City of Saint John

Public Transit and Fleet Low-Carbon Migration Strategy

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The City of Saint John

Public Transit and Fleet Low-Carbon Migration Strategy

Final Report

Signatures

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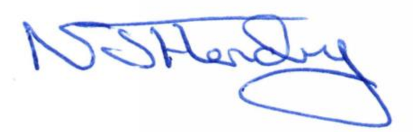

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1.0 Executive Summary

1.1 Goals of the Low-Carbon Migration Strategy

The goal of the Public Transit and Fleet Low-Carbon Migration Strategy was to identify and evaluate potential reductions in greenhouse gas (GHG) emissions from the City's public and transit fleet operations. The results from the evaluation have been incorporated into the Carbon Migration Strategy Roadmap, which outlines actions for the City to take in achieving its corporate emission reduction targets, presented below:

City of Saint John	2025 Emission Target	2040 Emission Target
Public and Transit Fleet	30% below 2015 levels	Carbon neutral

1.2 Recommended Pathway to Achieve City Climate Goals

The review of the City's current operations revealed that the 2021 Public and Transit Fleet emissions were 36% below the 2015 baseline. Therefore, the City had already achieved its short-term target and now needed to focus on how to achieve its long-term transition to carbon neutrality.

From the time of this report's publication, the City has 18 years to transition its entire fleet to a new low-carbon technology. To determine the preferred technologies for achieving the City's 2040 emission target, a Green Fleet Plan (GFP) was created to compare multiple adoption scenarios. The first scenario, business-as-usual, modeled the continued procurement of diesel and gasoline vehicles and was compared with three (3) scenarios (#2, #3, and #4) that incorporated low- and zero-emission technologies. All scenarios assumed that the storage of Public and Transit fleets would be consolidated at the City's 55 McDonald street depot. Furthermore, hydrogen procurement was limited to zero-emission "green" hydrogen, and the electrical grid carbon emission intensity was forecasted to linearly decarbonize to zero-emissions by 2035, in line with recent federal targets.

- In Scenario #2 – BEV (Battery Electric Vehicles), battery electric vehicles were the primary technology used to reach zero emissions. The primary fuel used will be energy purchased from Saint John Energy and will require the deployment of significant electric vehicle charging equipment and expansions to the electrical infrastructure.
- In Scenario #3 – FCEV (Fuel-Cell Electric Vehicles), hydrogen fuel-cell vehicles were the primary technology used to reach the zero-emission goal. The primary fuel used will be hydrogen purchased from a private gas utility (or utilities) and required the deployment of a hydrogen refuelling station at the City's depot. The hydrogen fuelling partner(s) will deliver green hydrogen to site such that no emissions are attributed to City operations. Additionally, the depot needed significant modifications to safely accommodate the hydrogen fuel-cell vehicles.
- Scenario #4 – CNG (Compressed Natural Gas) to BEV involved a deployment of CNG vehicles for the Class 6, 7, and 8 Truck Platform vehicle group. This vehicle group was identified for the opportunity as few green alternatives exist that can meet the service needs of the group, meaning that a CNG deployment may have been worthwhile in lowering emissions and costs while waiting for zero-emission technologies to be developed. This involved the deployment of a CNG refuelling station and facility modifications to safely accommodate the deployment CNG vehicles.

The analysis of GFP results revealed that battery-electric technology was preferred, as it outperformed hydrogen fuel-cell technologies in terms of financials (Table 1.1, below), opportunities, and risks (Section 6.0). Note that additional sensitivity scenarios were analyzed to evaluate other implementation strategies and test assumptions. Examples of additional scenarios include varying the price of fuel/energy and operating a mixed fleet of battery electric and hydrogen fuel-cell vehicles. These results supported the findings of the scenarios presented above.

Table 1.1 GFP Net Present Value Comparison

City of Saint John Green Fleet Strategy	Scenario Results (NPV)			
Scenario Summary [Gross Costs]	**Saint John BAU**	**BEV**	**FCEV**	**CNG to BEV**
Model Duration	2022-2040	2022-2040	2022-2040	2022-2040
Total	**225,845,226**	**213,886,615**	**267,798,511**	**214,746,589**
NPV GHG Comparison	**100.0%**	**94.7%**	**118.6%**	**95.1%**
NPV Difference		**-5.3%**	**18.6%**	**-4.9%**

Emission reductions between 2022 and 2040 were similar between each green scenario, all of which achieved carbon neutral emissions by 2040 (Table 1.2.)

Table 1.2 GFP Gross Emission Comparison

City of Saint John Green Fleet Strategy	Scenario Results (Real)			
Scenario Summary [Gross Emissions]	**Saint John BAU**	**BEV**	**FCEV**	**CNG to BEV**
Gross Public Fleet Emissions [Tonne CO2]	32,689	22,845	22,766	22,113
Gross Transit Fleet Emissions [Tonne CO2]	42,040	13,737	13,299	13,737
Total	**74,729**	**36,582**	**36,065**	**35,850**
Sub-totals	**100.0%**	**49.0%**	**48.3%**	**48.0%**
Difference		**-51.0%**	**-51.7%**	**-52.0%**

Figure 1 below presents the financial and environmental results from each scenario graphically.

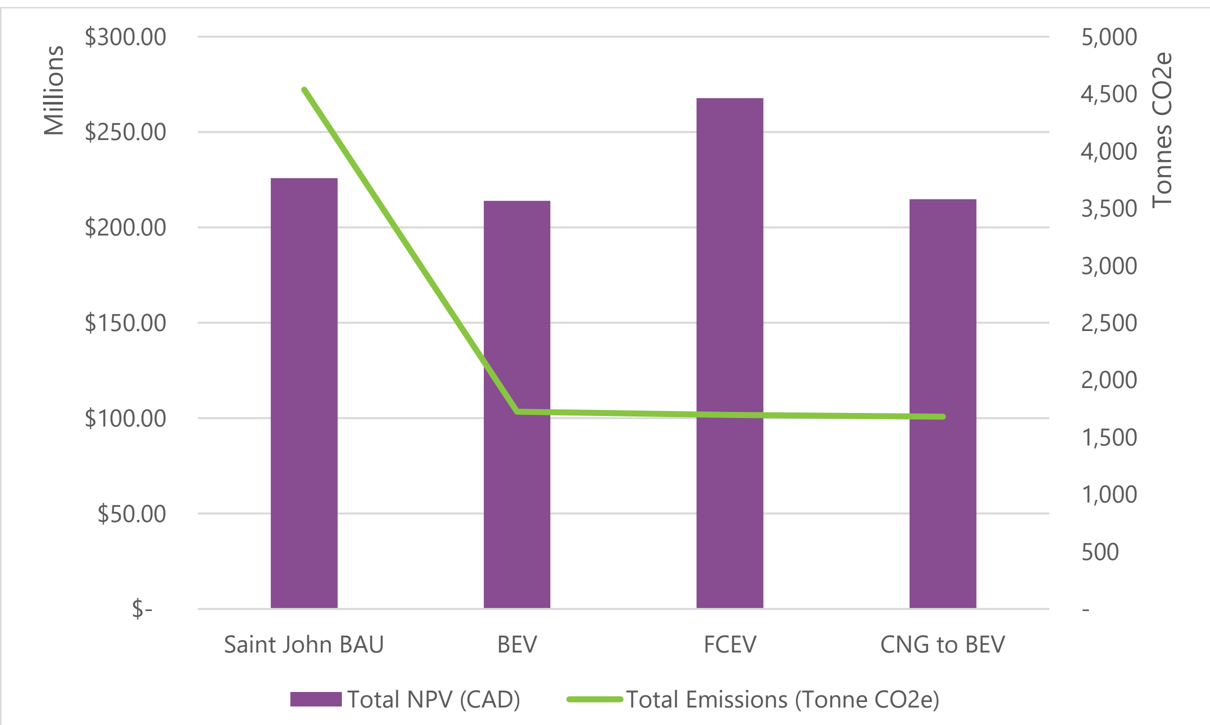


Figure 1 GFP Scenario NPV and Emission Comparison

The Carbon Migration Strategy Roadmap was developed to outline activities necessary to transition to a zero-emission fleet by 2040. It is divided into three phases, corresponding to short-, medium-, and long-term activities.

- Phase 1 is the shortest of the three phases with a 3-year duration, beginning in 2022 with anticipated completion by 2025. Phase 1 serves as a launching point to explore funding programs, partnerships, and leverage implementation opportunities. "Easy win" battery electric vehicles will begin to be adopted to introduce the new technology to City staff. Pilot programs will begin for the vehicles planned for adoption in Phase 2. During this time the City will work with hydrogen producers and the Atlantic Hydrogen Alliance to explore partnerships that could potentially make fuel-cell technologies more competitive.
- Phase 2 is five (5) years long from 2025 to 2030. During this time the next vehicle groups will begin their transition to battery electric alternatives, with the next round of pilots launching for vehicles identified for Phase 3. During this time the City's charging needs will exceed the available capacity at its fleet depot, necessitating electrical infrastructure upgrades. This significant investment should be sized accordingly to the portion of the fleet being electrified and any additional hydrogen fuel cell analysis should be completed before proceeding with any major infrastructure upgrades.
- Phase 3 is ten (10) years long from 2030 to 2040. During this time all remaining assets (vehicular and equipment) will need to be transitioned to zero-emission technologies. Actual progress should be compared to planned progress to understand any shortfall in meeting the 2040 net-zero emission goal. In particular, the rate at which the electrical grid decarbonizes will have the largest impact on reducing

The roadmap is presented in full on page 14. More context regarding implementation opportunities and next steps have been identified in Section 8.0. The opportunities and next steps explored have been organised into five (5) themes, for which an overview of their content is presented below.

8.3.1. Continuous Improvements

This theme explores updates to the Public Transit and Fleet Low-Carbon Migration Strategy, such as:

- Green Technology Adoption: what is the City progress in implementing its planned adoptions?
- Technological Progress: how are technologies maturing compared to City predictions?
- Financial Performance: are the operational savings of zero emission technologies being realized?

8.3.2. Implementation Opportunities

This theme explores opportunities for the City to further improve its zero-emission vehicle adoption plan through partnerships and phasing. This is in recognition to the strengths of the new vehicle technologies and supporting infrastructure that can be utilized for alternative functions for which GHG systems have no equivalent functionality. This includes the following topics:

- Phased Infrastructure Implementation
- Phased Tooling Implementation
- Procurement Opportunities
- Electrical Optimization and Resilience Opportunities
- Electrical Utility Opportunities
- Fleet Opportunities
- Community Emission Goal Opportunities

8.3.3. Piloting Programs

This theme explores which vehicles the City should begin piloting and what key performance metrics (KPI) should tracked as part of each pilot. An overview of KPI are provided below:

- Utilization – how many kms are driven
- Availability – number of days ready for service
- Infrastructure availability – number of days ready for use
- Vehicle availability – Mean distance between road calls
- Charger reliability – Number of days unavailable for use – warranty issues
- Cost per km – Energy costs per km driven collated to fuel cost savings
- Environmental Impact – Emissions reduction, value of carbon savings
- Equity and Environmental – Kms driven through these areas

The roadmap recommends piloting the vehicle groups and equipment in the following phases.

Phase 1	Phase 2	Phase 3
• Class 2 – Light Duty Pickup Truck • Class 7 – Streetsweeper • Class 8 – Refuse Truck	• Class 1 – Police Cruiser • Class 3, 4, & 5 – Heavy Duty Pickup Truck • Class 6, 7, & 8 – Heavy Duty Truck Platform • Class 8 – Pumper Fire truck	• Excluded asset classes: construction equipment, armored vehicles, etc. • Pilot zero-emission tools and equipment (Optional)

8.3.4. Staff Readiness

This theme explores the steps that should be taken to manage the change in operations with regard to City stakeholders. This includes internal stakeholders such as user groups and staff, and external stakeholders such as partnering firms/agencies and the public.

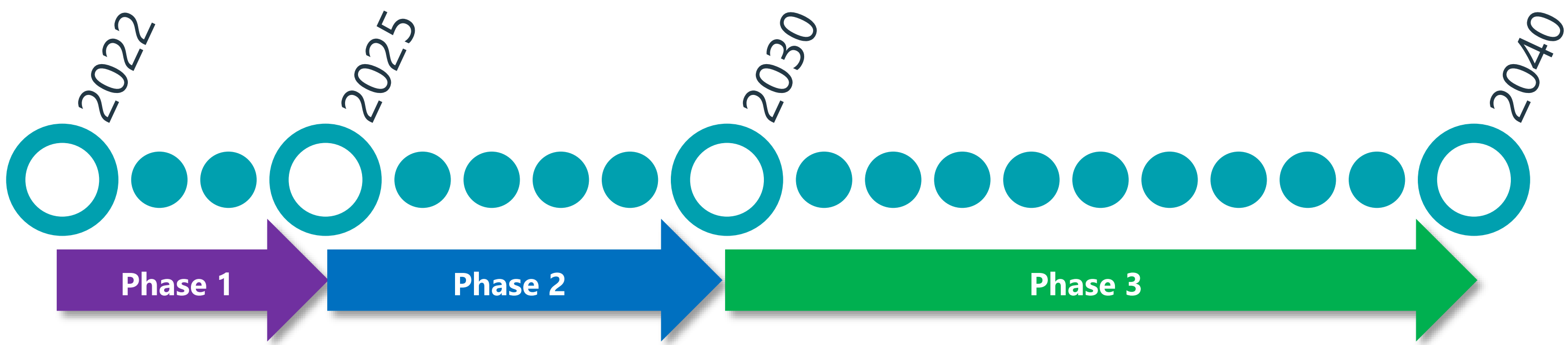
Specific guidance is provided for anticipated labour negotiations and for training packages that City staff will required to safely work with battery electric vehicles.

8.3.5. Facility Modifications

This theme explores the range of facility modifications that are recommended to accommodate battery electric vehicles. This includes physical changes to the City's depot to accommodate the size and needs of the vehicles, as well recommended locations for the charging equipment. These items have been organised into the following topics:

- Vertical Clearances
- Electrical Infrastructure
- Candidate Power Control Unit Locations
- Primary Dispenser Locations
- Auxiliary Dispenser Locations
- Static Free Workplaces and Storage
- Staff Spaces
- Additional Modifications

1.3 Carbon Migration Strategy Roadmap (Phases 1, 2, and 3)



Phase 1	Phase 2	Phase 3
• Begin grant/funding applications. • Implement PHEV and BEV for General Purpose Vehicles. Implement HEV for Police and heavy-duty vehicles. Implement BEV for the transit fleet. • Pilot BEV light-duty trucks, street sweepers, and refuse trucks. • Explore green fleet transition opportunities (public charging, on-demand transit, community targets). • Explore external partnerships and investments that would make FCEV technologies competitive with BEV.	• Review/update migration plan to review the competitiveness of hydrogen technologies. • Implement electrical utility upgrades/expansions. • Implement BEV for light-duty trucks, street sweepers, and refuse trucks. • Pilot BEV for remaining vehicles classes. • Expand market scan to remaining assets (equipment/construction/off-road).	• Review/update migration plan to review planned vs actual progress of the migration plan. • Implement additional electrical utility upgrades/expansions. • Implement BEV for remaining vehicles classes. • Implement zero-emission solutions for City equipment, construction, and off-road assets. • Review the progress of electrical grid decarbonization. Consider options to offset carbon should the grid fail to achieve carbon neutrality by 2035.

2.0 Introduction

2.1 Background

Climate Change is one of the greatest challenges facing humanity today. As a coastal city, sea-level rise is of great concern for Saint John. Other challenges include increasing temperature and higher intensity precipitation events. This directly results in severe flooding, coastal erosion, and loss of land. To counter this, Saint John has become a pioneer in implementing a range of policies and strategies to address the impact of climate change and adapt itself to these changes.

To mitigate the climate change impact, the City of Saint John's (the City) Common Council approved its Climate Change Action Plan. The Action Plan has identified some high-level Green House Gas (GHG) emission reduction strategies in the transportation sector. The Action Plan has separate GHG and Energy Action Plan for both the Corporate and the Community, which are detailed below.

City of Saint John	2025 Emission Target	2035 Emission Target	2040 Emission Target
Corporate	30% below 2015 levels	-	Carbon neutral
Community	9% below 2015 levels	18% below 2015 levels	-

Additionally, the City has also implemented several fleet management strategies like Optimum replacement procedure, Idling policy and fleet monitoring systems.

The City understands that transportation is a major contributor to GHG emissions. The City’s transportation sector accounts for more than one-third of total GHG emissions. To meet the goals outlined in the Climate Change Action Plan, the City plans to implement low- and zero-emission technologies in its public and transit fleets. This is to be achieved by transitioning the vehicles to a mix of technologies like electric, hybrid-electric, compressed natural gas, or hydrogen. Additionally, the City aims to review and update its policies, measures, technologies, and installing telematics in the transit buses. This has all been in service of aiding the City to identify appropriate actions to increase operating efficiency, maintain levels of service, and achieve its climate change mitigation goals.

2.2 Goals of the Low-Carbon Migration Strategy

The goal of the Public Transit and Fleet Low-Carbon Migration Strategy was to identify and evaluate potential reductions in greenhouse gas (GHG) emissions from the City’s public and transit fleet operations. The results from the evaluation have been incorporated into the Carbon Migration Strategy Roadmap, which outlines actions for the City to take in achieving its corporate emission reduction targets. The applicable targets for the Public and Transit Fleet are presented below:

City of Saint John	2025 Emission Target	2040 Emission Target
Public and Transit Fleet	30% below 2015 levels	Carbon neutral

The 2025 emission target was considered the short-term goal, whereas the 2040 target for carbon neutrality (or net zero-emissions) was considered the long-term goal. The Low-Carbon Migration Strategy sought to achieve these goals through the implementation of low- and zero-emission vehicles. This implementation would be mapped using a roadmap indicating major transition milestones up to the 2040 target.

2.3 Methodology Summary of the Low-Carbon Migration Strategy

This began through an assessment of the current state of City operations, with a focus on fleet mix and performance requirements. Following the review of the current state, a market scan of available technologies was performed to identify what low- and zero-emission products were currently available on the market. A key piece of the market scan was aimed at understanding the performance opportunities and limitations of each technology to support user group discussions regarding technology readiness. A landscape review was performed to understand the actions taken by similar municipalities, such that lessons learned could be leverage by Saint John. Furthermore, the landscape scan extended to transit deployments of zero-emission buses, some of which had publicly published the findings of their deployments.

With the results of the City's current state, the market scan, and the landscape scan, the project proceeded to a future state analysis. A key component of the future state analysis was to consult with the City's user groups, the fleet managers from throughout the City departments that operate vehicles. This allowed for each proposed low- and zero-emission technology to be discussed in terms of the needs of each user group, allowing for a forecast of when technologies are expected to mature to the point where they can be incorporated into the fleet. These discussions were structured in terms of the opportunities, constraints, and risks of each technology such that solutions could be developed that would mitigate negative aspects of each technology while leveraging its strengths. These consultations were extended to relevant external stakeholders, namely electric and gas utilities, such that fuel availability and resiliency could be considered.

The forecast of when technologies could begin their adoption into the City fleet was used to generate a transition pathway to reach the City's emission goals. This pathway was analysed using a Green Fleet Plan which assessed implementing different low- and zero-emission technologies to understand their associated capital costs, operational costs, and emission reductions. This allowed the City to compare the performance of different technologies to select a technology mix that best suited the City's needs. The additional benefit from the Green Fleet Plan analysis is that major milestones, such as electrical utility upgrades, could be forecasted in terms of cost and timing.

The preferred technology had a roadmap developed that sought to realize as many benefits as possible, while mitigating risks. Continued discussions for partnership opportunities and external funding are included in the process. Vehicle piloting programs are prominent in the plan as they are critical for identifying gaps between existing technology and proposed low- and zero-emission technologies. Another consideration for the roadmap was to provide flexibility in the recommended next steps which would allow the City to adapt the plan should different technologies become more competitive in the future. This is accomplished by flagging opportunities to review competing technologies in advance of infrastructure commitments that require significant investment.

The implementation opportunities section was developed to provide additional context for the action outlined in the roadmap. These opportunities were categorized into five themes: Continuous Improvements, Implementation Opportunities, Piloting Programs, Staff Readiness, and Facility Modifications.

Transit route modelling was performed as an immediate next step to the Low-Carbon Migration Strategy Findings. The modelling assessed the feasibility of current battery electric buses to best understand which routes could be served by the new technology. Additional benefits of the modelling would be to understand the specific vehicle specification necessary to best deliver service, in addition to quantifying the equipment and infrastructure necessary to support the deployment. The results of the route modelling analysis are provided in Appendix B.

3.0 Current State

This section will assess and summarize the current state of the City's key facilities, fleet size and mix, operations, and environmental baseline. The development of this section involved a data request from the City, including information from Saint John Energy. Additional stakeholders were consulted on an as-needed basis throughout the engagement. The Wood Project team also conducted user group surveys and consultations with representation from all impacted fleets.

The following sections outline City of Saint John's current state across its facilities, fleet, and current environmental emissions.

3.1 Key Facilities

The City of Saint John has facilities in 69 different locations which includes parks, community centres, fire stations, vehicle maintenance facilities, and offices. The focus of this study would be where the municipal and transit fleet vehicles are operated and maintained to enable the development of a green fleet plan. This would include locations where the fleet vehicles are parked most of the time such as the City Hall. This section briefly summarizes the current state of the following three key facilities.

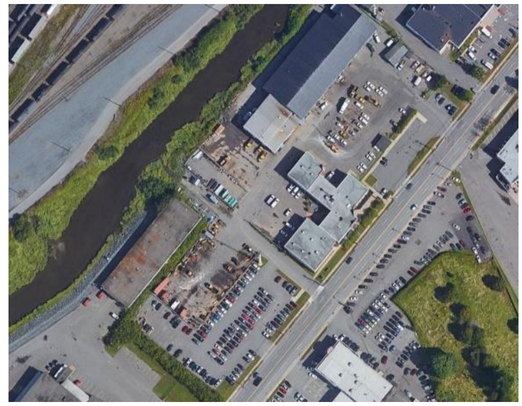
1. City Hall
    a. Building at 15 Market Square
    b. Parking Garage at 17 Chipman Hill
2. Public fleet Operations
    a. Building and Garage at 175 Rothesay Avenue
3. Transit Fleet Operations
    a. Building and Garage at 55 McDonald Street

3.1.1 City Hall

The City of Saint John's City Hall is located at 15 Market Square and the building's parking garage is located at 17 Chipman Hill, adjacent to the City Hall on the south. The City Hall hosts multiple departments of the City and there are some public fleet vehicle users based out of the City Hall. The City's Fleet Management department currently operates a few general-purpose vehicles such as sedans and SUVs from the City Hall. The City does not own any yard or spaces near the City Hall which can be used for operating the City's public fleet. The City and the Fleet Management department have indicated potential for short-term deployment of light-duty chargers in the City Hall that could be utilized by both public fleet vehicles and staff's own electric vehicles.

3.1.2 175 Rothesay Avenue – Public Fleet Operations

The City of Saint John has a fleet facility at 175 Rothesay Avenue where most of the public fleet vehicles excluding the transit fleet vehicles are stored and maintained. The core of the public fleet operations is at the Rothesay Avenue facility where the City's Fleet Management department functions. Based on inputs from the City, the Rothesay Avenue facility is currently at capacity and cannot accommodate any growth to the public fleet. The City has also indicated that it is not interested in making any facility upgrades or modifications to the Rothesay Avenue facility to accommodate the future green fleet vehicles.



