary charging stations have been installed at both ends of Route 100. TransLink previously tested a BYD K9 40ft electric bus for three months from June to August 2017[20]. Translink's new Low Carbon Fleet Strategy has a target of acquiring up to 635 BEBs to replace is fleet over the next 10 years.

Toronto Transit Commission (TTC), Ontario

The Toronto Transit Commission (TTC) operates a fleet of over 1,800 transit buses as the public transit service provider in the City of Toronto. In 2017, Toronto City Council approved the TransformTO Climate Action Plan to reduce greenhouse gas emissions (GHG) 80% by 2050. As part of the TTC's strategy to target a zero emissions fleet by 2040, the TTC plans to purchase only zero emission buses after 2025 and is currently in the process of procuring a fleet of 60 BEBs for the first stage of their BEB program. The TTC's procurement will be sourced from three major manufacturers present in North America: New Flyer, BYD and Proterra. The TTC is tapping into the Canadian federal government's Public Transit Infrastructure Fund (PTIF) for approximately 50% of the BEB acquisition cost.

The TTC hopes to leverage the lessons learned with its previous fleet of hybrid and trolley vehicles such as dealing with a large number of electrical system failures, high-voltage maintenance, electric motor repairs and a lack of replacement components through the vehicle's supply chain.

The TTC is installing plug-in chargers and the charging infrastructure at three (3) garages which will be able to support the charging of 25 BEBs. The TTC has noted that any future adoption of BEBs will require a detailed feasibility study to understand energy requirements, facility and infrastructure constraints as well as evaluating the need for on-route charging.

York Region Transit (YRT), Ontario

YRT has a goal to achieve a zero emissions fleet by 2051 and is currently part of the Canadian Urban Transit Research and Innovation Consortium (CUTRIC) lead Pan-Canadian Electric Bus Demonstration and Integration Trial. In 2019, York Region Council approved the $7.7 million purchase of an initial six electric buses for their fleet as part of the CUTRIC trial. In 2019, YRT also engaged WSP for a Facilities and Infrastructure Review to determine the feasibility and gap assessment for upgrading their current transit facilities in support of their BEB adoption plan.

YRT launched the start of their BEB operation in June 2020 with the deployment of two BEBs that will serve Route 55 Davis Drive and Route 44 Bristol in the Town of Newmarket, operating out of the TOK North garage at 18106 Yonge St. The remaining four BEBs are undergoing testing and final inspection and scheduled to enter service later in the year. The deployed BEBs are going to be 2 Nova LFSe (76 kWh) and 4 New Flyer Xcelsior XE40 (213 kWh), both models are suitable for rapid on-route charging.

Edmonton Transit Service (ETS), Alberta

The City of Edmonton is currently working towards a 50% reduction of its fleet emissions by the year 2030 with the ETS transit fleet playing a major role in achieving this target. ETS is currently in the midst of launching a fleet of 40 electric buses from Proterra as the first step in its electric bus program.

[20] https://www.translink.ca/About-Us/Media/2017/May/TransLink-showcases-electric-bus-trial.aspx

ETS has past experience with the piloting of demo/test electric buses. ETS carried out testing and analysis of BEBs during the winter of 2015 and 2016 to determine the operational feasibility of electric buses in Edmonton's winter conditions, customer and staff perceptions, environmental impacts, and financial impacts.

Figure 19 ETS Pilot BYD K9 Electric Bus

The pilot tested one New Flyer Xcelsior (XE40) with on-route charging and two BYD electric buses (K9) with plug-in depot charging. The ETS report on this pilot testing suggests a 15% to 25% reduction in range if electric heaters are used as opposed to diesel heater during the winter seasons. Positive customer and staff perceptions were observed, with 78% of customer survey respondents indicating they would "like ETS to purchase electric buses". Operators felt electric buses are ready to be placed in-service, and mechanics noted a longer trial is required to understand performance and requirements. Though the buses cannot be considered zero emission buses due to the use of diesel auxiliary heaters, they are relatively low emission buses compared to conventional propulsion buses.

Environmental impacts of the pilot project included current emission reduction of 38% to 44% less CO_2 equivalent. Projected emission reduction would be 72% to 74% less by 2034.

3.1.2.2 *BATTERY ELECTRIC REPOWER OPTION*

MTB Transit Solutions provide bus repair and refurbishment services for transit vehicles, as well as repower options for diesel buses. MTB offers a diesel to electric conversion or repower at the midlife for the diesel vehicles. As part of the repower, at the mid-life (8 -10 years), the bus is refurbished and its diesel components are removed (engine, transmission, steering, fuel tanks etc.). MTB then installs an electric powertrain (motor, electric steering, electric HVAC, battery packs etc.). MTB is in the process of converting their first bus from diesel to electric, and have a process that requires 6-months for the conversion.

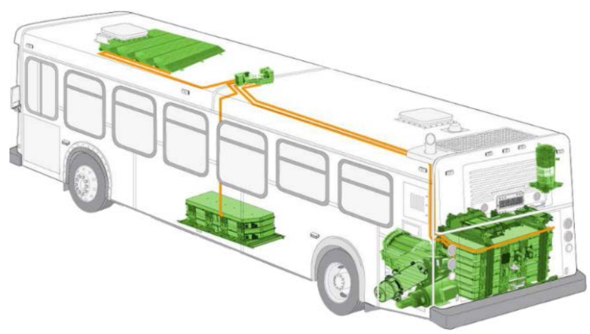

Figure 20 MTB Installation repower with electric powertrain

MTB expects the total costs for the repower to be in the vicinity of $500,000 to $600,000 per bus (with additional costs for the refurbishment of the bus body, and the buses would be expected to operate for an additional 10 years following the electrification process. The repowered bus powertrain are primarily Canadian content and will have a TM4 motor, an Electrovaya battery pack (300 kWh) and be compatible with SAE1772 plug-in charger (depot charging only available). Their will be a 10 year warranty on the battery and 2 years on the traction motor. MTB will also be exploring a battery leasing program for potential clients, allowing them to the repower vehicles at a lower capital cost of approximately 60% of total costs. MTB estimates the oldest age of the bus for conversion is 8-10 years to get economic payback.

In addition to 12 m electric bus conversion options, MTB will also be exploring a repower process for articulated buses and shuttle buses in the future. MTB estimates that they will be able to conduct 50-100 repower conversions per year by year 5 of their program. They are also currently in the process of conducting performance testing on the vehicles in collaboration with UOIT (University of Ontario Institute of Technology).

Repower options allow transit agencies to acquire electric buses at a lower capital costs than new electric buses, however they are not currently proven options from an economic perspective. In addition, as they are based on a repurposed diesel chassis, they also don't have the added benefit of the efficiencies in design of battery electric buses, and thereby would be expected to have higher energy consumption and lower range capabilities.

3.1.2.3 *SPECIALIZED AND ALTERNATIVE SIZED VEHICLE MARKET SCAN*

The vehicles and manufacturers outlined in this market scan may not be representative of the specialized vehicles that Barrie Transit has traditionally deployed or would be able to utilize given its operating environment (travel distances and frequency of use). This market is still under development are there aren't many traditional options/manufacturers available yet in the specialized marketplace.

LIONM

Founded in 2011, Lion Electric is a fully integrated Canadian BEB manufacturer based in Quebec. Lion designs and assembles their bus for a 10-year service life.

The LionM has an overall vehicle length of 26ft[2] and is classified into the integral body style BEB. It has capacity of up to 31 passengers with a total of 20 seated and a total GVWR of 22,500 lbs. The BEB is equipped with one front curbside bi-fold door which can have a fold out ramp and passenger seating can be planned for one wheelchair location.

The LionM has an electrical powertrain with a 160 kW (1,200 Nm) output traction motor and battery capacity up to 160 kWh. The OEM stated operating range is up to 240 km (150 miles). The BEB is charged with a 19.2 kW plug-in AC charger, compatible with SAE J1772 Level 2 and Level 3 Combined Charging System (CCS) standards. Level 2 charges the battery in 5 to 10 hours, while Level 3 can recharge the battery in approximately 2.5 hours. The LionM complies with CMVSS but has yet to complete the Altoona Test. Lion responded to Calgary Transit's 30ft low-floor shuttle RFI with this vehicle.

BYD K7M

The BYD K7M ER is an integral body style BEB and falls into the 30ft category with a vehicle length of 29.9[21] ft. This BEB has an electrical powertrain with a 266 kWh (lithium iron phosphate) battery and two in-wheel AC synchronous traction motors with 150 kW (550 Nm) power (torque) output. The OEM stated range is up to 298 km (185 miles). The BEB is compatible with 80 kW plug-in AC charging using BYD's standard charger.

The gross vehicle weight rating (GVWR) is 35,274 lbs with passenger capacity up to 20 seated passengers and configuration options for up to 2 wheelchair positions. The BEB has Canadian Motor Vehicle Safety Standards (CMVSS) certification and has completed the Altoona Test program. BYD also offers a 12 year battery arranty. BYD responded to Calgary Transit's 30ft low-floor shuttle RFI with this vehicle.

KARSAN JEST

Karsan is a Turkish bus manufacturer with a strong presence in Europe and entered the US market in 2015 with their diesel Jest minibus. The North American division of Karsan is Morgan Olson. The electric Karsan Jest is an integral body style BEB with an overall vehicle length of 19ft[1] (5.8m). The BEB powertrain is supplied by BMW and has a 135 kW (290 Nm) traction motor and 88 kWh battery pack with an OEM stated range up to 210 km. The BEB is compatible with 22kW plug-in AC or up to 80kW DC charging.

The Jest has a maximum passenger capacity of 25 riders with 10 fixed seats and 2 foldable seats which permit space for a mobility aid wheelchair position. The Jest has a single bi-fold door located in the middle of the vehicle which can be equipped with a fold out ramp. The vehicle has CMVSS certification but has not completed the Altoona Test. Karsan (Morgan Olson) responded to Calgary Transit's 30ft low-floor shuttle RFI with this vehicle.

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[21] Vehicle lengths are indicated approximately, with measurement points unspecified

KARSAN ATAK

Karsan also has an electric model of their diesel Atak bus platform. This is a larger integral style BEB with an overall vehicle length at 26.9ft[22] thereby increasing the passenger capacity up to 52 riders. The BEB has front and rear bi-fold doors offering rear low-floor entry which can be equipped with a fold out ramp.

The electrical powertrain is supplied by BMW. It features a TM4 230 traction motor with 230 kW (2,400 Nm) output and five 44 kWh battery packs for a total of 220 kWh. The OEM stated range is approximately 300 km. The BEB is compatible with 22kW plug-in AC or up to 80kW DC charging. The vehicle has CMVSS certification but has not completed the Altoona Test.

GREENPOWER EV250

GreenPower is a Canadian BEB manufacturer, headquartered in Vancouver, BC and with a manufacturing facility in Porterville, California. GreenPower has a 30ft[2] integral body style BEB called the EV250. The EV250 can accommodate 25 seated passengers and has the option for 1 or 2 curbside bi-fold doors.

The EV250 has a 210 kWh battery pack offering an OEM stated range up to 280km. The electrical powertrain includes two Siemens ELFA traction motors, each providing a 65 kW output power. The BEB can be configured with either Level 2 AC or Level 3 DC plug-in charging in accordance with SAE J1772, up to 100kW. The BEB complies with CMVSS but has yet to complete the Altoona Test.

GRANDE WEST VICINITY LIGHTNING

Grande West is a Canadian bus manufacturer based in British Columbia. In November 2020, the Vicinity Lightning BEB was announced. This 28ft BEB has capacity for up to 37 passengers, a listed curb weight at 16,000 lbs and GVWR of 22,000 lbs. The electrical powertrain is comprised of a Brusa 220 kW traction motor and a lithium-ion battery pack manufactured by BMW. The 168 kWh battery pack is stated to provide an operating range of up to 200 km. There is also an option to expand the battery capacity to attain an OEM stated 300 km range. The BEB is compliant with SAE J1772 AC and DC charging standards for Level 1 through 3 charging. The Vicinity Lightning will comply with CMVSS.

GREENPOWER EV STAR

GreenPower also has an EV Star model vehicle which is 25ft[23] in length and built as an integral van body style. The EV Star can accommodate up to 25 passengers and has the option for ADA wheelchair location on-board. It has a front sliding door with low single step entry.

The EV Star has a 118 kWh battery with an OEM stated range of 240km. The vehicle is driven by a Dana TM4 traction motor and can be charged with SAE J1772 Level 2 or CCS Level 1 plug-in charger. The vehicle complies with CMVSS but has yet to complete the Altoona Test.

OPTIMAL EV

Optimal is an US based manufacturer of vans and "built-on-chassis" cutaway style shuttle buses. The Optimal EV, currently under development, is built on a Ford E450 chassis with an electrical powertrain supplied by Proterra. The vehicle is undergoing a prototype build, scheduled for completion by the end of 2020. The follow-on activity is for Altoona Test completion and sales to start by Q3 of 2021. The Altoona Test will certify for a 5 year (150,000 mile) service life.

[22] Vehicle lengths are indicated approximately, with measurement points unspecified
[23] Vehicle lengths are indicated approximately, with measurement points unspecified

The overall vehicle length is 26.5ft[3]. The passenger capacity ranges from 22 seated passengers with one wheelchair location or to 12 seats with maximum of three wheelchair locations. The BEB will have a front curbside bi-fold door, entry step (11in step-in height) and can be equipped with a fold out ramp. The GVWR is stated at 14,500 lbs.

The electrical powertrain will be built with a 113 kWh battery pack with a maximum OEM stated operating range up to 200km (125 miles) under optimal conditions. The peak output from the traction motor is specified at 280 kW (1,700 Nm). The BEB can be charged with SAE J1772 standard plug-in Level 1 or Level 2 AC with an on-board 13.2 kW charger or with a Proterra Level 3 DC fast charger up to 60 kW.

URBAN MOBILITY SYSTEMS

Founded in 2016, Urban Mobility Systems is an electric vehicle manufacturer headquartered in the Netherlands and has expanded into North America. One of their vehicles in development is the Mission low-floor BEB. This vehicle has limited specifications available but is stated to have a maximum seating capacity for 16 passengers and its low-floor entry enables the vehicle to be configured with a ramp and wheelchair location. The vehicle body construction is a monocoque composite material.

Due to the state of development on this model it is unlikely it will be an available option for the Calgary Transit pilot but could be of interest to track its development for future fleet procurements.

ARBOC SPIRIT OF EQUESS EV

ARBOC is a subsidiary of New Flyer Industries and is a transit industry leader in 30ft cutaway, body on chassis style shuttle vehicles. ARBOC has released information on their development of a 30ft[4] low-floor shuttle bus scheduled to start production in Q2 of 2021. The vehicle is called the Spirit of Equess EV and will be equipped with a XALT battery pack with capacity of approximately 350 kWh and powered with a Siemens ELFA 3 direct drive traction motor. The vehicle is to be compatible with plug-in SAE J1772 DC Type 1 charging and have a range of up to 320 km (200 miles). Further details are limited at this time, including passenger capacity and vehicle dimensions.

3.1.3 TRAINING AND TOOLING REQUIREMENTS

Typically, bus OEMs provide training to their clients as part of the bus purchase price along with including all related operating and maintenance manuals. Training requirements can be specified in the RFP procurement process and contract negotiations. If additional training is necessary, it can be provided through a third party institution. Further, adoption of BEBs will require the installation of a customer-owned substation to meet the required power demands, and this will create additional requirements for maintenance and training.

Maintenance training shall focus primarily on the electrical systems of the bus, as most non-electrical components are similar to those on a diesel bus. While the amount of necessary training will depend on the particular bus 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 buses. 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 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.

Lastly, training should be provided for emergency responders and utility workers such that in the event of an accident involving an electric bus these personnel are aware of the potential high voltage and chemical hazards associated with electrical buses. They should have mitigation strategies and a safe response procedure in place. OEMs including Proterra have been working with the National Fire Protection Association (NFPA) to provide safety plans on how to respond to incidents involving their BEBs.

Maintenance of electrical buses can require specialized tools in order to service the more complex and high voltage electrical systems not present on a diesel bus. 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.
- Battery pack and inverter lifting jigs for maintenance work of rooftop batteries.
- Gantry platforms/ movable scaffold platforms for roof access, along with required fall arrest and protection equipment for maintenance workers working on the roofs of the electric buses.

Furthermore, PPE is a requirement for technicians working on electric vehicles. The American Society for Testing and Materials (ASTM) has published PPE usage specifications 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 BEBs are further described 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 CAD.
- **Mobile Gantry Platforms:** are used with fall arrest PPE as a secure standing platform for maintenance technicians to have rooftop access and perform maintenance on battery packs and other components mounted on in the BEB roof structure. For example, the New Flyer Xcelsior BEB has roof mounted batteries, power electronics and battery cooling system, refer to Figure 22.
- **Static-Free Tools:** Electro Static 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 (i.e. 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 safely working on electrical components.

Figure 21 Gantry Platform for BEB Rooftop Maintenance/Access

- **Specialized BEB Tools:** Any OEM specific tools required to service and maintain the BEB (i.e. for the traction motor or battery pack installation/removal) can be specified and included as part of the procurement process.

For an estimate, an itemized list of some of the major tooling needs has been summarized in Table 6 for reference.

Table 6 Specialized Tooling & Upgrades Cost Estimates

Item Description	Est. Unit Cost ($)
Fluke Multimeter - CAT 111 c/w Test Leads	$ 835
Wiha Insulated Master Electrician's Tool Kit	$ 3,760
Wiha 1/4 in ratchet set insulated SAE	$ 506
Wiha 1/4 in ratchet set insulated Metric	$ 510
wiha open end wrench insulated metric	$ 572
wiha open end wrench insulated sae	$ 574
Wiha insulated Serrated Tweezers Straight	$ 61
Wiha insulated Serrated Tweezers Angled	$ 86
Insulated Torque Wrench 1/4"	$ 612
Insulated Torque Wrench 3/8"	$ 683
Insulated Torque Wrench 1/2"	$ 737
Torque screwdriver set	$ 418
Insulated crimper 30 - 6 Awg 7"	$ 62
Insulated hex key set 10pc metric	$ 333
Long SAE Natural insulated hex key set 12 pc	$ 295
Wiha Insulated "bitFlip" Set	$ 126
Phase tester	$ 206
Pulse width meter	$ 492
Fluke meter	$ 364
Modular test lead kit	$ 166
Test probe flat blade	$ 20
Test probe back probe	$ 20
Total PPE Cost (Set per Person):	**$ 11,440**

3.2 DIESEL HYBRID

3.2.1 TECHNOLOGY FUNCTIONAL OVERVIEW

A diesel-hybrid operates on a dual electrical/mechanical powertrain system, thereby essentially combining the powertrain concept from an electric vehicle and with the conventional diesel powertrain. The main components of the hybrid drive system are illustrated in Figure 23 as a Series Hybrid configuration[24]. The functionality of each major component is described in the following.

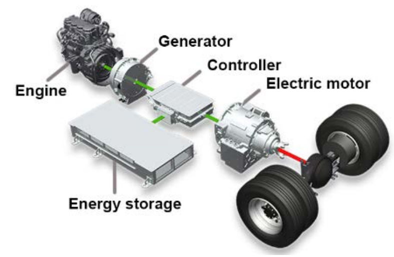

Figure 22 BAE Systems Hybrid Drive Schematic

Functionality Overview:

- Diesel fuel stored in the on-board fuel tank is pressurized in the fuel system and injected into the combustion chamber of the engine.
- Auto-ignition of the diesel fuel produces a combustion release of chemical energy which is transferred into mechanical rotational kinetic energy through the engine pistons and outputted through the engine crankshaft.

[24] http://www.hybridrive.com/series-e.php

- The crankshaft is connected to an electrical generator which converts this mechanical energy into electrical energy and power which can be either transferred to the electric motor thereby driving the axle/wheels or stored in the on-board battery.
- A power electronics controller regulates energy storage and power distribution between the battery, engine and electric motor.
- An electric motor powered by the on-board battery and/or the diesel engine output through the generator is used to power the drive axle/wheels. The electric motor is also capable of being driven in reverse under braking conditions to convert the kinetic energy of the bus into electric energy which can be stored in the vehicle battery. This also aids vehicle braking system and can reduce wear on the conventional caliper brake pads.
- The energy storage system (ESS) or battery is used to store excess energy during regenerative braking and assist vehicle acceleration/deceleration. This battery is comparably smaller than a battery electric bus as its main purpose is to assist the diesel engine output and partially recapture energy during braking. It does not serve as the primary power supply and is only used in an assistive function. However, some hybrids do have an EV functionality mode that the bus can enter and drive exclusively on the battery, although only for limited distances (i.e. less than 5km)[25].

In general, hybrid buses are costlier to maintain due to the operation of both mechanical and electrical powertrain components. There are also additional overhaul costs to consider for a hybrid bus regarding battery replacement, traction motor rebuilds and the power electronics module.

3.2.2 INDUSTRY TRENDS

Diesel-hybrid bus technology has greatly progressed from the 1st generation hybrids notably in the area of battery technology. Early adopters such as the Toronto Transit Commission (TTC) experienced difficulties managing their fleet of Orion VII hybrids which entered service in 2006. Lead-acid battery cells used in the hybrid powertrain system were subject to quick deterioration and required early replacement. Furthermore, the expected fuel savings were not realized in part to the TTC operating the diesel-hybrid buses on high speed routes which did not capitalize on the electric powertrain functionality and regenerative braking as much as stop-start high traffic routes[26].

Battery technology is now improved with lithium-ion cells comparable to those used in fully battery electric buses. However, the need to maintain a dual mechanical/electrical powertrain leads to higher maintenance costs in comparison to an equivalent diesel bus and does offset savings from an improved fuel economy. WSP's historical fleet data collected over the years hybrid buses are on average 11% more expensive than diesel buses to maintain on a per km basis. In addition, the capital purchase cost for a diesel-hybrid bus can have up to 60% premium when compared to a diesel bus[27].

Despite early setbacks with hybrid technology several large transit agencies continue to expand their hybrid bus fleets in order to help reduce GHG emissions. The Association du Transport Urbain du Quebec (ATUQ) awarded a 5-year contract in June of 2018 to Nova Bus from 2020 to 2024 for the delivery of 497 hybrid 40ft LFS HEV buses[28]. The STM is obtaining 830 new hybrid buses as part of the city's plan. Since November 2019, STM has received 32 of the 300 hybrid buses ordered and have put them into services.

[25] BAE Systems
[26] https://www.theglobeandmail.com/news/national/ttc-hybrid-bus-batteries-losing-their-power/article672622/
[27] TransLink Diesel vs. Diesel-Hybrid purchase price comparison
[28] https://thedevelopcorp.com/nova-bus-awarded-largest-north-american-order-companys-history/

STM is expecting to receive an average of 30 additional hybrid vehicles per month[29]. In total, currently, there are 477 hybrid buses in operations for STM which constitutes 25.5% of their bus fleet, and plans to be diesel bus free by 2029[30]. STM has also expressed concerns on the performance of these hybrid buses that consumed, on average, 47.5 l/100 km which only showed a 11.2% savings compared to their diesel fleet[31].

Diesel-hybrids offer a way for transit agencies to reduce between 10-30% of their GHG emissions without assuming some of the risks associated with operating fully battery electric buses (i.e. range anxiety, infrastructure and charging requirements). However, the emissions savings are minimal compared to battery electric buses. Some of the key drawbacks of the technology are that the vehicle purchase cost can range from $150,000 up to $300,000 premium compared to diesel buses, making them more expensive than CNG buses. In addition, hybrid buses come at a higher cost premium for fleet maintenance, and the powertrain is less efficient than diesel buses at operating speeds greater than 12km/hr. For these reasons, the hybrid technology was excluded from Barrie Transit's long-term fleet conversion, as it is seen as a transitional technology that would be replaced as CNG, electric vehicles or hydrogen vehicles are integrated into the fleet.

3.2.3 MARKET OVERVIEW

In Canada there are currently two (2) OEMs with diesel-hybrid buses available in the marketplace. Nova Bus based in Montreal, QC offers their LFS transit bus in both 40ft and 60ft options. New Flyer in Winnipeg, MB also offers their 40ft and 60ft Xcelsior bus in hybrid models.

3.2.3.1 NOVA BUS

Nova Bus is a Canadian subsidiary of the Volvo Group which has supplied diesel, CNG, hybrid, and battery electric buses to the North American market for nearly 40 years. Based in Montreal, QC, Nova Bus has the engineering support of Volvo Group.

The 40ft LFS HEV is the hybrid version of the Nova Bus LFS and is powered by either Cummins L9 330 or Cummins B6.7 280 hp engine with either an Allison H 40 EP or BAE HDS200 hybrid drive system. The LFS HEV has a stainless-steel body structure. The bus can accommodate up to 41 seated passengers with a total passenger capacity of 80 people. The newest generation of the LFS HEV does not yet have a published Altoona Test report.

The LFS HEV Artic 60ft bus has an increased passenger capacity up to 62 seated and 112 total passengers. The LFS HEV Artic runs on a Cummins L9 330 hp diesel engine with either an Allison H EP 50 or BAE HDS300 hybrid drive system. The body structure is also stainless-steel and has achieved Altoona Test certification. The 60ft LFS HEV demonstrated an average fuel economy of 0.60 L/km (3.95 mpg) under the Altoona Test program completed in 2017. The bus configuration tested included one on-board wheelchair location and a fold-out ramp design located at the front door.

Transit agencies in Canada currently operating hybrid Nova Bus LFS HEVs include MiWay, Grand River Transit, the Société de Transport de Montreal (STM), the TTC and the Coast Mountain Bus Company (CMBC) in Vancouver, BC, and more.

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[29] https://www.masstransitmag.com/bus/vehicles/hybrid-hydrogen-electric-vehicles/article/21121147/first-wave-of-new-hybrid-buses-already-serving-stm-riders
[30] http://www.stm.info/en/about/major_projects/major-bus-projects/bus-network-electrification/hybrid-buses
[31] https://montrealgazette.com/news/local-news/fuel-savings-of-stms-hybrid-buses-less-than-half-what-was-promised-documents-show

3.2.3.2 *NEW FLYER*

New Flyer is a Canadian bus manufacturer based in Winnipeg, MB, which has a long history supplying vehicles for the diesel, compressed natural gas (CNG), hybrid, trolley, and battery electric bus markets in North America. New Flyer also offers fuel-cell electric buses. Currently, all of New Flyer's alternative propulsion options are built on their Xcelsior base model.

The diesel-hybrid version of the Xcelsior comes in 35ft, 40ft and 60ft models both the 40ft and 60ft have Altoona Test certifications. The Xcelsior hybrid is powered by a Cummins B6.7 hp engine for the 35ft and 40 ft., and Cummins L9 for the 60ft bus. The hybrid model comes with the option for Allison, Voith or ZF transmission options. The hybrid drive system is supplied by either Allison or BAE systems.

The hybrid Xcelsior 35ft (XDE35) has a curb weight of 27,000 lb (12,247 kg) with a passenger capacity of 32 seated and up to 33 standees with up to two on-board wheelchair locations and flip out ramp design.

The hybrid Xcelsior 40ft (XDE40) has a curb weight of 29,100 lb (13,200 kg) with a passenger capacity of 40 seated and up to 43 standees with up to two on-board wheelchair locations and flip out ramp design. Altoona Test results demonstrated a fuel economy of 0.40 L/km (5.84 mpg) for comparative purposes, actual in-service fuel economy is highly dependent on passenger load, route topography and start/stop conditions.

The hybrid Xcelsior 60ft (XDE60) has a passenger capacity of 61 seated and up to 62 standees for a total capacity of 123 passengers. The XDE60 can be outfitted with up to three (3) wheelchair locations and has flip out ramps deployable from the front and boarding doors. The curb weight of the bus is approximately 42,000 lb (19,096 kg). The Altoona Test fuel economy is published at an average of 0.58 L/km (4.09 mpg) which is an approximate 30% drop in efficiency from the XDE40 due to vehicle size and weight. The fuel economy is also comparable to the Nova LFS HEV 60ft at 0.60 L/km (3.95 mpg).

Currently, Canadian transit agencies with the XDE40 in service include Brampton Transit, Lethbridge Transit, London Transit Commission and Windsor Transit. Brampton Transit was the first to launch the XDE60 as part of their Zum Bus Rapid Transit (BRT) service in 2012. While the CMBC has operated XDE60 for TransLink in Vancouver, BC since November 2012. In 2020, MiWay also started the operation for an XDE 60.

3.2.4 TRAINING & TOOLING REQUIREMENTS

Typically, bus OEMs provide training to their clients as part of the bus purchase price along with including all related operating and maintenance manuals. Training requirements can be specified in the RFP 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 bus, as most non-electrical components are similar to those on a diesel bus. While the amount of necessary training will depend on the particular bus and OEM it should cover the basics of working with electric propulsion (traction motors), inverters and batteries. 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 diesel-hybrid and diesel buses. In addition, similar standardized operating procedures and training need to be developed for charging infrastructure 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 diesel vs. 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 a hybrid bus these personnel are aware of the potential high voltage and chemical hazards associated with hybrid buses. They should have mitigation strategies and a safe response procedure in place.

The tooling requirements for hybrid buses is similar to diesel vehicles, with some additional requirement of static-free tools for working with the electrified components.

3.3 NATURAL GAS (CNG/ RNG)

3.3.1 TECHNOLOGY FUNCTIONAL OVERVIEW

Compressed natural gas (CNG) vehicles operate in a similar manner to gasoline vehicles with a spark ignition system and internal combustion engine (ICE). However, the main difference is the pressurized fuel system and storage tanks in which the natural gas fuel is stored on-board the vehicle.

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 below Table 7 for the main components in a CNG vehicle powertrain.

Figure 23 TransLink New Flyer 40ft CNG (XN40)

Functionality Overview:

Table 7 CNG Powertrain 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 interior functioning of 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	Power 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

CNG tanks are refueled through a TN1 or TN5 fill type nozzle engaging with the receptacle on the vehicle's fuel tank. Refueling times are comparable to that of a diesel transit bus. Most often the CNG storage tanks are located on the bus rooftop in order to maximize interior space for passengers as well as serving as a strategic mounting location in the event of a fuel leak. As natural gas is lighter than air it will rise and quickly dissipate in a well-ventilated area, thereby mitigating the fire risk of pooled combustible gas.

3.3.1.1 *SOURCE OF NATURAL GAS*

As a subset of natural gas technology, the fuel supply can be classified in a couple categories namely liquified natural gas (LNG) and renewable natural gas (RNG) with CNG used as a broader term to describe the propulsion class.