3.1.3 55 McDonald Street – Transit Fleet Operations

Saint John Transit, the public transit agency serving the City of Saint John operates and maintains its transit fleet vehicles from the 55 McDonald Street facility. All transit functions such as service planning, scheduling, fleet daily servicing, and maintenance are performed at the McDonald facility. Currently, Saint John Transit operates forty-seven (47) conventional 40-foot diesel buses from the McDonald facility. There are also ten (10) smaller transit vehicles and two (2) service trucks that are operated and maintained from this facility. The City of Saint John identified that the McDonald facility has abundant space and electrical power, much more than what the transit fleet requires. This includes 550 kW of additional electrical capacity that can be utilized by future electric vehicles without the need for any utility upgrades (i.e., transformers/power lines). The City has also indicated a preference to transition all public fleet vehicle operations from the Rothesay Avenue facility to the McDonald Street facility. The City provided input that the McDonald facility is also better positioned in case of future expansion requirements to accommodate a larger fleet.

3.2 Public fleet

The City of Saint John currently operates a total of 300 public fleet vehicles. This includes vehicles operated by the various City departments, Police, and Fire and Emergency Services. The public fleet vehicles are managed by the Fleet Management department which is responsible for the entire lifecycle of the fleet assets including purchase, maintenance, utilization monitoring, and disposition.

3.2.1 Fleet Inventory and Mix

The City of Saint John's 300 public fleet are distributed across various fleet functions and user groups. Vehicle classes were used to help identify the vehicle mix in the fleet and by user group. The vehicle classes are set according to the Gross Vehicle Weight Rating (GVWR) of the vehicle, which is the maximum weight a vehicle is designed to carry including the net weight of the vehicle with accessories, plus the weight of fuel, passengers, and cargo. The range of vehicle weight classes and the City's public fleet count by each vehicle class are summarized in Table 3.1.

To further refine the fleet classification, Wood classified the public fleet vehicles into vehicle groups based on vehicle classes and the fleet functions as shown in Table 3.2. Unlicensed vehicles and other vehicles considered out of scope for this study were classified into the "Misc. (out of scope)" group.

Table 3.1 Vehicle Class by GVWR (lbs)

Vehicle Class	Min Weight (lbs)	Max Weight (lbs)	Fleet Count
Class 1	N/A	< 6,000	87
Class 2	6,001	10,000	74
Class 3	10,001	14,000	17
Class 4	14,001	16,000	15
Class 5	16,001	19,500	32
Class 6	19,501	26,000	7
Class 7	26,001	33,000	5
Class 8	> 33,001	N/A	63
Total	-	-	**300**

Table 3.2 Vehicle Grouping by Function and Class

Vehicle Group	Class and Function	Fleet Count
Group 1	Class 1 General Purpose	46
Group 2	Class 1 Police Cruiser	23
Group 3	Class 2 Light Duty (LD) Pickup Truck	73
Group 4	Class 3, 4 & 5 Heavy Duty (HD) Pickup Truck	39
Group 5	Class 6, 7 & 8 Truck Platform	32
Group 6	Class 7 Streetsweeper	2
Group 7	Class 8 Pumper Fire Truck	12
Group 8	Class 8 Refuse Truck	10
Misc. (out of scope)	Graders, Backhoes, Loaders, Forklift, Unlicensed, etc.,	63
Total	-	**300**

The City's public fleet has 54% of the fleet running on gasoline and the remaining 46% running on diesel as shown in Figure 2.

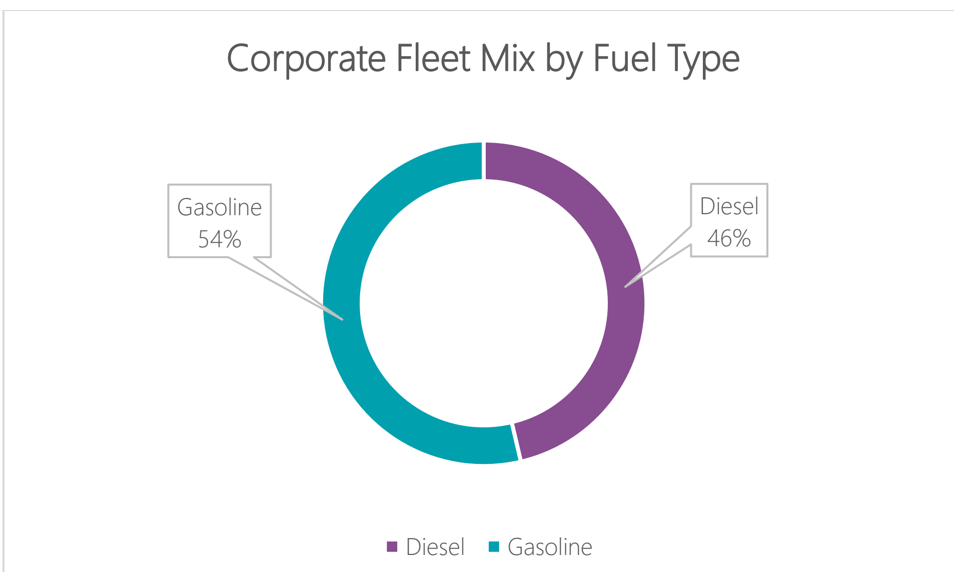


Figure 2 Number of Vehicles by Fuel Type

3.2.2 User Groups

While the public fleet vehicles are managed by the Fleet Management department, most of the vehicles are assigned to various City departments. Some of the public fleet vehicles are classified as "Pooled" vehicles which are assigned to the "Public Works and Transportation - Fleet Management" category. The pooled vehicles are assigned to the different City departments on a rotational basis or as required. Wood analysed the Fleet Inventory document provided by the City's Fleet Management department and identified the following user groups. Please note that Public Works and Transportation (PW&T) department has been further divided into Fleet Management, Public Works, Roadway & Surface Maintenance, and Solid Waste Collection based on functionality for this study. The different public fleet user groups are shown below:

- Fire & Emergency Services
- Police
- Pooled Vehicles
- PW & T - Fleet Management
- PW & T - Public Works
- PW & T - Roadway & Surface Maintenance
- PW & T - Solid Waste Collection
- Saint John Water
- Transportation & Environment
- U & I - Infrastructure Asset Management

The public fleet vehicle split across the different user groups is shown in Figure 3.

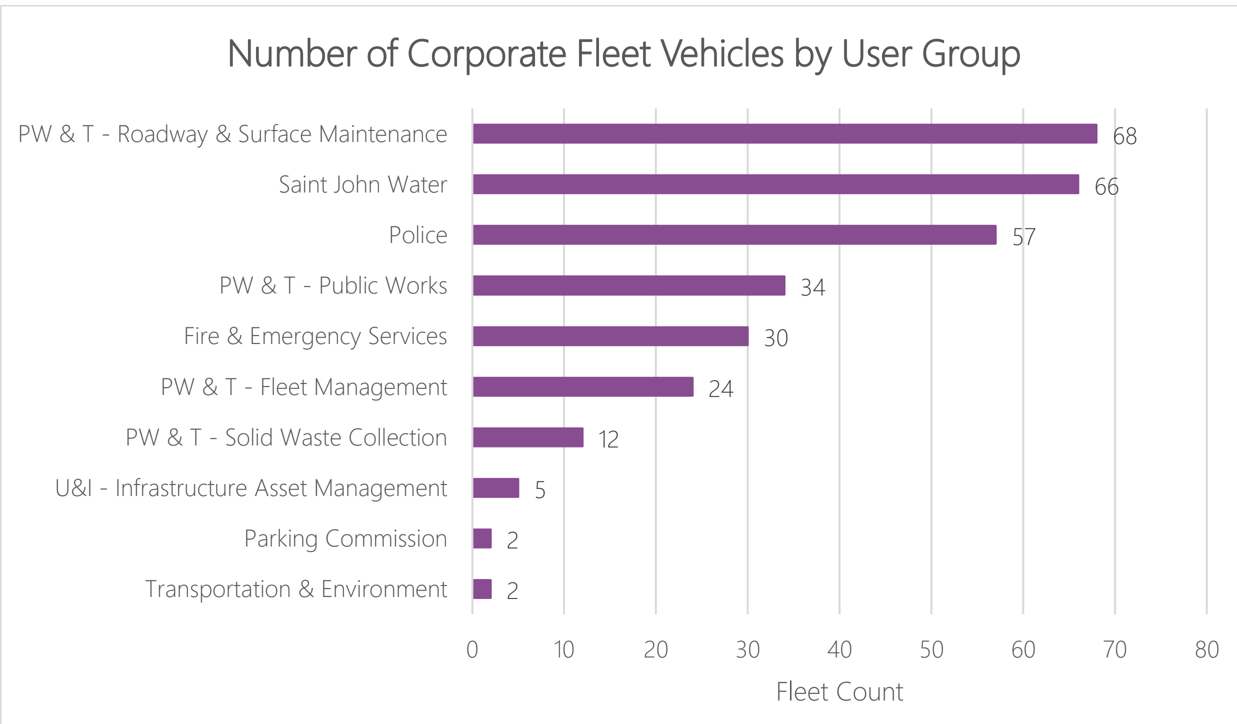


Figure 3 Number of Vehicles by User Group

PW & T – Roadway & Surface Maintenance, Saint John Water, and Police use a majority of the public fleet vehicles as can be seen in Figure 3. Wood also performed a fuel consumption analysis for the period 2018 – 2021. This analysis did not include the Police vehicles and a summary of this analysis is shown in Table 3.3. The fuel consumption analysis shows that PW & T – Roadway & Surface Maintenance, and Saint John Water consume the most fuel. While PW & T – Solid Waste Collection has only 12 fleet vehicles of the overall 300 vehicles, they stand second in terms of fuel consumption. There are 10 refuse trucks in this fleet of 12 vehicles operated by PW & T – Solid Waste Collection, the remaining two vehicles being one pickup truck and one SUV. This is in line with the expectation that the refuse trucks will consume fuel at a higher rate compared to other fleet vehicles due to more frequent start and stop operation, lower average speed, and the use of the power take off (PTO) for the hydraulics.

Table 3.3 Average Annual Fuel Consumption (litres) by Public fleet User Group

Public fleet User Group	2018	2019	2020	2021
PW & T - Roadway & Surface Maintenance	276,831	271,974	220,963	225,632
PW & T - Solid Waste Collection	173,083	173,832	169,545	169,050
Saint John Water	57,116	182,514	207,723	213,140
PW & T - Public Works	44,943	46,275	47,438	45,162
Fire & Emergency Services	-	3,772	23,327	24,285
PW & T - Fleet Management	3,709	10,387	13,171	18,704
U&I - Infrastructure Asset Management	440	7,058	5,718	7,536
Pooled Vehicles	2,628	7,055	5,874	-
Transportation & Environment	2,683	405	3,648	-

3.2.3 Fleet Operating Statistics

This section presents the key fleet operating statistics of the City of Saint John's public fleet vehicles such as average annual distance, fuel efficiency, and useful life by each vehicle group and user group. Please note that Wood identified there were several data gaps during the review of the City's current state which was attributed to the November 2020 cyberattack on the City's network. This cyberattack disabled many City systems that had to be restored and information across the network was lost in the process. This made a detailed fleet data analysis for the period 2016-2021 difficult.

Table 3.4 Average Annual Distance (km) by Vehicle Group

Vehicle Group	Class and Function	2018	2019	2020	2021
Group 1	Class 1 General Purpose	4,583	5,447	6,060	6,094
Group 2	Class 1 Police Cruiser	-	-	-	-
Group 3	Class 2 LD Pickup Truck	13,376	12,106	14,697	15,598
Group 4	Class 3, 4 & 5 HD Pickup Truck	16,272	13,402	15,792	13,189
Group 5	Class 6, 7 & 8 Truck Platform	15,240	13,547	9,829	12,496
Group 6	Class 7 Streetsweeper	7,715	7,648	10,222	9,029
Group 7	Class 8 Pumper Fire Truck	-	199	4,106	3,182
Group 8	Class 8 Refuse Truck	18,816	18,924	19,480	19,623

The source data for this analysis was derived from the City of Saint John's fleet telematics provider, GeoTab's online database. Table 3.4 presents the average annual distance (km) for each vehicle group. Please note that the mileage information for the "Group 2 – Class 1 Police Cruiser" was not available for this analysis since the Police Fleet Information are stored in an independent database. It can be found that the "Group 8 – Class 8 Refuse Trucks" travel the most distance annually compared to other fleet vehicles. Each Refuse Truck travels approximately 19,000 km consuming 16,900 litres of diesel each year.

Table 3.5 Average Annual Fuel Efficiency (kmpl) by Vehicle Group

Vehicle Group	Class and Function	2018	2019	2020	2021
Group 1	Class 1 General Purpose	13.16	11.52	9.98	8.81
Group 3	Class 2 LD Pickup Truck	5.39	5.30	5.22	5.39
Group 4	Class 3, 4 & 5 HD Pickup Truck	3.49	3.50	3.74	3.75
Group 5	Class 6, 7 & 8 Truck Platform	1.55	1.59	1.54	1.56
Group 6	Class 7 Streetsweeper	2.16	2.24	2.36	2.59
Group 7	Class 8 Pumper Fire Truck	-	2.20	3.53	3.11
Group 8	Class 8 Refuse Truck	1.09	1.09	1.18	1.19

Table 3.5 shows the average annual fuel efficiency in kilometres per litre of fuel by each vehicle group. It can be found that the "Group 1 – Class 1 General Purpose" vehicles are the most fuel efficient and "Group 8 – Class 8 Refuse Truck" are the least fuel efficient. The "Group 5 – Class 6, 7, & 8 Truck Platform" vehicles are the second least fuel efficient vehicles.

Table 3.6 Average Annual Distance (km) by User Group

User Group	2018	2019	2020	2021
Fire & Emergency Services	-	1,272	5,948	5,897
Pooled Vehicles	5,685	7,356	5,017	-
PW & T - Fleet Management	4,389	9,423	11,585	20,311
PW & T - Public Works	12,960	12,713	12,751	12,802
PW & T - Roadway & Surface Maintenance	16,094	15,214	14,516	14,588
PW & T - Solid Waste Collection	18,816	17,362	18,881	18,944
Saint John Water	14,124	10,908	13,054	13,284
Transportation & Environment	10,314	3,773	11,794	-

Table 3.6 shows the average annual distance travelled by each user group's fleet vehicles.

Table 3.7 Expected Vehicle Useful Life by Vehicle Group

Vehicle Group	Class and Function	Assessment Age	Expected Useful Life
Group 1	Class 1 General Purpose	6	10
Group 2	Class 2 LD Pickup Truck	3	6
Group 3	Class 3, 4 & 5 HD Pickup Truck	6	10
Group 4	Class 6, 7 & 8 Truck Platform	7	6
Group 5	Class 7 Streetsweeper	12	10
Group 6	Class 8 Pumper Fire Truck	12	12
Group 7	Class 8 Refuse Truck	15	10
Group 8	Class and Function	12	13

Table 3.7 shows the vehicle assessment age and the expected useful life for the public fleet vehicles by each vehicle group. The City of Saint John has an internal policy to evaluate the condition of each fleet vehicle after the assessment age. This assessment will determine the appropriate maintenance or overhaul required to keep the fleet vehicle in good state of health. This assessment will also decide whether a fleet vehicle needs to be replaced.

3.3 Transit Fleet

Saint John Transit is the public transit agency serving the City of Saint John. Established in 1979, Saint John Transit is the largest public transit system in the province in terms of both ridership and mileage. Saint John's Transit system handles approximately about 2.5 million passengers per year. Saint John's Transit Fleet consists of predominantly conventional 40-foot diesel buses. Saint John Transit's fleet includes ten (10) smaller transit vehicles, two (2) non-revenue service vehicles, and two (2) service trucks. The focus of this study would be transition Saint John Transit's the conventional buses to low/zero carbon propulsion technologies.

3.3.1 Services

Saint John Transit currently provides both conventional fixed-route and on-demand paratransit services. Saint John Transit provides services 7 days a week with a network of main and feeder routes that connects four (4) major hubs throughout the City. Saint John Transit also provides the Comex, a rapid transit service providing fast commuter bus service. The commuter bus service runs Monday to Friday connecting Rothesay and Quispamsis to uptown in the morning and the opposite direction in the after-work service.

- Fixed conventional routes
- On-demand paratransit
- Exploring "conventional" on-demand transit hybrid model

3.3.2 Fleet Mix

As mentioned before, Saint John Transit's fleet is predominantly made up of conventional 40-foot transit buses. Table 3.8 shows Saint John Transit's fleet inventory with the acquisition year, model, current age, and vehicle count. Likewise, Table 3.9 shows Saint John Transit's specialized transit fleet inventory. Saint John Transit currently has forty-seven (45) conventional 40-foot diesel buses out of which five (5) are inactive. The transit roster includes two (2) articulated 60-foot diesel buses "Nova Bus LFS Artics", both of which are inactive and in the process of being retired. The revenue fleet also has two (2) gasoline and eight (8) diesel paratransit buses. Saint John Transit's non-revenue fleet includes two (2) Ford F350 service trucks and two (2) Chevrolet Equinox service vehicles.

Table 3.8 Conventional Diesel 40′ Transit Fleet Inventory

S. No	Acquisition Year	Model	Current Age	Vehicle Count
1	2002	OBI Orion VII	19	2
2	2004	OBI Orion VII	17	2
3	2005	OBI Orion VII	16	2
4	2004	OBI Orion VII	17	1
5	2006	OBI Orion VII	15	3
6	2007	OBI Orion VII NG	14	11
7	2008	OBI Orion VII NG	13	4
8	2010	OBI Orion VII NG	11	3
9	2012	OBI Orion VII EPA10	9	2
10	2015	Nova Bus LFS	6	2
11	2016	Nova Bus LFS	5	1
12	2018	Nova Bus LFS	3	12
Total			-	**45**

Table 3.9 Specialized Transit Fleet Inventory

S. No	Acquisition Year	Model	Current Age	Vehicle Count
1	2008	Ford E-450 / Diesel	13	1
2	2009	Ford E-450 / Diesel	12	2
3	2011	Chevrolet 4500 / Diesel	10	1
4	2012	Chevrolet 4500 / Diesel	9	1
5	2013	Chevrolet 4500 / Diesel	8	1
6	2014	Chevrolet 4500 / Diesel	7	1
7	2015	Chevrolet 4500 / Diesel	8	1
8	2019	Ford E-450 / Gasoline	2	2
Total			-	**10**

Currently, Saint John Transit does not have detailed digital fuel consumption and annual mileage records due to IT system migration issues. Hence, Wood has not presented the Transit Fleet's Operating Statistics. Based on inputs from Saint John Transit staff, the conventional 40-foot transit buses have an average fuel efficiency of 1.95 kilometre per litre (kmpl) and average annual mileage of 38,550 km. Conversely, the specialized 28-foot transit buses have an average fuel efficiency of 3.28 kilometre per litre (kmpl) and average annual mileage of 16,500 km.

Table 3.10 Expected Vehicle Useful Life by Vehicle Group

Vehicle Group	Class and Function	Assessment Age	Expected Useful Life
Group 9	40' Conventional Transit Bus	NA	12
Group 10	28' Specialized Transit Bus	NA	8

Table 3.10 shows the expected useful life for the transit fleet vehicles by each vehicle group. This value is a new metric for Saint John Transit that will be applied to future procurements. The vehicle assessment age is not formalized for the transit fleet and is done on an ad-hoc basis.

3.4 Fleet Policies

Wood reviewed the various fleet policy documents provided by the City of Saint John and a high-level summary of the fleet policies and measures in place is presented below. For summarizing, Wood has classified the fleet policies into fleet management, vehicle replacement, fleet greening measures, and vehicle assignment.

3.4.1 Fleet Management

The City's Fleet Management department assumes the role of the Asset Manager for the City's Fleet and is responsible for the purchase, maintenance, utilization monitoring, and disposition of the fleet assets. Fleet Management also manages the City's vehicle pools and assigned vehicles in collaboration with the fleet user groups. Fleet Management develops the standards for developing vehicle pools (i.e., shared fleet) and vehicle assignment to each service area (i.e., user group). Fleet Management is also responsible for the overall asset monitoring including fleet utilization and lifecycle costs. Based on utilization and other requirements, Fleet Management is responsible for redistributing the fleet vehicles to different service areas on an on-going basis.

The City uses Fleet Telematics for the purpose of tracking and monitoring various fleet key performance indicators such as utilization, fuel consumption and efficiency, engine run time, high idling, and long hauling. GeoTab is the City's Fleet Telematics providers and all fleet vehicles except the police vehicles are equipped with GeoTab telematics devices. GeoTab also has other useful capabilities such as geo-fencing monitoring to ensure that fleet vehicles are performing the intended functions.

The Fleet Management group serves as the City's Fleet Asset Manager and is responsible for the acquisition of vehicle and associated equipment. Fleet Management ensures that all vehicle and equipment comply with all municipal policies and procedures. Further, Fleet Management also ensures that all vehicle and equipment purchases are sufficiently funded and charged to the correct budgets. The City has established a Fleet Reserve Fund to support the annual cost to replace existing vehicle and equipment assets. This is a mechanism developed by the City to ensure that the fleet always has sufficient funds given the importance of the City's fleet vehicles to deliver critical services, without needing to conform to an annual budget which may require council approval and delay acquisitions. Fleet Management is also responsible for providing the required training for the operation and maintenance of any new vehicles.

3.4.2 Vehicle Replacement

Fleet Management is responsible for identifying when a vehicle/equipment asset needs to be replaced. The replacement decision is made using the Optimum Replacement Point (ORP) analysis. The ORP calculation considers the asset's purchase year, annual mileage, overall condition, ratio of maintenance to the initial cost of purchase and overall mechanical condition. When an asset reaches the ORP, Fleet Management begins to evaluate the replacement decision. It does not necessarily mean that an asset needs to be replaced when it reaches the ORP. After an asset reaches ORP, Fleet Management consults with the related Service Area and revaluates the ORP based on available budget and estimated remaining useful life. Thereafter, the asset renewal decision will be revaluated periodically until the time when the asset will be replaced.

Fleet Management maintains a library of standard vehicle and equipment assets specifications. This library retains a database of general specifications to identify the basic common items requirement for each class of vehicle and equipment assets. When an asset needs to be replaced, the purchase of a renewal asset will consider the standardization of asset specifications along with specialized requirements as required. The standard specifications practice helps Fleet Management and the City in multiple areas such as better supply chain for parts, simplified personnel training, and improved maintenance efficiencies. The standardized vehicle and equipment assets specifications library need to be updated periodically as the City moves towards low-carbon and zero-emission fleet technologies in the future.

3.4.3 Fleet Greening Measures

The City of Saint John adopted the "Greening Our Fleet" policy in June 2019 which applied to City's Fleet Management and Operations. Before adopting this policy, the City recognized that unnecessary vehicle and motorized equipment idling, and long hauling wasted fuel and generated needless harmful emissions. Recognizing its responsibility to conserve natural resources, be environmentally conscious, and prevent air pollution, the City wanted to implement fuel efficient practices and improve environmental performance.