Liquified Natural Gas (LNG)

The main difference between CNG and LNG is the compression ratio. CNG vehicles store the natural gas in a gaseous state in on-board pressurized tanks usually with an internal tank temperature around -160ºC. With LNG technology the natural gas fuel is further compressed and cooled into a liquified state, this requires the used of higher pressure rated tanks as well as specialized personal protective equipment (PPE) including safety goggles, face shields, cryogenic rated gloves and personal gas detectors[32]. As LNG reverts back to a gaseous state after release from its pressurized storage tank there is a handling risk of cryogenic burns due to the cold gas contacting exposed skin. Furthermore, the vapor is highly flammable and can pose a fire hazard if not handled in a well-ventilated area. The main advantage of LNG over regular CNG is the energy density of the fuel, as in a liquified state a higher energy content can be stored in the fuel tanks.

Figure 24 Cryogenic LNG Refueling Process

Refueling with CNG is comparable to diesel or gasoline as in it does not require any specialized PPE. CNG is also more readily available, has lower storage and station costs than LNG. As a result, public transit fleets and OEMs prefer to run CNG for their transit buses.

Renewable Natural Gas (RNG)

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 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. In contrast, RNG offers a carbon-neutral GHG gas emissions impact by recycling and repurposing gas which would have been emitted into the atmosphere. Figure 26 illustrates the high-level process of producing RNG[33].

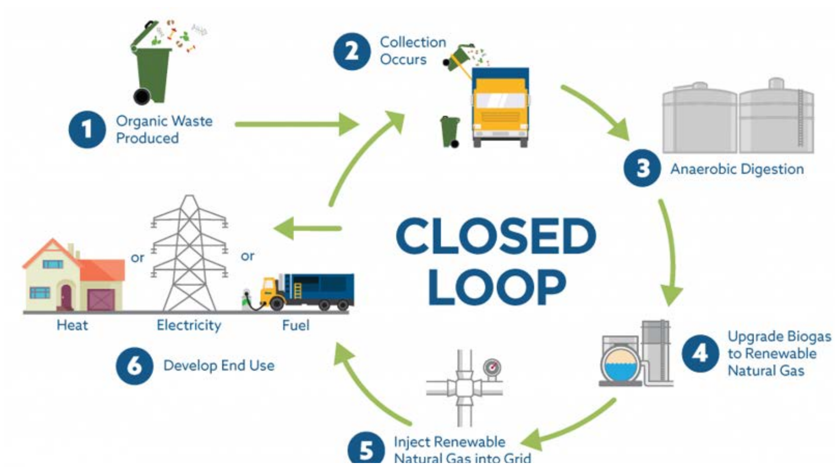

Figure 25 RNG Production Process

[32] https://envoyenergy.ca/2018/07/03/cng-vs-lng/

[33] https://www.toronto.ca/services-payments/recycling-organics-garbage/renewable-natural-gas/

3.3.2 MARKET OVERVIEW

In Canada, there are four OEMs that have CNG buses available for purchase and are currently in operation. Three of these OEMs are Canadian (New Flyer, Nova Bus and Grande West) while El Dorado National is an American based bus manufacturer. This section provides details on the CNG bus models provided by each of these OEMs.

3.3.2.1 NEW FLYER

The 40ft Xcelsior CNG bus (XN40) has been in operation since 2012 and has completed Altoona testing when it entered service for the Centre Area Transportation Authority in Pennsylvania. It has since been adopted into Canadian fleets mostly in the west regions, including Coast Mountain Bus Company in Vancouver, BC, Kamloops Transit System and by Calgary Transit. The XN40 has a Cummins L9N 280 hp engine and roof mounted CNG fuel tanks (26,400 SCF, 8 Type 4 Natural Gas Vehicle Fuel Cylinder with 3300 SCF at 3600 psi service pressure). The bus width is 8.5ft (2.6m) and height 11.1ft (3.4m). Passenger capacity totals 83 (40 seated plus 43 standees).

The Xcelsior 35ft (XN35) is a slight variant of the XN40 however with shorter length, its passenger capacity is reduced to a total of 65 (32 seated plus 33 standees). Both the XN35 and XN40 provide an accessibility ramp for wheelchair access at the front door of the bus.

The 60ft Xcelsior CNG (XN60) is an articulated bus that first entered service in 2012 for Omnitrans in California. It has since been acquired by many fleets across North American including the Hamilton Street Railway transit service in Hamilton, ON. The XN60 runs on a Cummins L9N 320 hp engine and has roof mounted fuel tanks (26,400 SCF, 8 Type 4 Natural Gas Vehicle Fuel Cylinder with 3300 SCF at 3600 psi service pressure) maximizing interior passenger accommodation. Exterior dimensions are 8.5ft (2.6m) width, 11.1ft (3.4m) height and 60ft (18.3m) length. The XN60 can transport up to 123 passengers (61 seated + 62 standees) and has front door wheelchair ramp access.

3.3.2.2 NOVA BUS

The Nova LFS 40ft CNG was first brought into operation in 2013 and has since completed Altoona testing in 2014. Current operation continues for Calgary Transit as well as in Hamilton, ON and Red Deer Transit, AB.

The bus measures 8.4ft (2.6m) wide and 11.2ft (3.42m) in height. The drivetrain consists of a Cummins L9 250 or 280 hp engine with multiple options for transmission (Allison B400R, Voith D864.6 or ZF 6AP1400B). Fuel tanks are roof mounted having a capacity of 18,765 scf and are under a 20-year warranty.

Passenger capacity is listed at a total of 75 passengers (41 seated + 34 standees). It is equipped with front door wheelchair ramp access.

3.3.2.3 GRANDE WEST

Grande West is a Canadian bus manufacturer founded in 2008 and is headquartered in Aldergrove, BC. Grande West manufactures mid-sized transit buses and their flagship model, the Vicinity, is available with CNG powertrain in 30ft and 35ft options. Grande West has completed Altoona testing for a diesel-powered 30ft Vicinity in 2016, yet to complete testing for a CNG option.

The Vicinity CNG bus measures 8.2ft (2.5m) wide, 9.8ft (3m) in height and length is dependent on the model chosen for service (27.5ft, 30ft or 35ft). It runs on a Cummins Westport B6.7N 220 hp engine with Voith or ZF transmission available and has CNG fuel tanks roof mounted to optimize interior vehicle space.

Passenger capacity ranges from 24 seated, 18 standees for the 30ft bus and up to 31 seated, 18 standees for the larger 35ft bus. All models come equipped with a front door access flip-out wheelchair ramp. In 2016, Grande West signed a contract with BC Transit that had the option for CNG powered buses.

3.3.2.4 *ELDORADO NATIONAL*

ElDorado National is an American bus manufacturer with operations in California and Kansas. ElDorado is a subsidiary of the REV Group and produces buses for public transit and airport shuttles. Currently, ElDorado has a number of their CNG powered buses operating in fleets across Canada in Brandon Transit, Brantford Transit, and York Region Transit. Their three models with CNG options are the National Axess, E-Z Rider II and the XHF. All CNG models run a Cummins Westport ISL-G 280 hp engine and have a multitude of transmission options available (Allison, Voith or ZF).

The National Axess is available in 35ft or 40ft models, and measures 8.5ft (2.6m) in width and 11.25ft (3.4m) in height. Passenger capacity for 35ft model can seat up to 35 and the 40ft model can seat up to 43, depending on configuration of the floor plan. Several different seating configurations are available and wheelchair access is provided with a front door ramp.

The E-Z Rider II comes in 30ft, 32ft or 35ft configurations. Exterior dimensions for width are 8.5ft (2.6m) and overall height (including roof mounted CNG tanks) at 11.5ft (3.5m). Altoona testing was completed for the 30ft and 32ft models and all have been in operation since 2005. Passenger capacity for 30ft model can seat up to 30 and the 32ft model can seat up to 33, and the 35ft model can seat up to 41, depending on configuration of the floor plan. Several seating plans are available all accommodating at least one wheelchair position with ramp access at front and/or rear doors.

The XHF has 29ft, 33ft, 35ft and 40ft variants with Altoona testing complete for the 33ft XHF model as of 2003. The XHF is compact measuring 8ft (2.4m) in width and 11.4ft (3.5m) in height. CNG tanks are roof mounted to free up interior space for passenger seating. Passenger capacity for 29ft model can seat up to 29 and the 33ft model can seat up to 39, the 35ft model can seat up to 39, and the 40ft model can seat up to 47 depending on configuration of the floor plan. A front platform lift is also provided for accessibility devices.

3.3.3 *TRAINING AND TOOLING REQUIREMENTS*

Bus OEMs producing CNG models commonly provide standard training, operating and maintenance manuals with the purchase of their buses. For a CNG bus, the majority of the vehicle maintenance activities will be similar to that of a diesel bus. 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 of a bus. Furthermore, workers should be aware and service CNG buses 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 $135, 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.

Maintenance technicians servicing the pressurized gas components onboard the buses will require an appropriate gas fitters' certification.

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

- Gantry platforms/ movable scaffold platforms for roof access, along with required fall arrest and protection equipment for maintenance workers working on CNG tanks commonly roof mounted on vehicles
- Gas leak detectors (e.g.; the Honeywell RAE series) worn by maintenance workers to monitor any gas leakage that could become a safety concern to workers and potential fire hazard. These units may range in price from $400 to $800.
- Tools for the removal and inspection of CNG tanks (gas extractor, torque wrenches and tensioner straps).

3.4 HYDROGEN FUEL CELL

3.4.1 TECHNOLOGY FUNCTIONAL OVERVIEW

Hydrogen fuel cell technology has been in use on city transit buses since the early 2000's. Early adopters include Daimler having piloted three (3) fuel cell electric buses (FCEBs) in Beijing, China in 2006[34]. Elsewhere, the Alameda-Contra Costa Transit District (AC Transit) operating in the Oakland, CA bay area and Sunline Transit in Palm Springs, CA began piloting FCEBs as early as 2004 from manufacturers Gillig and Van Hool. The technology and reliability on FCEBs have improved from those first buses tested. However, operating cost and infrastructure requirements still tend to be a concern. Illustrated in Figure 27 are the main powertrain components of a FCEB currently provided in the New Flyer Xcelsior bus[35]. A functionality overview is listed below:

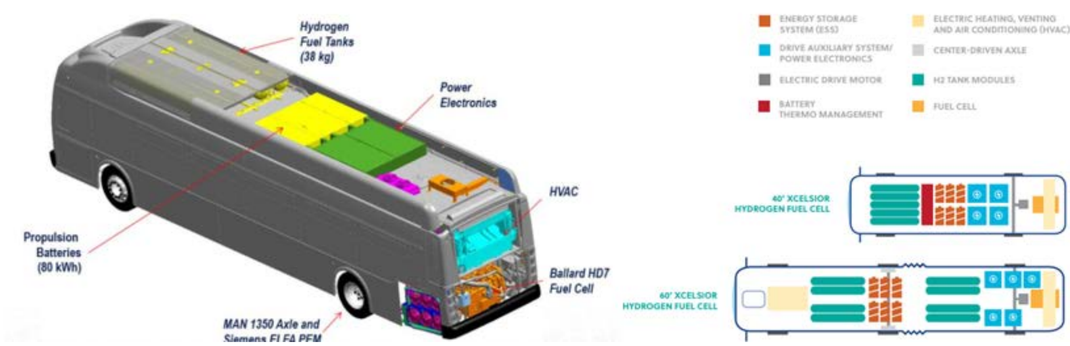

Figure 26 Hydrogen Fuel Cell Powertrain

Functionality Overview:

- Compressed hydrogen gas is stored on-board the vehicle in pressurized tanks as the fuel source of the bus. In order to generate energy/power used for the electrical powertrain the hydrogen gas travels from the storage tanks through a regulated supply line into an on-board fuel cell.
- The hydrogen is released into the fuel cell in which it undergoes a chemical oxidation process reacting with oxygen to generating an electrical current and producing water vapour as a by-product.
- The electrical current is then either stored within a battery or energy storage system (ESS) or sent to the traction drive motor used to propel the vehicle. A FCEB can also function with regenerative braking similar to a BEB and store this energy in the on-board batteries.

[34] http://www.gov.cn/english/2006-06/21/content_316521.htm
[35] https://www.newflyer.com/buses/xcelsior-chargeh2/

- The hydrogen fuel supply is replenished in a similar manner as a CNG vehicle as pressurized refueling station nozzles engage with a receptacle on the vehicle to allow the transfer of hydrogen gas filling the on-board tanks.

In general, compressed hydrogen has a higher energy content and thereby with using fuel cell technology vehicles can achieve a greater operating range with energy per unit mass resulting in vehicles with a greater operating range relative to a comparable BEB.

There are currently a limited number of vehicles available in the marketplace for 40ft and 60ft transit buses powered by hydrogen fuel cell technology. The broader market both in North America and Europe/Asia is primarily focused on the advancement of electric buses. Nevertheless, there remains optimism on the potential for hydrogen powered buses as stated by New Flyer the exclusive Canadian OEM offering 40ft and 60ft hydrogen buses in their vehicle portfolio.

New Flyer has stated several advantages looking towards the future of FCEBs:

1. FCEBs store the energy/fuel supply in the form of compressed hydrogen gas which is lighter and has a higher energy density (more energy per unit mass) when compared to the current battery pack designs on electric buses.
2. With a reduced overall vehicle weight due to weight savings in the fuel/energy supply system a FCEB can achieve a greater operating range in relation to a comparable BEB.
3. The time to refill the hydrogen storage tanks on a FCEB is comparable to a diesel or CNG bus. Thereby, reducing the out-of-service time in comparison to BEBs which require fast charging pantograph systems or otherwise can take 4 to 5 hours of charging time with plug-in depot/end-point charging. New Flyer states that a FCEB can be fully refueled in about 15 minutes[36].

FCEB produce environmentally friendly emission bi-products notably water vapour (steam) but past trials of FCEBs have demonstrated high operating costs. Whistler, BC at one point operated the largest fleet in the world of 20 FCEBs financing in part by the Canadian government as a showcase for the 2010 Winter Olympics. However, high operating costs halted the program and subsequent retirement of the buses in 2015. The main reason cited was a lack of a viable hydrogen fuel supplier in Vancouver/Whistler and infrastructure which led to the fuel being transported by diesel trucks from Quebec[37] thereby negating the reduction of FCEB zero emissions.

As per the National Renewal Energy Laboratory (NREL) report issued in 2017 the capital and operating costs of FCEBs are still much higher than conventional diesel buses. In a summary of published data collected from at the time the most recent year of operation August 2016 to July 2017 the following agencies were included which are operating FCEBs:

- Alameda-Contra Costa Transit District (AC Transit)
- SunLine Transit Agency
- University of California at Irvine
- Orange County Transportation Authority (OCTA)
- Massachusetts Bay Transportation Authority (MBTA)

The following Table 8 presents the NREL report findings on the technological readiness of FCEBs in comparison to targets set forth by the Department of Energy (DOE) and Federal Transit Administration (FTA)[38] for the assessment period of 2018. Results are converted into appropriate units for the Canadian market (i.e. cost per km).

[36] https://www.newflyer.com/leading-the-charge/breakthrough-fuel-cell-electric-bus-technology-interview/
[37] http://gas2.org/2015/03/10/vancouver-ends-hydrogen-bus-program-amid-high-costs/
[38] NREL, Fuel Cell Buses in US Transit Fleets: Current Status 2018

Table 8 NREL Report Hydrogen FCEB Feasibility Targets

	Units	2018 period status (Average)	Ultimate Target
Bus lifetime	years/ km	4.5/192,780	12/ 804,600
Bus availability	%	72	90
Fuel fills	per day	1	1(< 10 min)
Bus Cost	CAD	2.5 million	0.8 million
Roadcall frequency (bus/ fuel cell system)	km between roadcalls	6,800/ 39,000	6,400/ 32,100
Operation time	hours per day/ days per week	11.8/6	20/7
Scheduled and unscheduled maintenance	$/km	0.39	0.33
Range	km	428	480
Fuel Economy	km per diesel litre equivalent (km/dLe)	11.3	12.9

The results from this report highlight that FCEB technology is currently at pace with expectations for fuel economy and range. However, the capital vehicle cost and operating cost ($/km) are still very high as the supply chain is still in the process of maturing.

3.4.2 MARKET OVERVIEW

There are currently two North American based OEMs producing hydrogen FCEBs: New Flyer Industries (NFI), the largest transit bus manufacturer in North America and Eldorado National (ENC) based in Riverside, California.

3.4.2.1 NEW FLYER

New Flyer offers their Xcelsior bus in both 40ft (XHE40) and 60ft (XHE60) models termed Xcelsior Charge H_2 operating on fuel cell technology manufactured by Ballard. Both can be equipped with either TN1 or TN5 for low noise high flow rate fueling receptacles taking from 8 to 12 minutes to refuel.

The 40ft Xcelsior (XHE40) has an equivalent energy capacity of 700 kWh and has on-board storage capacity for 37.5 kg of hydrogen. Passenger capacity accommodates 40 seated and up to 42 standees with the vehicle curb weight at approximately 32,250 lb (14,630 kg) it can operate over 480 km based on Altoona test results[39].

Figure 27 New Flyer XHE60 at Altoona Test Track

The 60ft Xcelsior (XHE60) recently completed Altoona Testing in May 2018 becoming the first 60ft FCEB to do so. The XHE60 has an equivalent energy capacity of 1100 kWh and can store 60 kg of hydrogen on-board. Based on the Altoona test results the XHE60 demonstrated a fuel economy capable of reaching 480 km before refueling needs. The XHE60 can accommodate a seating configuration of up to 61 passengers and has a total passenger capacity of 123 people.

New Flyer has delivered 25 FCEBs through California. The newest model XHE60 had its first commercial order from Champaign Urbana Mass Transit District (CUMTD) in Illinois for two buses to be delivered in 2020 while the XHE40 has received orders from the Orange County Transportation Authority (OCTA), Alameda-Contra Costa Transit District (AC Transit) and SunLine Transit Agency in the Coachella Valley, CA.

3.4.2.2 EL DORADO NATIONAL (ENC)

ENC has two models of FCEBs based on their National Axess in both 35ft and 40ft varieties powered by Ballard HD6 fuel cells. The expected lifespan of the fuel cell is 10-years before needing replacement.

Figure 28 El Dorado Axess FCEB

[39] https://www.newflyer.com/buses/xcelsior-chargeh2/

The National Axess 40ft FC bus recently completed Altoona Testing and is now available for purchase as announced in July 2018[40]. With a curb weight of 34,800 lbs (15,785 kg) the vehicle range demonstrated the capability to exceed 410 km. Refueling time for the bus is estimated around 20 minutes. Furthermore, there is the option for several interior layouts capable of accommodating up to 43 seated passengers and 17 standees depending on the number of wheelchair locations, this layout is shown in Figure 30.

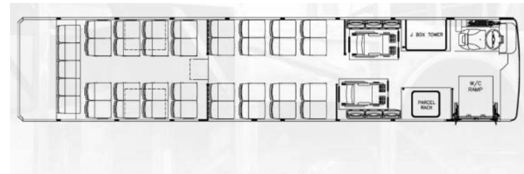

Figure 29 ENC 40ft FC Interior Layout

The 35ft FCEB model of the National Axess is currently undergoing the Altoona Test and offers a seating capacity of up to 35 passengers.

Details are limited on these new bus models and none have yet entered service.

3.4.3 TRAINING & TOOLING REQUIREMENTS

Bus OEMs producing hydrogen models commonly provide standard training, operating and maintenance manuals with the purchase of their buses. For a hydrogen bus, the majority of the vehicle maintenance activities will be similar to that of an electric bus. 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 hydrogen tanks which are commonly located on the roof of a bus. Furthermore, workers should be aware and service hydrogen buses in a facility equipped with proper ventilation and meeting applicable codes and standards.

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

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

- Gantry platforms/ movable scaffold platforms for roof access, along with required fall arrest and protection equipment for maintenance workers working on hydrogen tanks commonly roof mounted on vehicles
- 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 hydrogen tanks (gas extractor, torque wrenches and tensioner straps).

Another safety consideration for battery electric buses and fuel cell buses is arc flash. An Arc Flash is a severe electrical hazard that is the result of 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 to maintenance technicians if proper protective equipment (PPE) and preventative measures are not used while working on high voltage equipment such as electric bus battery packs and high voltage components including the energy storage system (ESS) on a FCEB.

In Canada, the voltage threshold of 30V mandates maintenance personnel to have an high voltage qualified training for working on energized electrical components and circuitry and the usage of specific PPE. Working on any components at or above this 30V threshold requires the use of Arc Flash PPE (minimum Category 1) and establishing a work safe perimeter that only those who are high voltage qualified personnel wearing appropriate Arc Flash PPE can enter. For illustrative purposes, the PPE required according to the Arc Flash risk is presented in Figure 30.

[40] http://www.ballard.com/about-ballard/newsroom/news-releases/2018/07/17/ballard-powered-el-dorado-fuel-cell-electric-buses-ready-to-deliver-zero-emission-transit-throughout-california

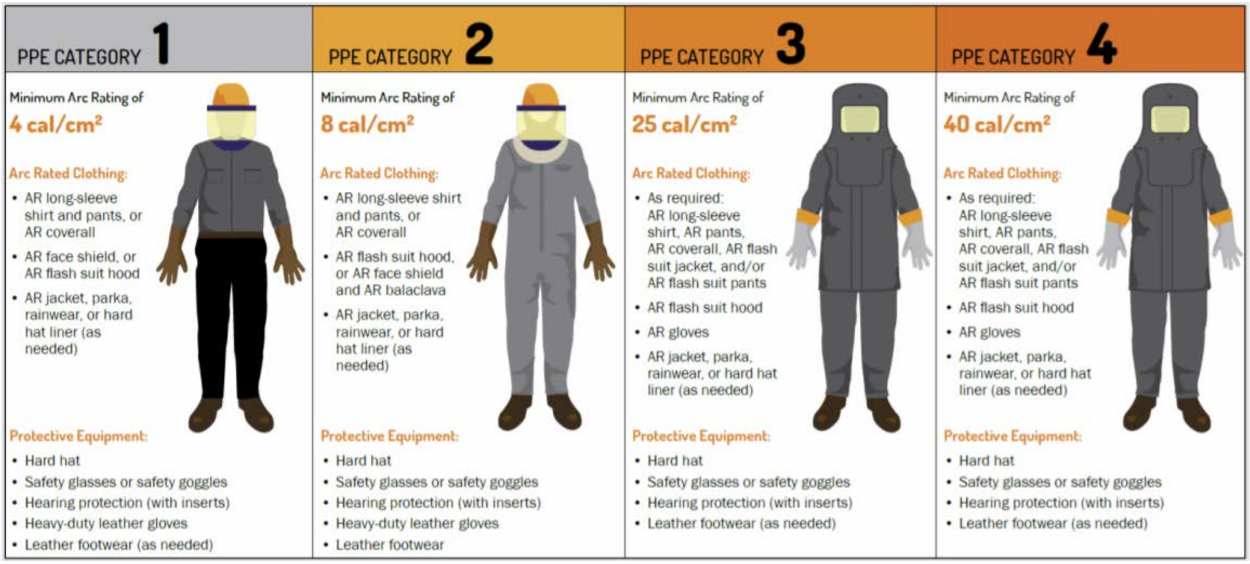

Figure 30 Arc Flash PPE Requirements

Additional safety equipment that should be incorporated in the workplace around high voltage equipment should include an insulated safety hook which can be used to pull someone safely away from an electrocution incident without putting the responder at risk of electrocution. Also, safety barriers should be used to close off the high voltage work safe zone (arc flash boundary) that can only be entered by personnel who are high voltage qualified and equipped with the proper PPE. Furthermore, within this zone maintenance personnel should not wear metallic items due to the risk of thermal conduction from an Arc Flash. Warning labels should be put on the exterior encasement where access to high voltage components are located to provide the technician clear information on the electrical risk as well as the PPE as required to work on the components.

Work on energized circuits of 30V or higher is not considered a routine activity. Personnel shall not work on such energized circuits unless they are qualified to do so, or if they are working under the direct supervision of a qualified person in an approved on-the-job training program. Shock hazard boundaries should be respected.

High voltage qualification training is based on the NFPA 70E & OSHA (Occupational Safety and Health Administration) standards and shall include on-the-job and/or instructor-led training in a classroom setting. The participants shall be trained in, and be familiar with (but not limited to): safety-related work practices (hazard identification and analysis; proper selection, use and care of PPE), skills and techniques to distinguish exposed energized parts of electrical equipment, skills required to determine the nominal voltage to which a qualified person might be exposed, how to lockout/tagout energized equipment and how to use rated test instruments. Refresher training is recommended at intervals, not to exceed three years, to provide an update on new regulations and electrical safety criteria. The high voltage certification training and required PPE per mechanic is estimated to cost $1000 and $2000 per individual.

3.5 RECOMMENDED TECHNOLOGIES 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 Transit's transition.

The initial total cost of ownership (TCO) analysis indicated that CNG fleet scenario would result in some cost savings compared to BAU due to expected fuel price savings over the model period and would result in an emissions reduction of approximately 20 tonnes of CO_2e per year (16% reduction).

BEB are most expensive than diesel buses when looking at the asset TCO (17% more expensive), however they have the potential to reduce yearly emissions by 91%. Hydrogen fuel cell deployment would also lead to large emission savings but would cost about 50% more than the diesel scenario. In additions, Ontario currently lacks a streamlined hydrogen strategy to produce clean hydrogen sufficiently to serve the province.

The evaluation of the technologies considered from a total cost of ownership and market availability perspective demonstrated that the most currently viable technologies for potential adoption are CNG and battery electric for conventional transit. Adoption of CNG vehicles demonstrated a savings over the long term due to expected reductions in fuel costs. Further CNG vehicles have range capabilities closer to their diesel counterparts, and therefore there would be a reduced impact on Barrie Transit’s schedule. However, CNG technology will ultimately not enable near zero emissions and will limit the potential of the City to achieve net carbon neutral operations.

Adoption of electric vehicles will lead to an increase in CAPEX costs, however it will also lead to the greatest decline in expected OPEX costs as well. Further, this option offers a large decline in expected emissions, and provides a path towards environmentally sustainable long-term operations. As a result, the following sections in this report focus on the technical details to assess the feasibility to adopt a fully electric fleet and a CNG fleet as two realistic scenarios.

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 peer agencies which had the most pertinent information with regards to transit fleet vehicles.

Toronto Transit Commission

TTC has around 2,500 buses as part of the transit fleet, 10% of which are conventional diesel, 41% are clean diesel buses which are Nova Bus diesel buses with a cleaner engine and aftertreatment system, 34% are 1st generation hybrid, 12% are 2nd generation hybrid and 3% are BEBs. In terms of transit facilities, there are 8 transit garages, 2 NRV (non-revenue vehicles or operational vehicles) garages, and most of the transit and para-transit fleet are stored indoor.

TTC is currently engaged in a pilot program with 60 BEBs from three different OEMs (Proterra, New Flyer and BYD). These buses were procured and added to fleet in 2019 and have been operating on Toronto's street since their deployment. Their procurement was gradual as the board approved the purchase of an initial 30 buses, followed by 30 more in 2018. Lessons learned regarding the factors that played into the success of this program and part of the monitoring are summarized below:

Vehicle Performance Evaluation:

- Simulated revenue service with ballast for passenger load
- Four season testing
- Tracking energy consumption, regenerative braking, acceleration/braking performance
- Bus reliability and availability (MDBF)
- Ergonomics (accessibility, operator area, passenger area and seats)
- Brake wear (brake pad life, impact to maintenance programs and cost)
- Noise and vibration testing (interior/exterior)

Vendor Performance Evaluation:

- Quality of Contractual Deliverables (i.e. test reports)
- Adherence to BEB delivery schedule (i.e. days late)
- Production quality (i.e. defects/snags noted per bus) and days required to complete final BEB acceptance on delivery
- Parts availability
- On-site customer service and engineering support

Hybrid Bus Fleet (~255 buses):

- Improved fleet reliability
- 45% reduction in fuel consumption and GHG emissions measured (42 L/100km for 40ft bus)
- Payback period is 12.5 years (additional capital cost vs. fuel savings).
- Payback occurs within bus 13-year lifecycle.

The most significant infrastructure challenge to grow alternative fuel fleet for transit fleet are:

- Electrical infrastructure challenges of upgrade/modification to existing garages which are running at capacity
- Range limitations on existing BEB technology
- Flexibility in deployment of BEBs (i.e. shuttle bus deployment to backup subway operations)

The most significant infrastructure challenge to grow alternative fuel fleet for NRV are:

- Range anxiety and availability of charging/fueling stations due to work at remote site locations.
- 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.

Limited or no market of alternate vehicle options for specialized vehicles

Because of PTIF (Public Transit Infrastructure Fund), TTC examined different propulsion technology, and decided on installing a battery electric depot. Opportunity charging was not pursued due to timing restrictions of the funding. Moreover, at the time of the project, hydrogen technology was not matured and the high cost would not make a good business case. TTC also examined CNG, but none of the garages are equipped for natural gas.

The key lessons learned were the time and resources issues experienced in BEB program implementation. There were not enough team resources assembled. TTC realized that it is important to bring in resources early in the implementation stage, and partner up early with local utilities. Modelling all routes to get a decent estimate of energy consumption, which informs overall charging strategy, is another key lesson learned. In addition, from an operational standpoint, BEBs are generally cheaper than diesel and hybrid, around 10 cents/km in savings.

TTC has experienced some charging issues with New Flyer's initial ten BEBs ordered, "manual sequence" were required to start BEB charging (i.e. restart bus, enable switch, then can start charge). TTC is looking to convert this initial procurement to "auto charge" which the second order is compatible with. The issues between charger OEM (ABB) and NF were typically programming issues but now morphing into a robust and reliable system as issues are being worked out.

City of Calgary Transit

City of Calgary's transit fleet contains approximately 800 40ft. buses, 98 60ft. buses, 156 30ft. buses and 230 Light Rail Vehicles. All of the 30ft. buses use gasoline, and 570 of the 40ft. buses and 98 of the 60ft. buses use diesel. The remaining 230 of the 40ft. buses use natural gas. The average useful life for the fleet is shown below:

Table 9 Average Useful Life of City of Calgary's Fleet

Vehicle Type	Expected Useful Life
LRV	35 Years
60 ft. Bus	18-20 Years
40 ft. Bus	18-20 Years
30 ft. Bus	5-8 Years

*Calgary Transit has a mid-life overhaul program implemented

City of Calgary has transitioned a significant amount of their fleet from Diesel to CNG in the past 5 years and have targeted to transition more. City of Calgary has North America's largest indoor CNG fuelling facility, and is planning on explore greater availability of locally produced RNG and developing a pilot for electric shuttle buses.