The City's "Greening Our Fleet" policy aims to reduce GHGs and other air pollutants and fuel consumption from the operation of its fleet vehicles and motorized equipment while also reducing maintenance requirements and fuel costs. This policy applies to the entire City fleet regardless of being owned, leased, or rented and the day-to-day administration of this policy is rested with the supervisory and management staff of all departments which operate the fleet vehicles. The highlights of the policy include the following:

- Fleet vehicles shall never be left idling when unattended
- Engine warm-up period to not exceed three (3) minutes provided safety critical items such as airbrake pressure have been reached
- Fleet vehicles to shut off whenever the idling time is expected to exceed three (3) minutes
- Fleet vehicles are not to be utilized for long hauling
- Employees are required to take the most direct and safe route to the destination

There are certain exclusions to the fleet policy where the policy cannot be implemented, examples include operation during extreme temperatures (below -10° C and above 27° C) and presence of emergency response vehicles in the scene of an emergency. The maximum distance for long hauling (i.e., over 40 kms) was chosen based on the service area of the City. The City indicated that the fuel consumption of the fleet vehicles had significantly dropped since the implementation of the "Greening Our Fleet" policy. The City has also committed to reduce the Public fleet's GHG emissions and air pollutants and eventually move towards zero emissions in the City's Race to Zero pledge document. There were also several fleet reduction measures introduced between 2017 and 2019. The fleet downsizing was done in two phases, beginning with a reduction of light-duty fleet in 2017 and then a heavy-duty fleet reduction in 2019. This was done with right sizing considerations such that service delivery was not impacted. These measures along with the "Greening Our Fleet" policy have significantly reduced the overall fleet fuel consumption of the City's fleet.

3.4.4 Vehicle Assignment

The City has a "Vehicle Assignment" policy which aims to optimize cost-effective deployment of vehicles among staff and promote the shared utilization of fleet assets which would reduce the City's fleet environmental footprint. The policy directs that the job requirements shall determine the assignment of vehicles to individual members of the staff, and such determination will be made by the City Manager based on operations-centred focus of the position, after hours response needs, and average annual usage. This policy covers the assignment and utilization of "light fleet" i.e., passenger vehicles without lighting packages and/or other specialized equipment for use in operations. The policy provides guidelines for vehicle rotation to optimize the cost-effectiveness of the vehicle assignment model as required. The Service Level Agreements (SLA) established by Fleet Management with each service area outlines the service area's operational and maintenance responsibilities. The SLA helps Fleet Management on Vehicle Assignment and Fleet Right-Sizing decisions.

This policy also promotes the use of shared use of vehicles (i.e., pooling) which has been designated as the primary vehicle assignment strategy. The City operates a pool of shared vehicles that can be used by one or more operators (i.e., staff) or service areas. The pooled vehicles are managed by Fleet Management and the cost to operate the pooled vehicles are recovered through usage charges to the service areas. The introduction of vehicle pooling has allowed the City to maintain similar service levels with a smaller fleet, subsequently leading to reduced fuel consumption and increased fleet utilization levels.

3.5 Environmental Baseline

This section provides a brief introduction to the different emission scopes and the relevance to Saint John's fleet operating context. This section also presents the province of New Brunswick's emissions profile along with a comparison of the City of Saint John's 2015 and current (2021) emissions baselines.

3.5.1 Scope 1 Emissions

The U.S. Environmental Protection Agency (EPA) defines Scope 1 emissions as direct greenhouse gas (GHG) emissions that occur from sources that are controlled or owned by an organization[1]. In the context of Saint John's fleet operations, the emissions associated with the fuel combustion in vehicles is considered Scope 1 emissions (i.e., tailpipe emissions). The City of Saint John has committed to include Scope 1 emissions in this study to evaluate the past and future fleet emissions.

3.5.2 Scope 2 and Scope 3 Emissions

The U.S. EPA defines Scope 2 emissions as indirect GHG emissions associated with the purchase of electricity, steam, heat, or cooling. Scope 2 emissions physically occur at the facility where they are generated and needs to be accounted in an organization's GHG inventory because the emissions are a result of the organization's energy use. In the context of this study with conventional fleet vehicles that use fossil fuels such as diesel and gasoline, Scope 2 can be considered out of scope for the past and current GHG emissions since there is no use of electricity or steam in the vehicles.

Likewise, the U.S. EPA defines Scope 3 emissions as the result of activities from assets not owned or controlled by the reporting organization, but that the organization indirectly impacts in its value chain. In other words, an organization's Scope 3 emissions are the Scope 1 and Scope 2 emissions of another organization. Scope 3 are also referred to as value chain emissions, often representing the majority of an organization's total GHG emissions. Scope 3 emissions fall within a wide array of 15 categories including

[1] https://www.epa.gov/climateleadership/scope-1-and-scope-2-inventory-guidance

emissions from both upstream and downstream activities, though not every category will be relevant to all organizations. Figure 4 illustrates the key Scope 1, 2 and 3 GHG emissions. According to the GHG Corporate Protocol, all organizations are required to account for the Scope 1 and Scope 2 emissions when reporting and disclosing GHG emissions while Scope 3 emissions quantification is not required. While the consideration of Scope 3 emissions provides a good opportunity to reduce GHG emissions, Scope 3 emissions presents unique complications such as difficulty in identifying applicable emission categories and uncertainty in data collection. Hence, the City of Saint John has agreed to use applicable and accepted emissions factors as required throughout this study and refine them in future report updates when more information, clarity and direction is available for the use of Scope 3 emissions.

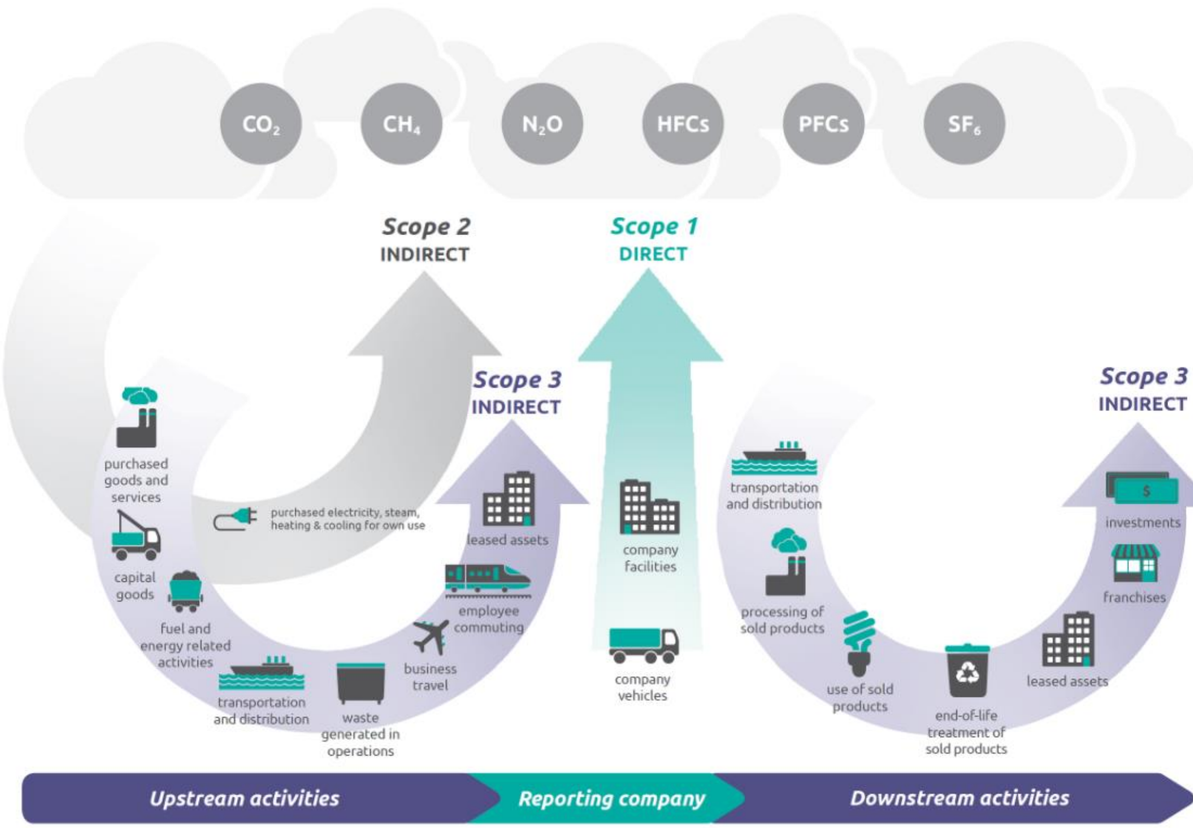


Figure 4 Scope 1, 2 and 3 GHG emission illustration (EPA)

3.5.3 New Brunswick Emissions Profile

As per the Canada Energy Regulator's Provincial and Territorial Energy Profiles[2], the Province of New Brunswick generated 12.2 terawatt hours (TWh) of electricity in 2018, which is approximately 2% of total Canadian generation. New Brunswick has a generating capacity of 4,521 megawatts (MW). Figure 5 shows New Brunswick's 2018 electricity generation split by different sources: 39% from Nuclear, 30% from fossil fuels, 21% from hydroelectricity, and the remaining 10% from wind and biomass.

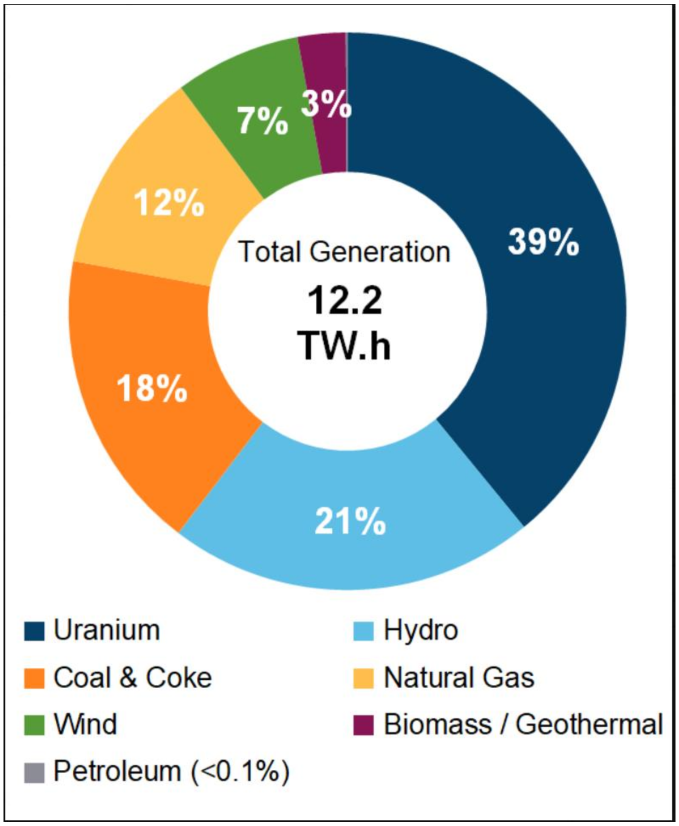


Figure 5 New Brunswick Energy Production by Type (REC)

Approximately, 70% of New Brunswick's electricity in 2018 was generated through net-zero carbon emitting sources. Based on inputs from external stakeholders, this figure is estimated to above 80% in 2020. It is important to understand the current state of New Brunswick's emissions profile, because transitioning to green fleet vehicles that uses electricity as a fuel becomes truly sustainable only when the electricity grid is clean and low carbon emitting.

As per a 2017 report by Statista[3], the 2015 electricity generation GHG emissions intensity for the Province of New Brunswick was 280 grams of CO_2e per kWh of electricity, two times the national average of 140 g/kWh of CO_2e. The Statista report showed information consolidated from the *Canada Energy Regulator* (CER). Figure 6 shows the GHG emissions intensity value by each province. The GHG emissions intensity value depends on the source of electricity the region primarily uses.

[2] https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-new-brunswick.html
[3] https://www.statista.com/statistics/917172/emission-intensity-canada-by-province/

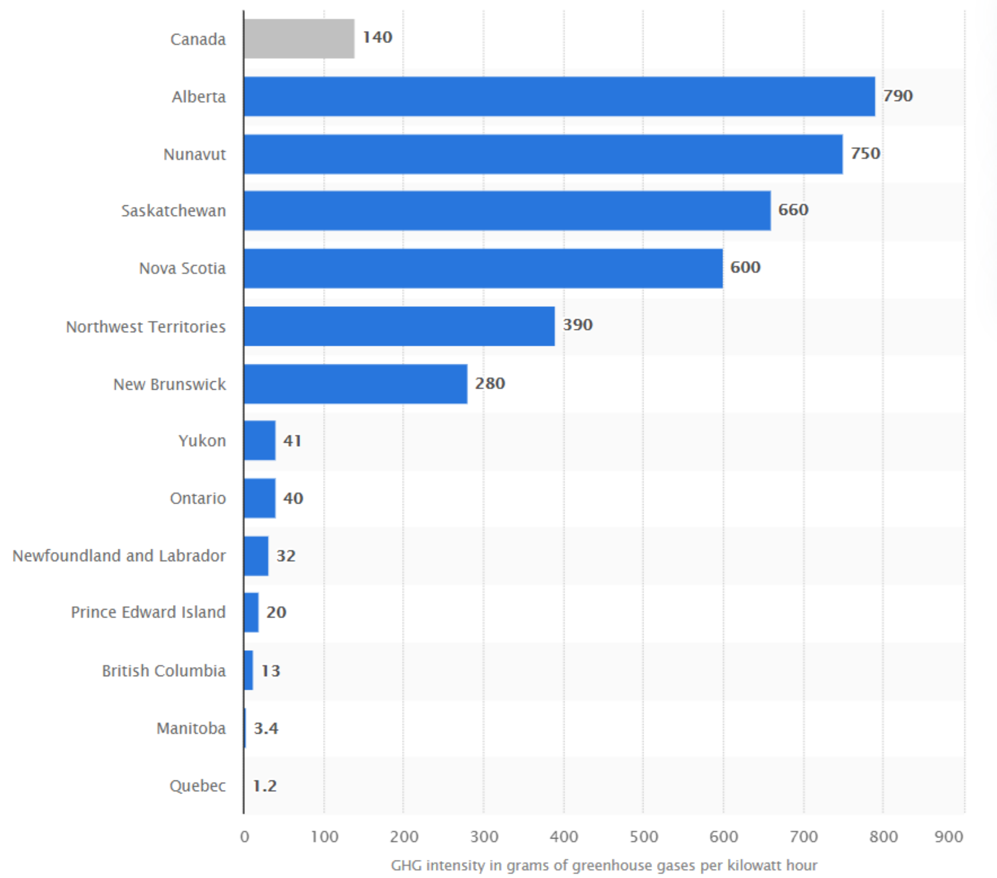


Figure 6 Provincial Carbon Intensity of Energy Production (2015)

Note that the 2015 electricity generation GHG emissions intensity for the Province of New Brunswick of 280 grams of CO_2e per kWh of electricity is specifically for generation. There are also emissions produced in the distribution of energy from producers to consumers. When the City calculates its carbon footprint it should use the electricity consumption emissions intensity, which was 290 grams of CO_2e per kWh of electricity in 2015. This distinction is inconsequential for the transportation emissions in the 2015 baseline, as no transportation assets consumed electricity as a fuel. When comparing the viability of adopting electric vehicles, the consumption emission intensity will be used.

3.5.4 2015 Baseline

As per the *2019 City of Saint John Corporate GHG & Energy Action Plan*, the fleet vehicles alone contributed to 7,390 tonnes of CO_2e in 2015, contributing to almost a third (31.1%) of total corporate GHG emissions. As per the report, in 2015 fleet vehicles consumed 2,037,035 litres of diesel and 788,719 litres of gasoline. This resulted in an estimated 5,466 tonnes of CO_2e emissions for diesel fuel and 1,924 tonnes of CO_2e emissions for gasoline fuel. This estimation was used to calculate the following GHG emission factors that were used in this study for equivalent comparison:

- Gasoline fleet GHG emissions factor: 2.440 kg/litre
- Diesel fleet GHG emissions factor: 2.683 kg/litre

The total fleet GHG emission of 7,390 tonnes of tonnes of CO_2e will be considered as the 2015 GHG emission baseline in this study.

3.5.5 Current Emissions (2021)

Wood performed a fuel consumption analysis on the City's public fleet vehicles using the fleet telematics data from GeoTab. This showed that in 2021 the public fleet vehicles consumed 514,108 litres of diesel fuel and 192,741 litres of gasoline fuel. A separate analysis showed that Transit fleet vehicles consumed 824,400 litres of diesel fuel in 2021. This resulted in a total fleet GHG emissions of 4,062 of tonnes of CO_2e, a 45% reduction from the 2015 GHG emission baseline. The comparison between the 2015 GHG emissions baseline and current (2021) GHG emission is shown in Figure 7.

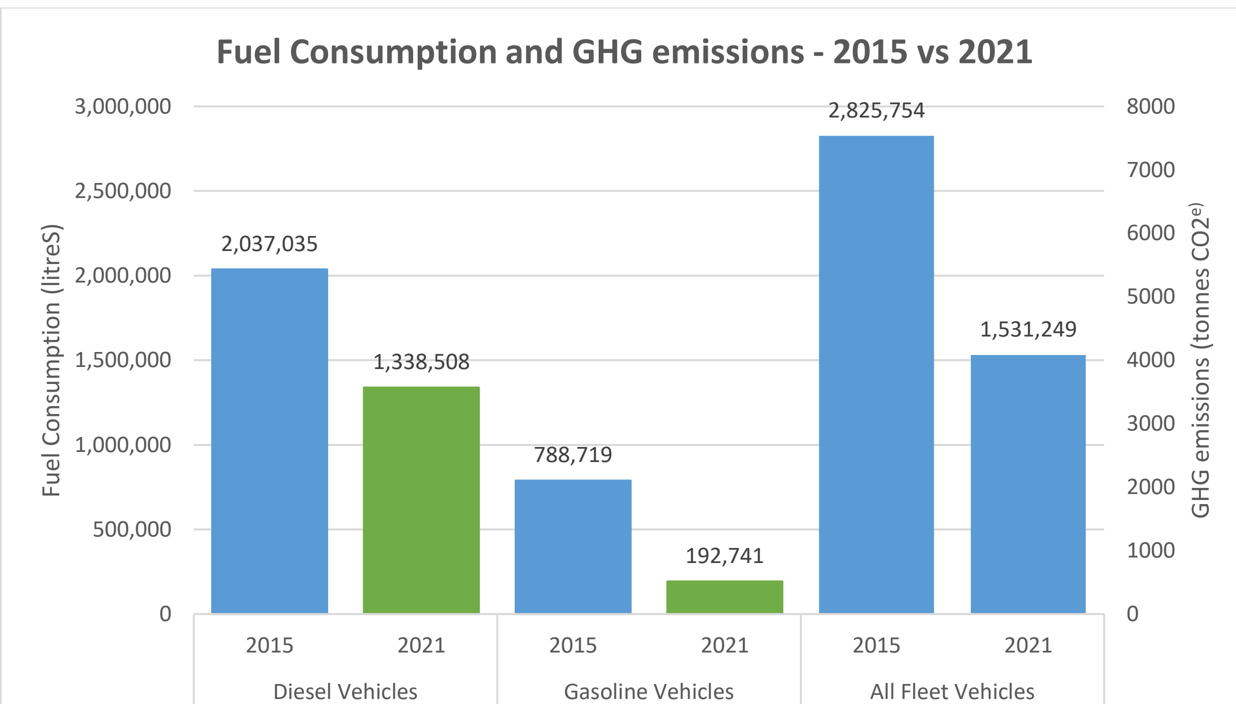


Figure 7 2015 vs 2021 Fleet Fuel Consumption and GHG emissions comparison

4.0 Market Scan

A market scan was performed to explore lower emission alternatives for each vehicle class. This included understanding key performance indicators such as range, cost, horsepower, and fuel economy. This information was compared with the operational requirements of the user groups at the City that participated in focus group sessions to understand which alternatives could be feasibly incorporated into the City fleet.

This section is structured to begin with a brief overview of fleet technologies, followed by an exploration of public vehicle (based on vehicle class) and transit vehicle alternatives.

When identifying alternatives for each vehicle class, the goal of the Carbon Migration Strategy is to prioritize zero-emission solutions (battery-electric and hydrogen) before transitional technology solutions (CNG, hybrid-electric, plug-in). This Carbon Mitigation Strategy informed the selection of vehicles for the Market Scan.

4.1 Technology Overview

When discussing fleet technologies in the context of reducing emissions, it can be helpful to categorize vehicles by the carbon intensity of their emissions.

4.1.1 Conventional Internal Combustion Engine (ICE) Technologies

Conventional internal combustion engine technologies include gasoline and diesel vehicles, which are currently the most common technology used in public fleets and in private ownership. These vehicles rely on fossil fuels which are very carbon intensive. Other propulsion technologies using similarly carbon intensive fuels, such as propane, are sometimes included in this category.

Benefits to these technologies include a mature supply chain with ubiquitous availability of fuelling infrastructure leading to a proven track record of successfully delivering fleet duty-cycles and services. Further, the wide adoption of these technologies has led to a matured industry for supporting and maintaining these vehicles.

Vehicles using these technologies are generally the starting point for most fleets aiming to reduce their carbon footprint. Due to the widespread adoption and dominance in the current fleet mix, conventional ICE technologies generally serve as a baseline for comparing alternative technologies.

4.1.2 Transitional Propulsion Technologies

Transitional propulsion technologies include plug-in hybrid, electric hybrid, compressed natural gas (CNG), renewable natural gas (RNG), and biodiesel, which are aimed to bridge the gap between the high emission ICE technologies and zero-emission technologies which do not currently meet requirements of all fleet needs.

The major benefit of transitional propulsion technologies is the reduced carbon emissions in the short term and reduced need for operational and facility modifications and staff training; however, these technologies are not zero-emission meaning that they will likely need to be phased out again to meet corporate net-zero emission targets. With the rapid evolution in battery and hydrogen fuel cell technologies and the corresponding decline in their prices, the risk to municipalities in procuring the transitional propulsion technologies is being “locked-into” these relatively more carbon-intensive technologies for the period of the vehicle lifecycle while missing out on cleaner zero-emission vehicle alternatives. This leads to a delayed adaptation of the facilities, operations and staff into these zero-emission technologies. Because of this, it could be advantageous to avoid these solutions in order implement zero-emission vehicles, even at the cost of operating conventional ICE technologies for a short period of time.

However, in the event where the zero-emission technologies are not expected to meet operational requirements in the short to medium term and continued operation of ICE vehicles will lead to significant emissions, transitional propulsion technologies should seriously be considered to enable the city to achieve its carbon reduction goals. In this situation, transitional propulsion technologies can bridge this gap by meeting the dual requirements of reduced emissions while meeting service duty requirements.

4.1.3 Zero-Emission Technologies

Zero-emission technologies include battery electric and hydrogen fuel cell technologies. These technologies can be defined as the final state for the Carbon Migration Strategy as the goal is ultimately to reach a state of carbon neutrality.

4.1.3.1 Battery Electric

The most notable benefits of battery electric technologies are lower GHG and pollutant emissions. Rather than consuming fuels to propel the vehicle, energy is drawn from an on-board battery resulting in zero tailpipe emissions. Additional benefits include reduced maintenance requirements due to less wear and tear due to lesser number of rotating/moving parts. Despite the zero-emission label, the act of recharging the batteries does generate emissions as the electricity grid is not made up of entirely renewable sources. Overall, zero-emission technologies do significantly reduce emissions, which is expected to continuously improve as electricity grids decarbonize.

Another benefit of battery electric technologies is the reduction in noise pollution that current diesel and gasoline vehicles produce across many different situations from Pass-by, Cruise-by, Take-off, idling, and at constant speed.

The main limitation to battery electric vehicles is that they require long periods of time to recharge and have limited range compared to ICE/GHG technologies. This makes the technology well suited for consistent duty cycles (both range and time) with the expectation that vehicles will return to the same location each night for recharging, which is the case for public fleets and transit. Other charging strategies include opportunity charging (fast charging using high-power chargers) and continuous operations as well as wireless inductive charging; however, these approaches are less mature than overnight recharging strategies at time of writing.

An alternative to waiting until the evening to charge the vehicles in the depot is to Opportunity Charge the vehicles when they return to the depot throughout the day. With the use of a Charger Control System, a vehicle can be assigned to a charger with enough time to charge the vehicle to a sufficient charge level plus a reserve that will enable it to complete its next duty cycle. This method of charging reduces the time and energy required to fully charge the vehicle in the evening.

Scalability can be a concern for electrification as significant power demands may be difficult for utilities to support, particularly for large fleets. Transit agencies are often constrained in terms of available upstream power from utilities and associated electric infrastructure which could limit the charger power levels or the number of chargers at the facilities. Also, the high-power levels due to simultaneous charging of electric vehicles through fast chargers contribute to high demand charges being levied on municipalities by the utilities. To address this, battery-based energy storage devices can be employed at transit facilities which could trickle charge (low-power charging) during the non-peak hours at cheaper rates and can be used for peak-time charging of the electric vehicles. This results in peak-shaving and load shifting, thereby leading to reduced costs.

4.1.3.2 Hydrogen Fuel Cell

Hydrogen fuel cell technologies are also zero-emission, with no emissions being emitted directly from the vehicle. The emissions associated with creation of hydrogen vary depending on the method of production, which are categorized by colours to represent the respective emissions profile. The spectrum of colours has expanded and been refined over time, with the current key colours being black, brown, blue, green, and turquoise.

- **Black & Brown Hydrogen:** carbon intensive hydrogen produced through the gasification of coal or lignite, or through steam reformation which consumes natural gas.
- **Blue Hydrogen:** moderately carbon intensive hydrogen from steam methane reformation. In this method, emissions are mitigated (by approximately half) using carbon capture and storage.
- **Green Hydrogen:** zero-emission hydrogen produced by electrolyzing water using power from renewable sources (solar, wind, tidal). This can be particularly advantageous as renewable power can be abundant outside of peak times and would otherwise be wasted.
- **Turquoise Hydrogen:** zero-emission hydrogen produced by separating methane into hydrogen and solid carbon. The carbon can then be repurposed for industrial processes or buried.

The benefits of hydrogen fuel cell technology are the emissions reduction achieved when using green or turquoise hydrogen. Beyond the emission reduction, the gaseous nature of hydrogen and its higher energy density than conventional fuels enable larger amount of hydrogen being packed on to the vehicles leading to significantly longer range. An additional advantage associated with hydrogen refuelling is the ability to use of existing CNG refuelling infrastructure with some modifications for hydrogen dispensing leading to much faster refuelling times than battery electric. The ability to use the existing CNG infrastructure with minor modifications results in reduced fuelling infrastructure costs for hydrogen.

In summary, while both the technologies can lead to zero-emissions based on the fuel source or grid profile, battery-electric technology has been adopted more extensively in North America. Hydrogen fuel availability is a big concern for municipalities and the uptake scale and production methods impact the fuel costs. With the capital costs for both these zero-emission technologies being expensive than conventional vehicles, municipalities generally prefer the relatively cheaper battery electric vehicles above the hydrogen fuel cell vehicles, although scaling up battery electric technology could lead to high power demand thus requiring large scale facility refurbishment and grid-side infrastructure upgrades while scaling up hydrogen fuel cell vehicles is easier on account of hydrogen refuelling process being operationally similar to CNG refuelling. Scaling up hydrogen production is also expected to result in a decline in production costs. While hydrogen fuel cell vehicles can reduce the need for cabin heating in winters due to heat being a by-product of the process, battery electric technologies have superior power and torque.

The operational end-use, the expansion plans, state of infrastructure, and fleet-readiness levels are other critical deciding parameters that could impact the selection of the zero-emission technology variants. Another aspect is the lifespan of the vehicles and in the case of battery electric vehicles, the lifespan of the batteries themselves. The batteries' lifespan is generally accepted to be around 7 years and the City will be required to carry out battery refurbishment beyond that time-period leading to additional costs. It is critical to compare the vehicle lifespan against the general timeline for transitioning while projecting procurement requirements for these technologies into the future to prevent sub-optimal use or premature retiring of the vehicles.

4.1.4 Battery Electric Charging Equipment and Levels of Charge

There are three (3) different types of chargers available on the market. The first and most prevalent are plug-in chargers. Plug-in chargers are typically less expensive than other charging equipment and the mechanism for charging most resembles how GHG vehicles are fuelled. Drawbacks include a lower comparative rate of charge and that they require more depot space per dispenser.

The second type of charger are overhead chargers. These chargers generally provide the highest rate of charge and are often referred to as 'fast' chargers. It is important to note that fast chargers are not limited to overhead chargers, instead, 'fast' or 'slow' is a function of the charger power rating. Overhead chargers are also commonly referred to as "pantograph chargers" as they mechanically function by making contact between charging rails and a pantograph apparatus. The high rate of charge and automated connection capability makes overhead fast chargers ideal for opportunistic charging strategies.

The third type of charging equipment is inductive charging. Inductive is the newest commercially available charging technology which leverages electromagnetic induction to wirelessly charge vehicles. These chargers offer the same opportunistic charging capabilities without any moving parts. The main drawback to this method of charging is its lower charging efficiency of 80% compared with 95% of the first two methods. This lower charging efficiency means that a larger proportion of energy is used in the act of charging rather than being transferred into the vehicle's battery. Additional concerns include complex construction requirements and significant considerations with respect to maintenance.

Plug-in charger **Overhead (pantograph) charger** **Inductive Charger**

Similar to different types of chargers, there are different levels of charging. The Society of Automotive Engineers surface vehicle standard J1772 classifies these as AC and DC charging (Alternating Current and Direct Current). With AC charging, energy is delivered to the vehicle's On-Board Charging (OBC) system which converts it into DC to charge the battery. This is necessary because electric vehicles use DC batteries, meaning they can only be charged using DC power. Using a DC charging system, energy is supplied directly to the vehicle's battery bypassing the OBC. This allows for faster charging rates and is commonly called DC fast charging (DCFC).

The AC and DC charging configurations are further classified into Level 1 and 2 depending on the maximum rate of charge. For both AC and DC, Level 1 refers to a slower rate of charge while Level 2 is faster. It is common in the electric vehicle industry for AC level 1 (up to1.92 kW) and level 2 (up to 19.2 kW) to simply be referred to "Level 1" and "Level 2" respectively. When referring to DC charging, both levels are referred to as "Level 3" (up to 400 kW) for simplicity.

4.1.5 Environmental Protection Agency (EPA) fuel efficiency for zero-emission vehicles

Cars manufactured and marketed in North America need to meet a range of regulatory standards such that they can be sold in US and Canadian markets. One governing agency in the US is the Environmental Protection Agency (EPA) which certifies and reports fuel economy of commercial vehicles. The calculated unit for efficiency is Miles per Gallon (MPG), which is the distance, measured in miles, that a vehicle can travel per gallon of fuel. This metric is often reported in Canada as litres per 100 km (L/100km). The higher a vehicles' MPG, the more fuel efficient it is. Using the L/100km metric, a lower value is more efficient.

To compare ICE vehicles to electric vehicles, the EPA developed a Miles per Gallon Equivalent (MPGe), which considers 33.7 kilowatt-hours (kWh) of electricity is comparable to a gallon of fuel in terms of its energy content. This value was calculated based on the carbon intensity of the US electricity grid in the early 2000s. Using the average carbon intensity of Canadian electricity grid, the effective MPGe would be doubled as the Canadian grid emits half as much carbon per kWh generated. Unfortunately for Saint John, the New Brunswick electricity grid is very comparable to the EPA MPGe baseline (2% less efficient) meaning that no additional carbon emission reduction can be calculated until the local grid becomes more efficient than the EPA baseline.

4.2 Public Fleet Vehicle Alternatives

This section outlines the key manufactures of public fleet vehicles, followed by alternative vehicles technologies for each class. Each class includes a summary table of two (2) or three (3) alternative technologies. A baseline vehicle, selected from the existing fleet, was included in the summary table for comparative purposes.

Note that all zero/no-emission vehicle technologies were considered for each vehicle, however the number of vehicles highlighted were limited to three (3) to focus on the alternatives that provide the best fit with the goals of the Carbon Migration Strategy, i.e., identifying long-term replacements (mainly zero-emission alternatives like battery-electric, hydrogen fuel cells) and short-term transition alternatives (mainly CNG, hybrid-electric, etc.)

It was observed that comparatively more transitional and zero-emission options are available for lighter-duty vehicles (lower weight class vehicles) as compared to higher-class, heavier-duty vehicles (excavators, backhoe, trucks, etc.). However, with growing impetus on municipal and industrial decarbonization, more heavy-duty vehicle and specialized vehicle manufacturers are in the process of developing and launching transition and zero-emission alternatives.

4.2.1 Key Manufacturers

4.2.1.1 Ford Motor Company

Ford Motor Company (commonly known as Ford) is an American multinational automobile manufacturer headquartered in Dearborn, Michigan, United States. The company sells automobiles and commercial vehicles under the Ford brand, and luxury cars under its Lincoln luxury brand. Ford is the second-largest U.S.-based automaker (behind General Motors) and the fifth largest in the world

The 2022 Ford F-150 Lightning full-size battery electric pickup truck is a notable alternative for light/medium duty fleets scheduled for first delivery mid-2022. The approximate battery capacity of 125 kWh has an estimated range of 370 km. The maximum payload is listed as 2,000 pounds with a maximum towing capacity of 10,000 pounds.

4.2.1.2 General Motors Company (GM)

General Motors Company (GM) is an American multinational automotive manufacturing company headquartered in Detroit, Michigan, United States. It was founded in 1908, as a holding company, and was restructured into as its current establishment in 2009. The company is the largest American automobile manufacturer and one of the world's largest automobile manufacturers. In North America, GM products focus primarily on its four core divisions: Chevrolet, Cadillac, Buick, and GMC.

4.2.1.3 Chevrolet

Chevrolet is Division of General Motors Company. In North America, Chevrolet produces and sells a wide range of vehicles, from subcompact automobiles to medium-duty commercial trucks. Due to the prominence and name recognition of Chevrolet as one of General Motors' global marques, 'Chevrolet', 'Chevy' or 'Chev' is used at times as a synonym for General Motors

Chevrolet's current battery electric vehicle offering is limited to the Bolt EV, a subcompact hatchback launched in 2016. The 2022 model has a battery capacity of 65 kWh with a resulting range of 417 km. The model has a maximum horsepower of 200.

The all-electric Chevrolet Silverado has also been announced for debut in 2022, however few details are available at time of writing.

4.2.1.4 GMC

GMC (formerly the General Motors Truck Company, or the GMC Truck & Coach Division (of General Motors Corporation), is a division of the American automobile manufacturer General Motors (GM) that primarily focuses on trucks and utility vehicles. GMC currently makes SUVs, pickup trucks, vans, and light-duty trucks, catered to a premium-based market. In the past, GMC also produced fire trucks, ambulances, heavy-duty trucks, military vehicles, motorhomes, transit buses, and medium duty trucks.

GMC's zero-emission entries are currently limited to the Hummer EV Pickup and the Hummer EV SUV. These vehicles are expected to have a 560 km range, up to 1,000 horsepower, and 11,500 pound feet of torque.

4.2.1.5 Toyota Motor Corporation

Toyota Motor Corporation, commonly referred to as Toyota, is a Japanese multinational automotive manufacturer headquartered in Toyota City, Aichi, Japan. It was founded in 1937. Toyota is one of the largest automobile manufacturers in the world, producing vehicles under five brands: Toyota, Daihatsu, Hino, Lexus, and Ranz.

Toyota is a historic leader in the development and sales of more fuel-efficient hybrid electric vehicles, starting with the introduction of the Toyota Prius in 1997. The 2022 Prius Prime is Toyota's most recent plug-in hybrid offering. The vehicle has 40 km of EV range using its 8.8 kWh battery. Once battery state of charge for EV propulsion is depleted, the 1.8L ICE engine is engaged to propel the vehicle.

4.2.1.6 Tesla Inc.

Tesla, Inc. is an American electric vehicle and clean energy company based in Palo Alto, California, United States. Tesla designs and manufactures electric cars, battery energy storage from home to grid-scale, solar panels and solar roof tiles, and related products and services. The company is the most dominant EV provider in the US, accounting for over 65% of all EV sales in 2021[4].

[4] http://www.experian.com/blogs/insights/2021/10/ev-registrations-grow-first-half-2021-non-electric-remains-dominant/?sid=bi%7C61719189d861f955f72277ae%7C16378719206072f8l1lz6

Tesla vehicles, including the Model S, Model 3 and Model Y, have seen recent pilot deployments as police cruisers in California, West Virginia, Ohio, Colorado, and Massachusetts.

4.2.1.7 Rosenbauer

Rosenbauer is ranked among the top three largest fire and rescue apparatus vehicles manufacturers globally. Their products range from Aerials, Pumpers, Rescues, Tankers, Industrial and Aircraft Rescue vehicles.

Rosenbauer has launched a product line for hybrid electric fire trucks in 2014 which are currently in service at Berlin, Amsterdam and Dubai. BMW diesel engines are used to charge the batteries. While the hybrid trucks are sold at a premium over the conventional fire trucks, the cost differential is matched by savings on fuel and maintenance.

4.2.1.8 Lion Electric

Lion Electric Company is a Canadian based manufacturer of commercial heavy-duty battery based electric vehicles including public transit buses, school buses, semi-trucks, bucket trucks, and garbage refuse trucks. It designs, manufactures, and assembles all components in its vehicles including chassis, battery packs, cabin, and powertrain.

In 2018, Lion Electric ventured into the electric truck market by launching its class 8 fully electric truck Lion8 in a cabover configuration with a 480 kWh battery pack designed for urban and vocational use. In addition, it has also launched a class 6 electric truck Lion6 and Lion 8 Refuse truck with 336 kWh battery pack.

4.2.1.9 Global Environmental Products

Global Environmental Products stands out as one of the leading manufacturers of specialized street cleaning equipment focusing on heavy-duty and customized street sweepers. Global has focused on ease of accessibility and claims the lowest total cost of ownership for its range of prod uct as compared to others in the market which can be shared with potential clients upon request. Global is ISO 9001:2015 certified and has integrated features on to their products such as the chassis-mounted AIR sweeper, high-capacity Gutterbrooms with ability to pick up to 3-tons of sand per hour.

Their product range is inclusive of a CNG variant (M4 HSD CNG), a battery electric variant (M4 Electric), and a hydrogen fuel cell variant (M4 HSD Fuel Cell) of their Global 'M' heavy duty sweeper series.

4.2.1.10 CASE Construction Equipment

CASE Construction Equipment company is an American manufacturer of construction equipment with an experience of around 175 years. Its range of products include excavators, motor graders, wheel loaders, vibratory compaction rollers, crawler dozers, skid steers, and compact track loaders.

In 2019, CASE Construction Equipment launched its Project TETRA which comprised of a methane-powered wheel loader which was the brand's first foray into alternative fuel vehicles. It comprises of an engine that is powered by CNG ensuring 15% less CO_2 and 99% less particulate matter.

This significant launch was followed by the launch of its Project ZEUS which comprised of a CASE 580 EV- the industry's first fully electric backhoe loader with a 480 V, 90 kWh lithium-ion battery pack.

4.2.1.11 Volvo

Volvo Construction Equipment is a Volvo group subsidiary and a major international player that develops, manufactures, and markets equipment for construction industries. It has a global presence, and its range of products include wheel loaders, hydraulic excavators, articulated haulers, motor graders, soil and asphalt compactors, pavers, backhoe, loaders, skid steers, and milling machines. Volvo Construction Equipment has launched its range of electrical equipment and machinery that comprise of Volvo L25 Electric compact wheel loader and Volvo ECR 25 Electric compact excavator.

The L25 Electric compact wheel loader has an electric drivetrain peak power of 48 hp and utilizes a battery pack of 48 V, 39 kWh which can provide a runtime of 8 hours.

The Volvo ECR 25 Electric compact excavator has the peak power capacity of 24 hp supported by a 48 V, 20 kWh battery pack that can provide a runtime of 4 hours.

4.2.2 Vehicle Class Description

The United Stated Federal Highway Administration has developed the following classification system for vehicles. For the purpose of this project, Wood will leverage this existing classification for finding classifying the existing vehicle fleet and suggesting suitable zero-/low- emission alternatives to the City. The following Table highlights the Vehicle classes and their distinguishing aspect of Gross Vehicle Weight Ratings:

Table 4.1 Federal Highway administration: Vehicle Class Description by GVWR

Vehicle Class	Gross Vehicle Weight Ratings (GVWR)
Class 1	<6000 lbs
Class 2	6001-10,000 lbs
Class 3	10,001- 14,000 lbs
Class 4	14,001-16,000 lbs
Class 5	16,001-19,500 lbs

Class 6	19,501-26,000 lbs
Class 7	26,001-33,000 lbs
Class 8	>33,001 lbs

Using a combination of vehicle class as defined by weight ratings and the functional use of the vehicles, Wood worked collaboratively with the City to define eight (8) vehicle groups that would encompass the range of on-road public fleet assets. Note that the vehicle class number was included as a guide to the size of vehicles included in the group, however some assets may belong to a vehicle group without conforming exactly to the class number listed.

Table 4.2 City of Saint John: Public fleet Vehicle Groups

Vehicle Group #	Municipal Vehicle Group Name
1	Class 1 – General Purpose
2	Class 1 – Police Cruiser
3	Class 2 – Light Duty Pickup Truck
4	Class 3, 4, & 5 – Heavy Duty Pickup Truck
5	Class 6, 7, & 8 – Heavy Duty Truck Platform
6	Class 7 – Streetsweeper
7	Class 8 – Pumper Fire truck
8	Class 8 – Refuse Truck

The eight (8) vehicle groups included most the City's transportation assets. The fleet elements outside of this report's scope included diesel generators, historic/museum vehicles, hyper specialized vehicles that were not planned to be renewed, ice makers, and construction equipment. The construction equipment, made up of loaders and excavators, was identified as a future vehicle group for the City to consider moving to green alternatives. To serve as a starting point for future studies, the market scan was expanded to include an additional vehicle group: Class 4 – Loader & Backhoe Equipment.

4.2.3 Class 1 Propulsion Technologies (General Purpose)

Many low- and zero-emissions alternatives exist for Class 1 vehicles. In particular, battery electric vehicles (BEV) have seen many announcements in 2021 from a wide range of OEMs. Car and Driver Magazine lists 55 Class 1 battery electric vehicles that are expected to launch between 2021 and 2025, the majority of which are launching in 2022[5].

There are few consumer vehicles in this Class that are propelled using hydrogen fuel cell technology, though several OEMs are actively developing products. This includes OEMs such as Honda, Toyota, Audi, Mercedes, and BMW. The notable exception to this is the Toyota Mirai which initially debuted in 2014. The current 2022 model has limited availability (only available in California and Hawaii) due to lacking hydrogen fuelling infrastructure. This barrier may be easier for a fleet to overcome, especially if it is incorporated into a wider hydrogen fuelling strategy for multiple vehicle types.

[5] https://www.caranddriver.com/news/g29994375/future-electric-cars-trucks/

When comparing the performance metrics of low-emission Class 1 vehicles, presented in Table 4.3, the hydrogen-fuelled Mirai maintains the longest range. However, it also comes at the highest price and lowest fuel efficiency. The plug-in hybrid Prius Prime had the highest fuel efficiency at the lowest cost, however the EV Mode Range is limited to 40 km, after which the ICE propulsion system will be engaged. The result for the Prius Prime is that emissions will significantly increase for duty-cycles beyond 40km. The battery electric alternative, the Bolt EV,

Table 4.3 Class 1 (General Purpose) Alternative Technologies

Vehicle Characteristics	Sample Current Fleet (Gasoline)	Battery Electric	Hydrogen Fuel-Cell	Plug-in Hybrid
Image				
Make	Toyota	Chevrolet	Toyota	Toyota
Model	Corolla	Bolt EV	Mirai XLE	Prius Prime
Model Year	2020	2022	2022	2022
Starting MSRP	$23,000	$38,198	$62,750	$28,220
Fuel Efficiency (EPA-estimation)	33 MPG	120 MPGe	74 MPGe	133 MPGe
EV Mode Range	-	417 km	647 km	40 km
Charging Time	-	3 hours (level 2)	-	-
Engine/Battery Size	1.8L	65 kWh	5.6 kg	1.8 Litre/8.8 kWh
Power	203 kW	150 kW	134 kW	219 kW

4.2.3.1 Class 1 alternatives by technology

The following tables list the market products available for each technology at time of writing.

Table 4.4 Class 1 – Battery Electric Vehicles

BMW i3	Nissan LEAF
Chevrolet BOLT	Smart fortwo Electric
Ford Mustang Mach-E	Tesla Model 3
Hyundai IONIQ Electric	Tesla Model S
Hyundai KONA Electric	Tesla Model X
Jaguar I-PACE	Tesla Model Y
Kia Niro	Tesla Cybertruck (pre-order)

Kia Soul Electric	Volkswagen e-Golf
MINI Cooper SE	

Table 4.5 Class 1 – Hydrogen Fuel-Cell Vehicles

Toyota Mirai	Honda Clarity
Hyundai Nexo	

Table 4.6 Class 1 – Plug-in Hybrid Vehicles

BMW i3 REx	Kia Niro PHEV
BMW i8	Kia Optima PHEV
BMW X3 30e	Range Rover PHEV HSE,
BMW X5 45e	Mercedes-Benz GLC 350e
BMW 330e	MINI Cooper S E Countryman ALL4 PHEV
BMW 530e xDrive	Mitsubishi Outlander PHEV
BMW 740e xDrive	Porsche Cayenne S E Hybrid
Chrysler Pacifica Hybrid	Toyota Prius Prime
Ford Fusion Energi	Volvo XC60 T8 eAWD
Honda Clarity PHEV	Volvo XC90 T8 eAWD
Hyundai IONIQ Plug-In Hybrid	

Table 4.7 Class 1 – Hybrid Vehicles

Acura RLX	Lexus GS 450h
Audi Q5 Hybrid	Lexus LS 600h L
Audi R8 E-Tron 2017	Lexus NX 300h
Ford Fusion Hybrid	Lincoln Aviator Grand Touring
Honda Accord Hybrid	Lincoln MKZ Hybrid
Hyundai Ioniq	Mercedes-Benz GLC 350e 4MATIC
Hyundai Sonata Hybrid	Toyota Camry Hybrid
Infiniti QX60 Hybrid	Toyota Highlander Hybrid
Kia Optima Hybrid	Toyota Prius
Lexus CT 200h	Toyota Prius c
Lexus ES 300h	Toyota Prius v
Lexus RX 450h	Toyota Rav4 Hybrid

4.2.4 Class 1 Propulsion Technologies (Police Cruiser)

Police cruisers are class 1 vehicles, though they have a specialized function with duty-cycle requirements separate than general purpose sedans. This includes meeting the operator's expectation for horsepower, torque, top speed, and handling. Furthermore, modifications are required to meet all of the functions of a police cruiser, including lights, secured rear seating, engine optimizations, and much more.