The implemented CNG buses received excellent customer feedback. The buses are very much liked from an emission and noise perspective and passengers also appreciate the transition to a local fuel which supports the Canadian economy.

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.

Table 10 Replacement Guidelines

Type of Vehicle	Replacement Guidelines
Cars	12 years or 150,000 km
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

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.

CNG is not an economical option for the City 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 the City may not have money to move to electric as soon as possible. Whereas renewable diesel is an economical option and the City is currently in process of getting council approval.

In the City'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 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 the City is trying to switch diesel fleet on renewable diesel. The City looks for alternate fuel for all new procurements and new cars and SUV purchased in 2020 onwards will be BEV. The City 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. The City wants to meet the council target of 20% reduction in GHG emission by 2025. The City will not conduct any pilot programs, the City 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.

Organizations/Institutions Engaged

UITP Alternative Fuel Procurement Experience

WSP engaged with UITP (The International Associate of Public Transport) for experience with alternative fuel fleet procurement experience. UITP is an international association for public transport authorities, operators, policy makers, scientific institutes and sector service, headquartered in Belgium, Brussels. It consists of 1,800 members from all around the world. UITP shares data, knowledge, and guidelines with their members which helps them formulate their specifications. UTIP hosts conferences to share knowledge and publish documents called eSort, which contains overall guidelines for procurement. In Canada, STM, TTC and TransLink are involved. UITP is open to additional Canadian municipalities and transit authorities to join for knowledge sharing and wishes to expand its North American member base

In discussion with UITP, some of the key lessons learned by the UITP from the adoption of electric/ hydrogen vehicles include the following:

- Consider range issues expected with technology early in the piloting and adoption process and plan for infrastructure developments accordingly
- Important to have an understanding of the city context and routes, different solutions are viable based on local context
- For longer routes, consider moving towards fuel cell as battery prices increase for large battery packs, the market may shift in the future with battery prices continuing to drop
- Average life of electric buses are approximately 12-15 years in Europe, and 7-8 years in China
- Market is very controlled by the OEMs currently

Metrolinx TPI (Transit Procurement Initiative)

The City of Barrie along with numerous other transit authorities are part of a transit procurement initiative (TPI) led by Metrolinx. The aim of the TPI initiative is to find best fit for joint procurements, and members are able to engage with other agencies to share and address their procurement requirements. The transit agencies rely on TPI for RFP and specifications development. Following procurement process, TPI members present bid results to a steering committee which makes the final decision on the selected proponent.

With regards to electric buses, the general procurement may not be suitable for all transit agencies based on their specific routing needs and demands, impacting battery size requirements, charging strategy and motor specifications. Metrolinx is planning to launch a joint BEB TPI and looking to develop BEB specifications based on industry best practices. It will be important to consider the context of each transit agencies to support the adoption of electric buses which is challenging in a context of a joint procurement initiative.

5 REGULATION, CODES & 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 OPERATIONAL RANGE ASSESSMENT

6.1 ALTERNATIVE FUEL TECHNOLOGY RANGE

Another major consideration for fleet alternative propulsion technologies is the operating range and the range anxiety that comes with limited on-board energy supply with BEBs and FCEBs. This section presents a general overview on the operating range of the technologies considered in this study. The operating range of BEBs is investigated in further depth in Section 6.2 with simulations of BEBs operating on Barrie's route network, with WSP's BOLT simulation tool.

For a general comparison of propulsion technology range a combination of OEM specifications, Altoona Test results and data on fuel economy are used to project the operating range of a 40ft bus for each technology. The assumptions used for generating this comparison are noted below:

- Diesel 40ft bus average fuel economy (0.55 L/km) based on historical data. The range calculated is based on a Nova Bus LFS model diesel bus with a 507 L (134 US gal) fuel tank. The max/min range is based on +/- 5%
- Diesel-hybrid 40ft bus average fuel economy (0.48 L/km) based on peer Canadian transit agency operating data. The range calculated is based on a Nova Bus LFS HEV model diesel-hybrid bus with a 473 L (125 US gal) fuel tank.
- CNG 40ft bus average fuel economy based on average of Altoona Test results for the Nova CNG LFS and New Flyer Xcelsior (XN40).
    - Min range based on the Nova CNG LFS with smaller CNG tank size of 18.8 scf (at 3,600 psi, 24.8 MPa)
    - Max range based on the New Flyer XN40 with larger CNG tank size of 23.1 scf (at 3,600 psi, 24.8 MPa)
    - The average range is close to 600 km, which is sufficient to accommodate Barrie Transit's blocks
- BEB range based on Proterra Catalyst E2 (440 kWh) mid-sized battery pack model and OEM published energy efficiency range (1.1 to 1.6 kWh/km) from compiled BEB operations across North America and usable percentage of 440 kWh battery capacity

The range comparison of technologies based on these assumptions is presented in Figure 31.

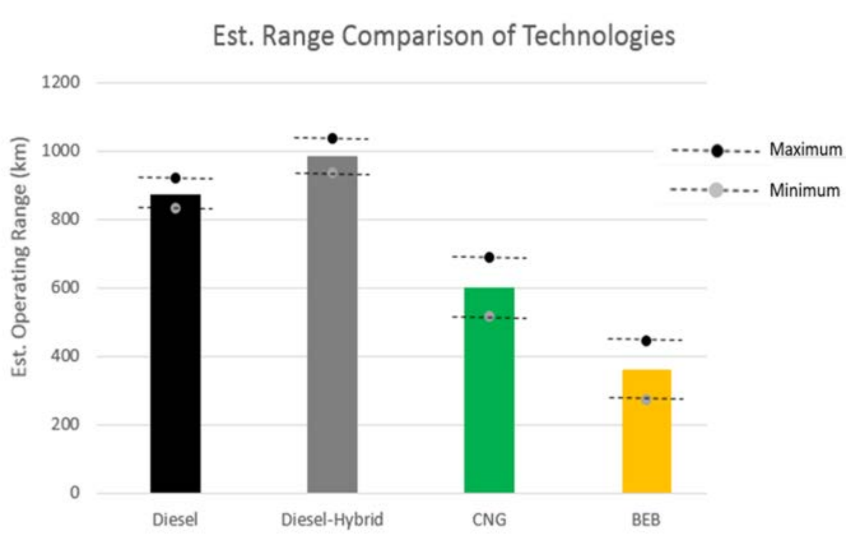

Figure 31 Propulsion Technology Estimated Range Comparison

This comparison shows the range anxiety associated with BEBs and FCEBs as the range of conventional diesel buses is in most cases more than 2x greater based on fuel economy and fuel tank size. However, this does not necessarily rule out deployment of these alternative propulsion types in fleets as a feasibility assessment can be warranted to compare the range of BEBs and FCEBs against the range needed to service the transit network. In addition, larger battery packs and hydrogen tanks are expected on future models of these buses, allowing for increased range abilities.

Due to the larger variation in energy efficiency of electric buses in the winter and summer conditions and limited range, the performance of electric buses was modelled in greater details, as described in the following section.

6.2 ELECTRIC BUS MODELLING (BOLT)

6.2.1 BOLT OVERVIEW

The Battery Optimization Lifecycle Tool (BOLT) was developed in-house by WSP and has been used by many transit agencies around the world to assess the impacts of BEB adoption on range and charging requirements.

BOLT can model an array of BEB models with varying battery pack sizes. It can simulate their operations on selected transit routes or entire networks. Ridership, auxiliary load (i.e. headlights, vehicle monitoring and communication devices, etc.), route constraints (i.e. length, bus stops and topography), and weather conditions (HVAC use) are all simulated to determine the energy efficiency (kWh/km) and battery state-of-charge (SOC) over time.

BOLT calculates the energy consumption of the buses as they proceed along a series of trips over the course of a day. Charging infrastructure can be added into the simulation to simulate plug-in or fast charging at various power levels (kW). One of BOLT’s key output is the Electrification Index (EI) of a transit network. This index reflects the percentage of a transit agency’s network that can be served using BEB at charging at the end of the route. Overall, BOLT provides an indication of the electric fleet performance on the network.

A second toolkit called BOLT Post Processing (BOLT-PP) was developed by WSP to link BOLT’s fleet results to its impact on facility energy requirements and peak load depending on the charging strategy. BOLT PP imports the route performance results from BOLT and lets the user simulate charging strategies with different constraints. The key outputs of BOLT PP is the facility load profile, the expected number of buses charging simultaneously and the peak demand.

6.2.2 METHODOLOGY

BOLT uses physics equations to simulate the performance of BEBs and their operations, as opposed to empirical data. This offers several advantages, such as the freedom to choose to model different scenarios and predict the impact of technology improvements on range performance.

BOLT uses two key databases: a Transit Network database and a Vehicle Specification database. The former uses information related to the existing schedule, route pattern, non-revenue trips and daily bus assignment to simulate the operating conditions of the buses. Ridership and road elevation are also core parts of this database. The later contains technical specifications pertaining to the vehicles physical characteristics, electric powertrain efficiencies, ideal performances and charger specification.

The speed profile of the vehicle is modeled according to a trapezoid shape for an individual segment with a constant acceleration phase, followed by a constant speed phase and a constant deceleration phase between each bus stop. The average speed of each segment corresponds to the average speed calculated from the schedule provided by the City of Barrie and therefore would match the scheduled time between each bus stop. A simplified sample speed profile is shown in Figure 32 below with the following phases.

1. Phase I: Constant Acceleration
2. Phase II: Constant Speed
3. Phase III: Constant Deceleration

4. Phase IV: Complete Stop

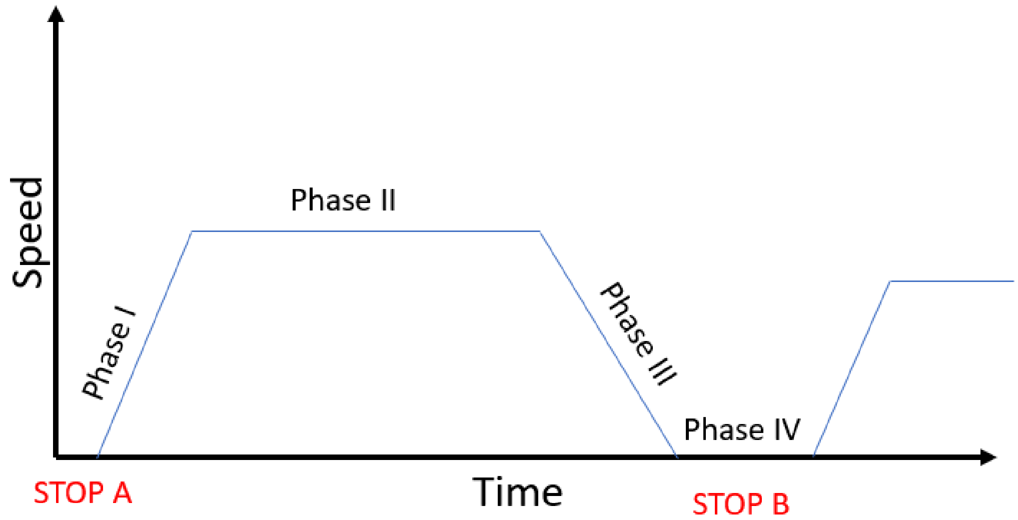

Figure 32 Speed Profile Generation

The primary calculation assesses the propelling force required to move the bus at a given speed and with specified operating conditions (route elevation, temperature and passenger weight). Energy recuperated from regenerative braking when the driver lifts off the acceleration pedal is added at that point. Up to 70% of the braking force can be recuperated in electric and hybrid vehicles, which varies depending on the driving conditions [41]. Transit bus manufacturers must limit the amount of energy that can be recuperated as it creates a heavy drag force which can be uncomfortable for drivers and passengers. According to information gathered from discussing with BEB manufacturers in North America, this limit is usually set between 35% to 40% to ensure a comfortable ride, which is what has been used in this study.

Once the propelling force is known, the instantaneous power $P(t)$ can be calculated as follows:

$$P(t) = F_{propel}(t) \times V(t)$$

Where $V(t)$ is the speed and $F_{propel}(t)$ is the propelling force. The energy used (E_{cons}) is then calculated as the integral of power over time. The state-of-charge (SOC) of the batteries is then calculated as follows:

$$SOC_{t+1} = SOC_t - \frac{E_{cons}(t)}{cap}$$

Where SOC_{t+1} is the SOC at the next time interval, SOC_t is the SOC at the instant t, $E_{cons}(t)$ is the instantaneous energy consumed and *cap* is the battery capacity in kWh.

The impact of the grade of each segment is accounted for in the equations, as going uphill will consume more energy. The auxiliary load refers to the load from accessories that are not required to propel the vehicle and is also accounted for in the modeling (i.e. air conditioning, lights, doors opening and closing etc.)

The energy consumption is computed for each phase of each segment of each route patterns and then aggregated for to be carried forward into block and depot level analysis, as shown in Figure 33. Note that the average energy consumption (kWh/km) was assumed as a constant for the deadhead distances.

[41] (Björnsson & Karlsson, 2016; Martins, Brito, & Roch, 2009)

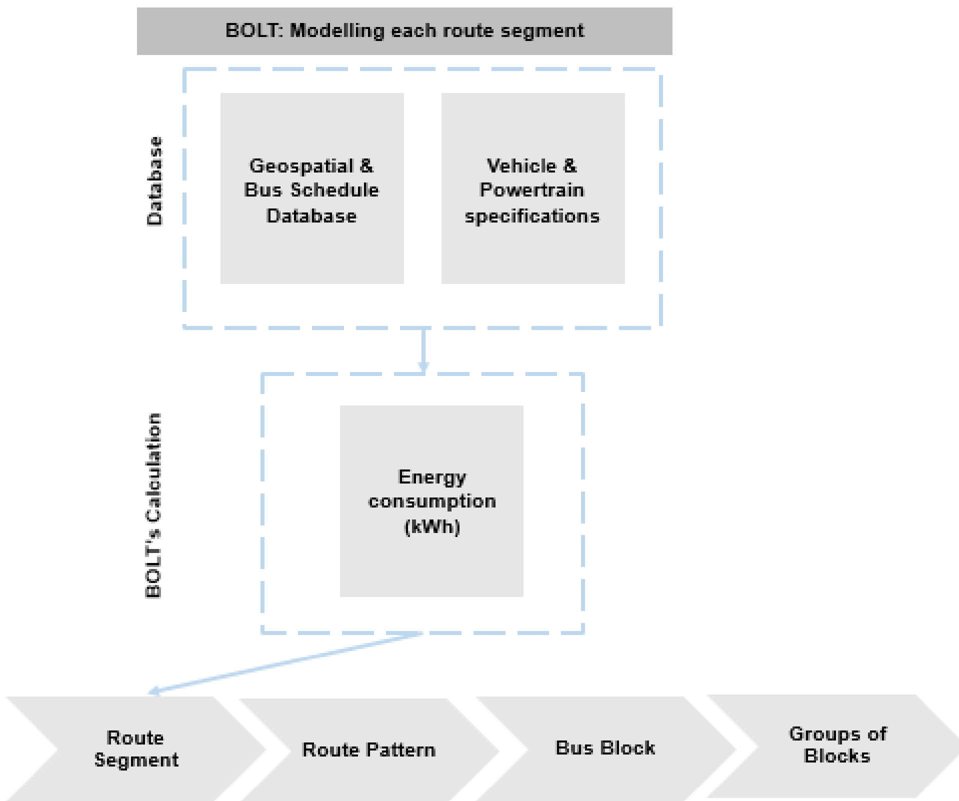

Figure 33 BOLT Calculation Process

6.2.3 INPUTS AND SIMULATION SCENARIOS

BEB and charger types

The different generic BEB models that have been simulated are shown in Table 11.

Table 11 BEB Specifications

Type number	Bus model	Battery Capacity	Size	Battery SOC buffer	Curb weight (kg)
#1	Generic	320 kWh	40 ft.	10 – 90%	15 320
#2	Generic	470 kWh	40 ft.	10 – 90%	16 320
#3	Generic	660 kWh	40 ft.	10 – 90%	17 560

The chargers modeled in this study are plug-in chargers. The plug-in chargers operate under a constant current, constant voltage (CC-CV) charging profile, shown in Figure 34 below.

During the constant current (CC) phase, a near constant current is delivered to the battery. Once the battery pack hits a critical state-of-charge (SOC), labelled SOC_k in Figure 34 below, the current starts decreasing while the voltage increases. The output power drops significantly during the constant voltage (CV) part of the charge. This profile is designed to protect the battery from overcharging.

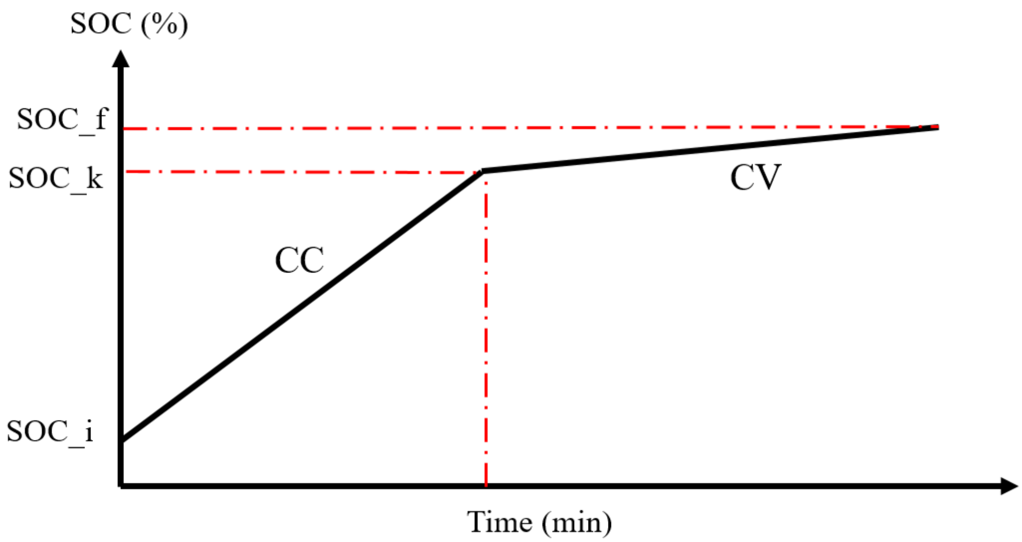

Figure 34 Plug-in Charging Profile

The charger specifications used in this study are shown in Table 12.

Table 12 Charger Specifications

Charger type	Rated power	Overall charging efficiency **	Constant charge rate between 0-85% SOC	Constant charge rate between 85%- 100%SOC
Plug-in charger	150 kW	85%	2.05 kWh/min	1.02 kWh/min

Weather Conditions

The outdoor temperature in Barrie vastly varies between the summer and the winter. The use of auxiliary cooling and heating system draws a large amount of power from the batteries to operate. To account for this temperature variation, winter and summer scenarios were developed, with an average temperature of -15°C in the winter and 30°C in the summer.

To model the impact of cold and hot weather temperature on the energy consumption, data from the Center for Transportation and Environment was used[42]. More specifically, the energy consumption data trends of DTA in Duluth Minnesota were extrapolated to get a percentage of energy increase as a function of ambient temperature. DTA piloted a fleet of Proterra Catalyst e12 (40ft, 440 kWh) between November 2018 until June 2019.

The DTA experienced temperatures as cold as -30°C during the trial, and the buses travelled 51% of the total miles during days where the temperature was below freezing point. To improve the fleet energy consumption and ensure a comfortable temperature in the bus, the DTA installed diesel heaters on-board their electric vehicles.

[42] https://cte.tv/wp-content/uploads/2019/12/Four-Season-Analysis.pdf

In Canada, diesel heaters are recommended for battery electric buses as well due to cold and long winter conditions. The presented modelling assumed a hybrid heating system whereby electric heating is on until the outside temperature reaches 5°C, then a diesel auxiliary heater is turned on.

Power Demand at the Facility

To model the fleet energy requirements, it was assumed that once a bus battery is depleted, it returns back to depot to recharge and is then replaced by another fully charged bus. The power demand curve presented in the results section doesn't take into account existing facility load, but solely the additional load brought by the charging equipment and charging of buses.

6.2.4 RESULTS SUMMARY

6.2.4.1 WORST CASE SCENARIO – WINTER ENERGY CONSUMPTION

One key indicator to measure the ease of electrifying a system is the fleet electrification index (EI). The EI is the percentage of blocks that can be electrified with today's schedule with a single 1-to-1 replacement to diesel, that is the number of blocks that can complete their blocks and return to depot to charge at the end. Table 13 shows the electrification index for Barrie's fleet with three generic powertrains with different battery sizes varying between 320 kWh up to 660 kWh, which is the highest battery capacity available in the market. The modelled scenario uses winter operating conditions at -15 °C with diesel heaters.

Table 13 Electrification Index for the Fleet, Winter Conditions

Type number	Battery Capacity	Percentage of fleet electrification
#1 – 40ft	320 kWh	**3%**
#2 – 40ft	470 kWh	**8%**
#3– 40ft	660 kWh	**24%**

These results indicate that in a worst-case situation, 24% of Barrie' blocks - defined as the sequence of trips taken by a bus on a given day - can be electrified today without adjusting the schedules or adding options for on-route chargers. If the City of Barrie was to purchase BEBs with 320 kWh battery pack, only 3% of the current block system could be electrified which would be insufficient.

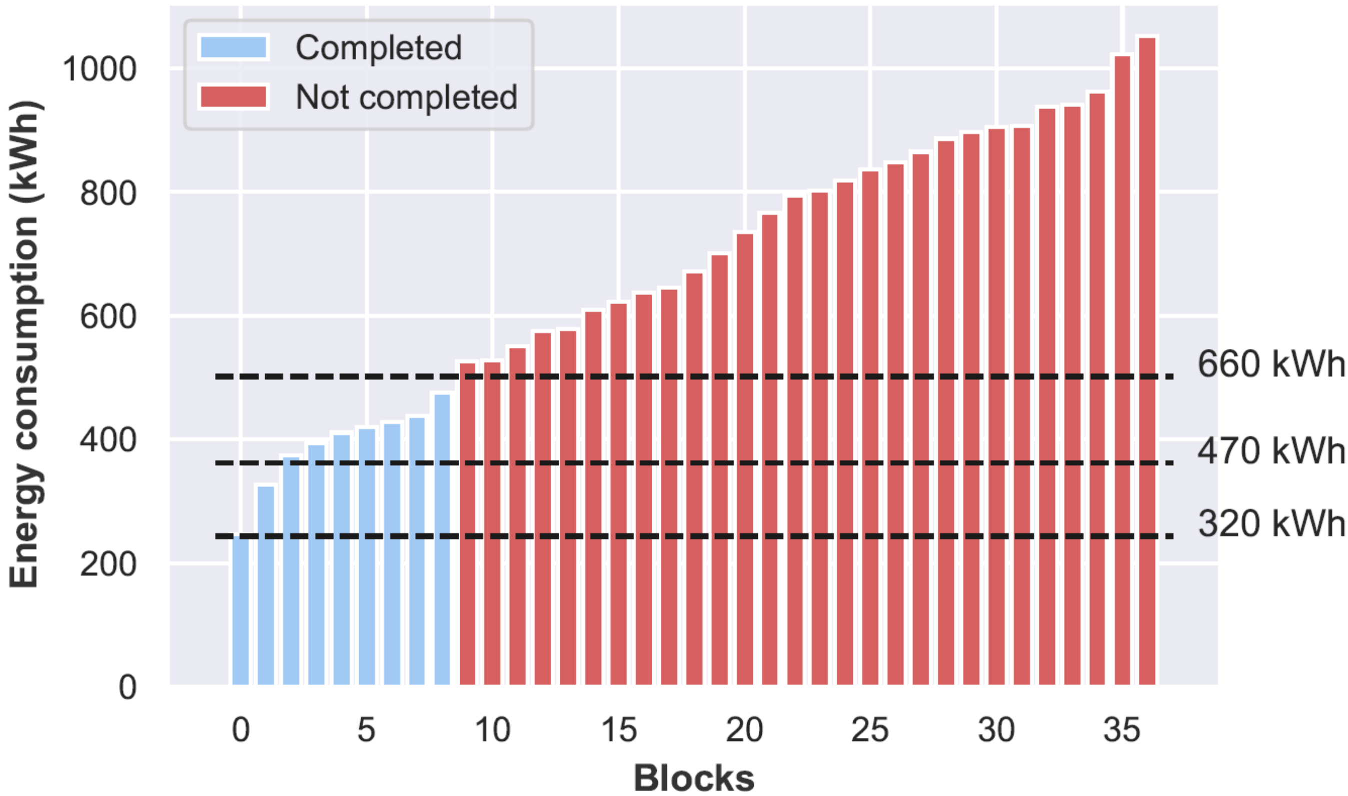

Figure 35 Block Energy Consumption (kWh)

Figure 35 illustrates the results of Table 13 by showing the average energy consumption of Barrie's system if it was electrified with 660 kWh BEBs. 9 blocks out of the 37 can be electrified with depot charging only in this scenario. Based on the current schedule, the energy requirements for the fleet can go as high as 1,000 kWh daily, which cannot be served by relying solely on depot charging at the end of the day.

It should be noted that the energy consumption depicted in this graph is estimated for a 660-kWh bus (40ft). The actual energy consumption of a 320 kWh and 470 kWh bus would be different than what is shown in these graphs. Hence, these results can only be used as a high-level indication of how many blocks could be electrified if buses with smaller batteries were deployed.

6.2.4.2 *SUMMER ENERGY CONSUMPTION*

Changing the operating condition scenario has a critical impact on powertrain energy efficiency, as depicted in Figure 36. Here, the outdoor temperature was changed from -15 °C in the winter to +30°C in the summer. This caused a difference in energy efficiency (kWh/km) of 12.5%.

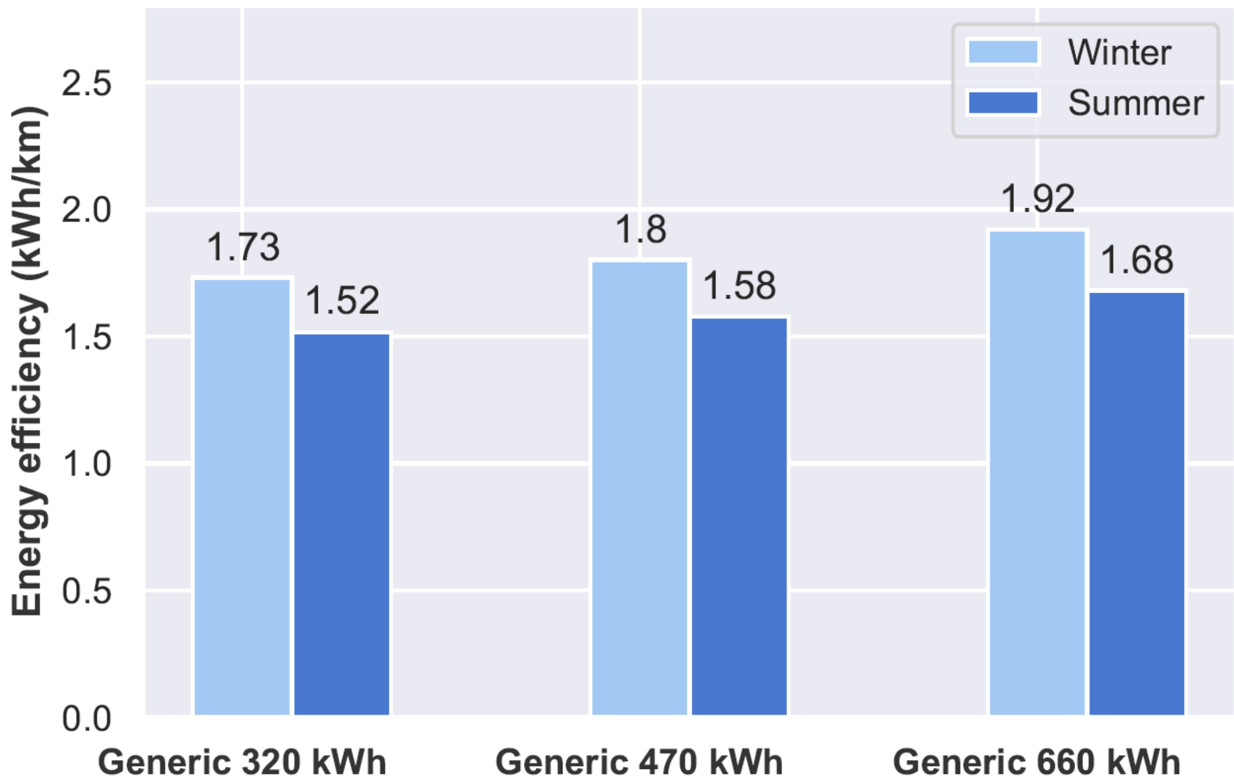

Figure 36 Average Energy Efficiency (Winter and Summer Conditions)

Table 14 shows the fleet electrification index for summer operating conditions. In a hot day, the use of HVAC strains the battery which in turns increases the energy consumption. If Barrie was to procure BEBs with 660 kWh battery packs, they could electrify 32% of their network with 1-to-1 diesel bus replacement, which is 8% more than in the winter.

The remaining blocks that cannot be electrified would require additional buses in order to compensate for the lesser number of service hours for an BEB on a single charge versus a conventional diesel bus. A methodology was developed to assess the required additional BEB-to-diesel bus ratio:

- Each block that could not be completed by a 660 kWh bus was identified
- The remaining kWh required to complete the daily run was calculated
- Blocks with small remaining kWh were “combined” and added so that only one spare bus was required to complete both blocks. This assumption is intended to model buses constantly return to the garage to charge.
- Blocks with a higher remaining kWh were associated with one additional spare bus

In total, 14 spare buses were required to fully electrify the present daily schedule with 46 buses, equivalent to a 1.3 BEB-to-diesel bus ratio, that is, for every 10 new BEBs purchased, 3 additional BEBs are required to meet systems routing and contractual requirements. This ratio is consistent with another recent feasibility study completed for a peer transit agency in Ontario.

Table 14 Electrification Index for the Fleet, Summer Conditions

Type number	Battery Capacity	Percentage of fleet electrification
#1 – 40ft	320 kWh	**3%**
#2 – 40ft	470 kWh	**19%**
#3– 40ft	660 kWh	**32%**

As the technology continues to improve, this ratio will decrease with time. The assumed battery capacity improvement is an increase of 30% by 2030, following Wood Mackenzie's most recent predictions[43]. With this improvement in battery capacity, the BEB-to-diesel ratio becomes 1.1. For every 10 BEBs procured, only one additional bus is required.

6.2.4.3 *POWER DEMAND AT THE GARAGE*

To assess the peak demand at the facility from the use of chargers, the charging schedule of the fleet was modelled. This exercise assumed that once a bus battery gets depleted, the bus returns to charge while a new fully charged bus replaces it.

Figure 37 shows the power demand curve for the facility solely based on the charger's load. The peak occurs at around 8PM at night, with a 3.77 MW MW occurring close to 8pm for an estimated 35 buses charging simultaneously, bringing the charger-to-bus ratio to 3:4. The industry standard is usually set at a 1:2 ratio for larger transit agencies, operating with larger fleets and more garage midday layover time. However, Barrie Transit has different operations which are more challenging for the adoption of BEBs, as the buses are deployed all day and return to the garage once at the end of their daily runs. As a result, the ratio of charger-to-bus is higher for Barrie Transit.

Given this load increase, the City of Barrie may need to upgrade its electrical infrastructure to meet the required demand, such as installing a transformer station on-site. Early discussion with the local utility is recommended to plan for the installation of the infrastructure and confirm power availability.

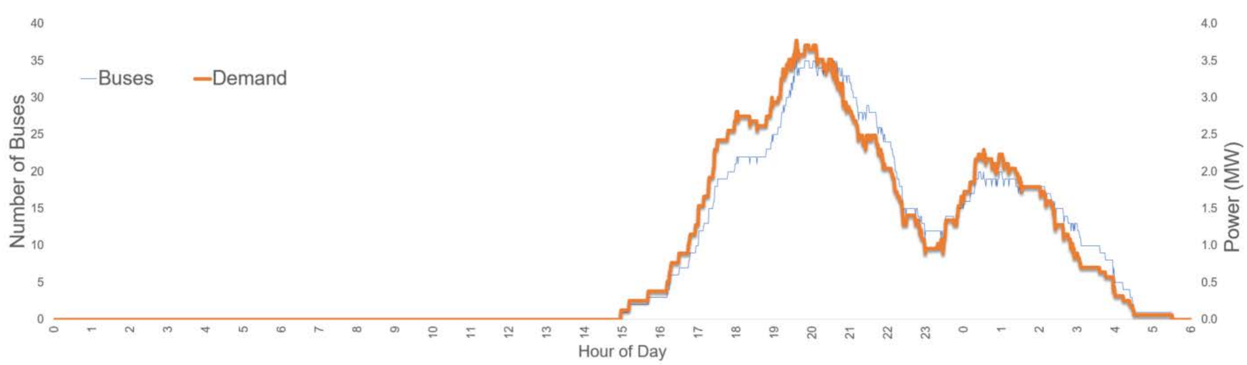

Figure 37 Power Requirements, with a Peak Demand of 3.77 MW and 35 Buses Charging Simultaneously

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[43] 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.

6.2.4.4 *AVAILABLE OPTIONS TO IMPROVE THE ELECTRIFICATION INDEX*

Under current operating scenarios (buses out most of the day and returning at similar times to the garage, short layovers etc.) and schedules, Barrie Transit will not be able to electrify its transit network by solely relying on overnight charging. There are several avenues that Barrie Transit can explore to increase the fleet EI and potential for BEB deployments:

- **Garage layover time charging:** Once a bus completes its block and returns to depot, it can take advantage of its layover time to charge. Smart algorithm, or fleet management software, can be used to dispatch buses according to their charge levels, and recharging the battery in the day can be an efficient way to increase the EI.
- **On-route charging at major terminal stations:** Barrie Transit can investigate the option of adding on-route charging at major terminal stations for their longest blocks. However, not all BEB designs are compatible with pantograph charging, and present battery designs with capacity higher than 400 kWh cannot currently accommodate high charging rates such as the ones provided by pantograph chargers. Studies have shown that under certain laboratory settings, fast charging accelerates the rate of battery degradation. Although, there have yet to be any real-world deployment publications showing battery degradation rates due to fast charging.

  In addition, land ownership is an important consideration when installing overhead pantograph chargers and the entire charging system is a semi-permanent installation. As a ballpark figure, a pantograph charger (450 kW) can cost $500,000, with another $500,000 to $700,0000 for electrical and civil installation work. Further studies are recommended to assess the feasibility and benefits of adding on-route chargers at the new Terminal hub as planned, as it might increase the electrification index.
- **Schedule optimization:** With the shift to electrification, one of the solutions that Barrie Transit may want to consider is to revise its existing schedule and route network, although it has notable implications to the operations process and is a significant task to accomplish. There are several approaches possible to modify the existing schedule with varying degrees of complexity.
  - One approach is about route alignment, that is to define shorter routes to ensure block completion while still servicing the ridership demand. This option would require redesigning the route system and likely requires additional buses to maintain the same level of service. It also brings the risk that the public may not welcome changes to the routes they know.
  - Another approach is to segment blocks into shorter assignments, so the energy demand for completion aligns with the technological capabilities of the BEBs available. This approach would result in additional BEBs for the fleet so that the segmented blocks can be completed (i.e. dividing long block into two smaller blocks with two BEBs deployed to serve each new segment).
  - The two approaches can also be combined and together result in additional BEBs.

  Figure 38 shows the current schedule distribution by portraying the number of buses deployed throughout the day. The highest number of buses deployed is 37 between 7 am to 5pm. According to the modelling results, some blocks would start running out of battery at 1.30 pm as indicated by the red portion of the graph. Schedule optimisation allowing for block splits and additional charge time throughout the day is a necessary step to increase the electrification index of the fleet while minimizing the number of additional buses to supplement the existing fleet.

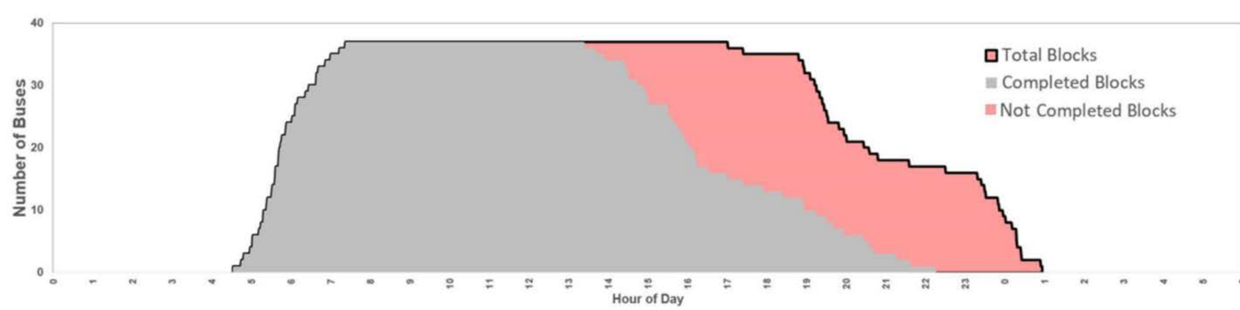

Figure 38 Block Dispatch on Barrie's Network

- **Battery technology improvement:** Impressive research efforts are being conducted world-wide to improve battery specific energy density and weight. Figure 39 shows the types of improvements that have been made in recent years, such that the energy density of lithium-ion cells used in automotive applications has tripled since 2010. New electrolyte materials are being tested, along with solid-state batteries for automotive applications. This technology improvement is expected to positively impact electric buses range as batteries can reduce weight and store more energy. This progress will naturally lead to higher fleet electrification indexes. More information is provided in Section 13 – Future Trends.

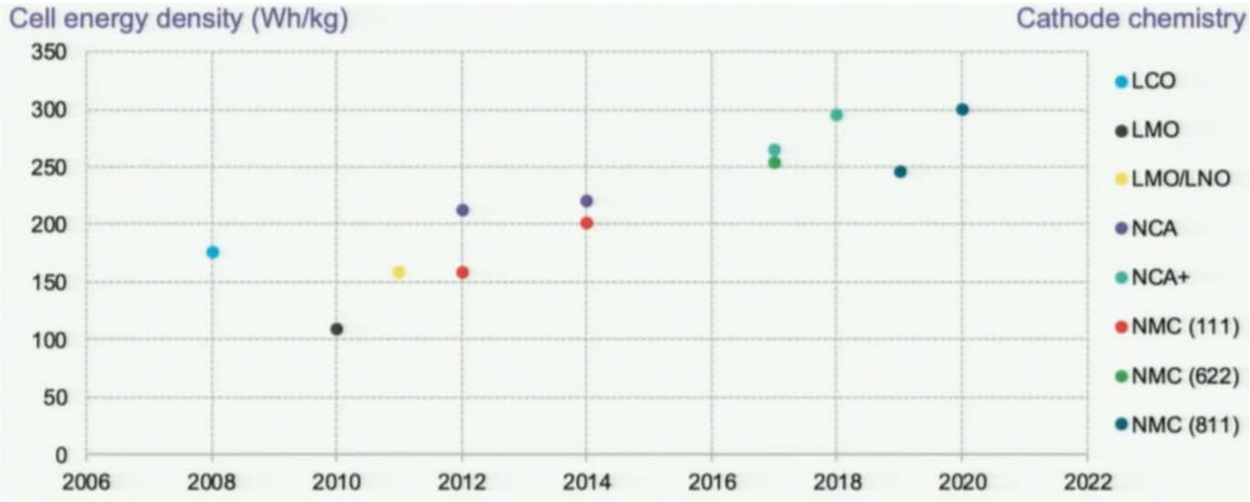

Figure 39 Lithium-Ion Cell Energy Density Improvement Trend[44]

6.2.5 IMPLICATIONS TO THE ANALYSIS

Based on the results obtained from the BOLT modelling the following implications were taken into account in the fleet plan and following analysis:

1. An BEB-to-diesel bus replacement ratio of 1.3 was used between 2021 to 2030
2. From 2030 onwards, this ratio was reduced to 1.1
3. The peak demand of 4 MW for a 46x 40ft BEBs was applied, corresponding to 87 kW/bus for the adoption plan
4. An average energy consumption of 1.92 kWh/km was used for OPEX estimates for the fleet as shown in Figure 36

[44] https://cleantechnica.com/2020/02/19/bloombergnef-lithium-ion-battery-cell-densities-have-almost-tripled-since-2010/

7 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 transit 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 B.

For the General Risks assessed, eight (8) risks were assessed as having High impact or probability. They have been outlined below:

- Technical Specifications: Due to failure to obtain input from users in specification 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.

- Resistance to Change: 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.

  Mitigation Method: 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.

- 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: 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.

- Indoor Storage Capacity: 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.

  Mitigation Method: Risk is avoided as fuelling and charging will be outdoors, if indoor charging required, new facility construction will be considered.

8 FLEET GROWTH PLAN

8.1 FLEET GROWTH AND GARAGE CAPACITY

The 2019-2041 Transit Asset Management Plan, published in April 2019, was shared by the City of Barrie. Figure 40 shows the planned conventional transit fleet growth, which varies between 0% to 10% annually. The planned growth for the specialized transit fleet is less detailed and shows an increase of 35% between 2018-2028 and an additional 35% between 2028-2041. A representation of the fleet size is shown in Figure 41 and Figure 42 for conventional and specialized transit respectively. This information was extracted from Table 11 and Table 16 of the Transit Asset Management Plan and represents a defined scenario, not a recommendation.

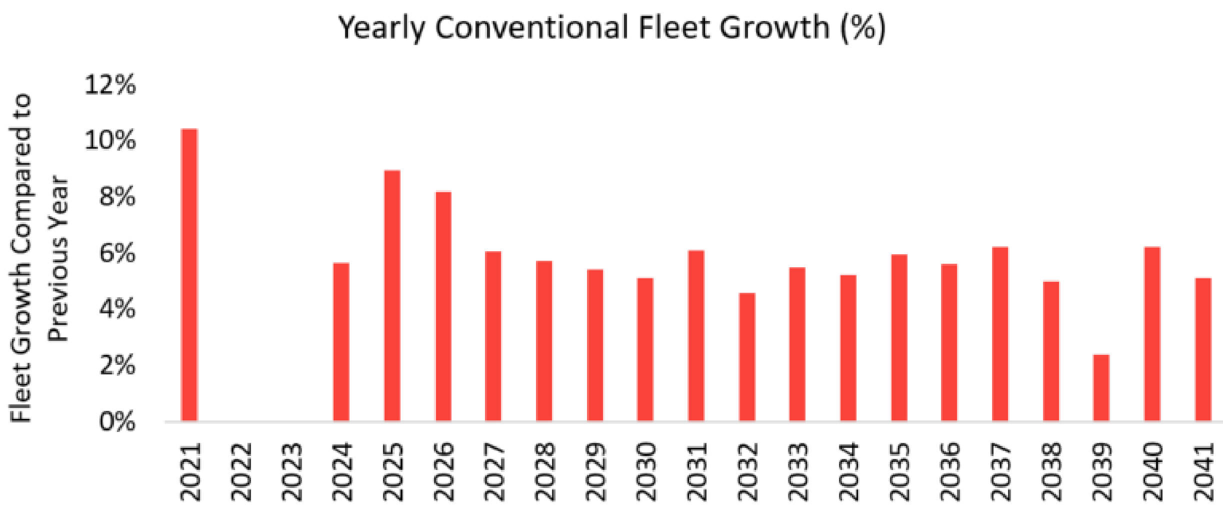

Figure 40 Yearly Conventional Fleet Growth

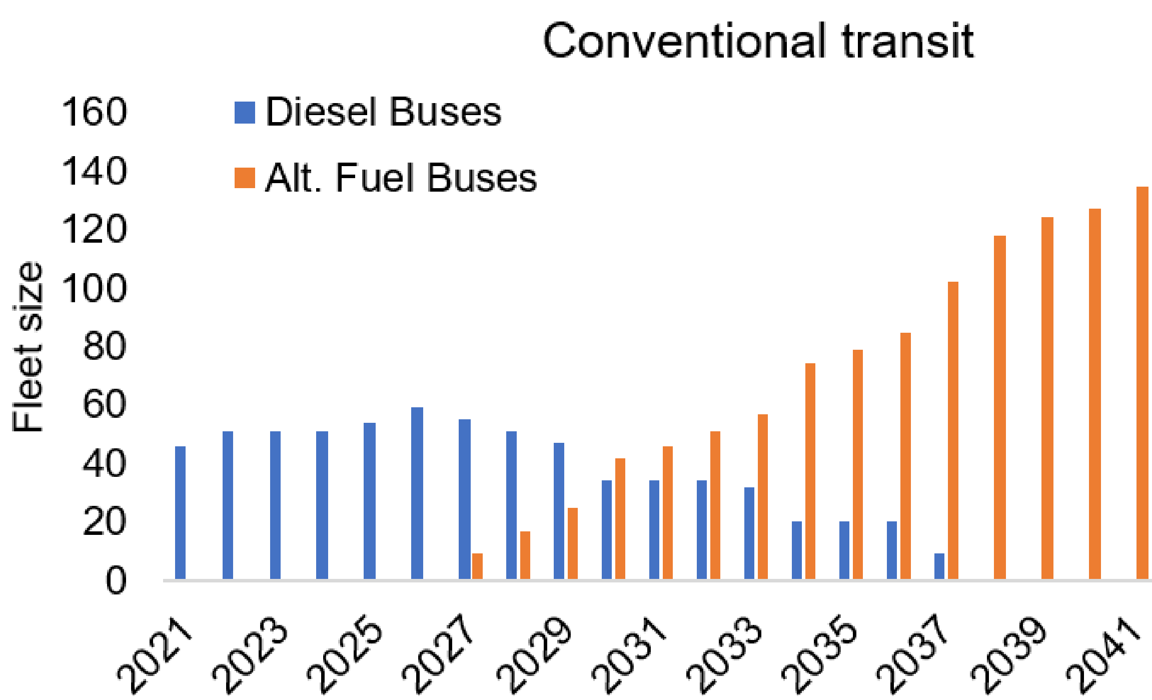

Figure 41 Conventional Transit Fleet Size (2021-2041)

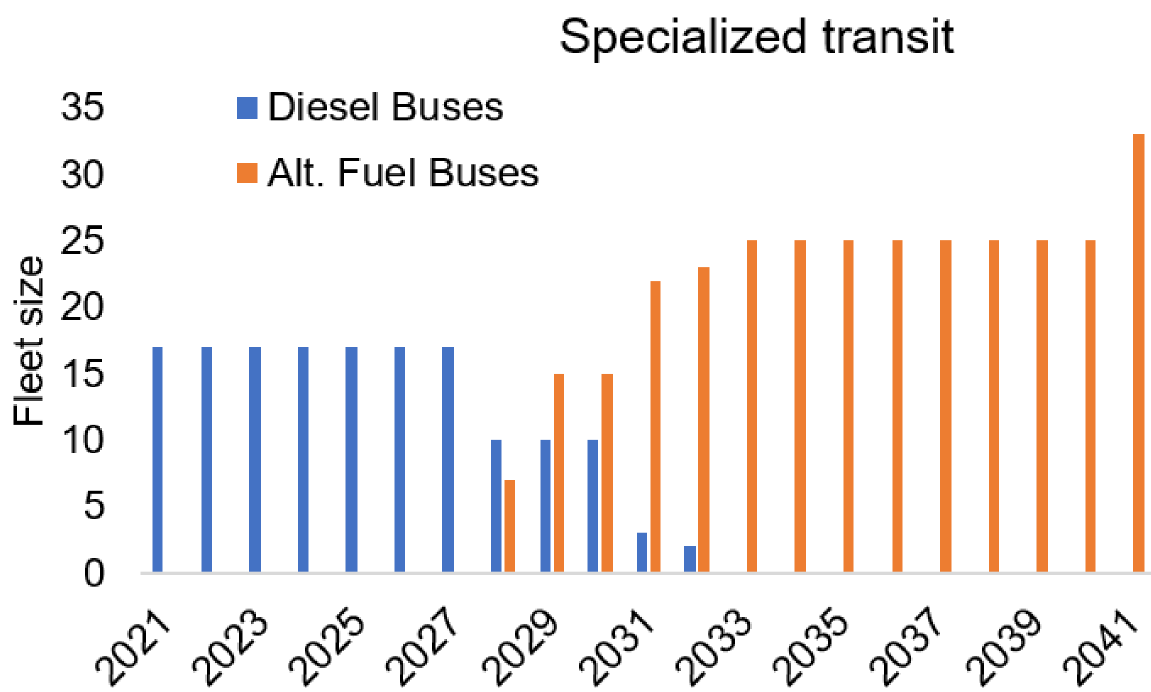

Figure 42 Specialized Transit Fleet Size (2021-2041)

Barrie Transit's garage currently has a capacity to host 56 transit buses (40ft) and 17 specialized transit vehicles. By 2026, an expansion is planned which would enable the addition of another 45 transit buses (40ft) and 10 additional specialized transit vehicles. Given the fleet growth provided in Figure 40, an additional garage build will also be required to accommodate the fleet growth.

The date for which this new facility needs to be commissioned will vary depending on the adopted technology. In fact, BEBs require various electrical equipment to operate including charging cabinets, dispensers, and switchgear. This equipment can occupy a valuable footprint in the garage parking area, hence reducing available parking capacity. In addition, BEBs have limited range and further studies recommended to develop effective charging strategy, route planning and schedule optimization.

8.2 ALTERNATIVE FUEL FLEET PLAN

8.2.1 CNG FACILITY

One key advantage of CNG technology is that a fleet of CNG vehicles require a fueling station that has a similar footprint to a diesel fueling station. Therefore, adoption of CNG buses should have a minimal impact on the garage capacity. However, while the fleet is transitioning, both the diesel and the CNG fuel stations will need to function concurrently. Considerations for CNG fueling space should be given to the facility upgrade requirements. Considering these requirements, and assuming the facility expansion occurs in 2026, it was estimated that a new garage facility will be needed in 2036 to accommodate fleet growth. Based on the transition plan there will not be anymore diesel buses in the fleet by 2038.

8.2.2 BEB FACILITY

As reviewed in Section 6.2.2, the BEB-to-diesel bus ratio for Barrie Transit was estimated to be 1.3 between 2021-2030, and 1.1 beyond 2030. In addition, the charger-to-bus ratio should be a minimum of 3:4 for the fleet to maintain required service levels and each DC charging cabinet would need to be installed on the ground within a few meters of the dispensers. Due to these two reasons, the garage will reach its maximum capacity quicker with an electric transition compared to a CNG transition.

Accounting for the space loss from the electrical equipment and the additional BEBs required to maintain service levels, the new facility will be needed by 2033. The new facility will host the growth vehicles starting in 2033, while the existing facility and its expansion will host the BEBs that are replacing the retiring assets. Figure 43 shows the evolution of the fleet size at the two facilities between 2021-2041. Based on the transition plan there will not be any diesel buses in the fleet by 2038.

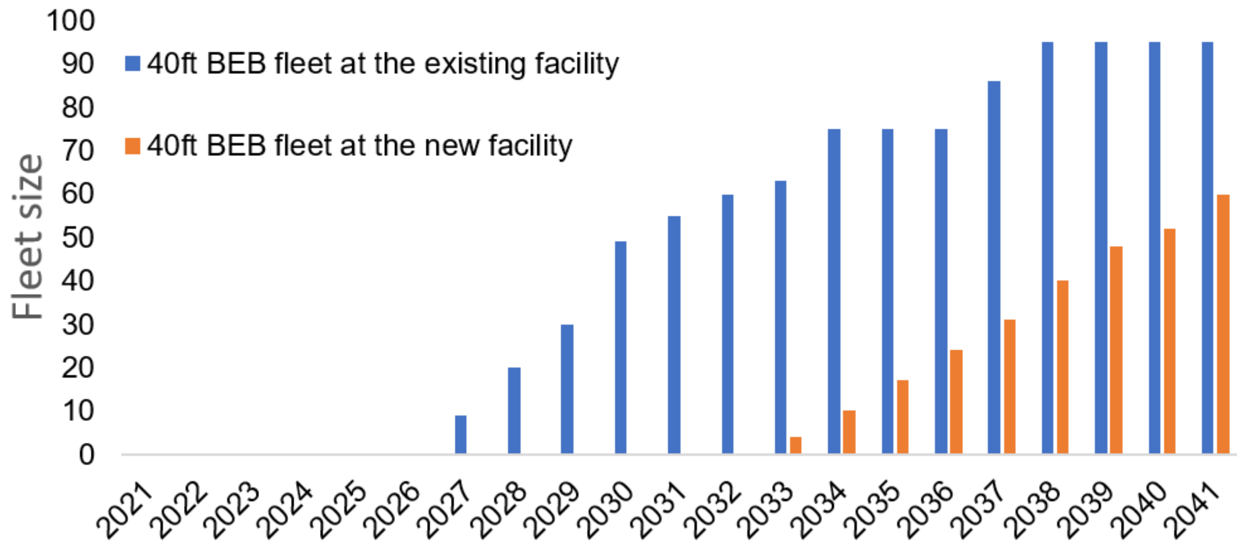

Figure 43 BEB Fleet Size at the Existing and New Facility

8.2.3 PILOT PROJECT CONSIDERATIONS

It is a common practise for transit agencies to want to test their technologies through pilot projects. Typically, the scale of the pilot project will vary between 1 to 30 buses depending on the size of the agency. Pilot project development requires dedicated staff and resources as the planning is intensive and the project success and public perception can dictate the following course of action for the agency.

It is expected that there may be minor deviations from the fleet plans shown in the previous section, notably due to the procurement of a limited number of pilot buses (i.e. 1 to 5 BEBs or CNG buses) in the years prior to 2027. This would enable Barrie Transit to gain familiarity with the BEB or CNG buses, charging technology and operational measures before engaging in a full program to start replacing all retiring buses with the alternative technology after the designated adoption start date. It would also enable the collection of critical operational data to update the initial plan, and assist in the negotiation/changes to the P3 Operating Contract.

CNG Technology Considerations

CNG vehicles can be piloted on a small scale with mobile refuelling equipment and trucked in compressed natural gas tube trailers. The costs associated with such an approach would depend on the size and duration of the pilot project. Even a temporary station such as this would require Technical Standards and Safety Authority (TSSA) applications and approvals.

For Barrie Transit, the following should be considered for the implementation of a CNG bus pilot project:

- The closest CNG retail station is located at Gain Clean Fuels on Britannia Road in Mississauga. This station is almost 100 km away from the garage, and would not be practicable to use on a daily basis.
- Minor repair maintenance activities such as oil changes and tire rotations are allowed in B-401 minor repair facilities. CNG vehicles in the shop for minor repairs are not to be left unattended.
- Major repair activities such as high-pressure fuel systems maintenance should be covered by the vehicle manufacturer under warranty for the extent of the pilot. These types of repairs would have to be negotiated with the vehicle manufacturer to be undertaken in a qualified CNG major repair facility.
- Major repair activities that are not covered by warranty, such as body work involving welding or grinding would have to be conducted either:
    a. outdoors or subcontracted to a qualified third party CNG major repair facility, or,
    b. at the client's facility if the CNG fuel tanks on-board the vehicles were depleted to below 500 psig, or,
    c. at the client's facility if it has been suitability outfitted for B-401 major repairs.

Battery Electric Bus Considerations

Battery electric buses can be piloted at a small scale, as manufacturers can provide pilot buses for an extended period of time (from a few months up to a year) through a leasing program similar to the 6 weeks pilot project led by Belleville Transit with BYD. The charging infrastructure required varies depending on the choice of the agency. Certain agencies have opted for portable plug-in chargers, while others, such as the TTC, invested in more permanent charging infrastructure. Recently, the City of Guelph voted in favor of installing up to four electric bus chargers to support their pilot project [45].

Depending on the number of electric buses required for the pilot project, electric chargers can be installed at the garage without requiring significant upgrades to the electric grid system. Charger providers can provide off-the-shelf charging units plugging directly into the existing transformers to recharge the vehicles. This type of solution is described in greater detail in Section 11.2.

Just like with CNG buses, most of the maintenance on these buses can be covered by the manufactures under warranty and contractual terms for the duration of the pilot project. An important aspect of pilot project is to collect and monitor enough data to learn as much as possible on the technology, and as such it would be recommended to install third party data loggers into the buses to access information such as energy and fuel consumption, speed profiles, battery utilization and downtime. The data collected will help validate the KPIs identified to quantify the success of the trial.

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[45] https://www.fleetbusiness.com/news/guelph-supports-electric-bus-pilot-project

9 FACILITY UPGRADES REQUIREMENTS

9.1 CNG FLEET CONVERSION

9.1.1 FACILITY UPGRADES

The following modifications may be required to accommodate CNG vehicles with increase height, due to roof mounted equipment (i.e. CNG fuel tanks). The extent of the modifications, if required, would depend on the physical dimensions and clearance requirements for the actual vehicles as procured as CNG buses tend to be higher than diesel or hybrid buses. Generally speaking, protecting for 3.5 m height should be sufficient. It would be prudent for the City to include vehicle clearance requirements and potential infrastructure modifications in its negotiations with the vehicle suppliers. Modifications to facilities may include:

1. Improve overhead clearance to the diesel exhaust hoods in the fuelling bays.
2. Improve overhead clearance to the vehicle wash equipment.
3. Improve clearance to the lighting fixtures.
4. Improve overhead clearance to the HVAC duct work, fans, and equipment.
5. Improve overhead clearance to the door openings.

In addition, facility modifications per the code CSA B401 for CNG fuelled vehicles in the maintenance bays will be required. 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.

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 amount of CNG indoors come with significant infrastructure upgrades to get the rooms rated against explosions, which add a significant cost to the budget.

For this reason, it is recommended that if Barrie Transit were to choose a CNG retrofit of its fleet, that the refuelling occurs outdoors. The detailed drawing “G-201.4 Transit Garage Proposed CNG Vehicle Refuelling Station” of the proposed refueling solution at the existing facility is shown in Appendix C, while a zoomed snapshot is provided in Figure 44 to illustrate the principles of the proposed solution explained below.

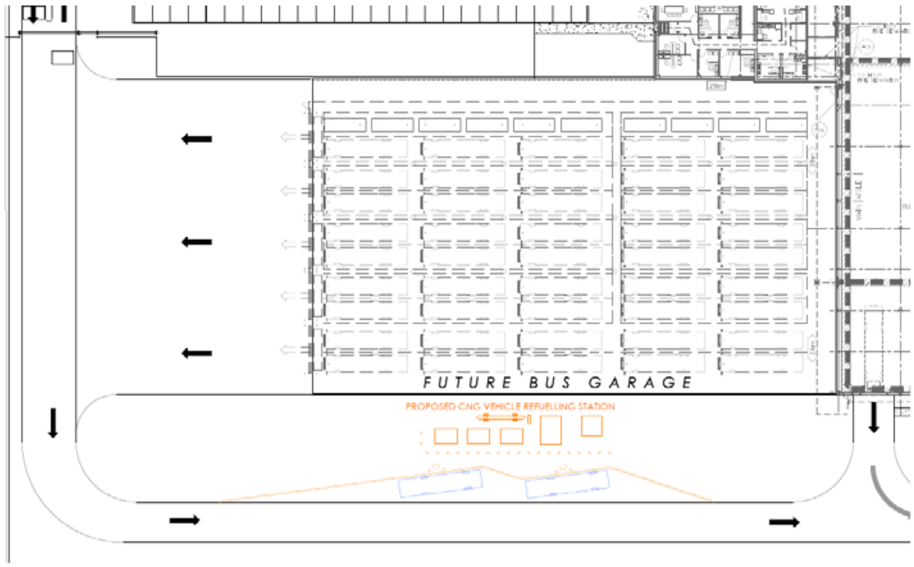

Figure 44 Outdoor CNG Refueling Station - Proposed Layout Zoom-in View

The CNG Vehicle Refuelling Station includes the following equipment:

- one (1x) Utilities Meter Set Assembly (MSA)
- one (1x) Natural Gas Dryer
- compressors in a 2 + 1 arrangement with two active compressors and one redundant compressor:
    - the first compressor and the redundant compressors are installed first in 2026 (Phase I), followed by the last compressor in 2030 (Phase II)
- one (1x) Buffer Storage Vessel
- one (1x) Gas Control Panel
- one (1x) associated Power, Controls and Communications Module
- two (2x) Heavy Duty Vehicle Dispensers.

The redundant compressor is installed to ensure system reliability. In practice one or two compressors would be run to meet the fuelling demands, with the redundant compressor idle. Subsequently, alternate compressors would operate in order to ensure that each compressor is exercised on a regular basis and that the total run hours per compressor are balanced.

Note that the CNG refuelling equipment is suitable for installation outdoors. The CNG refuelling dispensers and the refuelling operators would be sheltered from the elements under a canopy. The canopy would need to be designed and constructed such that it shall not accumulate lighter than air gases. The equivalent of at least 25% of the total of the canopy's perimeter walls shall be open to the outdoors.