Battery electric solutions are the only zero-emission technology to have been deployed in North America, which have had several pilot deployments in five (5) US states. To date the vehicles used have been limited to Tesla models, with the preliminary finding that the vehicles are able to meet the duty-cycle demands of the police fleets with few changes to operating practices. One operation adjustment is that officers aim to maintain at least 50% charge by ensuring the vehicle is always being recharged when officers return to the office. Early feedback suggests that departments prefer the Model Y over the Model 3, as it provides more space and better access to the rear seats. These models may be prohibitively expensive with base consumer models costing $76,690.

A potential battery electric alternative is the recently launched Ford Mustang Mach-E with similar performance specifications at a much lower price of $52,590. The Mach-E does not have current deployments however it is the first electric vehicle to pass the Michigan State Police 2022 Model Evaluation. The Michigan State Police is one of two law enforcement agencies that annually test new model year police vehicles and publish the results for use by agencies nationwide.

As identified for the Class 1 General Purpose vehicles, the only hydrogen fuel cell vehicle available in North America is the Toyota Mirai. Testing would be required to determine whether this vehicle could be adapted to meet the needs of a police department, but the additional range provided by hydrogen technologies may allow for better replacement ratio in the medium to long term (once the technology improves).

The Ford Interceptor Utility is an electric hybrid vehicle which has already been adopted by the City of Saint John. This technology may serve as an effective solution for reducing emissions as zero-emission alternatives are piloted and improved.

Note that the Ford Interceptor Utility is the only purpose-built police cruiser listed. Each other example vehicle will have an increased procurement price to accommodate the necessary modifications required for police cruisers. Further, these modifications will likely change other performance information, such as torque, power, top speed, range, etc. The price of these options will likely increase (approximately $10,000) when procuring a police model.

Table 4.8 Class 1 (Police Cruiser) Alternative Technologies

Vehicle Characteristics	Sample Current Fleet (Gasoline)	Battery Electric	Hydrogen Fuel-Cell	Electric Hybrid
Image				
Make	Toyota	Ford	Toyota	Ford
Model	Corolla	Mustang Mach-E	Mirai XLE	Interceptor Utility
Model Year	2020	2022	2022	2022
Starting MSRP	$23,000*	$52,590*	$62,750*	$53,680
Fuel Efficiency (EPA-estimation)	33 MPG	90 MPGe	74 MPGe	24 MPG
EV Mode	-	418 km	647 km	-

Range				
Charging Time	-	1 hour (Level 3)	-	-
Engine/Battery Size	1.8L	70 kWh	5.6 kg	3.3L
Power	203 kW	195 kW	134 kW	234 kW

4.2.5 Class 2 Propulsion Technologies (Light Duty Pickup Truck)

In general, a significant portion of all public fleets is comprised of light duty pickup trucks. Due to their number and use, they are a significant contributor to fleet emissions.

Currently, many municipalities have adopted transitional technology such as CNG and hybrid electric on the path to low/zero-emission technology like battery electric or hydrogen-fuel cell electric. While CNG has been utilized for smaller class of trucks since early 2010s, the relatively recent blending of Renewable Natural Gas (RNG) into the CNG has opened another potential pathway to further reduce the carbon intensity of the fuel.

For zero-emission technologies, no hydrogen fuel cell technology is commercially available, however battery electric options have begun to debut from various OEMs. The first battery electric light duty pickup truck targeted for public fleets set to launch is the Ford F150 Lighting. The F150 Lightning is available for pre-order now with expected delivery beginning in early 2022.Hybrid options are also available for light duty pickup trucks. The Ford Maverick was highlighted due to its relatively low price and high performance.

Table 4.9 Class 2 (Light Duty Pickup Truck) Alternative Technologies

Vehicle Characteristics	Current Fleet (Diesel)	Battery Electric	Electric Hybrid
Image			
Make	Dodge	Ford	Ford
Model	RAM 1500	F150 Lightning	Maverick XL
Model Year	2019	2022	2022
Starting MSRP	$35,500	$52,500	$25,900
Fuel Efficiency (EPA-estimation)	22 MPG	85 MPGe	37 MPG
EV Mode Range	-	370 km	-
Charging Time	-	10 hours (Level 2) 45 minutes (Level 3)	-
Engine/Battery Size	3.0L	125 kWh	2.5L

Power	194 kW	313 kW	183 kW

4.2.5.1 Light Duty Pickup Truck by technology

Table 4.10 Class 2 – Light Duty Pickup truck – Battery Electric

Tesla Cybertruck	Atlis XT
Rivian R1T	Hercules Alpha
Bollinger B2	Fisker Alaska
Lordstown Endurance	Nissan Titan Electric Truck
GMC Hummer EV	Canoo Electric Pickup Truck
Ford F150 Lightning	Alpha Wolf
Chevrolet Silverado EV	

Table 4.11 Class 2 – Light Duty Pickup truck – Hybrid Electric

GMC Sierra 1500 Hybrid Pickup Truck	Ford F-150 Hybrid
Toyota Hybrid A-BAT	Ford Maverick
Chevrolet Silverado 1500 Hybrid Truck	RAM 1500 Hybrid
Hyundai Santa Cruz	

4.2.6 Class 3, 4 & 5 Propulsion Technologies (Medium-to-Heavy Truck Platforms)

Trucks of Class 3-5 range are generally employed for medium- to – heavy-duty usage by municipalities. Public fleets employ vehicles of these classes for: i) logistical support for moving tools and crew to construction areas or for public fleets; ii) municipal activities such as tow-trucks, small bucket trucks and specialized equipment and; iii) delivery on routes ranging from 100 - 150 km/day.

CNG driven truck have been available in the market since the early 2010s and are offered by multiple manufacturers. These trucks offer some emission reduction due to the lesser carbon intensity of natural gas. Ford is providing CNG and Propane as advanced fuel options to unleaded gasoline as an optional package on the 2022 Super Duty F-350 6.2L gas V8 model. This package enables a bi-fuel capability to run either liquified propane gas or unleaded gas. This package does not include natural gas/propane fuel tanks and lines, while the optional package provides hardened exhaust valves and valve seats only

Some of the manufacturers are focusing on hybrid and plug-in hybrid alternatives such as XL Fleet, Hino, etc. In terms of zero-emissions alternatives, the battery electric technology is currently being explored by various manufacturers like Motiv, Endurance, Rivian, Ram, etc. and various models are currently in the development pipeline. Bollinger has come up with two Class 3 truck designs- B1 and B2- with design B1 being a Sports Utility Truck while design B2 being a pick-up truck. More applications from Bollinger in the Class 3-6 range are expected based on Bollinger's all-electric platform and chassis cab design.

Hydrogen fuel cell or combustion based pick-up trucks are still in early development with no commercially available vehicle on market yet in this Class range.

Table 4.12 Class 3, 4 & 5 (Heavy Duty Truck) Alternative Technologies

Vehicle Characteristics	Current Fleet (Diesel)	Battery Electric	Electric Hybrid	Compressed Natural Gas

Image				
Make	Ford	Bollinger	Hino Trucks	Peterbilt
Model	F350	B2	195h	Model 567
Model Year	2019	2022	2022	2022
Starting MSRP	$51,000	$125,000	-	-
Fuel Efficiency (EPA-estimation)	20 MPG	47.3 MPG_e	-	-
EV Mode Range	-	322 km	-	-
Charging Time	-	75 minutes (Level 3) 10 hours (Level 2)	-	-
Engine/Battery Size	6.2L	142 kWh	5.0 L (Hybrid Engine)	11.9L (CNG)
Power	385 HP	600 HP	206 HP (Engine)	400 HP (Engine)

4.2.7 Class 6, 7 & 8 Propulsion Technologies (Heavy-Duty Truck Platform)

Heavy-duty trucks are generally employed by municipalities as dump (end/side) trucks, mixer trucks (cement/concrete), cross-gate hopper (road maintenance), septic trucks, water trucks, deck trucks, etc. They are critical tools in providing necessary municipal services within the respective jurisdiction. They are employed for heavy-duty tasks and therefore exhibit a high fuel consumption rate as compared to lower class vehicles. This makes them the preferential candidates for transitioning to low/no emission technologies as this transition enables economic and energy savings. Apart from the lower fuelling costs, potential cost savings are also realized from lower maintenance costs in case of electric power transmissions in technologies like battery-electric, hybrid-electric and fuel cells due to reduced wear and tear because of lesser number of moving components.

These potential benefits have resulted in low/zero emission technologies variants of higher class of trucks gaining more prominence among users. CNG versions of the higher-class trucks have been available in the market since early 2010s. Hybrid electric variants of larger trucks have also entered the markets towards the late 2010s. In addition, industries are also supporting the customers in transitioning their existing diesel-based versions to hybrid electric by providing conversion kits. Hyliion 6x4HE is an example of a brand and engine-agnostic electric hybrid conversion kit providing a battery-powered electric-hybrid powertrain with additional support from an auxiliary power unit.

Many manufacturers are currently in the process of developing fully battery-electric variants of higher-class trucks with some options being currently available on the market. Lion8 battery electric truck has recently been launched with a battery pack that can be charged in two hours under Level 3 charging.

Table 4.13 Class 6,7 & 8 Alternative Technologies

Vehicle Characteristics	Current Fleet (Diesel)	Battery Electric	Electric Hybrid (Conversion Kit)	Compressed Natural Gas
Image				
Make	International	Lion Electric	Hyliion	Freightliner
Model	7600	Lion8	6X4HE	Cascadia Natural Gas
Model Year	2014	2022	2022	2022
Starting MSRP	-	-	-	-
Fuel Efficiency (EPA-estimation)	3.3 MPG	16.8 MPG_e	-	-
EV Mode Range	-	275 km	-	-
Charging Time	-	2 hours (Level 3)	-	-
Engine/Battery Size	12.4L	336 kWh	Engine agnostic	11.9 L (CNG)
Power	380 HP	470 HP	200 HP	400 HP

4.2.7.1 Class 6, 7 & 8 Truck Platform by technology

Table 4.14 Class 6,7 & 8 Trucks – Hydrogen Fuel Cell Alternatives

Hino XL8 (Prototype)	Nikola Tre FCEV (Available 2023)
Nikola Two FCEV (Available 2024)	

Table 4.15 Class 6,7 & 8 Trucks – CNG Vehicles

Kenworth T880S

Table 4.16 Class 6,7 & 8 Trucks – Battery Electric Vehicles

Freightliner eCascadia	BYD 8TT Tandem Axle
Tesla Semi	Kenworth T680E

4.2.8 Class 7 Propulsion Technologies (Streetsweeper)

Streetsweepers constitute an important component of the public fleet as apart from keeping the streets litter-free and aesthetically pleasing, they prevent the dispersion of PM_{10} and $PM_{2.5}$ particles- detrimental to both health and environment- into the atmosphere or into the drainage system. They also help to remove grit and salt residues as well. Streetsweeper comprise of specialized class 7 or 8 trucks with mechanical broom and suction systems.

Global launched its CNG version of the mechanized street sweeper system with a sweeping speed of 8-20 km/hour and a regular travel speed up to 90 km/hour along with a sweep rate of 3 tons per minute. It was followed up with another street sweeper model in the hybrid electric technology category comprising a diesel engine and electric drive motor and claiming 50% increase in fuel economy.

Global has also recently launched the battery electric variant of its streetsweeper with a 10-year battery life. This fully electric variant is capable of being fully charged with a SAE J1772 Level II charging system in 9-11 hours and in 4 hours through a Level III charging system.

There are a few other Hydrogen fuel cell-based variants at different stages of development. Global itself has developed a fuel cell powered variant Global M4ZE-Series which matches the operational performance of all the other technology variants of Global streetsweeper.

Table 4.17 Class 7 (Streetsweeper) Alternative Technologies

Vehicle Characteristics	Current Fleet (Diesel)	Battery Electric	Electric Hybrid (Plug-in optional)	Compressed Natural Gas
Image				
Make	Freightliner	Global	Global	Global
Model	Vacuum Sweeper	M4 BEV	M4 Hybrid	M4 HSD
Model Year	2015	2022	2022	2022
Starting MSRP	$200,000	-	-	-
Fuel Efficiency (EPA-estimation)	9.3 MPG	17 MPG_e	-	-
EV Mode Range	-	-	-	-
Charging Time	-	8-9 hours (Level 2) 4-5 hours (Level 3)	-	-
Engine/Battery Size	5.8L	210 kWh	6.7L	5.9L (CNG)
Power	200 HP	215 HP	200 HP	230 HP

4.2.8.1 Class 7 Streetsweeper alternatives by technology

Table 4.18 Class 7 Streetsweeper – Hydrogen Fuel Cell Alternatives

Global M4/M4 HSD Hydrogen Fuel Cell	Fulongma Hydrogen Fuel Cell Street Sweeping & Washing Truck- FLM5180TXSNJFCEV
Green Machines GM 500 H2	

Table 4.19 Class 7 Streetsweeper – Plug-in Hybrid Vehicles

Elgin Sweeper Broom Bear Plug-in Hybrid

Table 4.20 Class 7 Streetsweeper – Battery Electric Vehicles

Dulevo D.zero[2]	Bucher Municipal CityCat V20e

Table 4.21 Class 7 Streetsweeper – CNG Vehicles

TYMCO Model 500x	TYMCO Model HSP
TYMCO Model 600	

4.2.9 Class 8 Propulsion Technologies (Pumper Fire Truck)

Fire trucks are an integral component of public fleets and are required to deliver top performance with low response times.

The introduction of transitional technology-based vehicles has been recent with Magirus launching its Magirus (H)LF-CNG model in 2019 with a 400 litres CNG tank which imparts a range of 300 km with continuous pumping capability up to four hours. Other transitional technologies, like plug-in hybrids have recently been announced, such as the RT Rosenbauer, set to launch in 2022 with City of Brampton being the first municipality in Canada to place an order for the electric truck.

For this vehicle type, battery-electric zero-emissions options are more commercially advanced, with the Vector, produced by E-ONE having launched in 2021. The first order for the E-ONE has been placed by Mesa Fire and Medical Department, Arizona.

Table 4.22 Class 7 (Pumper Fire Truck) Alternative Technologies

Vehicle Characteristics	Current Fleet (Diesel)	Battery Electric	Plug-In Hybrid Electric	Compressed Natural Gas
Image				
Make	E-ONE	E-ONE	Rosenbauer	Magirus
Model	Typhoon	Vector	RT (Revolutionary Technology)	Magirus (H)LF iDL-CNG
Model Year	2015	2022	2022	2019
Starting MSRP	$505,000	-	$1.6 million	-
Fuel Efficiency (EPA-	-	-	-	-

estimation)				
EV Mode Range	-	-	-	-
Charging Time	-	-	-	-
Engine/Battery Size	8.9L	316 kWh	50 or 100 kWh battery	420L (CNG)
Horsepower	400 HP	268 HP	268 HP (Engine)	205 HP
Storage capacity	2952L (water)	4682L (water)	1000-4000L (water) 50-500L (foam)	1600L

4.2.9.1 Class 8 Pumper Fire Trucks alternatives by technology

Table 4.23 Class 8 Pumper Fire Truck – Battery Electric Vehicles

Magirus KLF iDL- Electric

Table 4.24 Class 8 Pumper Fire Truck –Hybrid Vehicles

Pierce Volterra

4.2.10 Class 8 Propulsion Technologies (Refuse Truck)

Refuse trucks are an essential public fleet constituent and comprise generally of Class 7 or 8 trucks. Given the heavy-duty application due to frequent starts and stops with heavy loads, these have conventionally been driven by diesel. Beginning in the early-2010s, we have seen CNG powered refuse trucks being adopted by public fleets which are able to serve the level of operations while providing a smaller carbon footprint.

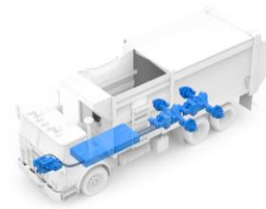
Other transitional technologies, such as hybrid and plug-in hybrid technology-based options, have also begun to make their impact in this niche sector by the mid-2010s. Wrightspeed Route is a hybrid electric vehicle powertrain which can provide extended range capabilities to existing heavy duty truck platforms. The Route 1000 model is designed to support refuse truck applications and comprise of a range-extending gas turbine generator in addition to the battery pack.

Since heavy-duty vehicles are the biggest consumers of energy, their transition to zero-emission alternatives would have the most impact on an individual basis. Battery-electric alternatives have begun to enter the market, offering the first zero-emission options to the clients. The recent Lion8 Refuse REL truck has an automated arm for sideloading and collection body and is driven by Lion8 HV batteries.

The most advanced hydrogen fuel cell alternatives are still in the demonstration phase, with Europe being the geographic leader for the technology. One example is the Scania, which is currently undergoing the trial for its fuel cell-based Refuse Truck in Europe.

Table 4.25 Class 8 Refuse Trucks Alternative Technologies

Vehicle Characteristics	Current Fleet (Diesel)	Battery Electric	Hybrid Electric (Powertrain)	Compressed Natural Gas

Image				
Make	Freightliner	Lion Electric	Wrightspeed	Mack Trucks
Model	Packer	Lion 8P Refuse REL	Route 1000 Powertrain	LR
Model Year	2020	2022	2022	2022
Starting MSRP	$300,000	Est. $400,000	-	-
Fuel Efficiency (EPA-estimation)	-	17.2 MPG_e	-	-
EV Mode Range	-	276 km	38 km	-
Charging Time	-	2-5 hours (Level 3) 5-16 hours (Level 2)	-	-
Engine/Battery Size	8.9L	336 kWh	80 kW (Hybrid Turbine)	8.9 L (CNG)
Horsepower	380 HP	470 HP	400 HP	315-348 HP

4.2.10.1 Class 8 Refuse Trucks alternatives by technology

Table 4.26 Class 8 Refuse Truck– Hydrogen Fuel Cell Alternatives

Scania Hydrogen fuel cell Refuse Truck (Available in Europe)	

Table 4.27 Class 8 Refuse Truck – Battery Electric Vehicles

Scania Hydrogen fuel cell Refuse Truck (Available in Europe)	BYD 8R-All Electric Class 8 Refuse Truck
Refuse Truck	Peterbilt 520 EV Battery Electric Truck
Mack LR Electric	Sea Econic EV

Table 4.28 Class 8 Refuse Truck –CNG Vehicles

New Way ROTOPAC	New Way Sidewinder XTR

4.2.11 Class 4 Propulsion Technologies (Loader & Backhoe Equipment)

The scope of this study is limited to on-street assets, however the City maintains a significant amount of construction equipment that contribute to its emissions. To serve as a starting point for future studies examples of loader and backhoe equipment is presented below. Other City owned off-street equipment includes forklifts, rollers, line painters, ice resurfacing machines, mowers, and handheld equipment.

Similar to fleets, pressure exists within the construction industry to transition away from GHG producing equipment. The primary driver for this is the significance of the emissions produced by the sector, which is exemplified by the 2018 IEA report that found the buildings and construction sector is responsible for 36% of the final energy use and 39% of energy and process-related CO_2 emissions in 2018.

Beyond meeting emission reduction targets, the industry is finding additional benefit with the adoption of low- and zero-emission technologies. Some examples include: a significant reduction in noise pollution and a lower overall cost of ownership (primarily from the reduced fuel costs).

This transition to low carbon technologies for construction equipment is less mature than the fleet technologies presented above. Several low-carbon alternatives are currently in states of development and pilot deployments from Volvo, Caterpillar, Bobcat, Wacker Neuson, and Hyundai.

Table 4.29 Class 4 (Loader Equipment) Alternative Technologies

Vehicle Characteristics	Current Fleet (Diesel)	Battery Electric	Battery Electric	Plug-In Electric Hybrid
Image				
Make	CASE	Volvo	Volvo	Huddig
Model	Excavator	ECR 25 Electric	L 25	1260T Tigon
Model Year	2016	2022	2019 (Europe) 2022 (North America)	2021
Starting MSRP	$179,000	-	-	-
Fuel Efficiency	20 litres/hour	-	-	-
EV Mode Range	-	4 hours	-	20 km (Travel) 2 hours (Excavation)
Charging Time	-	5 hours (level 2) 50 minutes (level 3)	8 hours (level 2) 2 hours (level 3)	1 hour (level 3)
Engine/Battery Size	-	20 kWh	39 kWh	-
Power	-	18 kW	35 kW	-

4.2.11.1 Class 4 Loader and Backhoe equipment by alternative technology

Table 4.30 Class 4 Backhoe – Hydrogen Fuel Cell Alternatives

JCB 220X (Under development)

Table 4.31 Class 4 Backhoe – Battery Electric Alternatives

John Deere E-Power (Under development)

Volvo EX2 (excavator)

4.3 Transit Vehicles Alternatives

Transit fleets have seen many zero-emission alternatives be developed and deployed. The preferred technology has primarily been battery electric however hydrogen fuel cell options have recently been announced and deployed.

4.3.1 Key Manufacturers

4.3.1.1 New Flyer Industries (NFI)

New Flyer is Canadian manufacturer based in Winnipeg, Manitoba. The company has a history of manufacturing diesel, hybrid, electric and CNG vehicles, having produced their first zero emissions bus in 1969. New Flyer has since grown its presence throughout the United States and Canada with major facilities in five states and two provinces. These facilities include five transit bus manufacturing facilities, three transit bus completion and service facilities, and one vehicle innovation centre.

New Flyer produces the Xcelsior family of buses which include a size range from 30' to 60' and six propulsion types. The battery-electric Xcelsior CHARGE models come in 35', 40', and 60' variants classified as XE35, XE40 and XE60 respectively. The battery-electric variants have multiple battery size specifications available that fall into two categories, rapid charge and long range.

4.3.1.2 Proterra

Proterra is an American automotive and energy storage company based in Burlingame, California. The company has a history of manufacturing compressed natural gas hybrid transit buses before transitioning their focus to manufacturing a range of electric buses and electric charging systems.

The Proterra ZX5 is the fifth and newest generation of battery-electric buses produced by the company. The ZX5 is a family of buses classified based on the size of the battery, they are in increasing order: ZX5, ZX5+, and ZX5 Max. These configurations can be equipped with either a Prodrive Drivetrain (a single 250kW Motor) or a Duopower Drivetrain (dual 205kW motors). The Duopower Drivetrain is more energy efficient and has better operating performance than the Prodrive Drivetrain, leading to higher maximum range, acceleration, and top speed.

4.3.1.3 Build Your Dreams (BYD)

BYD Auto is a Chinese multinational automotive manufacturer with a wide range of products. These automotive products include automobiles, buses, electric bicycles, forklifts, rechargeable batteries, and trucks. In addition to the diesel and hybrid buses, BYD produces three conventional battery-electric bus models: the K9S, K9, and K11. These vehicles come in respective lengths of 35', 40', and 60'. The highest capacity battery configuration for each vehicle is 266 kWh, 352 kWh, and 446 kWh resulting in maximum ranges of 350 km, 280km and 350km.