The proposed operating process to refuel the vehicles is as follows:

- CNG vehicles arriving at the facility, requiring refuelling would drive to the CNG Refuelling Station at the east side of the facility, following the counter-clockwise flow of traffic around the facility.
- Two saw tooth refuelling bays would allow for one or two vehicles to refuel at a time. The sawtooth arrangement also allows for traffic to bypass the refuelling vehicles if required.
- The vehicles would then continue the counter-clockwise flow of traffic around the facility to enter the facility through the existing doors on the west wall of the facility and proceed to the indoor service lanes for cleaning and replenishing of fluids as required. The vehicles would then be driven to the existing or future expansion for overnight storage.

9.1.2 FUEL SUPPLY

The local natural gas utility was contacted as part of the project and didn't disclose details on the availability of natural gas distribution through the existing pipeline network at the site vicinity. Given the dense distribution of natural gas in the area, it is unlikely that availability of natural gas at the required pressure will cause issues in the project. Should Barrie Transit decide to pursue the option of deploying CNG buses, it is recommended to engage in further discussions with Enbridge to obtain a clearer picture on the cost of fuel supply and natural gas availability.

9.2 BEB FLEET CONVERSION

9.2.1 FACILITY UPGRADES

The conversion of the current fleet to a fully electric fleet requires additional considerations and planning. This transition is less straightforward than a CNG conversion. In fact, the power requirements of the fleet are high (up to 10 MW when the fleet at the facility is fully electrified). This exceeds what power is currently available at the facility. Additionally, unlike a fuel conversion that requires the installation of a refueling station outdoors, electric bus technology requires close to individual charging ports to facilitate operations. Hence, the footprint of the equipment required for the upgrade is greater. The single-line-diagram and facility system drawing "G-200.4 Transit Garage Proposed Electric Vehicle Storage and Charging" are shown in Appendix D and E, respectively. To illustrate the solution discussed in this section, a higher-level drawing is shown in Figure 45.

The following modifications may be required to accommodate battery electric vehicles with roof mounted equipment (i.e. battery packs). The extent of the modifications, if required, would depend on the physical dimensions and clearance requirements for the actual vehicles as procured. It would be prudent for the City to include vehicle clearance requirements and potential infrastructure modifications in its negotiations with the vehicle suppliers. Modifications to facilities may include:

1. Improve overhead clearance to the diesel exhaust hoods in the fuelling bays.
2. Improve overhead clearance to the vehicle wash equipment.
3. Improve clearance to the lighting fixtures.
4. Improve overhead clearance to the HVAC duct work, fans, and equipment.
5. Improve overhead clearance to the door openings.

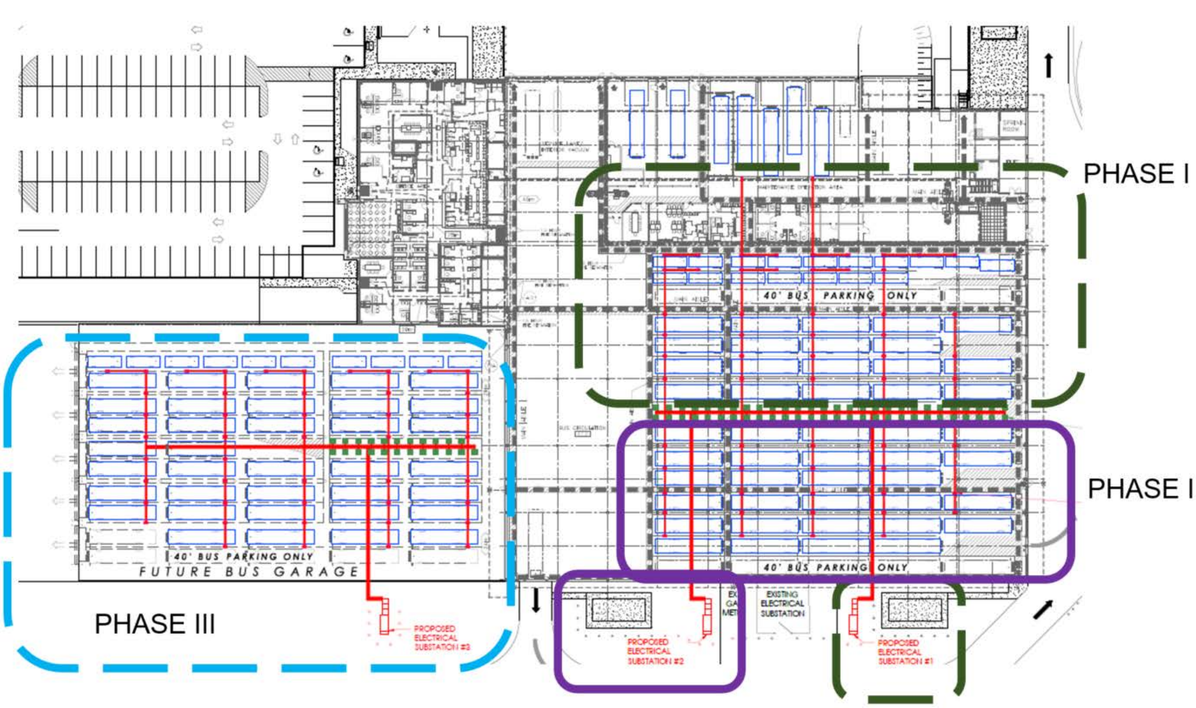

Figure 45 Conceptual Phasing Approach for the Facility Electrification

The installation of the equipment is phased in such that 25% of the required Electric Vehicle Supply Equipment (EVSE) such as charging cabinets and dispensers (and associated electrical supply equipment such as substations) are installed the year before the first electric vehicle is introduced, 50% of the required EVSE units have been installed by the time 25% capacity is reached, and 100% of the required EVSE have been installed by the time 50% capacity is reached. The charging cabinets proposed in the drawings are rated to 150 kW, based on WSP's BOLT modelling.

At the existing facility, it is assumed that a single 40ft transit vehicle is charged by a single charging cabinet and a single dispenser, however two para-transit vehicles are charged by a single charging cabinet and two dispensers (i.e. the specialized vehicles use dual charging cabinet).

At the expanded facility, it is assumed that two 40ft transit vehicles will be charged by a single charging cabinet and two dispensers, and that two specialized vehicles are also charged by a single charging cabinet and two dispensers. This assumption is based on projected improved battery capacity of electric vehicles, while keeping an overall charger-to-bus ratio above 3:4 which was shown as a requirement from the BOLT modelling.

One charging cabinet and two dispensers have been allocated to the maintenance operations area, to allow for charging of up to two vehicles (40ft or specialized transit) at two maintenance bays.

At the existing facility, one column is dedicated to the installation of charging cabinets. This forfeits four (4x) 40ft vehicle spaces. At the expanded facility, part of one column is dedicated to the installation of charging cabinets. This forfeits two (2x) 40ft vehicle spaces.

It is recommended that a 1.5 MW natural gas backup power generator is installed on the facility to supply enough power to charge at least 10% of the fleet concurrently in case of a power blackout.

It is recommended that Barrie Transit follows a phased approach for its fleet conversion following this order:

1. **Phase 0:** Facility expansion completed in 2027
2. **Phase I:** The existing facility should undergo the following electrical upgrades before 2027 (procurement date of the first BEB):
    - A 27.6 kV incoming switchgear, connecting the overhead line and utility feeder to one substation should be commissioned, including a metering system, rated for outdoor conditions
    - The incoming switchgear should be connected to one (1) substations. The substation should contain a 27.6 kV switchgear, a 3.5 MVA power transformer and a low voltage switchgear. Each substation should be rated to be stored outdoors.
    - The substation will then deliver the power to 28 x 150 kW AC-to-DC charging cabinets
    - Each charging cabinets will deliver DC power to one dispenser (total of 28 dispensers for the first phase of the upgrade)
    - Two plug-in chargers are planned to be installed in the maintenance area
    - The bus-to-charger ratio for this first phase is 8:10 for the 40ft, and 1:2 for the specialized transit fleet, with an additional two dispensers in the maintenance area
3. **Phase II:** The existing facility should undergo the following electrical upgrades before 2029 (BEB fleet exceeding 30 buses):
    - The 27.6 kV incoming switchgear should be upgraded with an additional circuit breaker to be connected to a new substation going into the existing facility
    - The incoming switchgear should be connected to one (1) additional substation. The substation should contain a 27.6 kV switchgear, a 3.5 MVA power transformer and a low voltage switchgear. Each substation should be rated to be stored outdoors.
    - The substation will then deliver the power to an additional 28 x 150 kW AC-to-DC charging cabinets
    - Each charging cabinets will deliver DC power to one dispenser (total of 56 dispensers for phase I and phase II)
    - The bus-to-charger ratio for this first phase is 8:10 for the 40ft, and 1:2 for the specialized transit fleet, with an additional two dispensers in the maintenance area
4. Assume all new electric buses are stored at the existing facility while the diesel fleet is being progressively replaced
5. Based on the fleet plan, the existing facility will be fully electrified by 2031, therefore starting in 2032 the new electric buses will need to be electrified on the expansion section
6. **Phase III:** the expansion area of the 133 Welham facility should undergo the following electrical upgrades by 2031:
    - The 27.6 kV incoming switchgear should be upgraded with an additional circuit breaker to be connected to a new substation
    - The incoming switchgear should be connected to an additional substation (three substations in total). The substation should contain a 27.6 kV switchgear, a 3.5 MVA power transformer and a low voltage switchgear.
    - The substation will then deliver the power to 23 x 150 kW AC-to-DC charging cabinets
    - Each charging cabinets will deliver DC power to two dispensers (total of 46 dispensers for the first phase of the upgrade)
    - The bus to charger ratio for this expansion is now 1:2 for the 40ft, and 1:2 for the specialized transit fleet
7. **Phase IV:** procurement of the new facility in 2033 to host the growth buses

9.2.2 ELECTRICAL GRID SUPPLY

Figure 46 shows the evolution of the daily peak demand in function of the fleet growth for each facility. Alectra confirmed that the nameplate rating of the existing transformer feeding the facility today is 1 MWA. After various engagements with the utility, the Alectra planning group confirmed that at present there is capacity on the existing 44 kV supply at the site vicinity to supply the Barrie Transit garage with the additional 5 MW load required to electrify the existing facility. However, by the time the first electric buses are deployed in 2027, Alectra cannot guarantee that the capacity will still be available as new clients might need this supply earlier on. The additional 3.4 MW required to electrify the expansion will require investments from Barrie Transit. The detailed investment costs required to upgrade the electrical equipment can be provided by Alectra through an application which costs about $10,000 to process. Alectra won't be able to account for how the system will change in the area over the next 10 years, and how those changes may impact the future scope of work. Based on feedback gathered from other agencies and previous fleet electrification studies led by WSP, the cost of upgrading the grid connections varies between $800,000 - $1,000,000 per MW added. These estimates include the installation of additional cabling, poles, metering, SCADA switchgears and the design, installation, inspection and administration cost. Note that before starting the process, Alectra requires an additional expansion deposit of about 5%. In this study, the cost of grid upgrades was included for the 8.4 MW required as a worst-case scenario, corresponding to $8,400,000.

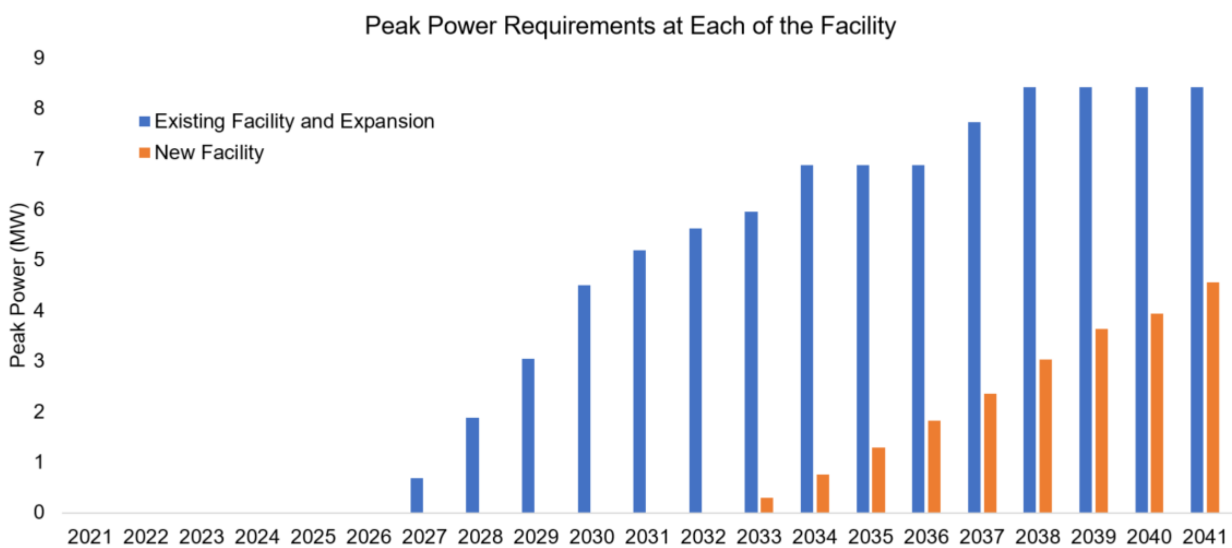

Figure 46 Evolution of the Charging Peak Demand at Each Facility

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 as the scenarios described are examples of what implementation may look like.

For Barrie Transit to assess the cost of alternative propulsion technology for their transit fleet vehicles WSP has developed a scenario planning tool which Barrie Transit can use to help forecast the fleet transition as well as capital investment, operating expenses and greenhouse gas (GHG) reduction moving toward 2041. This model takes inputs from the following key areas:

1. General Financial Inputs (i.e. inflation, discount rate, forecast period)
2. Fleet Asset Inventory (40ft transit buses, 30ft para-transit cutaway buses and para-transit vans)
3. Infrastructure Capital Expenditures (i.e. CNG or hydrogen fueling stations, BEB charging stations). Note: the CAPEX estimates provided in this analysis only consider the cost of added equipment and infrastructure upgrades required to host the new technology. The CAPEX doesn't include base building costs (such as expansion or commissioning of a new facility)
4. Infrastructure Operational Expenditures (i.e. fuel station maintenance)
5. Fleet Capital Expenditures (i.e. vehicle procurements, midlife/overhaul programs)
6. Fleet Operational Expenditures (i.e. vehicle maintenance, electricity, fuel, specialized tooling and training)
7. Environmental (i.e. GHG emissions in tonnes of CO_2e)

This information is structured into a financial forecast (i.e. start 2021 to end of 2041) to output the annual capital (CAPEX) and operating (OPEX) expenditures in year-of-expenditure dollars (YOE$) as well as in net present value (NPV) terms (2021$) and totals for the forecast period, assuming an inflation rate of 2.1%.

10.1.1 COST ANALYSIS – CNG FLEET CONVERSION

10.1.1.1 *DETAILED ASSUMPTIONS*

This section provides a detailed review of the capital and operating cost assumptions used in the cost analysis.

OPERATING AND FLEET CAPITAL COSTS

The lifecycle cost comparison for a 40ft transit bus is made over a 12-year lifecycle, according to the Barrie Transit Asset Management Plan. This 12-year lifecycle agrees with the Altoona testing program which is used to validate the lifecycle of transit buses in North America. Barrie Transit does not currently engage in a planned midlife overhaul program for their transit buses. Therefore, the capital cost for midlife rebuild/rehabilitation of the bus is excluded.

Maintenance costs for diesel buses depend on many factors, including the age of the asset. The Maintenance Records Worksheet provided an average maintenance cost from 2016-2020, which wasn't sufficient to determine maintenance cost for each year of the asset. As a result, industry maintenance average costs were used between 0.5$/km for a new bus up to 1.5 $/km for a 12 years bus.

The following set of lifecycle inputs and assumptions are used:

Table 15 Bus Lifecycle Cost Input Parameters

Input/Assumption	Value			Source
	40ft Transit	Cutaway-Specialized	Van-Specialized	
Vehicle Lifecycle	12 years	7 years	5 years	Barrie Transit AM Plan
Annual Usage	77,509 km/year	30,500 km/year	20,000 km/year	Barrie Transit Data
GHG Bus Purchase	$650,000	$185,000	$54,000	Barrie Transit AM Plan
CNG Vehicle Purchase	$700,000	$210,000	$65,000	Clean Energy ($50,000 premium over diesel bus); Peer Agency ($25,000 premium over diesel chassis); US EPA MV1 Van Report
GHG Vehicle Fuel Economy	55.2 L/100km	33.6 L/100km	15.5 L/100km	Historical Barrie Transit data; US EPA MV1 Van Report
CNG Bus Fuel Economy	55.2 DLe/100km	33.6 DLe/100km	18.1 DLe /100km	Assumption, same as diesel, based on dLe units; US EPA MV1 Van Report
GHG Bus Maintenance	0.5 to $1.5/km	0.30 to 1.10 $/km	0.50 to 0.90 $/km	Based on historical Barrie Transit data and industry averages.
CNG Bus Maintenance	95% of Diesel Bus Maintenance cost			WSP Bus Asset Management Lifecycle Data Analysis Diesel vs. CNG
Salvage Value (SV)	1%			Assume scrap value, percentage of purchase cost
Emission Factor for CNG Heavy-Duty Vehicles	2.20 kg CO2e/L			Calculated using GHGenius for Ontario, Wheel-to-Wheel
Emission Factor for Diesel Heavy-Duty Vehicles	2.65 kg CO2e/L			Calculated using GHGenius for Ontario, Wheel-to-Wheel
Emission Factor for Gasoline Vehicles	2.50 kg CO2e/L			Calculated using GHGenius for Ontario, Wheel-to-Wheel
Diesel and Gasoline fuel cost	0.97$/L or $0.53/km	0.97$/L or $0.32/km	0.97$/L or $0.15/km	Historical Barrie Transit data
CNG	0.5 $/DLe or $0.28/km	0.5 $/ DLe or $0.17/km	0.5 $/ DLe or $0.09/km	Change Energy Services

CNG STATION CAPITAL COSTS

- The total station costs provided in Table 16 include the cost of all equipment, installation, commissioning, training, project management, engineering services, general contractor fees, approvals, and a contingency fund.
- The cost estimate includes two (2) dryer towers that have been sized to provide a total of 16,610 m^3/day at the expanded existing facility, and two (2) dryer towers that have been sized to provide a total of 14,740 m^3/day at the new facility. At the expanded existing facility, one (1) dryer tower is installed the year before the first CNG vehicle is introduced, while the second is introduced the year before the facility reaches 50% of its capacity. At the new facility, one (1) dryer tower is installed when the facility is built in 2036. The second should be installed the year before the new facility reaches 50% of its capacity which (based on the fleet plan) occurs after 2041.

- The daily site consumption values at both the expanded facility and the new facility are based on the average fuel consumption of each transit bus type considered, which was provided by the City of Barrie. This consumption was then rounded to the nearest hundred and a redundancy adjustment of 10% was added to ensure that each station has adequate capacity.
- The cost estimate includes two (2) compressor units that have been sized to provide a total of 16,610 m^3/day at the expanded existing facility, and two (2) compressor units that have been sized to provide a total of 14,740 m^3/day at the new facility, based on an assumed suction pressure of 60 psig and an assumed discharge pressure of 4,500 psig. At the expanded existing facility, one (1) compressor unit is installed the year before the first CNG vehicle is introduced, while the second is introduced the year before the facility reaches 50% of its capacity. At the new facility, one (1) compressor unit is installed when the facility is built in 2036. The second should be installed the year before the new facility reaches 50% of its capacity which (based on the fleet plan) occurs after 2041.
- One (1) redundant compressor unit has been included in the cost estimates for both the expanded existing facility and the new facility, in addition to the aforementioned compressors and is available on standby in the event of a problem with the on-duty compressor(s). In both cases, the redundant compressor unit is installed the year before the first CNG vehicle is introduced.
- The total site power includes compression and an additional 10% for ancillaries.
- Approximately 285 m^3 of ground storage has been included at both the expanded existing facility and the new facility and was sized based on a fast buffer fill system. In both cases, this ground storage is installed the year before the first CNG vehicle is introduced.
- This scenario does not consider slow filling any of the transit buses and therefore, slow fill posts have not been included in the cost estimate.
- The cost estimate includes two (2) fast fill dispensers that are capable of handling the station's daily refuelling events. In both cases, both fast fill dispensers are installed the year before the first CNG vehicle is introduced.
- An allowance of 3% has been included to account for auxiliary equipment at both the expanded existing facility and the new facility.
- A total allowance of 35% has been included to account for installation at both the expanded existing facility and the new facility. In both cases, an allowance of 17.5% is reserved for the installation of the second phase of equipment, the year before the facility reaches 50% of its capacity, while the remainder of the total allowance is applied during the first phase, the year before the first CNG vehicle is introduced.
- The site is assumed to be mature at both the expanded existing facility and the new facility and therefore, civil costs (i.e. fences and gates, jersey barriers and guardrails, site preparation, paving and landing strips, and surface treatment other than paving) have been excluded.
- An allowance of 8% has been included to account for commissioning, acceptance, testing, and start-up activities, training, project management, and engineering at both the expanded existing facility and the new facility.
- An allowance of $20,000 has been included to account for the approvals process at both the expanded existing facility and the new facility.
- An allowance of 7% has been included to account for general contractor fees at both the expanded existing facility and the new facility.
- An allowance of 10% has been included as a contingency fund at both the expanded existing facility and the new facility.
- A 400 kW natural gas generator was included in the cost to provide backup power.
- Inflation has not been included in these infrastructure costs.

Table 16 Equipment Cost Breakdown for the CNG Stations

Station Component	Existing Facility + Expansion		New Facility
	Phase I	Phase II	Phase I
Equipment			
Dryer	$62,555	$62,555	$62,526
Compressor	$761,484	$380,742	$761,351
Ground Storage	$70,243	$0	$70,243
Priority Panel	$30,977	$0	$30,977
Fast Dispenser	$119,076	$0	$119,076
Slow Dispenser	$0	$0	$0
PCC Panel	$59,236	$0	$59,236
Building Modifications	$1,000,000	$0	$0
Auxiliary Equipment	$45,000	$0	$45,000
Backup power generators	$257,200	$0	$257,200
Utility Upgrade (Placeholder)	$2,000,000		
Civil and Installation			
Installation Budget	$685,280	$77,577	$385,297
Fences & Gates	$0	$0	$0
Jersey Barriers & Guardrails	$0	$0	$0
Site Preparation	$0	$0	$0
Paving & Landing Strips	$0	$0	$0
Surface Treatment (other than paving)	$0	$0	$0
Design and Execution Allowances			
Gas Service	$0	$0	$0
Electrical Service	$0	$0	$0
CATS, Training, Proj. Mgmt., & Engineering	$219,841	$0	$133,425
Approvals	$20,000	$0	$20,000
General Contractor Fee	$116,761	$0	$116,747
Contingency	$379,693	$0	$230,464
Owner Oversight & Admin. Fees	$0	$0	$0
Total	**$5,827,346**	**$520,874**	**$2,291,542**

FACILITY AND FUEL SUPPLY UPGRADES

- The cost of upgrading the rooms and ventilation system to safely park and maintain the CNG buses to comply with the CSA B401 was estimated at $1 million from past projects
- Since the refueling stations are planned to be located outdoors, no major mechanical or structural upgrades are required for the facility.
- It is very difficult to estimate the cost of upgrading the natural gas line to the site as this cost varies depending on design characteristics and conditions and requires detailed design and planning. A placeholder value of $2M was added to the total CAPEX required, but this value needs to be updated in collaboration with the utility if this project goes ahead.
- To add redundancy, a 400 kW CNG backup generator was included in the costing to provide electricity in case of a power blackout. The CNG backup generator is assumed to be fueled

directly by the site natural gas supply and it was assumed that no substantial upgrades would be required to the local gas line to run these generators. A unit cost of $643/kW was assumed and the generators are installed at both the expanded existing facility and the new facility. In both cases, the cost is allocated the year before the first electric vehicle is introduced.

CNG STATION OPERATING COSTS

- The cost of maintenance includes routine inspections of major equipment, as well as top end and bottom end overhauls of the compressor units, which are scheduled based on the hours of operation accumulated by each compressor. Furthermore, the cost estimates associated with routine inspections and compressor overhauls are based on correspondence with members of industry (i.e. experienced technicians).

NEW CNG FACILITY

- If the scenario of a CNG transition is adopted by Barrie Transit, a new facility will need to be built by 2036.
- It is difficult to estimate the cost of building a new facility without knowing any of the site constraints, expect that the facility needs to be sized for 100 CNG vehicles.
- The costs of building a new facility was excluded from this analysis.

10.1.1.2 *KEY RISKS ON ASSUMPTIONS*

The cost of upgrading the additional natural gas line may vary greatly depending on available supply. It is recommended that Barrie Transit pursues further engagement with the local natural gas providers to review local fuel supply and feasibility of upgrading local fuel lines to the site if this option is considered going forward. Based on previous projects, some utilities don't require any upgrade to their system as they can supply the required flow and pressure right away. Other projects require significant upgrades between $1.5 - $2M/km of line. Costs increase as the length of the line and service pressure go up. Conditions along the route also impact this cost. For instance, if the road needs to be excavated to upgrade the utility line, it will be significantly more expensive than running through a dedicated utility right of way with no finished surfacing. In this feasibility study, a placeholder value of $2M was added to the total CAPEX cost as a placeholder for the upgrade required.

In addition, ventilation and structural upgrades might be needed to retrofit the maintenance area and bring them up to standards and codes to operate natural gas. The extent of the work required to upgrade the facility should be studied in detail if a CNG transition is envisioned by Barrie Transit as the $1 million allowance provided in this report is a high-level estimate based on site-visit and past projects.

The technology is ever evolving, and the costs shown in this report may evolve by the time Barrie Transit procures its first alternative fuel vehicles.

10.1.1.3 *RESULTS*

This section outlines the results of the cost-analysis for CNG adoption. Figure 47 provides and overview of the fleet OPEX. Fleet maintenance cost make up a larger portion of the total OPEX for the fleet, and the yearly OPEX reached up to $14.1 million in 2041.

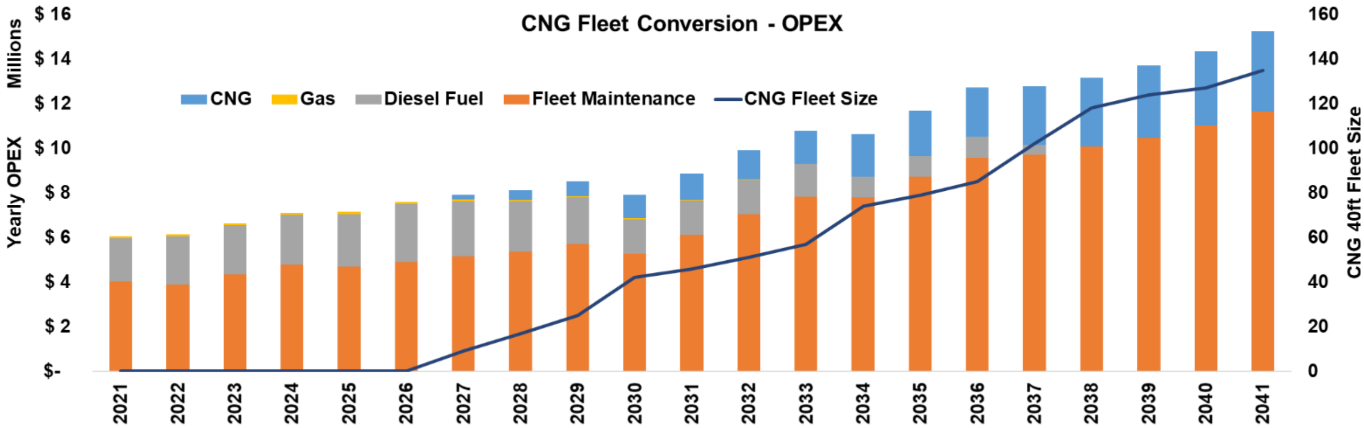

Figure 47 CNG Fleet OPEX (2021-2041)

The total fleet expenditures, including the infrastructure CAPEX, fleet procurements costs, fleet maintenance, fuel costs, training costs and infrastructure maintenance costs are shown in Figure 48. The greater costs are incurred by the fleet procurement CAPEX in this scenario. As the CNG fleet progressively grows, yearly expenses increase over time.

A comparison of the CNG fleet conversion cost analysis is performed with the electric fleet conversion scenario and the BAU in Section 10.1.3.