4.3.1.4 Nova Bus

Nova Bus is a Canadian bus manufacturer based in Saint-Eustache, Quebec. The company has 3 facilities, two in Quebec and one in New York State, and produces the popular LFS transit bus model.

The LFSe is the first fully electric drivetrain bus entry by Nova. The 40′ vehicle was designed to operate 40 km blocks between charges using on-route charging infrastructure. The reliance of the LFSe model on the use overhead chargers may have contributed to their limited market adoption. Outside of demonstrations and trials the LFSe is only used by the Montreal Transit Corporation for limited-service runs.

The newer "LFSe+" is Nova's new long-range BEB which expands the with a maximum range of 340-470 km, it is also 40′ in length. The new model incorporates dual charging options with both CCS plug-in chargers and an overhead pantograph charger capable of on-route charging. The maximum charging rate for the plug-in chargers is 150 kW, while the overhead charger is capable of 450kW.

4.3.1.5 Lion Electric Company

The Lion Electric Company is based in Saint-Jérôme, Quebec. Having sold their first bus in 2011 they have since released several fully electric vehicles. The company has an annual production capacity of 2500 vehicles and a build timeframe of 6-9 months.

One such vehicle is the LionM, launched in 2018 it is a 26′ low-floor mini-bus that houses an integrated wheelchair ramp. The LionM can be equipped with one (1) or two (2) 80 kWh lithium-ion battery packs leading to a max range of 240 km. The base model is equipped with a 19.2 kW charger with the option of including an SAE-Combo DC fast charger. Furthermore, the vehicle is capable of battery swapping, allowing for fully charged batteries to replace depleted ones which can quickly return the minibus to delivering service. Lion Electric has also launched flat-footed fully electric minibus for school application termed as LionA, respectively. Later, it also came up with upgraded electric school bus models LionC and LionD, catering to different sizes.

4.3.1.6 Karsan

Karsan is a Turkish commercial vehicle manufacturer based in Kçalar, Nilüfer, Bursa Province. The company has a history dating back to 1966 of producing light vehicles. The company has a global annual production capacity of 65,000 vehicles, however none of that is in North America.

The company has since begun manufacturing an electric minibus called the Atak Electric. This 27-foot-long vehicle has a battery capacity of 220 kWh, resulting in a maximum range of 363 km. Another of its model JEST comprises of a 44kWh battery pack with a maximum range of 105 km. There are several charger configurations with either a single or double AC Type 2 charger capable of 22 and 44 kW, with an optional inclusion of a CCS Type 2 charger capable of providing DC fast charging at 80 kW. These charging rates respectively allow for charging times of 10, 5, and 3 hours when charging from empty to 80% capacity.

4.3.1.7 Grande West Transportation Group

Grande West Transportation Group is a Canadian bus manufacturer headquartered in Aldergrove, British Columbia, Canada. The company designs and engineers mid-size multi-purpose transit vehicles for public and commercial enterprises.

The Vicinity Lightning EV is their first battery electric mini-bus entry featuring a range of 200 km, which can be expanded further to 300km. The base model features four (4) 42 kW lithium-ion battery packs, three (3) of which are located in the floor with the last located in the rear compartment.

4.3.1.8 Optimal Electirc Vehicles

Optimal Electric Vehicles LLC (Optimal-EV) is an American electric vehicle manufacturer located in Plymouth, MI. The company has partnered with Proterra to release its first electric vehicle, the S1LF Electric shuttle bus.

The S1LF launched at the end of 2021 with a battery capacity of 113 kWh capable of serving a range of 200 km. Depending on the desired configuration, the vehicle will be able to support a maximum of 23 seats or 12 seats with support for up to three (3) wheelchairs. All configurations can support one (1) accessibility ramp.

4.3.1.9 Green Power Motor Company

GreenPower is headquartered in Vancouver, British Columbia, with primary manufacturing and fleet operations in Porterville, California. The company released its first purpose built BEB, the EV350, in 2017 but has since moved its focus to the zero-emissions min-bus model EV Star.

There are currently three variants for this model, the EV Star, EV Star +, and the EV Star ADA. The EV star + variant can carry more passengers than the base model, while the EV star ADA had been designed for accessibility with capacity for two (2) wheelchairs.

The company reports that the EV Star model has a life expectancy of ten (10) years and that model can be equipped with a Momentum Dynamics charging system to allow for wireless charging. The battery used by the EV star have a capacity of 118 kWh which gives them a maximum range of 240 km. Other optional configurations allow for the vehicle to be made fully autonomous using the Perrone Robotics AV System.

4.3.2 Comparative Summary of Battery Electric and Hydrogen Fuel-Cell Buses

The nature of transit service makes it an ideal opportunity for zero-emission alternatives. This has made resulted in many Canadian municipalities choosing to advance their implementation of zero emission technologies. Some transit operation characteristics that facilitate the deployment of zero-emission technologies include:

- **Fixed Duty-Cycles** (mileage and topography). These mitigate the concerns regarding range anxiety because the daily duty-cycle that vehicles need to be able to perform can be readily predicted and designed for.
- **Overnight Depot Storage**. Transit fleets are generally stored overnight at a depot, allowing for charging infrastructure to be sized to accommodate fleet needs with opportunities for

advantageous overnight charging rates.

- **Frequent Stops**. The stop-and-go requirement to serve frequent rider embarkments/debarments allows ZEBs to benefit from their regenerative breaking. Other propulsion technologies consume fuel and utilize their brakes for this function, whereas ZEB use energy to accelerate – a portion of which is recovered when using regenerative breaking.

The Table below summarizes the two prevailing ZEB technologies: BEB and FCEB.

Table 4.32 Summary comparison of ZEB Technologies

Characteristic	Battery Electric Buses (BEB)	Hydrogen Fuel Cell-Electric Bus (FCEB)
Range	**Approximately 200 – 250km** BEBs can service most City transit routes; some Commuter routes may be challenging to complete in worst-case.	**Approx. 300 km** FCEBs are capable of servicing long-haul commuter routes as well as shorter urban transit routes.
Propulsion	Battery Electric	Electric Fuel Cell
Vehicle Cost	$700k - $1.5m	$850k - $1.2m
Fuel Cost	Reflects current rate environment including energy charge per kWh and demand charge based on peak kW. Requires electric power supply unit and charging dispensers.	Reflects current cost level and existing supply infrastructure. Requires hydrogen fueling station.
Infrastructure Requirements	• Charging power supply units and dispensers (2-4 buses per power supply cabinets). • Optional battery storage and co-generation facilities.	• Hydrogen refueling station required (fuel pump) • On-site fuel storage infrastructure • Storage infrastructure
Operating Expenses	• Requires diesel auxiliary heater for full winter range • High operating demand charge environment requires overnight charging	• Hydrogen fuel costs • No electricity peak demand charge • No diesel aux. heater required
Capital Replacements	• Battery replacement (~6yrs)	• N/A
Expected Lifecycle	12-15yrs	

4.3.3 Transit Propulsion Technologies 35-40 Foot Transit Buses

The primary providers for ZEBs are Proterra, New Flyer, and Nova Bus, out of which New Flyer and Nova Bus are based out of Canada. All these three Original Equipment Manufacturers (OEMs) provide BEB options between 35' and 40'. New Flyer and a Belgian based manufacturer Van Hool also provide hydrogen fuel cell variant in 35-40 foot range. In addition to this, Nova Bus and New Flyer also provide

CNG and hybrid diesel-electric variants as well. Proterra and New Flyer have also introduced innovative financing options with Proterra also introducing options to lease bus and batteries.

Vehicle Characteristics	Current Fleet (Diesel)	Battery Electric Bus	Hydrogen Fuel-Cell Bus	Compressed Natural Gas Bus
Image				
Make	Nova Bus	Proterra	NFI	NF
Model	LFS	ZX5+	XHE40	XN40
Model Year	2018	2022	2022	2022
Starting MSRP	Approximately $0.5M	Approximately $1.0M	Approximately $1.5M	Approximately $0.75M
EV Mode Range	-	375 km	-	-
Charging Time	-	3 hours	-	-
Engine/Fuel/Battery Size	473 litres (Fuel capacity) 8.9 litres (Engine)	450 kWh	37.5 kg (750 kWhe)	3,300 SCF at 3,600 psi service pressure
Power	280 HP	336 HP	215 HP	250 HP

4.3.3.1 Transit Buses alternatives by technology (35-40 Foot)

Table 4.33 35′ & 40′ Battery Electric Bus

- Nova Bus LFSe (40′)
- Nova Bus LFSe+(40′)
- Proterra ZX5 (35′ & 40′)
- Proterra ZX5+ (35′ & 40′)
- Proterra ZX5 MAX (35′ & 40′)
- NF Xcelsior Charge NG (XHE35) (35′)
- NF Xcelsior Charge NG (XHE40) (40′)
- BYD K8M (35′)
- BYD K9M (40′)
- BYD K9MD (40′)

Table 4.34 35′ & 40′ Hydrogen Fuel Cell Buses

- Xcelsior Charge H2 (XHE40) (40′)
- Van Hool A330 FC

Table 4.35 35′ & 40′ CNG Buses

- Xcelsior CNG (XN35) (35′)
- Xcelsior CNG (XN40) (40′)
- Nova Bus LFS CNG (40′)

4.3.4 Transit Propulsion Technologies 60-Foot Articulated Transit Buses

Some of the top manufacturers for 60-foot articulated electric buses include New Flyer, BYD and Van Hool. New Flyer also produces a fuel cell variant of 60-foot articulated transit bus. Van Hool is currently scheduled to deliver its articulated fuel cell based bused outside Canada. Nova Bus and New Flyer also produce the 60-foot articulated bus in battery electric, hybrid electric and CNG variants.

Vehicle Characteristics	Current Fleet (Diesel)	Battery Electric Bus	Hydrogen Fuel-Cell Bus	Compressed Natural Gas Bus
Image				
Make	Nova Bus	NFI	NFI	NFI
Model	Arctic	XE60	XHE60	XN60
Model Year	2008	2022	2022	2022
Starting MSRP		Approximately $1.6M	-	-
EV Mode Range	-	240 km	-	-
Charging Time	-	3.5 hours	-	-
Engine/Fuel/Battery Size	8.9 Litres (Engine)	525 kWh	60 kg (1,000 kWhe)	3,300 SCF at 3,600 psi service pressure
Power	260 HP	430 HP	430 HP	250-320 HP

4.3.4.1 Transit Bus alternatives by technology

Table 4.36 60' Articulated Transit Bus – Battery Electric Alternatives

BYD K11M

NFI XE60

4.3.5 Transit Propulsion Technologies 20-30 Foot

There are multiple battery electric options available within this size range. Ranges vary between 200 km and as high as 340 km. These options also range from regular public transit buses to smaller shuttle buses and cutaway buses. While there are no 20–30-foot buses in the City's fleet for now. a few variants are identified here.

Vehicle Characteristics	Current Fleet (Diesel)	Battery Electric Bus	Battery Electric Bus	Battery Electric Bus
Image				
Length	24'	25'	28'	30'
Make	Ford	Green Power	Optimal EV	BYD
Model	Handibus	EVA Star+	S1LF	K7MER
Model Year	2019	2022	2022	2022
Starting MSRP	-	-	$250,000	$775,000
EV Mode Range	-	240 km	200 km	315 km
Charging Time	-	Level 3: 2 hours	Level 3: 2 hours	Level 3: 3 hours
Engine/Fuel/Battery Size	6.8 L	118 kWh	Variants 113 kWh	266 kWh
Power	362 HP	150 kW	280 kW	300 kW

4.3.5.1 Transit Bus alternatives by technology

Table 4.37 20'-30' Battery Electric Bus

Karsan e-JEST (20')	Optimal EV S1LF (27')
Karsan Atak Electric (27')	Vicinity Lightning EV (28')
Green Power EVA Star (25')	ARBOC Equess Charge (30')
Green Power EVA Star+ (25')	BYD K7M (30')
Green Power EV250 (30')	BYD K7MER (30')
Lion M (26')	

5.0 Landscape Scan

This section presents a scan of the various approaches that municipalities across Canada are taking with respect to transitioning the corporate emissions to net-zero. This section will contribute to the overall assessment of the available policy options to identify the policies most relevant and suited for implementation at Saint John.

5.1 Municipal Green Fleet Landscape Scan

Wood has conducted an extensive landscape scan across Canada. The Table below provides a high-level summary of the approaches that a selected number of municipalities have adopted. The detailed assessment can be found in the subsequent section.

Table 5.1: Summary of the Landscape Scan for Municipalities

	Case Study	Targets	Technologies	Operations
1	City of Vancouver	• 100% Renewable diesel • 37% RNG into CNG supply • 200 EV in Public fleet by 2022 • Establishing 85 Level II charging stations and 4 DC fast charging stations • 85 hybrid or plug-in hybrid in Public fleet	• Renewable Diesel Fuel • Renewable Natural Gas • Compressed Natural Gas • Battery Electric	• Vehicle idling addressing with GPS and telematics system • Fleet size optimization and leasing options exploration
2	City of Abbotsford	• 20% by 2025 and 40% by 2040 against 2007 levels • Corporate emissions reduction through fleet replacement with alternative vehicles	• CNG and propane • 20% bio-diesel blends • Battery Electric Vehicle • Plug-in Hybrid Electric Vehicle	• Business-driven fleet replacement strategy with milestone targets • Benchmarking performance through Key Performance Indicators (KPIs) • Training for fleet maintenance
3	City of Lethbridge	• 40 % under 2018's levels by 2030	• Open to all technologies • Focusing on leveraging waste-to-energy locally • Identification of best solution based on triple bottom line analysis	• Identifying and integrating all stakeholders with multiple workshops to seek buy-in • Emissions and cost estimates for facility upgrades for fuelling/charging.

4	City of Toronto	• Transition 45% of City-owned fleet to low-carbon vehicles by 2030 • Reduction of greenhouse gas by 65% reduction by 2030 (from 1990 levels) • Net zero greenhouse gas footprint before 2050 (from 1990 levels)	• Accommodates different green technologies and renewable energy sources • Focus on fleet resiliency to address climate adaptation	• Comprehensive stakeholder inclusion including different City departments • Inclusion of installation as well as operational fueling requirements • Focus on climate change mitigation and adaptation in business continuity planning
5	Regional Municipality of Halifax	• Achieve net-zero municipal operations by 2030 • 100 DC fast and 1000 Level 2 charging ports by 2030 • 100% and 10-20% EV ready parking in new buildings construction. • 100% electrification of municipal light duty vehicles and reducing GHG emissions by 60%	• Electrification using EV, PHEV by using local, zero-carbon electricity • Renewable energy generation in municipal owned properties.	• Reduce residential waste and practice waste diversion • Advocating Zero-Emission Vehicle mandate provincially • Advocating federal and provincial purchase incentives for Zero-Emission Vehicle
6	City of St. John’s	• 40% reduction by 2030 and a stretch target of 50% by 2030 from 2018 emissions • Committed to net-zero by 2050 • Expected annual decrease needed in emission: 4.2%	• Battery Electric Vehicles • Plug-in Hybrid Electric Vehicle • Other low-emission technologies	• Fuel Consumption Monitoring and Reporting • Updating all current and future equipment and vehicles with their estimated fuel efficiency and lifecycle costs • Improve Energy Efficiency
7	City of North Vancouver	• 80% emission reduction by 2040 and 100% reduction by 2050 from 2007 levels	• Low emissions vehicles- Battery Electric Vehicles, Fuel Cell Vehicles	• Developing fleet transition strategy • Developing charging infrastructure strategy • Developing Low Carbon Fleet Transition Roadmap

5.1.1 Landscape Scan 1: City of Vancouver

Municipality/City/Region	City of Vancouver
Project Title	Greenest City Action Plan

Project description

Objectives

Focused on reduced greenhouse gas emissions and fossil-fuel use in City-run buildings and vehicles. This plan is disaggregated into ten measurable goals and fifteen measurable targets on achieving Green operations at the corporate City level.

Key Solutions/Recommendations

The City has identified the following approaches and solutions to meet the challenge of transitioning to net zero. The solutions that have been identified include exploring various technologies and phased uptake targets along with integration of best practices and the optimization of fleet and operations.

Some of these are highlighted below:

Fuels/Technologies

- Renewable Diesel Fuel
- Renewable Natural Gas
- Compressed Natural Gas
- Battery Electric

Energy mix target

- Shifting from 5% Biodiesel to 100% Renewable diesel fuel
- RNG integration into CNG up to 37% with CNG constituting 12% of the energy mix

Fleet electrification

- Addition of around 145 light electric vehicles to the City's fleet with the total number of electric vehicles (including medium and heavy-duty vehicles) in the fleet expected to reach 200 by 2022
- Establishing dedicated charging stations for these vehicles which comprise of i) 85 Level II charging stations and; iii) 4 DC fast charging stations
- Addition of 85 hybrid or plug-in hybrid vehicles to the fleet

Operations optimization through telematics and best practices

- Vehicle idling and wasteful fuel use was avoided in over 1000 City vehicles with GPS and telematics systems
- Fleet size optimization with respect to vehicle end use and exploring/leveraging other funding/financing/leasing operation

5.1.2 Landscape Scan 2: City of Abbotsford

Municipality/City/Region	City of Abbotsford
Project Title	Fleet Replacement Strategy

Project Description

Key Policy Initiatives:

- 2019 Green Fleet Strategy in 2019
- Emission reduction target of 20% by 2025 and 40% by 2040 against 2007 levels under the City's Official Community Plan
- Green Fleet Strategy focuses on public fleet emissions to support the planning process for fleet replacement and renewal planning with a focus on alternative vehicle integration

Objectives:

Various elements of Abbotsford's fleet replacement strategy are listed below and focus on achieving their 2040 emission reduction targets. This project focused on the following:

- Determination of the best strategy for the City to meet their GHG reduction targets after considering five (5) different green fleet options for Class 1 through 8 vehicles
- Assessment of the asset inventory of fleet with their current emissions levels, current operation conditions and maintenance servicing levels
- Development of the fleet replacement strategy by developing the business case for alternative vehicles through modeling of capital, operating costs and GHG emissions
- Conduct of gap analysis to identify facility upgrades requirements
- Design of fuelling & charging Station

Key Solutions/Recommendations

Market Scan and feasibility assessment

- A comprehensive and comparative market, cost and environmental scan was conducted in terms of the cost and GHG emissions for: i) CNG and propane; ii) 20% bio-diesel blends; iii) Battery Electric Vehicles and iv) Plug-in Hybrid Electric Vehicles

Sustainability Targets

- A milestone-based phasing strategy was identified to achieve the objectives in a cost-efficient manner

User group concerns

- An assessment of alternative fuel technologies in various government fleet assets based on the costs and carbon footprint was conducted

Training Requirements for Fleet Maintenance

- Training opportunities covering the basics of electric propulsion, batteries, safety procedures and correct safety procedures and tools were identified

Identification of Key Performance Indicators (KPIs)

- Specific KPIs were identified to monitor the health and performance of the assets

5.1.3 Landscape Scan 3: City of Lethbridge

Municipality/City/Region	City of Lethbridge
Project Title	Corporate Environmental Sustainability Initiative (CESI)

Project Description

Key Policy Initiatives

- City of Lethbridge's Corporate Strategic Plan
- City's Corporate Environmental Sustainability Initiative (CESI) emerging out of the need to develop a corporate environmental management strategy
- CESI incorporates inputs from City's Transit and Waste and Recycling department regarding alternate energy vehicles in City's fleet

Objectives

The key outcomes of an in-depth study under CESI are as follows:

- Developed a roadmap to adopt a greener fleet, which will improve air quality, reduce greenhouse gas emissions and reduce the carbon footprint of the city using GHGenius
- Reduced the operational cost of the current conventional fuel system completed using the University of Toronto Bus Lab and Lifecycle tool
- Developed financial cost estimates for modifications to the facility, infrastructure upgrades and conceptual layouts of fuelling/charging options
- Determined best operational solution among options through Triple Bottom Line analysis
- Identification of risks associated with each fuel option and development of mitigating solutions

Key Solutions/Recommendations

User Acceptance of Technology

- Multiple workshops were conducted using MentiMeter engagement to ensure stakeholder buy-in in order to address concerns around technology readiness and acceptance from various fleet users

Infrastructure Cost

- Detailed discussions were conducted through the City's electric utility and ATCO around utility cost and rate payer discussion on upgrades to achieve a comprehensive infrastructure costing estimate

Sustainability Targets

- Detailed discussion within the City's team were conducted to understand targets and achieve them in a cost-efficient manner with a phasing strategy and GHG trade-off analysis

Technology Bias

- Detailed walkthroughs and discussions around technology adoption and learning gradient were carried out to address previous challenges with respect to novel technologies and challenges

5.1.4 Landscape Scan 4: City of Toronto

TORONTO

Municipality/City/Region	City of Toronto
Project Title	2019-2023 Green Fleet Plan (The Pathway to Sustainable City of Toronto Fleets Plan)

Project Description

Objectives

The core coal for this Green Fleet Plan is to achieve sustainable, climate resilient, low-carbon City fleets. This core goal was further subdivided into the following objectives:

- **Objective 1:** transition 45 percent of City-owned fleet to low-carbon vehicles by 2030
- **Objective 2:** 65 percent greenhouse gas reduction by 2030 (from 1990 levels)
- **Objective 3:** net zero greenhouse gas reduction before 2050 (from 1990 levels)

Key Solutions/Recommendations

Comprehensive stakeholder inclusion

This new Plan covers approximately 98 percent of all City owned and operated motor vehicles and equipment. It includes the following City department fleets:

Toronto Zoo	Toronto Parking Authority
Fleet Services Division (Centrally Managed Fleet)	Toronto Paramedic Services
Toronto Transit Commission (TTC)	Toronto Community Housing
Toronto Police Service	Exhibition Place
Toronto Fire Services	Toronto Public Library

Climate Adaptation

- Incorporation of climate change adaptation goals in order to ensure resiliency of the City fleets

Technology agnostic

- Accommodates different green technologies and renewable energy sources along with maximizing the use of renewable and sustainable fuels through production, distribution and consumption

Comprehensive focus

- Both the infrastructure installation as well as operational requirements related a larger deployment

Methodology and Strategy

- Estimation of the range imparted by viable power sources and integration of robust fleet asset management and state of good repair practices for climate change mitigation and adaptation
- Enhance the level of operational preparedness for extreme weather and other shocks to minimize service disruptions
- Integration of climate change mitigation and adaptation in business continuity planning to ensure continuity in climate resilient operations and services

5.1.5 Landscape Scan 5: Regional Municipality of Halifax

Municipality/City/Region	Regional Municipality of Halifax
Project Title	HalifACT 2050, Halifax Regional Municipality Electric Vehicle Strategy

Project description

Objectives

Decarbonizing transportation remains one of the focus areas for action under Decarbonized and Resilient Infrastructure in the HalifACT 2050 plan. This was followed by the launch of Halifax Regional Municipality Electric Vehicle Strategy in November 2021.