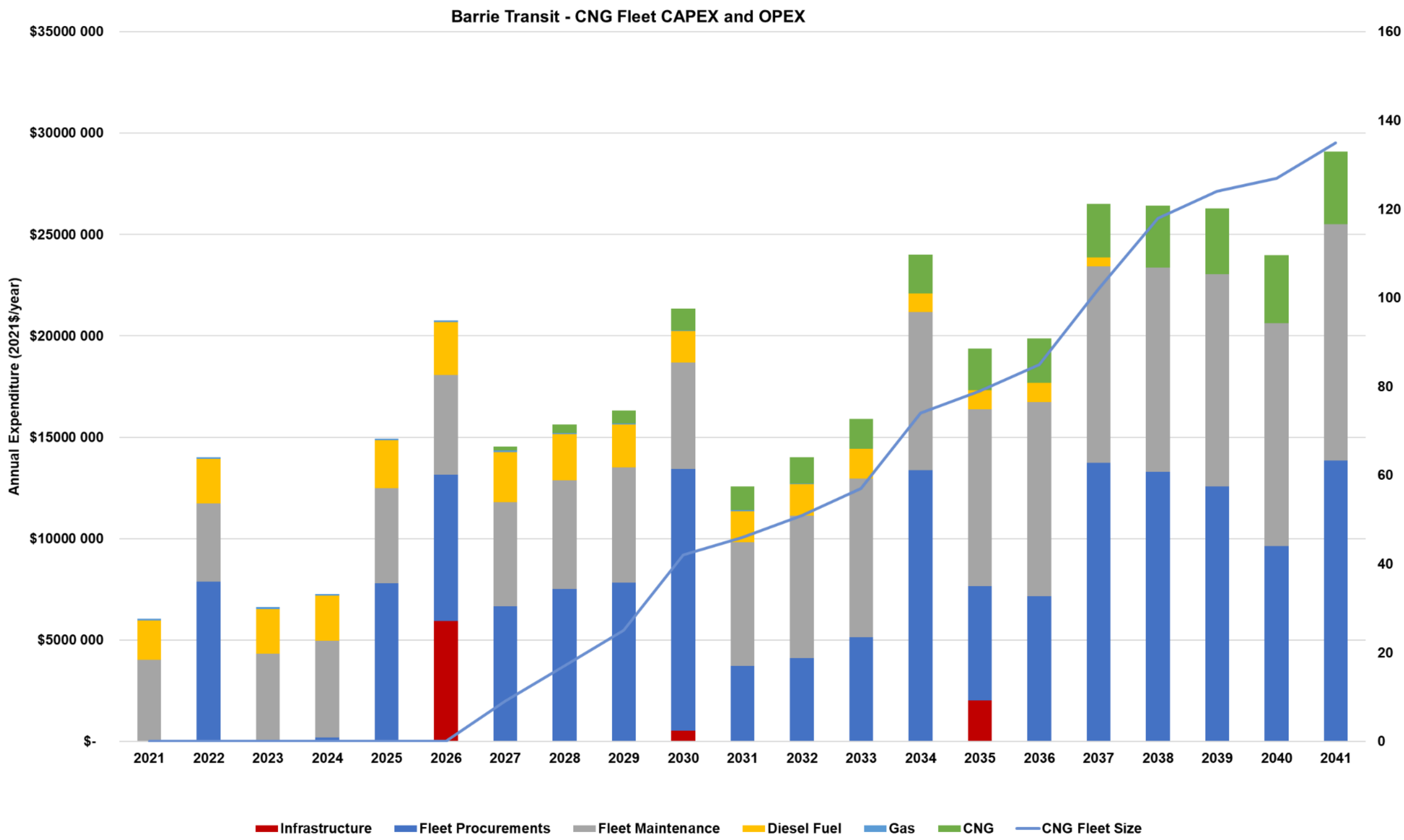

Figure 48 Annual CAPEX, and OPEX for the CNG Fleet Adoption

10.1.2 COST ANALYSIS – ELECTRIC FLEET CONVERSION

10.1.2.1 Detailed Assumptions

OPERATING AND FLEET CAPITAL COSTS

The following set of lifecycle inputs and assumptions are used to model the electric fleet transition:

Table 17 Bus Lifecycle Cost Input Parameters

Input/Assumption	Value			Source
	40ft Transit	Cutaway-Specialized	Van-Specialized	
Vehicle Lifecycle	12 years	7 years	5 years	Barrie Transit AM Plan
Annual Usage	77,509 km/year	30,500 km/year	20,000 km/year	Barrie Transit Data
GHG Bus Purchase	$650,000	$185,000	$54,000	Barrie Transit AM Plan
Electric Vehicle Purchase	$1,200,000	$300,000	$73,000	Clean Energy ($50,000 premium over diesel bus); LionM (High Level Estimate); Ford eTransit Van Quote (converted from USD to CAD) Wheelchair ramp installation (+$15,000 CAD est.)
GHG Vehicle Fuel Economy	55.2 L/100km	33.6 L/100km	15.5 L/100km	Historical Barrie Transit data; US EPA MV1 Van Report
BEB Bus Fuel Economy	1.92 kWh/km	0.83 kWh/km	0.42 kWh/km	WSP BOLT; OEM Published Range (200 km from 67 kWh with 20% safety)
Diesel Bus Maintenance	$0.73/km	0.30 to 1.10 $/km	0.50 to 0.90 $/km	Based on historical Barrie Transit data.
BEB Bus Maintenance	70% of Diesel Bus Maintenance cost			WSP Bus Asset Management Lifecycle Data Analysis
Salvage Value (SV)	1%			Assume scrap value, percentage of purchase cost
Emission Factor for Electric Heavy-Duty Vehicles	Varying from 0.031 kgCO2e/kWh in 2021 to 0.098 kgCO2e/kWh in 2041			IESO's 2020 Annual Planning Outlook
Emission Factor for Diesel Heavy-Duty Vehicles	2.65 kg CO2e/L			Calculated using GHGenius for Ontario, Wheel-to-Wheel
Emission Factor for Gasoline Vehicles	2.50 kg CO2e/L			Calculated using GHGenius for Ontario, Wheel-to-Wheel
Diesel fuel cost	0.97$/L			Historical Barrie Transit data
Diesel and gasoline fuel cost	0.97$/L or $0.53/km	0.97$/L or $0.32/km	0.97$/L or $0.15/km	Historical Barrie Transit data
Electricity	Administrative fee: 150.84$/month Electricity cost (including GA): 0.125$/kWh Demand cost: 8.9887 $/kW			Large Customer Rates, Alectra, 2021

CAPITAL COSTS

- The total station costs provided in Table 18 include the cost of transmission and distribution, entrance switchgear, power distribution and step-down transformation, charging units, architectural/civil/structural modifications, building system modifications, and construction management, overhead and power delivery.
- The cost of transmission and distribution refers to the cost to bring power to the property line at the expanded existing facility and is based on a previous project from WSP with a transit agency in Ontario. This value is a placeholder until more detailed costing are received from Alectra. It is assumed that the new facility will be located such that the cost of such an upgrade is not required – as such, this cost has not been included for the new facility.
- The cost of the entrance switchgear is $250,000, which has been applied to the expanded existing facility the year before the first electric vehicle is introduced. The same cost has been applied to the new facility in 2032 when the facility is built.
- Three (3) charging points have been provided for every four (4) vehicles.
- Equipment is phased in such that 25% of the required charging units (and associated construction management, overhead, project delivery, and installation costs) are installed the year before the first electric vehicle is introduced, 50% of the required charging units have been installed by the time 25% capacity is reached, and 100% of the required charging units have been installed by the time 50% capacity is reached.
- The charging units used in the cost estimate are rated for 150 kW, based on WSP's BOLT modelling.
- At the expanded existing facility, it is assumed that a single conventional transit vehicle is charged by a single charging unit and two (2) para-transit vehicles are charged by a charging unit (i.e., the para-transit vehicles use "duplex" charging units). At the new facility, all vehicles use "duplex" charging units.
- The cost per single charging unit has been derived based on past projects. An 80% cost increase is applied to the cost per "dual" charging units.
- A total of three (3) substations have been included at the expanded existing facility and are assumed to be installed in phases – the first is installed the year before the first electric vehicle is introduced, the second is installed when 25% capacity is reached, and the third is installed when 50% capacity is reached. One (1) substation has been included in the estimate for the new facility in 2032 when the facility is built. A cost of $700,000 has been assumed for each substation.
- The cost of architectural/civil/structural modifications is based past projects. The $750,000 allowance includes a conservative estimate for roof reinforcements modifications, as well as substation pads and fencing, and has been applied only to the expanded existing facility the year before the first electric vehicle is introduced. It is assumed that the new facility will be built such that no architectural/civil/structural modifications are required.
- The $200,000 allowance includes fire and flammable gas detection safety system modifications and has been applied only to the expanded existing facility the year before the first electric vehicle is introduced. It is assumed that the new facility will be built such that no building system modifications are required.
- The cost of construction management, overhead, and project delivery assumes a 20% allowance for professional services, a 10% allowance for project/internal administration, and a 20% allowance for construction management and overheads. This cost also includes the install cost per charging unit. An 80% cost increase is applied to the install cost per "duplex" charging unit. In both cases, this cost is applied as charging units are installed.
- A 1.5 MW natural gas generator was included in the cost to provide backup power
- Inflation has not been included in the costs

ELECTRICAL EQUIPMENT OPERATING COSTS

- Due to lack of available data, the annual operating cost was assumed to be 0.5% of the total installed infrastructure CAPEX.

Table 18 BEB Fleet Conversion CAPEX Cost

Station Component	Existing Facility + Expansion			New Facility
	Phase I	Phase II	Phase III	
Equipment				
Transmission & Distribution (Including Alectra's Upgrades)	$8,400,000	$0	$0	$0
Entrance Switchgear	$250,000	$0	$0	$250,000
Power Distribution & Step-Down Transformation	$322,750	$322,750	$0	$645,500
Backup power generator	$964,500	$0	$0	$964,500
Charging Units	$1,113,543	$1,417,236	$2,125,854	$2,328,317
Substations	$700,000	$700,000	$700,000	$700,000
Other				
Architectural/Civil/Structural Modifications	$750,000	$0	$0	$0
Building System Modifications	$200,000	$0	$0	$0
Construction Management/Overhead/Project Delivery	$2,501,892	$2,281,124	$3,004,623	$3,705,194
Station Total				
Total	**$15,202,685**	**$4,721,110**	**$5,830,478**	**$8,593,511**

10.1.2.2 Key Risks on Assumptions

Should Barrie Transit decide to implement the electrification plan for its fleet the following elements may impact aspects of the costing considered in this analysis:

- Alectra suggested that there is sufficient capacity to provide 5 MW of additional load to the facility without requiring a substantial grid infrastructure upgrade today. However, between present day and 2027 when the first electric buses are procured, other local customers may require that capacity and will therefore be prioritized. This will impact Barrie Transit's investments costs, which is why it is crucial that Barrie Transit keeps on communicating updates to its plan to Alectra throughout the planning process. Right sizing and timing the deployment of the infrastructure will be critical to ensure Barrie Transit doesn't pay for an over allotment of electricity if the infrastructure is not being used, but also to capitalize on opportunities to have available power supply at the site vicinity readily available.
- Roof-mounted plug-in chargers are heavy pieces of equipment that will likely require reinforcement of the roof structure. Though our analysis included a $750,000 allowance for roof structure reinforcement, a more detailed structural analysis is required to cost this component with a higher accuracy
- Sizing and costing a microgrid system were outside the scope of this feasibility study but can provide cost benefits in the long-run for Barrie Transit despite a high investment upfront cost. Should Barrie Transit decide to implement electric buses, it is recommended to pursue a study looking at the benefits of micro-grid and sizing the systems.
- Similarly, the proposed approach for power back-up generator and supply redundancy should be reviewed in greater details before implementation as the resilience strategy will impact the cost estimates provided in this section.
- The technology is ever evolving, and the costs shown in this report may evolve by the time Barrie Transit procures its first alternative fuel vehicles.

- Today, there aren't any transit agency that have fully converted their fleets to electric vehicles. As a result, little information is available on the maintenance cost for the charging and electrical equipment. Recent studies reported chargers availability between 98-99% for on-route charging from the Foothill Transit deployment project[46]. From 2017-2019, Long Beach Transit piloted 10 BYD electric buses using plug-in charging at the depot. Charger-related issues were reported to be responsible for 1.2% of downtime for the fleet (or 39 days in total) which has led National Renewable Energy Laboratory (NREL) to report that maintenance costs for plug-in chargers were negligible47. That said, charging units have not been in-service long enough to capture maintenance need and as such, the infrastructure maintenance cost were excluded from the analysis.
- Cost estimates for a 1.5 MW natural gas power backup generator were added to the equipment costs. The actual sizing of this generator will likely change depending on Barrie Transit's minimum service level requirements, and whether Barrie Transit introduces microgrid technologies to its site. The equipment cost was assumed to be $643/kW.

10.1.2.3 Results

This section outlines the results of the cost-analysis for a BEB conversion. Figure 49 provides and overview of the fleet OPEX. In this scenario, diesel fuel is used even when the fleet is fully electric due to the usage of diesel heaters in the winter which are recommended for Canadian winters. The total yearly OPEX expenditure goes up to $12 million in 2041. This cost assumes an inflation rate of 2.1% yearly.

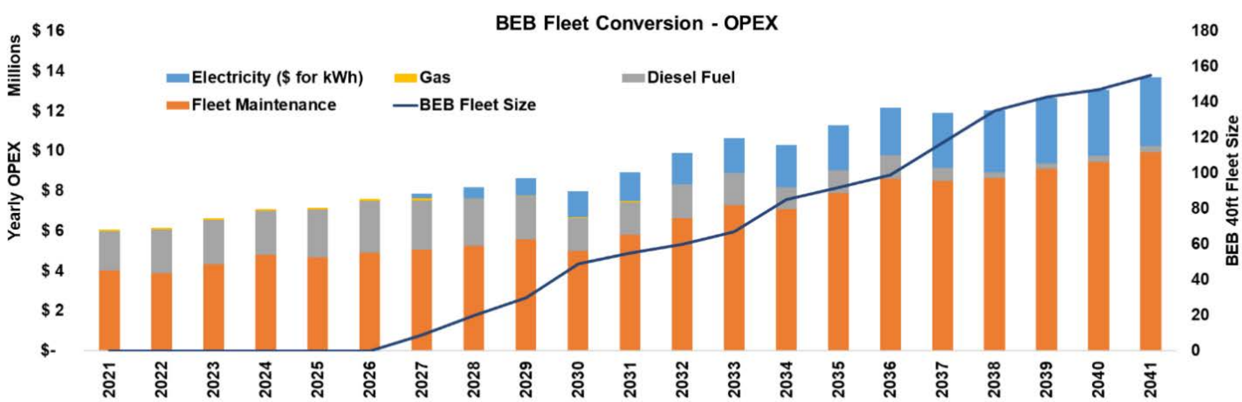

Figure 49 BEB Fleet OPEX (2021-2041)

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46 https://www.nrel.gov/docs/fy17osti/67698.pdf
47 https://www.nrel.gov/docs/fy20osti/75582.pdf

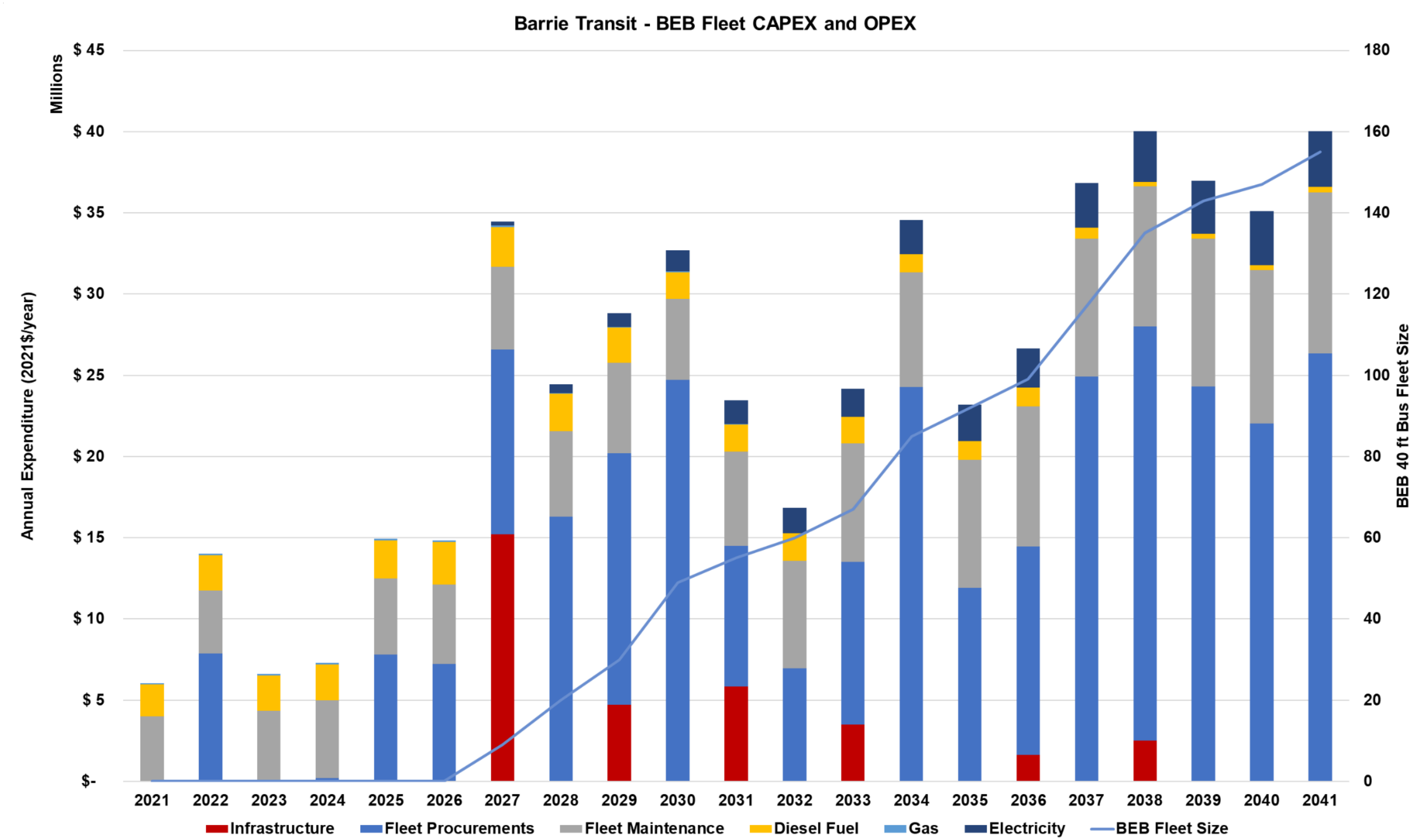

Figure 50 Annual CAPEX and OPEX for the BEB Fleet Adoption

Figure 50 shows the annual CAPEX and OPEX modelled as part of this cost analysis for the BEB conversion. A comparison of this cost analysis is provided with the CNG fleet conversion scenario and the BAU in section 5.1.3.

10.1.3 COST COMPARISON TO BUSINESS-AS-USUAL

The net present value (NPV) cost breakdown for each of these scenarios is presented in Table 19 while Figure 51 shows a representation of the capital and operating costs (in million $) as well as the total fleet emissions over the transition scenario.

Table 19 NPV Comparison of Fleet Technology Transition Plans (in Millions $)

2021$	BAU	Scenario 1 CNG Conversion (2021-2041)	Scenario 2 BEB Conversion (2021-2041)
CAPEX			
Infrastructure	N/A	$8.6	$34.3
Fleet Procurements	$151.2	$160.2	$288.8
Midlife/Overhaul	N/A	N/A	N/A
Salvage Value (SV)	($0.97)	($0.85)	($1.08)
Net CAPEX	**$150.4**	**$167.9**	**$322.0**
OPEX			
Fleet Maintenance*	$152.4	$148.0	$136.4
Fuel/CNG/Electricity	$85.5	$58.8	$63.4
PPE, Tools, Training**	N/A	N/A	$0.83
Infrastructure Maintenance	N/A	$0.85	$1.5
Net OPEX	**$237.9**	**$207.7**	**$202.2**
Fleet Emissions			
Total Emissions (tonnes CO2e) ***	209,124	187,309	102,263
Total NPV (CAPEX + OPEX)	**$388.3**	**$375.7**	**$524.2**

* Fleet maintenance for the BEB scenario is higher than 70% of diesel maintenance because there are more vehicles to maintain

**Note that for the CNG adoption case the cost of training is incorporated into the infrastructure cost of the CNG fueling station

*** In 2041, adopting a fully electric bus fleet would reduce emissions levels by 80% compared to BAU, compared to 16% when comparing CNG and BAU.

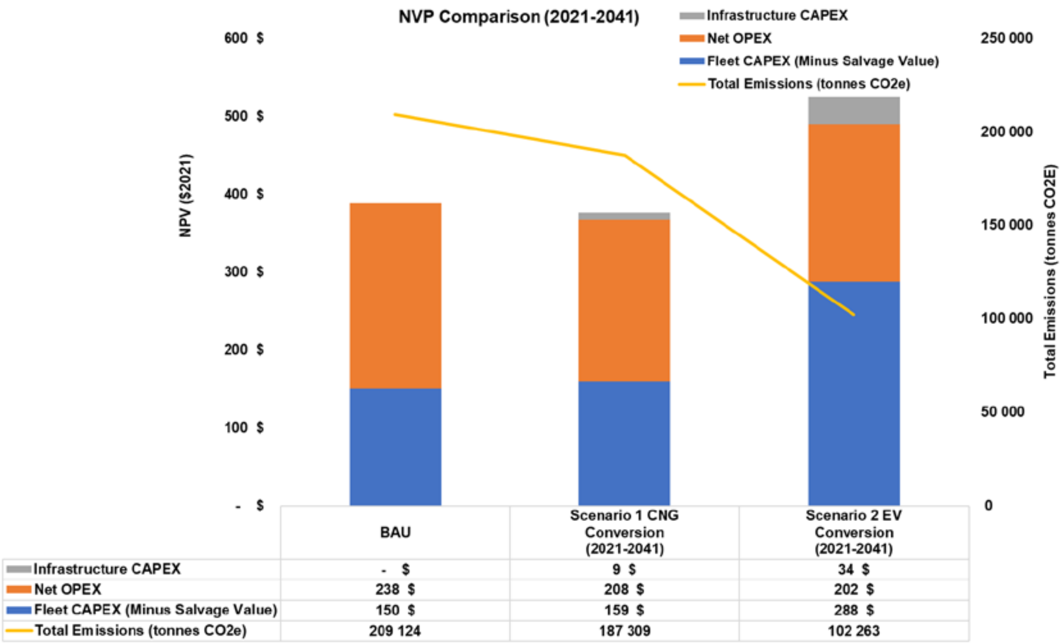

Figure 51 NPV Comparison Between the Different Technologies Over 20 Years (2021-2041)

One of the key takeaways from these results is that infrastructure upgrades end-up being a small portion of the overall CAPEX for the projects. The key elements driving the costs are the fleet procurement costs and the operations costs. While the BEB transition scenario provides 3% of operating cost savings compared to the CNG scenario, it also comes with an increased CAPEX of 48%.

The CNG adoption scenario shows an overall saving compared to BAU of $12.7M over 20 years, representing about 3.25% savings over the total BAU cost. The electric vehicle adoption scenario shows an additional expense of $135.9 million compared to BAU, which represents 35% of the total expenditure.

Table 20 shows a summary of the benefits of the technology depending on each adoption scenario. The electric vehicle scenario enables an emission reduction of 51% compared to BAU over the 20 years horizon, compared to a 10% for the CNG scenario.

Table 20 Cost Benefit Summary of Technology Adoption Over 20 Years (2021-2041)

Adoption Case (compared to BAU)	CNG	Electric
Incremental Investment ($ in millions)	-$12.7 million (saving)	+$135.9 million (expense)
Emissions Reduction (tonne CO2e)	21,815	106,861

10.1.4 CANADIAN CARBON TAX

In 2019, Canada passed the Greenhouse Gas Pollution Pricing Act, or carbon tax, in an effort to cutting 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 Transit[48].

Table 21 provides a review of the cost benefit assuming a gradual implementation of a carbon tax (increase of 2.1% yearly from 30 $/tonne to 170 $/tonne in 2030, or 390 $/tonne by 2041). Following this increase, the BEB scenario would lead to a cost increase of 26% compared to the BAU, and the CNG fleet adoption scenario would enable savings of up to 4.4% compared to BAU.

Table 21 Cost Benefit Summary of Technology Adoption Over 20 Years (2021-2041) Including Carbon Tax

Adoption Case (compared to BAU)	CNG	Electric
Incremental Investment ($ in millions)	-$19.2M (savings)	+$114.0 M (expense)
Emissions Reduction (tonne CO2e)	21,815	106,861

10.1.5 FUNDING 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.

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

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.

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 22 Summary of NRCan Incentives for Charging & Fueling Stations

Category	NRCan Repayable Incentives
BEB 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 BEB 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 23. 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[49].

Table 23 Federal BEB 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

These Transport Canada incentives could be most relevant to the para-transit fleet, specifically the para-transit vans.

CANADA INFRASTRUCTURE BANK (CIB)

In October 2020, the Federal Government of Canada announced $1.5 billion in financing for zero emission buses and charging infrastructure[50]. The goal is for this financial initiative is to help accelerate deployments of zero emission transit and school buses with the aim to get 5,000 vehicles on the road by 2025. This financing program is being managed through the Canada Infrastructure Bank (CIB).

Under the Program, the CIB will make direct loans to transit and school bus owners and operators to cover the higher upfront capital costs of ZEBs and charging infrastructure versus diesel buses. The CIB has established financing in the structure of a zero-interest type loan. Funds planned to be issued to help agencies cover the upfront capital cost of zero emission buses and charging infrastructure while the operational cost savings from the technology in part will be used for the loan repayment. Thereby, there is an element of risk sharing between the CIB and the participating agencies. The CIB is currently accepting applications for this funding program.

INFRASTRUCTURE CANADA

In March 2021, the federal government announced $2.75 billion in funding over five years starting in 2021 to support the deployment of 5,000 electric buses (public buses and school buses)[51]. This funding is part of an 8-year, $14.9 billion public transit investment recently outlined by the Prime Minister. This investment will come from Infrastructure Canada directly. Limited information is publicly available at this stage on what will be required to access this funding, but from the latest information gathered this funding stream is meant to work alongside CIB 's $1.5 billion financing initiative.

OEM LEASING PROGRAMS

Increasingly, electric bus manufacturers are starting to offer leasing programs to help mitigate the upfront capital costs of purchasing electric buses. One example is the Battery Leasing Program offered by Proterra. This program aims to reduce the upfront purchase price of the bus by having the cost of the vehicle's battery pack rolled into a leasing program made over the 12-year lifecycle of the bus. Thereby, operational cost savings in terms of maintenance and diesel fuel use can be used by the operator to make the lease payments. For reference, an eBus battery pack can cost on the order of $150,000. Through this battery leasing program, Proterra takes on the risk of battery performance over the entire 12-year life. This includes a midlife battery replacement (if required) in order to ensure the overall performance of the electric bus remains intact.

[49] Transport Canada, Zero-emission vehicles, Available at: https://tc.canada.ca/en/road-transportation/innovative-technologies/zero-emission-vehicles
50 https://electricautonomy.ca/2020/10/01/federal-investment-zev-bus-charging/
51 https://www.newswire.ca/news-releases/government-of-canada-investing-to-electrify-transit-systems-across-the-country-895599052.html#:~:text=Today%2C%20the%20Government%20of%20Canada,them%20to%20cleaner%20electrical%20power.

Some agencies which have opted for Proterra's Battery Leasing Program include Park City, Utah (fleet of six eBuses, additional seven eBuses upcoming) and MetroLINK in Illinois (fleet of five eBuses). This leasing program is available for any of Proterra's eBus models. In Canada, this type of leasing program is still limited and a potential risk is that it may limit access to government funding in the long run as it reduces upfront capital costs.

10.2 ENVIRONMENTAL AND SOCIAL IMPACTS

10.2.1 ELECTRIC TECHNOLOGY

The use of a BEB versus a diesel or CNG bus provides many benefits, the most prevalent being the elimination of tailpipe emissions that typically discharge GHGs and harmful air contaminants into local environments. The sulphur content in diesel fuel greatly impacts the tailpipe emissions produced. A high sulphur content can also lead to clogged of filters and reduce the positive effects of emission reduction systems (i.e. diesel particulate filters).

In North America, the Environmental Protection Agency (EPA) has made significant strides in regulating harmful emissions from combustion engine vehicles. However, BEB operations can eliminate tailpipe emissions of these harmful air contaminates. Table 24 lists some of the most prevalent air contaminates from gasoline, diesel and CNG vehicles along with their impact on health concerns and the environment.

Table 24 Tailpipe Emission Air Contaminates and Impacts

Air Contaminants	Environmental and Health Impacts
Carbon Monoxide (CO)	Bi-product from incomplete combustion of fuels. CO can react from tailpipe emissions to produce CO_2 and ozone (O_3).
Total Hydrocarbons (THC)	Bi-product from incomplete combustion of fuels. Hydrocarbons contribute to ground level smog and can cause skin, eye and respiratory irritation.
Nitrogen Oxides (NOx)	Bi-product from the combustion process. NOx emissions increase as a result of higher engine temperatures. NOx can react in the atmosphere to produce ozone (O_3), and acid rain.
Particulate Matter (PM)	Solid and liquid particulates suspended in the air, can be emitted in tailpipe emissions. Inhalation of airborne particulates can pose a risk to respiratory and lung health. Smaller sized particles (PM2.5 or less than 2.5 µm) are more dangerous than larger sized (PM10 or 10 µm).

10.2.2 CNG TECHNOLOGY

Use of CNG as a transportation fuel has multiple benefits, the most prevalent being a reduction in tailpipe emissions as compared to diesel. In addition to CNG, there is also the additional option of Renewable Natural Gas (RNG) which can be used for fueling. 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.

Natural gas provides an option that is not only cleaner than conventional petroleum fuels but is becoming increasingly more economical. Vehicles that use natural gas can demonstrate the following benefits:

- Produce up to 25% fewer GHG emissions than their conventional petroleum fueled counterparts;
- Decrease Nitrous Oxide (NOx) by more than 35%;
- Decrease Sulphur Dioxide (SO_2) by more than 45%; and
- Decrease Particulate Matter (PM) by 20% as compared to gasoline.

Percentages vary somewhat when compared to diesel, but natural gas burns cleaner than diesel for all priority pollutants. Cummins Westport's development of Near Zero CNG engine can reduce emissions even further.

10.2.3 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 and Table 17. Figure 52 demonstrates the potential of adopting electric vehicles in reducing yearly emissions compared to the CNG technology. Electric vehicles would reduce emissions of up to 51% compared to BAU over the next 20 years, while adopting CNG vehicles would reduce it by 10%.

At the end of the 20 years, once 100% of the fleet is electric, the yearly emissions are 3,077 tonnes of CO_2e, while the emissions from the natural gas fleet is at 13,183 tonnes of CO_2e, roughly four times as much. In 2041, adopting an electric bus fleet would reduce emissions levels by 80% compared to BAU (including emissions from diesel heaters and from the grid), compared to 16% between CNG and BAU. It should be noted that Canada's mandate is to achieve carbon neutrality, or "net zero" by 2050 and it is likely that more measures will be going towards advancing this goal in the future.

Although there are avenues to reduce GHG emissions for natural gas vehicle 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, whereas there the province of Ontario currently relies on a clean electricity grid.