Key Challenges

Some challenges to electrification and eventual decarbonization, as identified in the Electric Vehicle Strategy, are highlighted below:

- Incremental purchase cost of EV
- Home charging access for EV
- Range anxiety and public charging access
- Vehicle availability at dealerships
- Lack of Awareness

Key Solutions/Recommendations

Public Charging Infrastructure

- DC Fast charging: 100 ports by 2030 for urban/suburban areas and highway use in two Phases (2021-2025 and 2025-2030, respectively)
- Level 2 charging: 1000 ports by 2030 for on street and off-street use in two Phases (2021-2025 and 2025-2030, respectively)

Access to charging at home and workplace

- 100% EV ready parking in new residential construction
- 10%-20% EV ready parking in non-residential buildings

Municipal EV policies

- Advocating Zero-Emission Vehicle mandate provincially
- Advocating federal and provincial purchase incentives for Zero-Emission Vehicle

Electrifying municipal light duty fleet by 2030

- HalifACT 2050 has recommended Halifax Regional Municipality to adopt a resolution to achieve net-zero municipal operations by 2030. HRM Electric Vehicle Strategy targets 100% electrification of its light duty vehicles and reducing GHG emissions by 60%

Fuels/Technologies

- Electrification (municipal surface vehicles and fleet) such as BEV, PHEV for Pick-up Trucks, Car, Van and SUV using local, zero-carbon electricity

5.1.6 Landscape Scan 6: City of St John's

Municipality/City/Region	City of St. John's
Project Title	St. John's Corporate Climate Plan

Project description

Objectives

- Reduce Energy Intensity and Improve Energy Efficiency
- Create a Culture of Energy Conservation
- Increase Staff Energy Management Capacity & Knowledge
- Switch and/or Generate Energy to Reduce GHG Intensity
- Demonstrate Municipal Leadership

Key Solutions/Recommendations

Key Challenges

- Significant carbon footprint of transportation in corporate emissions (48%) in 2018 which is expected to increase to 60% in 2030

Goals

- 40% reduction by 2030 and a stretch target of 50% by 2030 from 2018 emissions
- Committed to net-zero by 2050
- Expected annual decrease needed in emission: 4.2%

Strategies

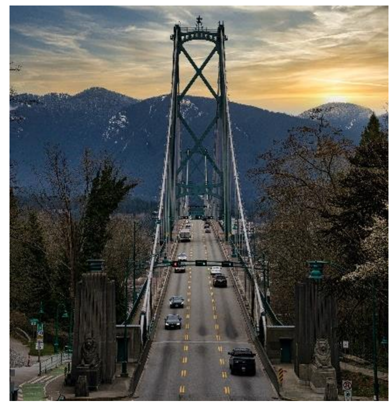
- Fuel Consumption Monitoring and Reporting
    - Updating existing vehicle inventory list to include all fuel-based and future non-fuel-based equipment and vehicles along with their estimated fuel efficiency and lifecycle costs.
- Public fleet electrification pathway development based on:
    - Corporate policy
    - Existing public fleet inventory and use
    - Differential capital cost forecast
- Low Carbon Vehicle Pilots for:
    - Piloting light duty low-carbon vehicles (BEV, PHEV)
    - Piloting heavy-duty fuel use emission reducing technologies
- Advanced Vehicle Replacement
    - Develop program to review cost of maintenance to the cost of replacement of fleet assets

5.1.7 Landscape Scan 7: City of North Vacouver

city of north vancouver		
	Municipality/City/Region	City of North Vancouver
	Project Title	Low Carbon Fleet Transition Roadmap

Project description

Objectives



- Identifying the most optimal pathway to Net-Zero emissions
- Detailed Fleet Transition Strategy (FTS) optimized to provide strongest financial case and GHG emissions reductions
- EV Charging Infrastructure Strategy (CIS) based on and supporting the FTS
- Informed capital and operational cost impacts of each of the above strategy
- GHG emission reduction modelling (annual and cumulative GHG emissions) of the Roadmap

Key Goals Identified

- Community-wide carbon emission reduction target of 80% reduction by 2040 and 100% reduction by 2050 based on 2007 levels, set in 2018
- Climate & Environment Strategy is under development and will include principles of Corporate Leadership plan requiring the City to transition to zero-emissions on an advanced timeline

Key Solutions/Recommendations

Some of the strategies that the City has identified for implementation while transitioning to zero corporate emissions are described below:

Fleet Transition Strategy (FTS)

- Updating existing vehicle inventory list comprising fuel-based equipment and vehicles along with their estimated fuel efficiency, associated lifecycle costs along with the detailed replacement plan
- Projecting the existing vehicle inventory list into the future and taking into consideration new alternative energy-based vehicle alternatives

Charging Infrastructure Strategy (CIS)

- Identifying the charging infrastructure that will be required based on the fleet requirements as replacement levels as identified in the FTS
- Estimating the cost associated with the projected charging infrastructure requirements
- Differential capital cost forecast

Low Carbon Fleet Transition Roadmap

- Assessing various pathways to net-zero corporate emissions based on associated costs (capital and operational) for vehicle fleet and equipment estimated through financial modelling
- Assessing various pathways to net-zero corporate emissions based on associated carbon footprint for the vehicles and infrastructure estimated through GHG modelling

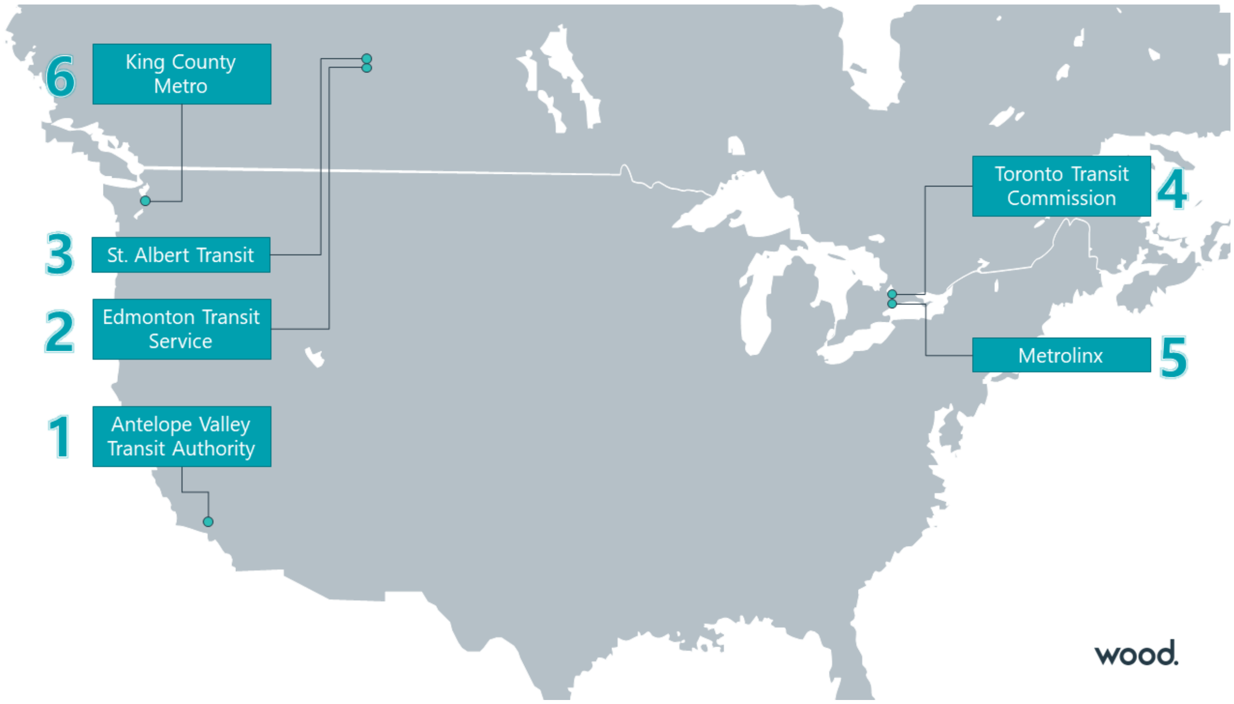
5.2 Zero Emission Transit Case Studies

Here is a summary table of the case studies showing their unique and shared characteristics.

Table 5.2. Case Study Summary Table

#	Case Study	# Buses	# BEB	Service population	Chargers Used	Highlight / notable point
1	Antelope Valley Transit Authority	90	45+	450,000	Plug-in Inductive	• Similarly sized agency • Committed to 100% Zero Emissions Fleet • Warm climate
2	Edmonton Transit Service	1,000+	60	820,000	Plug-in Overhead	• Large transit agency • BEBs primarily use pantograph chargers. • Cold climate
3	St. Albert Transit	63	7	66,000	Plug-in	• Small agency • Serves neighbouring municipality • Cold climate
4	Toronto Transit Commission	3,500+	60+	6,400,000	Plug-in	• Very large agency • Largest BEB Fleet in Canada • Committed to 100% Zero Emissions Fleet
5	Metrolinx	706	2*	9,360,000	Plug-in	• Crown agency tasked with managing and integrating road and public transit • Large transit agency (GO Transit)
6	King County Metro	1,600+	11 BEBs 174 ETBs	4,000,000	Plug-in Overhead	• Very large agency • Committed to 100% Zero Emissions Fleet • Coastal climate

**The Metrolinx BEB are not active as their electric bus pilot launch has been delayed due to COVID-19*



Antelope Valley Transit Authority (AVTA)

The AVTA was the first agency to commit to 100% electrification. With a fleet of 90 vehicles, its size and services are at a scale similar to Oakville transit.

Edmonton Transit Service (ETS)

The ETS is a large transit organisation operating in a very cold climate that is incorporating a substantial number of electric buses – currently 40. Notably all BEBs are primarily dependent on pantograph chargers.

St. Albert Transit (StAT)

The St.AT was the first Canadian municipality to own long range BEBs, in part due to their need to service many connections to a neighbouring larger municipality.

Toronto Transit Commission (TTC)

The TTC is a very large transit authority that has piloted the implementation variety of BEB. There is an opportunity to leverage TTC's experience with incorporating BEB to instruct Saint John transit's adoption.

Metrolinx

Metrolinx is a Crown Agency tasked with managing and integrating road and public transit in the Greater Golden Horseshoe Region. It is responsible for managing the electronic fare system used in the region. This agency is focused on servicing longer trips associated with regional travel.

King County Metro (Metro)

Metro is a very large transit authority that has committed to 100% zero emissions fleet by 2040, which will require 2,200 BEB/ETB. The majority of their current zero emission buses are electric trolley buses (ETB), though the agency is looking to integrate an increasing number of BEB.

5.2.1 ZEB Case Study 1: Antelope Valley Transit Authority

Key highlights:

- Primarily fleet ranging in sizes
- Similarly sized agency
- Committed to 100% Zero Emissions Fleet
- Warm climate

Name: Antelope Valley Transit Authority (AVTA)

Service population: 450,000

Number of electric buses: 45+ **Total fleet size:** 90

Summary

The AVTA services the cities of Lancaster, Palmdale, and unincorporated portions of northern Los Angeles Country, California. In 2016, the AVTA makes history by voting to purchase up to 85 new all-electric zero emission buses from BYD, officially becoming the first transit agency in the nation to commit to a 100% electric fleet.

In 2017, AVTA was the first agency to operate a zero emission 60' articulated bus in revenue service, and also completed the first ever WAVE inductive charging system in Southern California.

- Operates a network of 13 local transit routes, 6 commuter routes, 3 supplemental school routes;
- 58 buses dedicated to local service, 30 buses dedicated to commuter service; and
- Provides urban and rural "Dial-a-Ride" service;

Highlights

- Antelope Valley Transit Authority is operated under contract by Transdev and offers connecting services with Metro and Metrolink.
- Completed one million miles in May 2019, the equivalent of 250,000 gallons or $300,000 of fuel savings

Relevance to Saint John: Combination charging system implementation

Fleet Number Range	Year	Manufacturer	Model	Notes
27901-27908	2019	GPMC	EV Star 27'	
40089-40090	2020	BYD	K9	
40450-40451	2014	BYD	K9	
40452-40454	2014	BYD	K9	
40856-40875	2018	BYD	K9	2017 models
40976-40988	2019	BYD	K9	
60701-60705, 60707-60711	2017	BYD	K11M	
40856-40875	2017	BYD	K11M	Delivered in 2019

5.2.2 ZEB Case Study 2: Edmonton Transit Service

ETS

Key highlights:
- Large transit agency
- BEBs primarily use pantograph chargers.
- Cold climate

Name: Edmonton Transit Service

Service population: 820,000 **Service Area:** 700 km^2

Number of electric buses: 60 **Total fleet size:** 1000+

Summary

The ETS services the city of Edmonton with regional service to surrounding municipalities. In 2020, ETS became the first transit agency in North America to use overhead charging infrastructure to charge its 40 Proterra ZX5 40' E2 Max buses. Since this initial deployment ETS has procured 20 additional BEBs from Proterra.

- Operates a network of 191 bus routes, 230 school routes, and 2 light rail transit (LRT) lines.
- Over 1000 buses are used to service these routes with the LRT lines serviced by close to 100 light rail vehicles.

The charging infrastructure for the electrified feet was installed in the Kathleen Andrews Garage and included 26 ABB 150 kW overhead chargers and seven (7) 60 kW Proterra plug-in chargers. When vehicles connect to the charging system, a fleet management software system initiates charging at designated times to optimize energy usage and limit the maximum power draw of the facility. APEX Connected Vehicles Intelligence System is used to monitor ETS fleet and report on the state of charge, charger status, bus efficiency, distance traveled, etc.

In 2015, ETS ran a pilot study with several buses to determine the impacts of the region's climate, topography, and broad geographic transit area. The result showed that electric heaters consume between 20% and 25% more energy per kilometer, which could be mitigated using diesel fueled auxiliary heaters.

Highlights

- All regular ETS buses are equipped with Smart Bus Technology, providing real time data to both customers and ETS control.
- All ETS BEBs are equipped with overhead pantograph chargers to limit space requirements for facility storage.

Relevance to Saint John: Integrated use of depot plug-in and overhead (pantograph) chargers

Fleet Number Range	Year	Manufacturer	Model	Notes
8000-8039	2019-20	Proterra	ZX5MAX	

5.2.3 ZEB Case Study 3: St. Albert Transit

Key highlights:
- Small agency
- Serves neighbouring municipality
- Cold climate

Name: St. Albert Transit

Service population: 66,000

Number of electric buses: 7 **Total fleet size:** 63

Summary

The StAT services St. Albert with local routes while operating several express connect to directly to Edmonton destinations. Additionally, a local dial-a-ride is provided to further supplement accessibility options. In 2017, StAT deployed its first BEBs and has continued to adopt more into their fleet, which has led the agency to winning the Emerald Award, one of the province's most prestigious environmental honours.

- Operates a network of 15 local bus routes, 3 Dial-a-Ride routes, and 7 express Routes into Edmonton.
- This network is served by 52 buses, supplemented by 11 para-transit vehicles.
- St. Albert has deployed a 301kW solar panel system at the Dez Liggett Transit Facility, which supplies approximately one-third of the building's electricity. The aim of this installation is to both offset the peak energy demands of the facility and further the agency's environmental goals.

Highlights

- The number of daily transit trips has increased by nearly 9,000 between 2005 and 2021.
- St. Albert was happy with the initial deployment of (3) long-range BEB and have continued growing their electrified fleet by adopting four (4) more, with plans to expand further.
- In 2017, the City of Edmonton and the City of St. Albert Councils signed a Memorandum of Understanding (MOU) to begin taking steps to develop a Regional Transit Services Commission.

Relevance to Saint John: Use of BYD technology, including LFP batteries and 80kW plug-in chargers.

Fleet Number Range	Year	Manufacturer	Model	Notes
1400-1402	2017	BYD	K9S	First BEB in St. Albert
1403-1406	2018	BYD	K9S	

5.2.4 ZEB Case Study 4 Toronto Transit Commission

Key highlights:

- Very large agency
- Largest BEB Fleet in Canada
- Committed to 100% Zero Emissions Fleet by 2040

Name: Toronto Transit Commission (TTC)

Service Population: 3.0 Million

Annual Ridership: 525 Million

Number of electric buses: 60

Total fleet size: 3500+

Summary

The TTC is Canada's most heavily used transit system (3rd in North America), serving 2.76 million trips on an average weekday (2019). Vehicle electrification is a key component of the city's TransformTO climate action strategy, which targets an 80-percent reduction in local greenhouse gas emissions by 2050.

- Operates a network of over 150 bus routes, 4 subway lines, and 10 streetcar routes.
- The TTC has approximately 2563 buses (conventional/wheel-trans/community), 204 streetcars, and 878 rapid transit (subway/RT) cars in the active fleet

Throughout the adoption of their first 60 BEB, TTC allocated approximately half of their $140 million dollar funding from the federal Public Transit Infrastructure Fund to install charging infrastructure at Arrow Road, Mount Dennis, and Eglington bus garages. Two of these facilities are equipped with DC fast charging to support Proterra and New Flyer BEB, while the remaining facility has been equipped with an AC charging system to accommodate BYD models.

The TTC is currently testing the effects on battery capacity that come from maintaining passenger comfort (heating and cooling the cabin). They found that effects of air-conditioning in the summer reduced battery capacity by 15%. The winter testing still in progress to determine the effects of heating BEBs using an auxiliary heater.

Highlights

- Leading operator of BEBs in Canada with 60 buses comprised of three different models, each from a different manufacturer.
- Aims to be a zero-emissions fleet by 2040.
- Plans to develop specifications for its electric bus fleet and order 300 more in 2023

Relevance to Saint John: The TTC is currently testing a variety of BEB models in varied operating conditions.

Fleet Number Range	Year	Manufacturer	Model	Notes
3700-3724	2018-19	New Flyer	Xcelsior XE40	First TTC Battery Electric Buses
3725-3749	2019	Proterra	Catalyst BE40	
3750-3759	2019	BYD Auto	K9M	

5.2.5 ZEB Case Study 5: Metrolinx

Key highlights:
- Crown agency tasked with managing and integrating road and public transit
- Large transit agency (GO Transit)

Name: Metrolinx

Service Population: 9.36 Million	**Annual Ridership:** 74 Million
Number of electric buses: 2 on order (GO)	**Total fleet size:** 1671 (706 buses)

Summary

Metrolinx is a Crown Agency that is tasked with managing and integrating road and public transport in the Golden Horseshoe Region and Ottawa* (Metrolinx's role in Ottawa is limited to fare collection). The agency is responsible for the implementation and management of the Presto card, the electronic fare system used in all public transport systems in the Greater Toronto and Hamilton Area. Metrolinx aims to support local municipalities through programs like Smart Commute and the Transit Procurement Initiative which aim at reducing emissions and increasing transit efficiency. Additionally, Metrolinx operates GO Transit and the Union Pearson Express where it has committed to expanding the electrification of its rail network.

- Through GO Transit, Metrolinx operates a network of 42 bus routes and seven (7) rail lines.
- The Metrolinx fleet contains approximately 706 buses, 90 locomotives, 139 cab coaches, and 736 rail coaches.

Metrolinx is close to beginning their pilot for its new Enviro500EV, however the launch has been delayed due to COVID-19. Metrolinx has not committed to an electrification target for its bus fleet.

Highlights

- Presto has been fully implemented in 11 transit systems.
- The Transit Procurement Initiative has supported 21 municipalities and transit agencies, to purchase over 400 buses, and has saved an estimated $5 million.
- Two fast chargers have been installed at the Steeprock Bus Storage Facility in anticipation of electric vehicle pilot.

Relevance to Saint John: Regional transit management with a focus on intercity/regional transit (long route)

Fleet Number Range	Year	Manufacturer	Model	Notes
4000-4001	2021	ADL/Proterra	Enviro500EV "SuperLo"	GO Transit

5.2.6 ZEB Case Study 6: King County Metro Transit Department

Key highlights:
- Very large agency
- Committed to 100% Zero Emissions Fleet
- Coastal climate

Name: King County Metro (Metro)

Service Population: 4.0 Million

Annual Ridership: 122 Million

Number of electric buses: 11 BEBs and 174 ETBs

Total fleet size: 1600+

Summary

Metro is the county-wide bus transit system which serves King County Washington, which includes Seattle. It is the eight largest transit bus agencies with close to 400,000 weekday passengers. A high proportion of Metro's passengers are commuters, which has led to over 100 of its 215 routes being peak hours only, with many of those only operating in one direction at a time.

Similar to the PRESTO card deployed throughout Ontario's GTA, Metro participates in a regional smart card program called ORCA, where it is joined by six other transit agencies in the region.

- Metro operates a network of over 215 bus routes, which include approximately 26 Dial-A-Ride-Transit routes (Accessibility focused routes which can deviate to drop off and pick up passengers).
- Metro operates over 1600 buses which includes 174 electric trolly buses (ETB) and 11 battery-electric buses (BEB).
- The 132 park-and-ride facilities serve the commuter focused ridership of the Metro

Metro's conceptual plan for its charging infrastructure a its interim facility will include 100 pantograph down fast chargers with 35-50 plug in chargers. This equipment will later be moved to larger permanent facility as electrification continues.

Highlights

- Metro has committed to move to a 100% zero emissions fleet by 2040. This will require 2,200 BEBs and BETs.
- Metro is currently testing 11 BEBs for performance and reliability for King County operating conditions.

Relevance to Saint John: High proportion of passengers are commuters

Fleet Number Range	Year	Manufacturer	Model	Notes
4601-4603	2015	Proterra	Catalyst BE40	
4604-4611	2018	Proterra	Catalyst BE40	

6.0 Future State Analysis

The objective of this section is to assess the opportunities, risks, challenges, and solutions associated with the adoption of various alternative technologies and their suitability for City operations in close collaboration with various user groups.

While developing the proposed roadmap to zero-emissions, Wood will ensure consensus among key stakeholders from various user groups with respect to the chosen technology alternatives and deployment timeline. The key criterion for vehicle selection will be its ability to meet the operational requirements of the respective user groups.

In terms of the assessment of the operational alternatives, Wood's approach will involve assessing various zero- or low- emission technologies against the specified criteria of meeting operational requirements. Wood has developed an approach with respect to the evaluation of alternative technology options for replacing the City's existing fleet. This approach will give preference to technologies that result in zero-tailpipe emission technologies (battery-electric, hydrogen fuel cell). If the zero-emission technologies are not able to support the required operational profile of the respective user groups, other low emission technologies such as CNG-RNG engines, hybrid battery-diesel/CNG technology options, including plug-in hybrid options will be considered. In the event of these low emission technologies failing to meet operational requirements, Wood would evaluate optimization techniques such as right-sizing the vehicle fleet and the introduction of new assets (high speed chargers, vehicle-to-vehicle chargers, and fleet expansion) to meet the City needs – this is explored in Section 8.3.

The final listing of the alternatives will be presented to all municipal departments for their approval.

6.1 Future State Considerations – Public Fleet Vehicles

The City has committed to reduce its corporate GHG footprint by 30% by 2025 and to achieve carbon neutrality by 2040. To achieve this target, the City has planned to transition its public fleet to zero-emission by 2040. The roadmap to achieve this transition will consider the following factors:

- Lifecycles of the vehicles in the public fleet
- Current procurement orders
- Procurement cycles
- Municipal departmental operational requirements and needs
- Availability of fuelling supply
- Availability of required infrastructure
- Facility modification requirements
- Commercially available technologies
- Policies implemented in other Canadian jurisdictions

To ensure that the final roadmap meets the short- and long-term corporate goals while ensuring minimal disruptions to the current operations, Wood has reached out to the Operational Managers representative of the City's departments to seek their feedback through a User Group Survey and through focus group discussions. The user groups include:

- Utility & Infrastructure
    - Infrastructure-Asset Management
    - Saint John Water-Drinking Water
    - Saint John Water- Storm Water
    - Saint John Water- Wastewater
    - Saint John Water- Water and Sanitary Engineering

    - Saint John Water- Utility Business Manager
- Police
- Fire & Emergency Management
- Public Works and Transportation
    - Fleet Management
    - Parks and Public Spaces
    - Fleet Management
    - Pedestrian and Traffic Management
    - Roadway Maintenance
    - Sidewalk Maintenance
    - Solid Waste Collection
- Transportation and Environment- Parks and Public Spaces
- Agencies, Boards and Commission
    - Parking Commission

These interactive surveys and focus group sessions provided key information to Wood with respect to the duty cycles, application and other insights into vehicle use for user group.