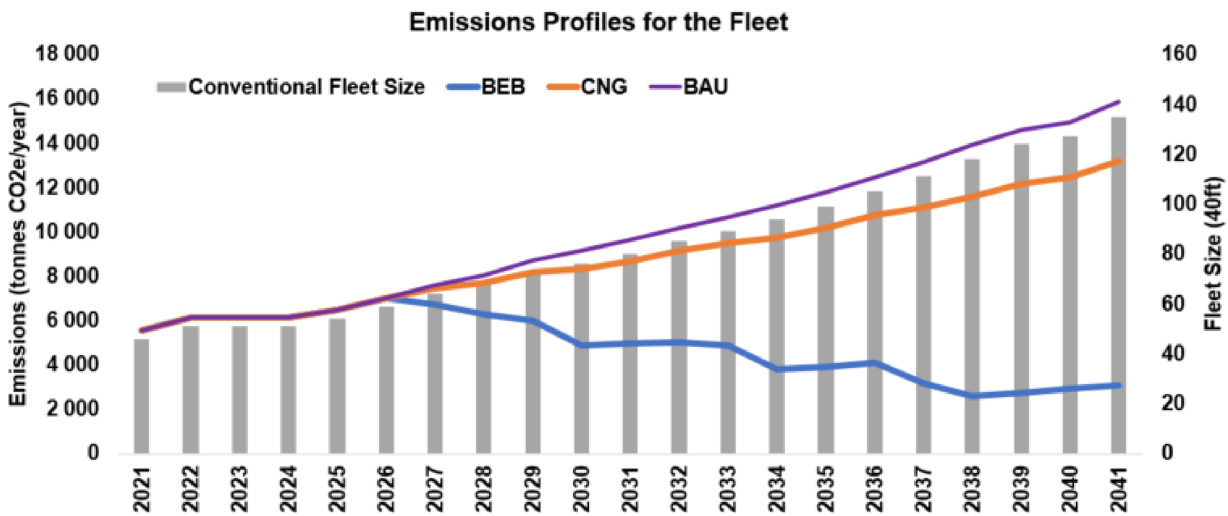

Figure 52 Emissions Profiles for the Two Scenarios Compared to Business-As-Usual

It should be noted that emissions from Ontario's electricity grid are expected to increase over the next 20 years as nuclear plants need to be decommissioned. The increase in GHG emissions intensity was considered in this analysis following the forecast published by IESO. Figure 53 shows an overview of the grid emission factor forecast throughout time.

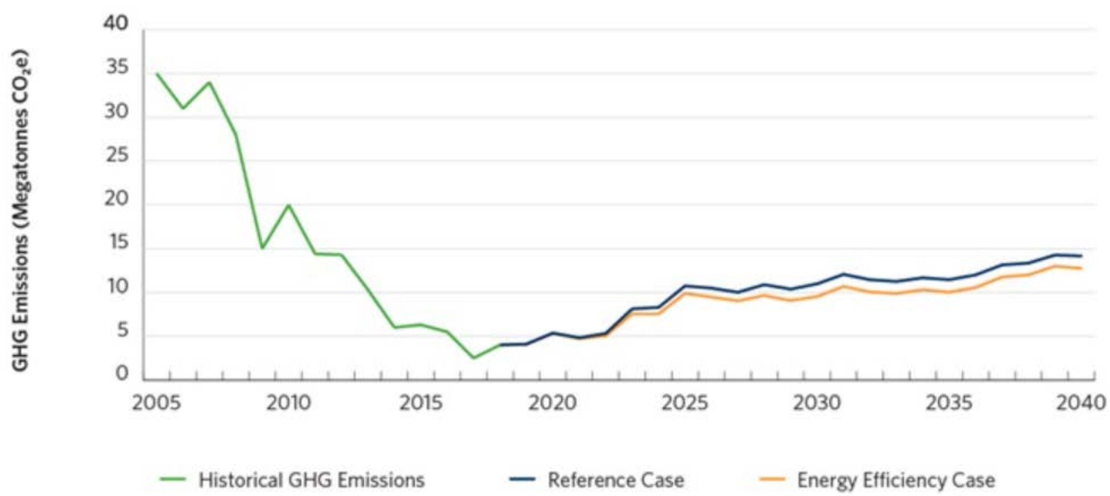

Figure 53 IESO's Electricity GHG Emissions Forecast[52]

[52] https://www.ieso.ca/Powering-Tomorrow/Data/The-IESOs-Annual-Planning-Outlook-in-Six-Graphs

10.2.4 SOCIAL IMPACTS

NOISE

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 noticeable impact on the health of people being exposed to the noise produced by the vehicle.

Noise produced by vehicles can be separated into Exterior Noise, which is important for nearby people not in the vehicle, and Interior Noise, which considers the passengers of the vehicle. There is a significant noise reduction with electric vehicles compared to conventional diesel/ gasoline vehicles. CNG vehicles typically have similar noise levels as conventional fleet vehicles.

There are several studied and measured societal benefits of quiet buses. For reference, there have 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), approximately a third of the total population, are exposed to unhealthy traffic-related noises.

To highlight the noise comparison between alternative propulsion technologies Altoona Test Results can be used as standardized tests for measuring interior and exterior noise levels. The Altoona Test results are shown in Figure 54. Overall, an electric bus can reduce ambient noise levels on the order of 10 dBA in comparison to diesel and CNG buses; yielding environmental and health benefits to the general population.

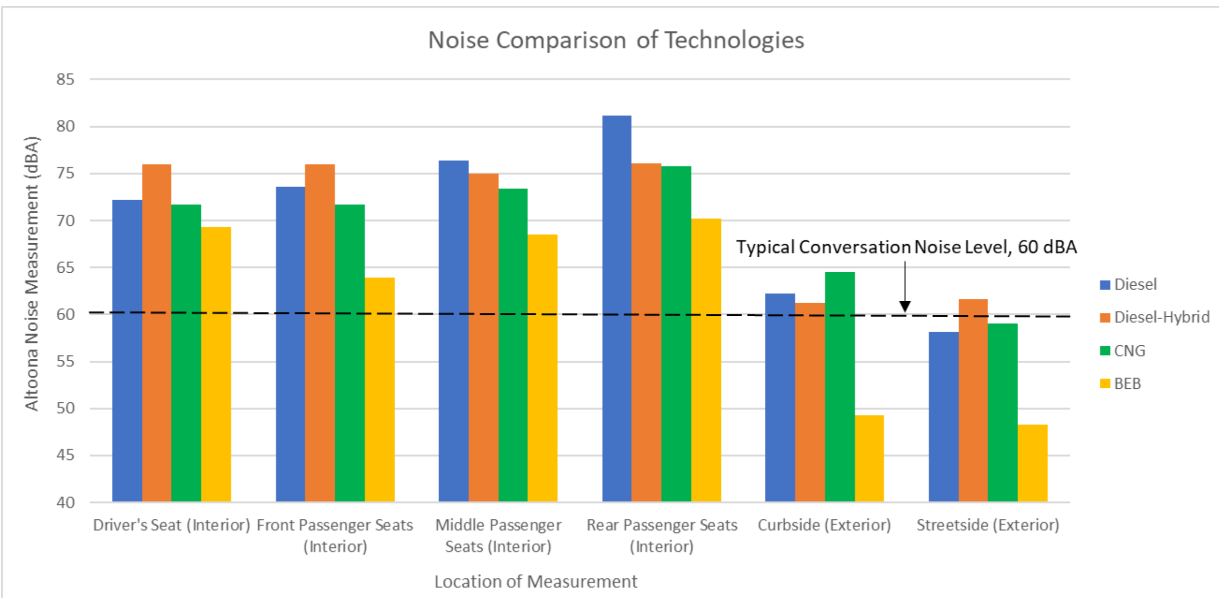

Figure 54 Noise Comparison of 40ft Buses

The Altoona noise measurements presented are for the "Interior Noise (0 to 35 mph Acceleration)" and "Exterior Noise (High Idle)" tests. To make comparisons between the technologies the New Flyer Xcelsior 40ft Altoona test results are shown for the diesel (XD40), diesel-hybrid (XDE40), CNG (XN40) and BEB (XE40) buses. By benchmarking the bus OEM make/model it can enable a better comparison on noise levels based solely on propulsion type. As shown in the above chart, electric buses produce less noise in all measured locations inside and outside of buses compared to all other propulsion types.

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 and negative health effects (including hearing loss)53. The magnitude of the health effects of road traffic noise is most likely to be similar in Canada. This problem is especially pertinent in high population dense urban areas. Figure 55 provides a summary of some of the primary and secondary health effects associated with undesirable noise exposure.

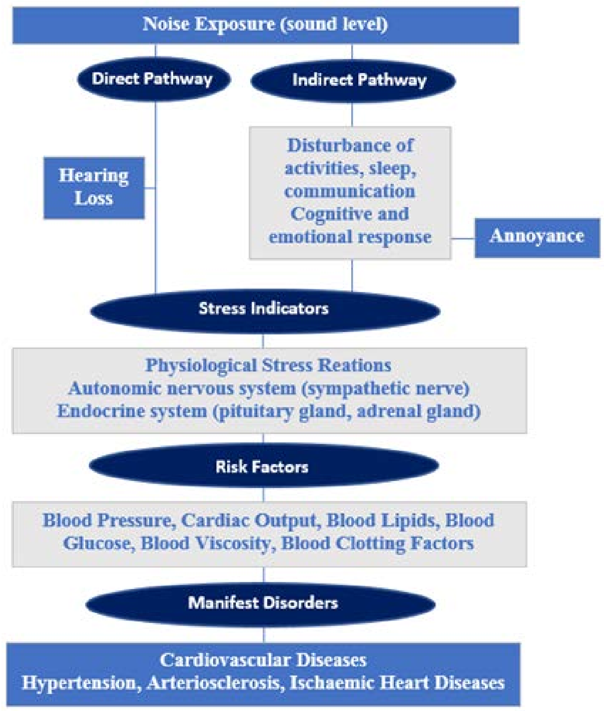

Figure 55 Effects of Noise Exposure

There is also a socio-economic cost aspect that must be considered when considering traffic-related noise levels. 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.

One concern that results from quieter operations is that users with disabilities or pedestrians may not hear the buses come by, as the public is used to the sounding queues of the diesel engines to know heavy duty vehicles are approaching. To counteract this concern, Transport of London has been implementing artificial sounds on the electric buses in response to a new law stipulating that all electric vehicles will need to produce artificial noise when traveling at low speeds as the lack of noise might lead to road accidents[54].

[53] Electric Buses and Noise by Janos Turcsany, Volvo
54 https://www.theverge.com/tldr/2019/12/20/21031524/london-electric-buses-artificial-fake-noise-safety-sound

AIR QUALITY

The exhaust emissions associated with internal combustion engine vehicles (CO_2 and other CACs) is associated with increased risk of lung and bladder cancers, along with other respiratory ailments such as asthma. Even electrification based on a carbon intensive grid brings about substantial benefits to air quality (due to separation of emissions and urban areas of vehicle operations), even though it will still lead to upstream carbon emissions. As electrical grids become more carbon neutral, this issue will also be further mitigated.

The increased health care costs, potential missed days of work and reduction in worked productivity caused due to air pollution costs the Canadian economy billions of dollars per year. These social costs are further compounded by loss of human welfare due to suffering from disease. It is estimated that even a modest reduction by 10% in ambient levels of ground level ozone and particulate matter across Canada would have tremendous health benefits such as a reduction in the number of premature deaths as well as reducing hospital and emergency visits.

These improvements would result in substantial savings to Canada's medical system, with the net social welfare benefit to Canadians to be estimated in excess of $500 million in direct financial benefits[55]. The electrification of vehicles is a solution that can assist in achieving these social benefits in a very tangible and measurable manner.

PUBLIC PERCEPTON AND SAFETY

Another aspect to be considered when adopting alternative fueled propulsion systems is the public perception of the 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 public. This is due to the perception that natural gas vehicles pose more explosive and combustion risks and are dangerous in accident situations[56]. 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 or 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 56). 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 occurs[57].

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 56 Properties of Natural Gas Fuel Compared with Gasoline and Diesel

[55] https://www.canada.ca/en/environment-climate-change/services/air-pollution/quality-environment-economy/economic-issues/human-health-costs.html
[56] CNG & LNG Safety: Perceptions & Reality, Clean Fuels Consulting https://www.unece.org/fileadmin/DAM/energy/se/pp/geg/geg2_jan2015/ai9_4_Seisler.pdf
[57] https://www.cngunited.com/why-is-cng-better-than-other-fuels/

Despite the lingering safety concerns that may be present with 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 than gasoline vehicles, reducing the risk of carbon monoxide exposure. As such, CNG fueling is viewed as more favourable from a human health perspective.

Public perceptions towards the safety of electric vehicles has been positive, and there have not been any notable concerns regarding the safe operation of electric vehicles. Batteries are typically mounted on the vehicle chassis, which provides a lower center of gravity, and more design freedom for having less dangerous collisions (less change of roll-over, more crumple space for dissipating kinetic energy safely, etc.)[58]. The greatest impact to the perception of electric vehicles is range anxiety and potential battery performance issues due to climate conditions and 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.

Electric vehicles are generally viewed as green technology by the public due to zero tail pipe emissions and a majority of the municipalities and transit agencies have reported a positive sentiment from their public regarding their deployment. A consideration that is of concern is the safe disposal of battery pack systems at their end of life, as battery packs consist of multiple chemical compounds that are hazardous if disposed inappropriately (like common household batteries). A successful and safe removal and disposal of batteries is imperative for minimizing the end of life environmental impacts (prevention of leakage of toxic chemical compounds into the surrounding environment) and to mitigate health safety risks to the community. An industry regarding the utilization of electric vehicle batteries at the end of their lives is in its initial stages and is currently growing. There is potential for having cost effective recycling programs for safe disposals in the future.

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. Furthermore, 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, the 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, which is expected.

The new skills and knowledge required by the mechanics may cause strain. However, the requirements for local high qualified personnel to meet the operational, maintenance and management needs of electric vehicles and electrification programs will increase job creation and provide the opportunity to develop technical talent and expertise.

There is also an opportunity for increased revenue from underutilized local electrical grids. Typically, the power generation, transmission and distribution sector operates at much lower than maximum capacity (they are designed to meet the expected peak which occurs rarely). Charging electric vehicles at off-peak or strategic times during the day will assist in increasing the productive utilization of the grid, in which will consequently increase the operational revenue of the grid operators. Efforts to minimize facility electrical peaks can also serve as a cost mitigation for facility owners.

[58] CleanTechnica, ‘Do electric vehicles have better overall safety?’, 2018. Available at: https://cleantechnica.com/2018/04/01/do-electric-vehicles-have-better-overall-safety-part-2/

11 DEPLOYMENT CONSIDERATIONS

11.1 TECHNICAL REVIEW OF THE OPERATING CONTRACT

This section provides a technical review of the P3 agreement between Barrie and MVT Barrie Bus Inc. (Project Co). The analysis comprised a deep dive into the legal framework and contractual arrangements between the various stakeholders and how a change in technology would impact the operations, financial and legal components of the agreement.

The overarching principle in the contractual framework between Project Co and Barrie is to approach the Change in a way not to trigger any sort of default event which would trigger contract termination between Project Co and Barrie and a subsequent breach of direct agreement between Project Co and the Service Provider.

Based on a rigorous review of contractual documents and direct agreements, the language and mechanisms specifically related to the P3 operational contract can allow for a Change to arise, although the steps to reach such an agreement and incorporate a new technology will require some heavy contract renegotiations to specified terms and conditions. The fact that the payment mechanism was crafted for a diesel bus fleet with a key variable being a secured diesel price over the operating period and a large proportion of the Annual Service Payment (ASP) being attributed to this variable, in conjunction with established performance mechanisms directly correlated to this variable, will require a complete review of the payment mechanism aspect. It is important to understand that from Project Co's perspective, and from a P3 Project Finance perspective being an off-balance sheet transaction, the main framework in computing the Special Purpose Vehicle (SPV)'s ASP is based on the risk profile of the contract and risk allocation. To clarify, from a contractual standpoint, P3 transactions are off-balance sheet, meaning that lenders to the project (who provide debt financing) have no recourse to the Sponsors of the project (i.e. they have no recourse to the assets of the Parent Company) should the project default. In return, a rigorous analysis of the risk profile and the risk allocation of the various construction and operations risk is typically undertaken by Lenders which affect both how they price the debt (i.e. interest rates, up-front costs, interest only periods, amortization, etc.) and thus affects the SPV's Annual Service Payment as they typically aim at achieving a minimum Internal Rate of Return (IRR). Should the project default for any reason (either during the construction or operations phase), Lenders (as well as the various counterparties) have no direct recourse to the Sponsor (or equity investor) and are only entitled liquidated damages and other modalities as stipulated in the contract.

Project Co. entered into a long-term contract with the City of Barrie, with a mostly fixed ASP which directly allocates revenue/market risk to Barrie. The foundation of P3 contracts is that up-front costs are high to structure the transaction and to negotiate contract terms, but that once financial close is achieved, the flexibility in changing material components of the project (such as in this case) is extremely hard since the fundamental components of structuring the transaction and terms were based on the forecasted levered free cash flows to stakeholders which priced the project based on long-term revenue contracts with minimal uncertainty. Our goal is to outline to Barrie the major contractual points which will have to be renegotiated with Project Co and the main sources in the contractual documents to refer to in crafting a strategy to approach Project Co.

11.2 FUTURE TRENDS

The industry is seeing rapid expansion of electric bus deployments and with that comes innovation and constant technology development.

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 [59]. In addition, automotive lithium-ion battery energy density (Wh/kg) is expected to improve by 25-35% by 2030 [60] 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 buses are able to deliver service hours similar to a diesel bus.

Another innovation that is expected to occur in the short to medium term and that is particularly interesting for Canadian conditions is on the heating system of the bus. Currently, battery electric buses need to have diesel heaters on-board to keep comfortable temperature levels for passengers in the winter. These heaters produce emissions. Bus manufacturers are developing increasingly efficient electric heat pumps that are more efficient that traditional electric heaters and as such, draw less energy from the battery packs. These systems could further reduce electric bus heater emissions in Canadian winters.

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 ABB called “Grid-eMotion Fleet” aims provide a scalable AC/DC rectification from a single unit to supply chargers between 50 to 600 kW[61] will reduced space requirements, cabling, shorter delivery time and integrated with SCADA and other energy management systems. Similarly, Proterra developed a 1.5 MW charging system that can plug directly into the grid to charge up to 40 vehicles. This system, which looks similar to a standard shipping container is scalable and enables space savings[62]. Both these new technologies have been introduced to the market in 2020 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.

Larger transit agencies are moving away from the traditional slow plug-in solution to implement pantograph charging at their garages. This solution offers notable operational benefits, such as automated connection of the pantograph to the bus once the bus is parked, as well as minimal footprint on the garage floorspace. Pantographs can also charge at higher power up to 600 kW with the required infrastructure in place. However, these overhead structures are heavy and come at a higher cost, about $100,000 per pantograph including their DC charger cabinets. Installing rows of pantographs chargers indoor likely requires roof structure reinforcement which can be an expensive and disruptive upgrade, which is why this solution was not recommended for Barrie Transit with a 40ft fleet of less than 100 vehicles per facility.

One last notable development is the creation of integrated charging management software solutions. This type of software can communicate with different charger make/models and provide detailed information on the charging status of the fleet to the operator in real-time. At the moment, there is not one dominate software in the industry integrating every aspects of BEB operations (from the charge management, to the optimal dispatching strategy or the parking space management) and these kinds of software suites are under development.

[59] https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/
[60] 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.
61 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
[62] https://www.proterra.com/wp-content/uploads/2020/10/SPEC_CHG-SYS_1.5M_V8_10.26.20.pdf

MICRO-GRID AND ENERGY STORAGE

Another trend observed in the industry is the notion of micro-grid or "vehicle-to-grid" capabilities for electric bus systems. In fact, transit introduces a 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.

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 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 57 illustrates different elements of a micro-grid that can be applied to a transit facility implementing battery electric buses to increase resilience.

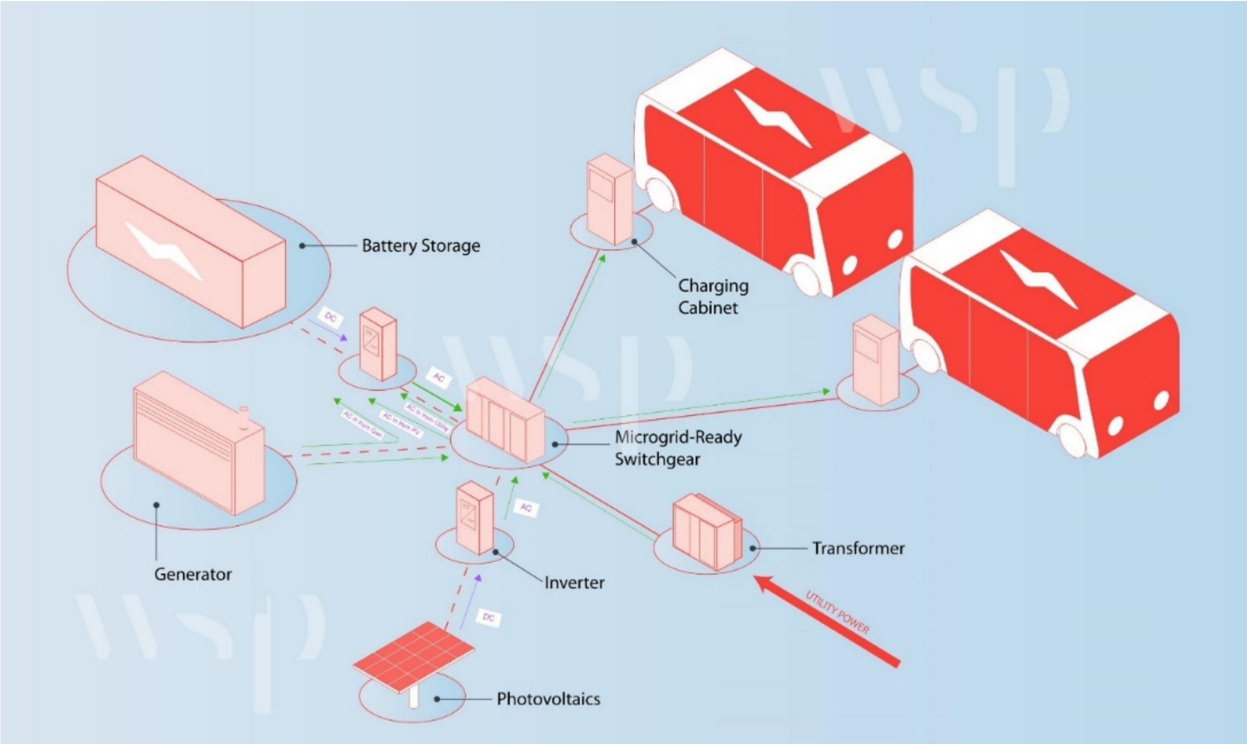

Figure 57 Illustration of a Local Micro-Grid System to Power an eBus Fleet

MANUFACTURING CAPACITY, SUPPLY CHAINS AND TRAINING

In Ontario, electric bus OEMs need to comply to the "25% Canadian Content" regulation to be funded. The Canadian Content policy is a mandatory requirement for provincial funding of transit vehicles[63]. To comply to this regulation and enter the Canadian market, BEB manufacturers are investing in assembly and manufacturing plants in Canada, or using Canadian-made components in their bus.

As an example, BYD expanded its North American operations by opening a 45,000 square foot bus assembly plant in Newmarket, Ontario[64]. New Flyer, one of the largest BEB manufacturers in North America is a Canadian company with a large manufacturing and assembly plant in Winnipeg, MB. Nova Bus also manufactures electric buses from St-Jerome, QC. The national trend that can be drawn is that BEB manufacturers are reinforcing their positions in Canada and are continuously growing their presence in the country.

[63] https://pub-hamilton.escribemeetings.com/filestream.ashx?DocumentId=114325
[64] https://en.byd.com/news-posts/byd-opens-first-canadian-bus-assembly-plant/

From a supply chain perspective, COVID-19 has impacted most stages of the electrical components supply chain: from the smallest resistors to the metal assembly, productions delays are expecting to cause up to two years of production delays. However, by the time Barrie procures its first electric buses in 2027 it is expected that the North American electric bus supply chain will have recovered from the impact of COVID-19 and be more developed.

Another innovation seen as part of the supply chain is how to recycle or repurpose batteries once they reach their end-of-life. Manufacturers such as Proterra propose a battery leasing program, whereby the customer is not required to pay the full price of the BEB upfront but rather spends approximately the same amount for a diesel bus, and pays the additional price of the battery on a monthly leasing basis. Figure 61 shows a snapshot of a sample lease program from Proterra. This can result in a lifetime cost savings of about $130,000 compared to diesel buses. Once the batteries reach their end-of-life, Proterra repurposes them as energy storage devices to be used for other applications.

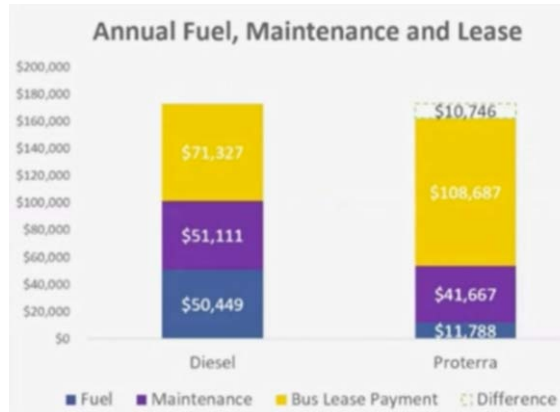

Figure 58 Proterra Bus Capital Lease Benefits Presented at the CUTA Conference (Fall 2020)

In January 2021, New Flyer, another BEB manufacturer, partnered with Ontario-based Li-Cycle, one of North America's leading lithium-ion battery recyclers to recycle 45 end-of-life electric bus batteries. These batteries correspond to the first battery salvage pilot in the heavy-duty vehicle sector[65]. As more electric buses are deployed and the recycling technology matures, the end-of-life process for lithium-ion batteries will see more avenues such as the ones descried above.

11.3 CONSIDERATIONS FOR FUTURE PARTNERSHIPS

UTILITY PARTNERSHIPS

The City of Barrie can look for potential partnerships with utilities that have proven records 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 on a 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.

ONTARIO POWER GENERATION

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

Partnerships with Enbridge will also be beneficial should the City decide to deploy CNG vehicles, 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[66]. Though the supply from this plant will be limited, Enbridge might consider the option of supplying RNG to Barrie Transit 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.

[65] https://electricautonomy.ca/2021/01/11/new-flyer-li-cycle-battery-recycling-pilot/#:~:text=New%20Flyer%20Industries%2C%20Winnipeg's%20flagship,the%20recycler's%20first%20battery%20salvage
[66] https://www.enbridge.com/stories/2020/october/enbridge-and-partners-break-ground-ontarios-largest-rng-plant

AGENCIES & ASSOCIATIONS

Networking with peer transit agencies and industry associations such as the Canadian Urban Transit Association (CUTA) can prove valuable to discuss lessons learned from deployments of fleet technology and infrastructure projects.

There are several transit agencies across Canada now with BEB and CNG buses deployed. The TTC is currently leading the way with a fleet of 60 electric buses. The initial findings from peer agency BEB operations as well as infrastructure setup (i.e. facility design and charging station installations) can help Barrie Transit with their adoption plans. Similarly, Calgary Transit has been operating a large fleet of CNG buses refueled indoors for years and will likely have valuable lessons learned to share with Barrie Transit.

Barrie Transit can also look to establish or join a working group to discuss lessons learned on technology deployments. As an example, the TTC holds bi-monthly calls with peer North American transit agencies to share lessons learned on their pilot programs. This peer group includes King County Metro, Los Angeles Metro (LA Metro), New York City Transit Authority and Société de Transport de Montreal. Agencies such as York Region Transit and Brampton Transit are also operating small fleets of battery electric buses.

FLEET TELEMATICS

With the deployment of new technology real-world performance data can be helpful in validating modelling and assumptions during the feasibility and planning stage. Third-party data logging units such as the ViriCiti DataHub have been installed in new buses by some transit agencies to monitor performance data including energy consumption (kWh/km), battery SOC (%), regenerative braking energy recapture (kWh) and other key metrics. This type of data can assist evaluating operations and planning for subsequent deployments.

LOCAL COLLEGES AND TRAINING CENTERS

Barrie Transit should consider approaching local colleges and training centers in Ontario, as maintaining alternative fuel technology requires new sets of skills and training. Georgian College, Barrie's local college offers many training and apprenticeship programs. Though none of the programs are currently specifically designed for battery electric buses 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.

CNG is an explosive gas, and batteries operate at high voltage. The CNG and BEB powertrains as sources of hazard if not handled properly. Colleges are also noticing the trend towards electrification and starting to develop tailored training programs to train the next generation of bus mechanics, but also experienced mechanics who need to learn how to use a new technology.

12 RECOMMENDATIONS AND CONCLUSIONS

12.1 SUMMARY OF THE TECHNOLOGY ADOPTION PLANS

The key findings of this report have helped bring into focus that both the CNG and the BEB transition plans are feasible for Barrie Transit from a technical standpoint. The choice really comes down to emissions reductions and cost. Graphical representations of both technical solutions are presented in the figures below for the existing facilities.

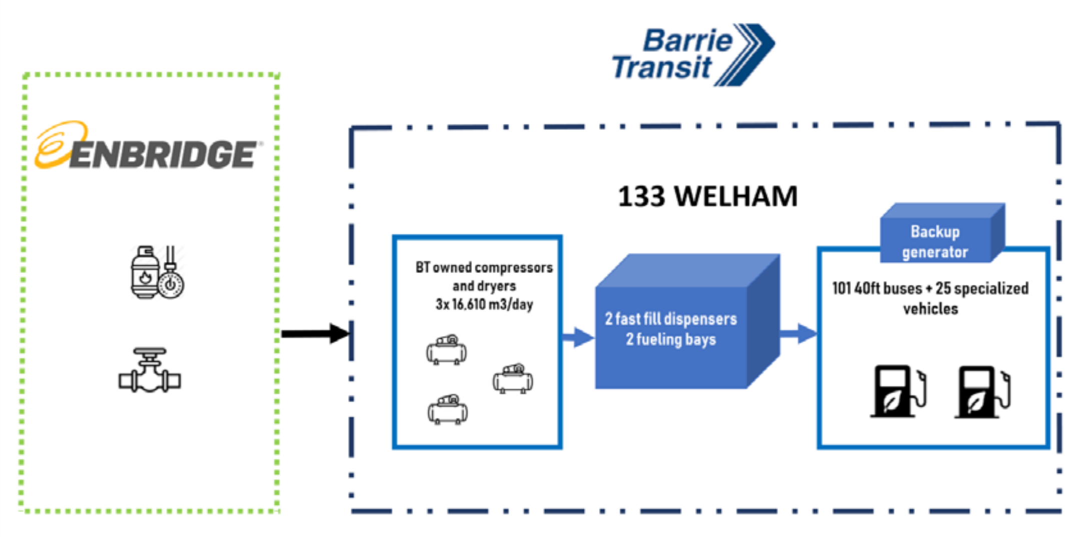

Figure 59 CNG Fleet Transition Schematic

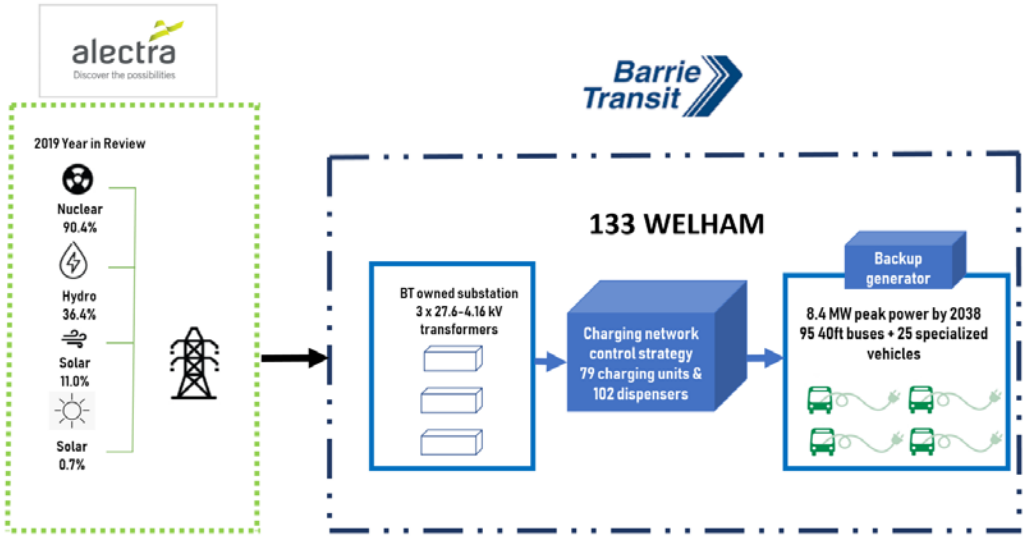

Figure 60 BEB Transition Schematics

Table 25 Key Takeaways for the Fleet Adoption Plans

Plan Aspect	CNG Transition	BEB Transition
Year of introducing the technologies	2027	2027
Facility Expansion Year	2026	2026
Year by which 100% is converted	2038	2038
Year when a new facility is required	2036	2033
Phase description at the existing and expanded facility	**Phase I:** The first compressor and the redundant compressors are installed first in 2026 along with the remaining supply. **Phase II:** the last compressor in 2030 (Phase II).	**Phase I:** The incoming switchgear and first substation is installed in 2026, along with 28 x 150 kW DC charging cabinets. **Phase II:** The second substation and 28x 150 kW DC charging cabinets are installed in 2029. **Phase III:** The last substation and 23x 150 DC charging cabinets and 46 dispensers are installed in 2031.
Fleet size at the existing and expanded facility	105x 40ft + 25 specialized vehicles	95x 40ft + 25 specialized vehicles
Fleet size at the new facility by 2041	30x 40ft	60x 40ft
Total OPEX and CAPEX between 2021-2041 compared to BAU	- 12.7 million (-3.2%)	+$135.9 million (+35 %)
Total OPEX and CAPEX between 2021-2041 compared to BAU with carbon tax	-19.2 million (-4.4%)	+$114.0 million (+26.0%)
Emissions saved compared to BAU between 2021-2041	10%	51%
Emissions saved compared to BAU between in 2041	16%	80%

Barrie Transit also can look to deviate from this fleet scenario by procuring a limited fleet of alternative vehicles (i.e. 1 to 5 BEB) to operations prior to 2027 so that familiarity and staff training can be achieved prior to initiating any larger scale of alternative technology procurements. Furthermore, these pilot buses can be added in the growth portion of Barrie Transit's fleet plan as to minimize the impact to Barrie Transit's current service.

12.2 RECOMMENDATIONS ON TECHNOLOGY CHOICE

Based on the cost analysis described in this report, the transition towards a battery electric bus fleet will require just over twice (2x) the CAPEX investment compared to a BAU from a fleet procurement and infrastructure perspective between 2021-2041, compared to 1.1x for CNG buses.

However, the cost analysis provided in this report assumed that the cost of the assets increased with inflation from 2021 cost levels. In reality, OEMs have predicted cost reductions of battery electric buses with reduction of battery costs and the economy of scale. BEB reduce OPEX costs by 15% compared to BAU, while the CNG scenario reduces OPEX cost by 12% compared to BAU.

The main advantage of the battery electric bus technology is its emissions reduction potential: by the time the whole fleet is converted to electric buses in 2038, yearly emissions are reduced by 80%. Each vehicle would emit about 19.85 tonnes of CO2e/year, compared to 97 tonnes CO2e/year for the BAU case.

The CNG option also has the potential to reduce emissions. However, by 2038, 81 tonnes of CO2e/vehicles are still being emitted which makes it difficult to reach Canada's net zero emission goal by 2050.

Given the industry trends, potential for future development and governmental support, it is recommended that the City of Barrie pursues the electrification option of its transit system. High upfront costs of the technology can be mitigated by partnering with manufacturers through lease programs, governmental supports, and potentials to collaborate with local utilities.

12.3 RECOMMENDATIONS FOR FUTURE STUDIES

Several key questions were raised during the study that will need to be addressed in the future. To start, it is important that Barrie Transit prepares a resilience strategy to prepare for what would happen in case of an emergency or power outage. It is recommended that Barrie Transit conduct a more in-depth review of the operational needs in case of an emergency to evaluate the number of buses that need to be in service and the size of the appropriate backup power generators. A range of fuels can be considered to power a small fraction of the fleet to provide emergency services. Similarly, the space requirements and locations of the generators at the facility will need to be considered.

Another consideration is the need to assess the benefits of adding energy storage and micro-grid capabilities to the facility. It is recommended that a more in-depth study be conducted to understand the load, space and financial requirements of these technologies and the impact these are expected to have on Barrie Transit's BEB operations.

One of the outcomes from this feasibility study was to estimate the date at which the garage will reach its full capacity. In order to accommodate the fleet growth estimated by Barrie Transit by the year 2041, a second garage will need to be commissioned by Barrie Transit. This report provided cost estimates of adding the refueling and electrical capabilities compared to a BAU case.

However, these figures should be treated as high-level cost estimates given that the sites, parameters and constraints of the new facility have yet to be fixed. This garage could be designed to only host electric buses, and be commissioned with the required electrical supply, maintenance equipment and charging infrastructure it needs for these purposes. From a cost and space usage perspective, this design choice would likely be one of the most efficient options for Barrie Transit.

Lastly, to maximize the use of its parking space at the facility, Barrie Transit could explore the solution of mounting the dispensers and pantographs on the roof structure of its garages. Figure 61 shows real-life demonstration of this concept.

Figure 61 Electrical Charging System Mounted on Roof System. Source: ETS

This solution is being pursued by several transit agencies North America, however it requires a robust roof structure integrity study to verify if the roof is strong enough to support the weight of the charging units and the dispensers. The weight of a single 150 kW charging unit varies between 1,000 to 1,500 kg depending on the manufacturer. The weight of these electrical devices therefore adds up and can cause significance stress on the roof structure.

Additionally, the weight would be concentrated mainly above the parking area and hence not evenly distributed, causing further stresses. It is recommended that Barrie Transit pursue this type of analysis if there is a desire to minimize the footprint of the electrical equipment on site.

A follow-up-study to be considered is the development of a Pilot Program, which would include the definition of the pilot framework, the key performance indicators indicating the success of the project, and the key steps to take to secure funding, procure the buses, updated the infrastructure and monitor the deployment performances.

When time comes to update the next Asset Management Plan, it will be important to consider the pathway forward chosen by the city in the development of the fleet plans and the consider the particularity of the technologies outlined in this report (for instance, for every ten diesel busses replaced, 13 electric buses are needed before 2030). Similarly, the findings of this study should be incorporated into the City’s GHG reduction plan.

It should be noted that the recommendations outlined in this study would warrant dedicated resources for the planning and implementation of the technology, especially if the City decides to move forward with a pilot project in the near term.

12.4 CONCLUSIONS

This report provided a summary of the feasibility study to implement two scenarios, namely a fully electric vehicle fleet and a CNG vehicle fleet for the horizon 2021-2041. The infrastructure upgrades required were identified based on the findings of the route modelling and estimation of the fuel requirements from the fleet. Both scenarios demonstrated the technical feasibility of achieving 100% electric bus or CNG fleet and converting the existing fleet to the alternative technology by 2038. This infrastructure planning was then used to develop a costs and emissions profile analysis for both transition scenarios.

Though the electric bus conversion scenario undeniably increases CAPEX costs due to higher procurement prices of the assets, this scenario also demonstrated substantial savings on the OPEX compared to the BAU case. The CNG scenario showed a 3.5-4.5% savings when summing the OPEX and CAPEX compared to the BAU case as the vehicles are cheaper to operate than diesel but require additional equipment to function (i.e. fueling stations).

The implementation of electric buses offers clear benefits from an emissions standpoint, as it enables an emission reduction of up to 80% yearly when the fleet is fully electric. CNG vehicles demonstrate a smaller environmental benefit, with a 16% reduction when the fleet is fully converted.

Considering the environmental, social, operational and cost aspects of each technology, as well as industry trends and increasing federal interests to drastically reduce emissions, it is recommended that Barrie Transit transition to battery electric vehicle technology over the alternative of CNG fuel.

Regardless of the pathway that the City chooses to investigate, the scenarios needs to be tied to the City's GHG reduction plan. Once this plan is developed, it will help guide future fleets plan with greater details.

APPENDIX

A

EMISSIONS ASSESSMENT

APPENDIX

The table below summarizes the CAC emissions factors (g/km) provided by NRCan's GHGenius modelling tool, for heavy-duty vehicles.

Emissions Type	Diesel	CNG	BEV	Hydrogen	Units
CO	0.502	0.153	0.000	0.186	g/km
NO_x	1.201	0.876	0.000	0.201	g/km
SO_x	1.026	0.117	0.000	0.021	g/km
PM	0.086	0.020	0.000	0.006	g/km
VOCs	0.175	0.172	0.000	0.015	g/km
CFCs / HFCs[71]	0.001	0.001	0.001	0.001	g/km

[71] CFCs and HFCs are independent of fuel type, as they are emitted by the vehicle's air conditioning system.

APPENDIX

B RISK REGISTER

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

Date: November 18, 2020

Participants:

	Rating Guide				
	1	2	3	4	5
	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

No.	Risk	Description	Mitigation Method	Applicability		Risk Assessment		
				Transit	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	**Transit - Supervisor of Operations and Infrastructure**	**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	**Transit - Supervisor of Operations and Infrastructure**	**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 - Operations: 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	**Transit - Maintenance Manager, MVT**	**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	**Transit - Supervisor of Operations and Infrastructure**	**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	**Transit - Supervisor of Operations and Infrastructure**	**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	**Transit - Supervisor of Operations and Infrastructure**	**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
7.0b	Resistance to Change (Transit)	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	**Transit - Maintenance Manager, MVT**	**4 - High**	**3 - Moderate**	- Transit, slow uptake in understanding of new tech, can result in higher chance of resistance to technology
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	**Transit - Maintenance Manager, MVT**	**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	**Transit - Maintenance Manager, MVT**	**4 - High**	**4 - High**	
10.0	Disposal Cost	New technology could incur additional and unforeseen disposal costs for components	**Mitigation Method TBD**	Y	**Transit - Maintenance Manager, MVT**	**3 - Moderate**	**2 - Low**	- Best practice for disposing that can be applied? - 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	**Transit - Maintenance Manager, MVT**	**2 - Low**	**2 - Low**	- Operations auctions vehicles with no cannibalizing - No more cannibalizing for transit end of life
12b	Premature Failure (Transit)	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	**Transit - Supervisor of Operations and Infrastructure**	**2 - Low**	**4 - High**	- Generally showing favourable lifecycle of at least 12
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	N	**Transit - Supervisor of Operations and Infrastructure**	**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
14b	Indoor Storage Capacity (Transit)	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	**Transit - Supervisor of Operations and Infrastructure**	**4 - High**	**3 - Moderate**	- Transit vehicles parked inside, charging inside will impact footprint, however if adding more will require new facility - Not an issue for 2-3 vehicle pilot
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	**Transit - Supervisor of Operations and Infrastructure**	**3 - Moderate**	**3 - Moderate**	

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

Date: November 18, 2020

	Rating Guide				
	1	2	3	4	5
	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						Risk Probability Rating			Risk Impact Rating			
No.	Risk	Description	Mitigation Method	Applicability		Hydrogen	Battery Electric	Natural Gas	Hydrogen	Battery Electric	Natural Gas	Comments
				Transit	Risk Owner							
Lifecycle Category: Procurement												
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	**Transit - Supervisor of Operations and Infrastructure**	3 - Moderate	3 - Moderate	3 - Moderate	4 - High	3 - Moderate	3 - Moderate	The lack of knowledge/experience of City staff involved in procurement result in the higher risk probability.
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	**Transit - Supervisor of Operations and Infrastructure**	3 - Moderate	3 - Moderate	3 - Moderate	2 - Low	2 - Low	2 - Low	While technology is evolving, it doesn't appear to be happening fast enough to impact a vehicle with a 12year lifecycle. The only concern would be the rapid advancement of BEB battery capacity/reliability.
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	**Transit - Supervisor of Operations and Infrastructure**	3 - Moderate	3 - Moderate	3 - Moderate	3 - Moderate	3 - Moderate	3 - Moderate	There appear to be enough OEM's in the market to ensure a competitive bid/purchase price. City is also linked to Metrolinx TPI program.
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	**Transit - Supervisor of Operations and Infrastructure**	4 - High	3 - Moderate	3 - Moderate	3 - Moderate	3 - Moderate	3 - Moderate	While moderately concerning - transit will likely install their own infrastructure to ensure fueling needs are met. Three identified technologies appear to have available fueling technologies in the marketplace.
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	**Transit - Supervisor of Operations and Infrastructure**	2 - Low	4 - High	3 - Moderate	4 - High	4 - High	4 - High	Current Barrie Transit routing would stretch the single charge capabilities of BEB's. Impact to not meet service (and the need for additional vehicles) would likely have a significant impact on operations and fleet #'s.
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	**Transit - Supervisor of Operations and Infrastructure**	3 - Moderate	2 - Low	2 - Low	4 - High	4 - High	4 - High	fuel - the vehicles don't operate. Not a lot of knowledge surrounding the availability of hydrogen but it is known that infrastructure work would be required to acquire the amount of electricity needed to charge a larger BEB fleet.
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	**Transit - Supervisor of Operations and Infrastructure Operations Manager, MVT**	2 - Low	2 - Low	2 - Low	2 - Low	2 - Low	2 - Low	City is protected from vehicle repair costs by P3 contract
8.0	Vehicle Operations/Drivers	Drivers are opposed to the new technology buses and initiate change-offs 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	**Transit - Supervisor of Operations and Infrastructure Operations Manager, MVT**	2 - Low	2 - Low	2 - Low	2 - Low	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	**Transit - Supervisor of Operations and Infrastructure**	2 - Low	1 - Very Low	2 - Low	2 - Low	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	**Transit - Supervisor of Operations and Infrastructure**	3 - Moderate	3 - Moderate	3 - Moderate	4 - High	3 - Moderate	3 - Moderate	
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	**Transit - Maintenance Manager, MVT**	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

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

Date: November 18, 2020

	Rating Guide				
	1	2	3	4	5
	Very Low	Low	Medium	High	Very High
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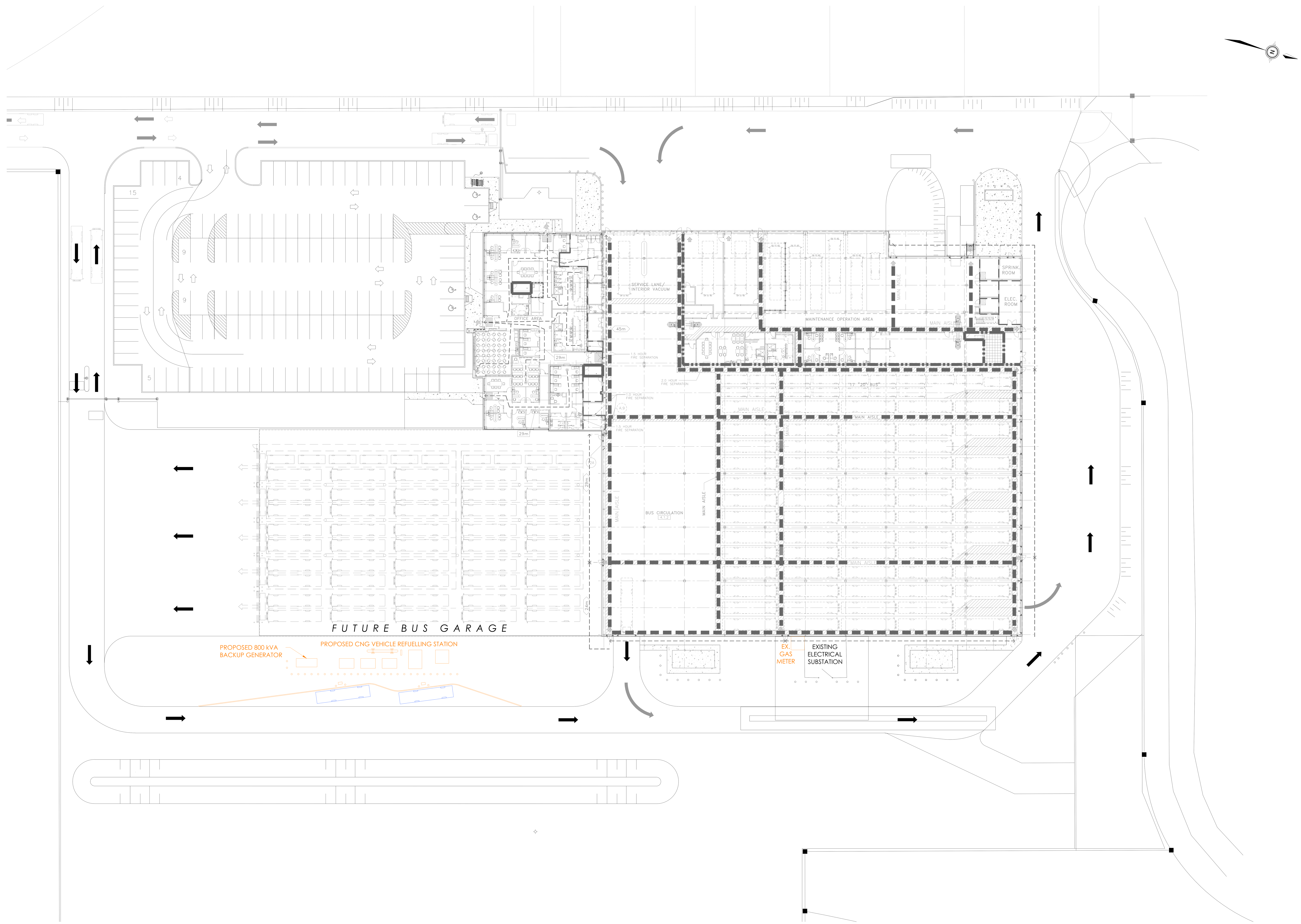
Quality	No impact	Partial/ small impact on requirements	Deviation from requirements, mostly	Deviation from requirements,	Can't meet requirements

Risk Register						Risk Probability Rating			Risk Impact Rating			
No.	**Risk**	**Description**	**Mitigation Method**	**Applicability**		**Hydrogen**	**Battery Electric**	**Natural Gas**	**Hydrogen**	**Battery Electric**	**Natural Gas**	**Comments**
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	**Transit - Maintenance Manager, MVT**	3 - Moderate	3 - Moderate	3 - Moderate	3 - Moderate	3 - Moderate	3 - Moderate	
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	**Transit - Maintenance Manager, MVT**	2 - Low	2 - Low	2 - Low	3 - Moderate	3 - Moderate	3 - Moderate	
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	**Transit - Maintenance Manager, MVT**	3 - Moderate	3 - Moderate	3 - Moderate	3 - Moderate	3 - Moderate	3 - Moderate	
Category: Overhaul												
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	**Transit - Supervisor of Operations and Infrastructure Maintenance Manager, MVT**	3 - Moderate	3 - Moderate	3 - Moderate	3 - Moderate	3 - Moderate	3 - Moderate	
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	**Transit - Supervisor of Operations and Infrastructure Maintenance Manager, MVT**	3 - Moderate	3 - Moderate	3 - Moderate	3 - Moderate	4 - High	3 - Moderate	Possibly limited shops servicing new technology vehicles.
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	**Facility Manager, MVT**	2 - Low	1 - Very Low	2 - Low	5 - Very High	1 - Very Low	5 - Very High	
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	**Facility Manager, MVT**	2 - Low	2 - Low	1 - Very Low	2 - Low	5 - Very High	1 - Very Low	

APPENDIX

C

G-201.4 TRANSIT GARAGE PROPOSED CNG VEHICLE REFUELLING STATION



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CONCEPTUAL

rev	description	by	m.d.y
0b	added backup generator	CR	02.23.2021
0a	as per engineers review	CR	02.22.2021
0	INITIAL ISSUE	CR	02.22.2021

change energy services
2140 Winston Park Drive - Suite 203, Oakville, ON L6H 5V5
www.changeenergy.ca PH: (905) 829-5756

City of Barrie
Alternative Fuels Study
Transit Garage
133 Wellham Road, Barrie, Ontario

scale [D size]	1:300
designed	G. STEPHANIAN
drawn	C. ROBINSON
checked	G. STEPHANIAN
approved	G. STEPHANIAN date

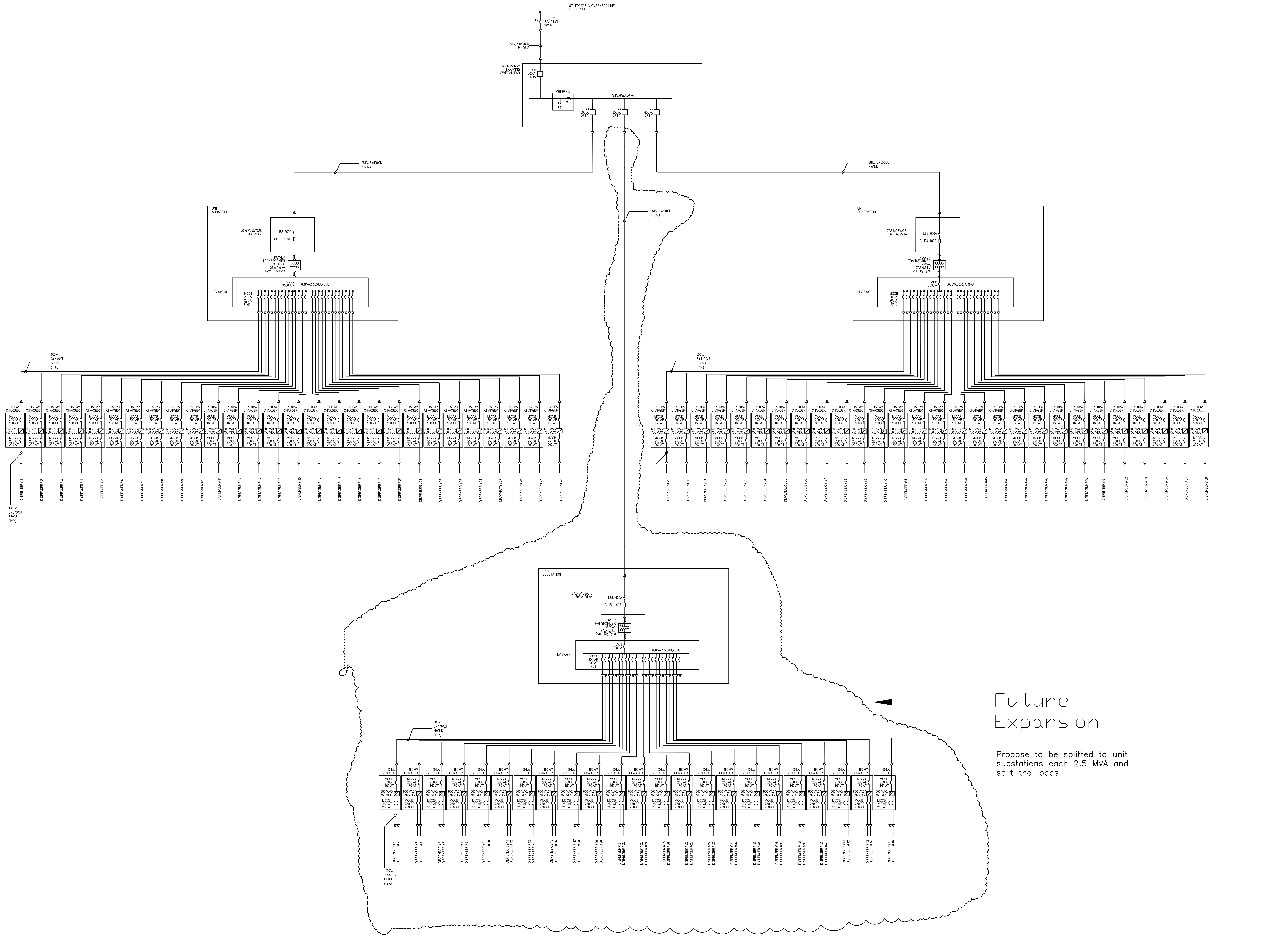
TRANSIT GARAGE
Proposed CNG Vehicle Refuelling Station

CES project number	sheet number
D20.011.05	G-201.4

APPENDIX

D

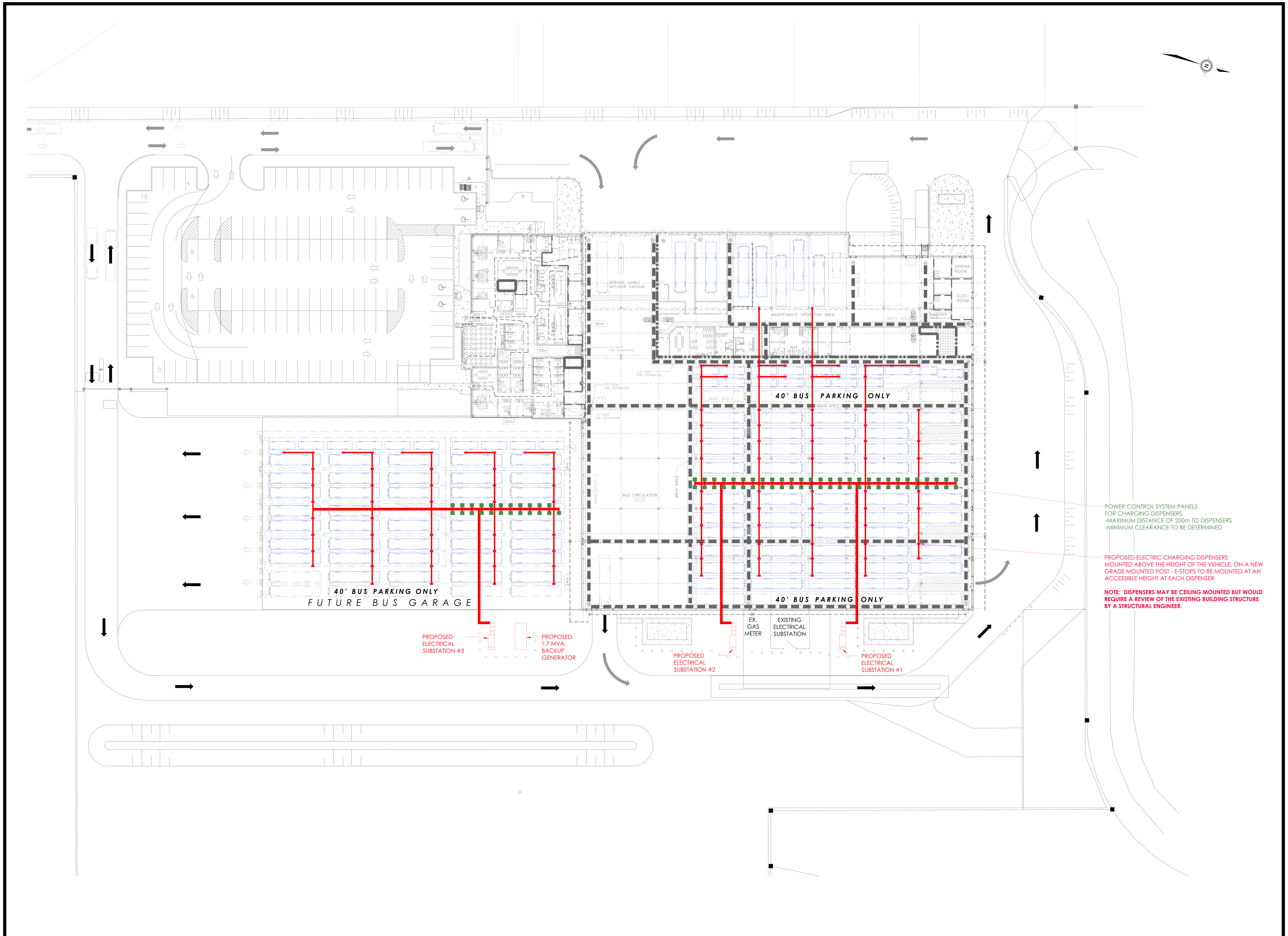
SINGLE LINE DIAGRAM FOR THE ELECTRIFICATION SOLUTION


UTILITY 27.6 kV OVERHEAD LINE FEEDER XX
UTILITY ISOLATION SWITCH
MAIN 27.6 kV INCOMING SWITCHGEAR
METERING
UNIT SUBSTATION
27.6 kV SWGR, 600 A, 25 kA
LBS, 600A
CL FU, 100E
POWER TRANSFORMER
Dyn1, Dry Type
LV SWGR
ACB
150 kW CHARGER
MCCB
Future Expansion
Propose to be splitted to unit substations each 2.5 MVA and split the loads

APPENDIX

E

G-200.4 TRANSIT GARAGE PROPOSED ELECTRIC VEHICLE STORAGE AND CHARGING



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CONCEPTUAL

rev	description	by	m.d.y
1j	added backup generator	CR	02.23.2021
1i	as per engineers review	CR	02.22.2021
1h	as per engineers review	CR	02.22.2021
1g	as per engineers review	CR	02.22.2021
1f	as per engineers review	CR	02.18.2021
1e	as per engineers review	CR	02.18.2021
1d	as per engineers review	CR	02.18.2021
1c	as per team review	CR	02.17.2021
1b	as per engineers review	CR	02.10.2021
1a	as per owner review	CR	02.09.2021
1	FOR SUMMARY REPORT	CR	12.30.2020
0	INITIAL ISSUE	CR	12.11.2020

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