6.1.1 User Group Survey

A User Group Survey was carried out to solicit preferences from each user group.

	Questions
1	What are the top 3 benefits you anticipate with the transition to alternatively fuelled vehicles in your fleet?
2	On a scale of 1 to 5 (1 being low and 5 being high), what level do you believe your department is ready to transition to alternatively fuelled vehicles?
3	If low carbon fleet transition is implemented, what type of fleet mix would you prefer?
4	Have you received feedback from other municipalities/transit agencies on their experience operating alternative fuel propulsion vehicles (i.e., CNG/RNG, hybrid-electric, biodiesel, hydrogen, electric)? If you answered "Yes" to previous question, what was their feedback?
5	Have you thought about how the 2025 and 2040 public fleet emission goals will be met and the impact on your fleet vehicles? If you answered "Yes" to previous question, please provide your views on the strategy to be used to achieve the public fleet goals.
6	On a scale of 1 to 5 (1 being low and 5 being high), how likely do you think the City can achieve its corporate goals using alternatively fuelled vehicles? (30% reduction by 2025, and carbon neutrality by 2040)
7	What is the first word that comes to mind when you think of an electric/hydrogen fuel cell vehicle?
8	What is the first word that comes to mind when you think of a CNG fuelled vehicle?
9	Please provide your thoughts on the life expectancy of your fleet vehicles.

10	What are your expectations for battery electric vehicles' battery life?
11	Are you concerned about Electric Vehicle (EV) technology becoming outdated faster than conventional vehicle technology? Example being EV batteries becoming more efficient and less expensive. If you answered "Yes" to previous question, would you consider swapping advanced batteries that may be available in the future?
12	What are your thoughts about disposal for end-of-life EV and their batteries?
13	For the near term to reduce Green House Gas (GHG) emissions, are you willing to adopt alternative fuels such as biodiesel and CNG/RNG for heavy-duty vehicles?
14	On a scale of 1 to 5 (1 being low and 5 being high), what level do you see alternative fuels such as CNG/RNG being successful in replacing conventional diesel heavy-duty vehicles 1:1?
15	For your fleet operations, do you have a preference on the alternative fuel propulsion technology to be favoured for further considerations? Electric / CNG/RNG / Biodiesel / Hydrogen Fuel Cell / Others
16	If "Others" was chosen in the previous question, please provide the propulsion type:
17	Where are your vehicles predominantly parked, specifically during extreme cold weather conditions?
18	Do you monitor Fleet Key Performance Indicators (KPIs) using GEOTAB and other information management systems? If you answered "Yes" to previous question, please share the KPIs that you monitor
19	Do your fleet vehicles have high idling as a functional requirement? If you answered "Yes" to previous question, please share your concerns on how the high idling would possibly hinder low carbon fleet transition with EV technology
20	Please provide your department fleet vehicle spare ratio.
21	How are vehicles assigned to individuals and tracked?
22	How are vehicles assigned to specific functions? Please provide high-level logic for each vehicle category that will enable us to understand the various duty cycles and operating requirements.
23	What do you believe would be the most significant operational challenge for introducing Electric/Hybrid/Hydrogen Fuel Cell vehicles into your fleet?
24	What do you believe would be the most significant operational challenge for introducing CNG/RNG heavy-duty vehicles into your fleet??2
25	In the case of EVs, where would you prefer to charge your vehicles?
26	Please provide some of the benefits you anticipate with facility charging and fast/on-route charging
27	What are some of your concerns for fast/on-route charging stations? Examples include service

	delays, peak demand pricing, grid reliability.
28	Are you concerned about local dealer support for maintenance and parts availability?
29	Are you concerned about the local availability and resiliency of alternative fuels such as biodiesel, CNG, and RNG?
30	Would you prefer to Buy or Lease new technology alternatively fuelled vehicles for your fleet?
31	What are your concerns and opinion on the electrical/fuel infrastructure and facility modifications required to host the alternatively fuelled fleet vehicles?
32	Which alternative fuel technology do you think is the way forward to meet the Public fleet GHG emission targets?
33	If 100% green fleet transition needs to be successful, do you think a fully developed pilot program followed by a robust monitoring program is required? If you answered "Yes" to previous question, please provide your thoughts on the expectations for the pilot program.
34	Which specific functions/vehicles in your department do you think are ready for a pilot with the deployment of alternative fuel technology? Please identify the most suitable technology.

Wood received a total of 14 responses from the user groups and follow-up stakeholder sessions were developed based on the feedback received. The follow-ups served as interactive question-and-answer sessions to solicit broader group discussion and identify the viability of each technology in terms of user group needs.

6.1.2 Class 1 Propulsion Technologies (General Purpose and Police vehicles)

Class 1 General Purpose vehicles are used extensively by all of the City's municipal departments with a total fleet size of 69 of which 23 are Police vehicles. Numerous zero- and low-emissions alternatives in this class are commercially available. Given the relatively low-duty application and the general-purpose deployment of these vehicles, most of the fleet vehicles can be readily transitioned to zero-emission alternatives using battery-electric vehicles. However, some of the municipal departments have also identified critical operational requirements that the potential replacement need to meet. For these specific municipal departments, the selection of replacement alternatives will incorporate testing against these specific requirements.

The Tables below highlight the key insights gained from the User Group Survey responses and focus group sessions.

6.1.2.1 Public Works & Transportation

Table 6.1 Future State Considerations for Class 1 Vehicles for Public Works and Transportation

Class 1 Propulsion Technologies (General Purpose)	Public Works & Transportation
Opportunities	The commercial availability of multiple zero-emission variants from different manufacturers provides a direct pathway to switch to zero-emissions vehicle for Public Works & Transportation. Given that these vehicles constitute a significant component of the entire fleet

	(approximately 28%), their direct transition to zero-emissions variants can lead to significant decrease in emissions. The presence of multiple manufacturers in this class also provides an opportunity to leverage competitive pricing for vehicle procurement and long-term contracts for maintenance. The procurement schedule has also identified several scheduled procurements for vehicles of this class all the way to 2030. The ready availability of zero-emission vehicles provides an opportunity to initiate the transition to zero emission sooner and at a faster pace.
Constraints	The operational requirements for the vehicles of Public Works and Transportation include year-round reliability for the vehicles, including in the months of winter to ensure timely delivery of municipal services. Additionally, high idling times and the need for adequate internal volume for the comfort of the staff are critical requirements. Due to their minimal down-time allowance, these vehicles are expected to adhere to a high level of operational readiness. A particular constraint with procuring transitional technology vehicles is futureproofing as they are expected to be soon replaced by zero-emission vehicles.
Risks	Class 1 vehicles generally comprise of sedans and smaller vehicles which might exhibit a challenge with respect to the volume requirements. These vehicles are generally equipped with battery of small to medium size. Most of the new zero-emissions and transitional technologies variants are currently deployed in areas with moderate climatic conditions. The performance of these vehicles in the New Brunswick climatic conditions could pose a significant challenge. Installing fast chargers for shorter turn arounds will require identifying new locations in case the existing depots are not able to accommodate them which will result in extensive refurbishment and civil works requirements. Given the pace of evolution for zero-emission technologies, it is expected that the vehicle ranges will continue to increase along with better safety features and reliability. Therefore, any procurement of hybrid diesel electric and CNG vehicles poses a risk to the municipalities of getting “locked-in” into these transitional technologies for the duration of their operational lifetime or risk additional expenditure or value loss on prematurely replacing or selling the existing assets. Therefore, any procurement of hybrid diesel electric and CNG vehicles poses a risk to the municipalities of getting “locked-in” into these transitional technologies for the duration of their operational lifetime or risk additional expenditure or value loss on prematurely replacing or selling the existing assets.
Solutions	The most optimal solution for this class of vehicles would involve a phased transition. This will involve managing the transition to zero-emissions in phases with the first phase focusing on the procurement of hybrid-electric variants starting 2022 onwards to 2023. This will be followed by the procurement of battery electric variants in the next phase 2023 onwards. There are several options for market for zero-emissions Class 1 vehicles generally comprise of sedans and smaller vehicles which might exhibit a challenge with respect to the volume requirements. These vehicles are generally equipped with battery of small to medium size. Most of the new

	zero-emissions and transitional technologies variants are currently deployed in areas with moderate climatic conditions. The performance of these vehicles in the New Brunswick climatic conditions could pose a significant challenge. Installing fast chargers for shorter turn arounds could be a solution which will, however, require identifying adequately suited locations.

6.1.2.2 Fire Department and Police

Table 6.2: Future State Considerations for Class 1 Vehicles for Fire Department and Police

Class 1 Propulsion Technologies (Police Vehicles)	Fire Department and Police
Opportunities	The commercial availability of multiple zero-emission variants from different manufacturers provides a direct pathway to switch to zero-emissions vehicle for Fire & Police. The Police have already adopted hybrid electric vehicles and the positive experience has demonstrated a great institutional buy-in into fleet transitioning. Given that there are 23 Class 1 Police cruisers currently in the Saint John Police fleet, they have gained confidence and operational experience in managing transitional energy vehicles that provides an opportunity for a direct transition to zero-emission operations. Class 1 sedans are also deployed by the Fire Department for general transportation, the vehicle sometimes includes emergency lights and sirens so that emergency staff can respond more quickly. The high idling requirements that have been identified as a critical operational necessity for both the Police and Fire Department can lead to a significant cost burden using IC engines. Shifting to highly efficient battery electric systems may lead to reduced operating costs due to the lower energy consumption when idling. The presence of multiple manufacturers in this class also provides an opportunity to leverage competitive pricing for vehicle procurement and long-term contracts for maintenance. The procurement schedule has also identified several scheduled procurements for vehicles of this class up to 2030.
Constraints	The operational requirements for the vehicles of the Fire Department and Police include high levels of reliability, high idling requirements, large internal volume for staff comfort and a measure of safety assurance associated with the vehicles. The adequate level of safety assurance required for policing operations could be challenging for Class 1 vehicles based on alternative energy propulsion. Due to their minimal down-time allowance, these vehicles are expected to adhere to a high level of operational readiness. A particular constraint with procuring transitional technology vehicles is futureproofing as they are expected to be soon replaced by zero-emission vehicles.
Risks	Class 1 vehicles generally comprise of sedans and smaller vehicles which might exhibit a challenge with respect to the volume requirements. These vehicles are generally equipped with a small to medium sized battery. As the majority of the new zero-emissions and transitional technologies

	variants are currently deployed in areas with moderate climatic conditions, the performance of these vehicles in the New Brunswick climatic conditions is unknown and could pose a significant challenge. There is a level of safety assurance and reliability that is expected by both Police and the Fire Department for their respective operations and meeting that level could be challenging in the given climate. There is a potential risk of existing Class 1 alternatives based on zero-emissions not being able to meet the required level of safety assurance and reliability. Given the pace of evolution for zero-emission technologies, it is expected that the vehicle ranges will continue to increase along with better safety features and reliability. Therefore, any procurement of hybrid diesel electric and CNG vehicles poses a risk to the municipalities of getting "locked-in" into these transitional technologies for the duration of their operational lifetime or risk additional expenditure or value loss on prematurely replacing or selling the existing assets.
Solutions	The optimal solution for this class of vehicles would be a phased transition to zero-emissions, with the first phase starting in 2022 and continuing to 2030 focusing on the procurement of hybrid-electric variants. This will be followed by the procurement of battery electric variants in the next phase beginning in 2030. There are several commercial options in the market for zero-emission Class 1 vehicles which can be considered for general purpose alternative energy vehicles. There are exclusive zero-emission options catering to the requirements of Police in the form of battery electric police cruisers and these can be evaluated against the idling, safety assurance and reliability requirements of the Police.

6.1.3 Class 2 Propulsion Technologies (Light-duty pickup trucks)

The City's Class 2 fleet comprises of 73 light-duty pickup trucks that are currently used for medium- to heavy-duty applications. These light-duty pickups constitute approximately a quarter of the entire City fleet. While there have been commercial variants based on CNG and hybrid diesel/gas-electric technology available since the mid-2010s, the advent of battery-electric variants has been recent with a selection of models already on the market while many other battery-electric variants are currently in the pipeline. The hydrogen fuel cell Class 2 truck market is still developing.

The following sections identify various aspects associated with the transitioning of the existing fleet of Class 2 Light-Duty Pickup trucks to zero/lower-emission vehicles.

6.1.3.1 Utility & Infrastructure

Table 6.3: Future State Considerations for Class 2 Vehicles for Utility & Infrastructure Departments

Class 2 Propulsion Technologies (Light Duty Pick-up Truck)	Utility & Infrastructure
Opportunities	Since Type 2 Light-Duty Pickup Trucks are already commercially available in battery electric variants, there is potentially a direct pathway to zero-emissions. Similar facility modifications are required to safely accommodate CNG and hydrogen fuel-cell vehicles. This could lead to a pathway where CNG naturally transitions to hydrogen fuel-cell vehicles. the

	CNG and hybrid-battery electric variants are proven technology with several commercial options currently available. The procurement schedule has also identified several scheduled procurements for vehicles of this class all the way to 2030. This provides an opportunity to initiate the transition to zero emission sooner and at a faster pace.
Constraints	Vehicles in the Utility & Infrastructure fleets have various uses, such as ferrying tools and service crews or conducting auxiliary operations. The Utility & Infrastructure departments also manage night operations with its vehicles distributed across multiple depots. These night operations, long durations of operational deployment and distributed vehicle depots present additional complexities of reduced downtimes and the need to equip all depots with charging equipment and have mobile charging equipment. The vehicles have large idling requirements and need to be on standby resulting in smaller windows of opportunities for charging. Durability and extreme-weather operational capability were identified as critical necessities as inclement weather causes more demand and hours of operation. Since the vehicles do not return to the same location after the work has been completed, distributed fueling/charging operations will have to be considered. A particular constraint with procuring transitional technology vehicles is futureproofing as these vehicles are expected to be replaced by zero-emission vehicles.
Risks	The adequacy of the existing zero-emission light-duty pickup truck to support continuous day-long operations of the Utility & Infrastructure Department possess a great risk. Limited availability of zero-emission vehicles exclusively designed and built for utility-operations enhances the reliance on transitional technologies-based vehicles. Given the pace of evolution for zero-emission technologies, it is expected that the vehicle ranges will continue to increase along with better safety features and reliability. Therefore, any procurement of hybrid diesel electric and CNG vehicles poses a risk to the municipalities of getting "locked-in" to these transitional technologies for the duration of their operational lifetime or risk additional expenditure or value loss on prematurely replacing or selling the existing assets.
Solutions	The optimal solution for this class of vehicles would be a phased transition to zero-emissions, starting in 2022 and continuing to 2024, focusing on the procurement of hybrid-electric variants. This will be followed by the procurement of battery electric variants in the next phase 2025 onwards. It is recommended that the City also procures a few battery-electric vehicles in the first phase in order to train the workforce and adapt the vehicles to the operational requirements of the fleet. A possible solution could be the deployment of battery electric vehicles at more central locations with hybrid vehicles catering to the needs of peripheral areas. To address the challenges associated with the high up-time requirements, additional options that can be explored include acquiring assets such as energy storage enabled DC fast chargers and mobile chargers to ensure minimal operational disruption.

6.1.3.2 Public Works and Transportation

Table 6.4 Future State Considerations for Class 2 Vehicles for Public Works and Transportation departments

Class 2 Propulsion Technologies (Light Duty Pick-up Truck)	Public Works and Transportation
Opportunities	Since Class 2 Light-Duty Pickup Trucks are already commercially available in battery electric variants, there is potentially a direct pathway to zero-emissions. Once hydrogen Class 2 trucks are matured, Similar facility modifications are required to safely accommodate CNG and hydrogen fuel-cell vehicles. This could lead to a pathway where CNG naturally transitions to hydrogen fuel-cell vehicles. The CNG and hybrid-battery electric variants are matured technology with several commercial options currently available. The procurement schedule has also identified several scheduled procurements for vehicles of this class all the way to 2030. This provides an opportunity to initiate the transition to zero emission sooner and at a faster pace.
Constraints	Some of the identified constraints include high idling requirements and snow ploughing applications which are extremely demanding. Due to the high usage of the auxiliary equipment and hydraulic/electric powered attachments/accessories there is a significant power draw. Given the significant operational deployment of these vehicles, there might be a requirement for mobile charging systems. A particular constraint with procuring transitional technology vehicles is futureproofing as they are expected to be soon replaced by zero-emission vehicles.
Risks	While there have been multiple announcements of zero-emission Class 2 light duty pick-up trucks, most of them focus on personal use and trucks with high battery capacity that can cater to municipal applications are still rare. This raises potential questions about the adaptability of these Class 2 trucks for municipal applications and constitutes a significant risk. High levels of operational deployments also result in narrower windows for charging. This results in the risk of the vehicle becoming stranded or having to return from the operational site for charging.
Solutions	Given the constraints of high operational readiness, limited downtime, long hours of deployment and distributed housing of vehicles, it is recommended that the transition of the fleet to zero-emission vehicles is done in phases with the first phase focusing on the procurement of hybrid-electric variants starting 2022 onwards all the way to 2024. This will be followed by the procurement of battery electric variants in the next phase 2025 onwards. It is recommended that the City also procures a few battery-electric vehicles in the first phase in order to train the workforce and adapt the vehicles to the operational requirements of the fleet. To address the challenges associated with the high up-time requirements, additional options that can be explored include acquiring assets such as energy storage enabled DC fast chargers and mobile chargers to ensure minimal

	operational disruption.

6.1.3.3 Fire Department and Police

Table 6.5: Future State Considerations for Class 2 Vehicles for Fire Department and Police

Class 2 Propulsion Technologies (Light Duty Pick-up Truck)	Fire Department and Police
Opportunities	Since Class 2 Light-Duty Pickup Trucks are already commercially available in battery electric variants, there is potentially a direct pathway to zero-emissions. Once hydrogen Class 2 trucks are matured, the existing fuelling infrastructure can be used with certain modifications for hydrogen. The CNG and hybrid-battery electric variants are matured technology with several commercial options currently available. The procurement schedule has also identified several scheduled procurements for vehicles of this class all the way to 2030. This provides an opportunity to initiate the transition to zero emission sooner and at a faster pace. The procurement schedule has also identified several scheduled procurements for vehicles of this class all the way to 2030. This provides an opportunity to initiate the transition to zero emission sooner and at a faster pace.
Constraints	Some of the identified constraints include high idling requirements by the vehicles and long operational deployment which is extremely demanding. Since these vehicles serve as mobile offices, there is a need for large internal volume and ergonomic design to ensure comfort of the staff. To incorporate specific policing related requirements, non-propulsion aspects related to vehicle strength such as chassis strength need to be tested. Due to the high auxiliary usage, there is a significant power draw by other vehicle accessories. Given significant operational deployment of these vehicles, there might be a requirement for mobile charging systems. A particular constraint with procuring transitional technology vehicles is futureproofing as they are expected to be soon replaced by zero-emission vehicles.
Risks	While there have been multiple announcements of zero-emission Class 2 light duty pick-up trucks, most of them focus on personal use and trucks with high battery capacity that can cater to municipal applications are still rare. This raises potential questions about the adaptability of these Class 2 trucks for municipal applications and constitutes a significant risk. Long operational deployments also result in narrower windows for charging. This results in the risk of the vehicle becoming stranded or having to return from the operational site for charging. In addition, the more ubiquitous low- and zero-emissions Class 2 Light-Duty Pickup Trucks might not be able to adhere to the security and protective measures that might be needed for Fire and Police Departments. This results in the risk of the vehicle becoming stranded or having to return from the operational site for charging.
Solutions	Given the constraints of high operational readiness, limited downtime, long

	hours of deployment and distributed housing of vehicles, it is recommended that the transition of the fleet to zero-emission vehicles is done in phases with the first phase focusing on the procurement of hybrid-electric variants starting 2022 onwards all the way to 2024. The initial transition to hybrid-electric vehicles is recommended given the already existing familiarity of the Police department with such vehicles with the final transition to zero-emission vehicles in the latter phase. Given the long operational deployment and quick turnaround needs, mobile chargers can be explored for battery-electric vehicles to be deployed at the sites to sustain operations without the need to return to base. A phased transition is recommended given that the existing zero-emission variants might not be able to meet high operational requirements for the Police and Fire Departments.

6.1.4 Class 3,4 & 5 Propulsion Technologies (Heavy Duty Pickup Trucks)

The City of Saint John's existing fleet comprises of 39 vehicles of Classes 3-5 heavy duty pickup trucks split across all user groups. These vehicles are currently used for medium- to heavy-duty applications and constitute approximately 20% of the City's fleet. While there have been commercial variants based on CNG and hybrid diesel/gas-electric technology available since the mid-2010s, the advent of battery-electric variants has been recent with some battery-electric models currently in the developmental pipeline and expected to debut this year. There are some hydrogen fuel cell vehicles currently under development, but no hydrogen fuel cell-based variant is currently commercially available.

Most of these trucks are engaged in medium-to heavy duty vehicle operations and do not have any unique department-specific functionality requirement, and the following analysis is relevant to all user groups for this class of vehicles.

Table 6.6: Future State Considerations for Class 3,4 & 5 Vehicles for all City Departments

Class 3, 4 & 5 Propulsion Technologies (Heavy Duty Pickup Trucks)	All City Departments
Opportunities	Plug-in hybrid and CNG variants of these vehicles are currently commercially available with battery-electric variants being currently in the developmental pipeline. Given that this vehicle class is subjected to medium-to-heavy loads which can be borne by upcoming battery-electric variants, this presents an opportunity to significantly reduce the GHG emission footprint by transitioning the existing fleet to upcoming zero-emission variant. The procurement schedule has also identified several scheduled procurements for vehicles of this class all the way to 2030. City of Saint John has already achieved considerable decline in their GHG emission levels from 2005 which provides the flexibility in terms of timeline for making the transition to zero-emission vehicles.

Constraints	There are no existing battery electric or hydrogen variants of the Class 3-5 vehicles currently commercially available in North America, although some battery-electric variants are currently in the pipeline. The lack of municipal deployments of vehicles of this class across Canada was identified as a key constraint along with the concerns of the existing variants meeting the operational requirements. For some of the vehicles of this class, long operational deployment of around 15-20 hours presents a significant challenge for any alternative technology with limited downtimes. A particular constraint with procuring transitional technology vehicles is futureproofing as they are expected to be soon replaced by zero-emission vehicles.
Risks	Given the nascent stage of the battery-electric and hybrid-electric variants of these vehicles, there is a risk of supply chain and spares availability. The severe operational deployment contributes to the prominent risk of vehicles being unable to find sufficient time for charging or poses of financial risk of needing fast charging equipment. Given the high capital costs for these vehicles, there is a significant concern of never being able to achieve break even for these trucks. Given that there are several zero-emission variants currently under development, any procurement of transitional technologies will lead to the City being "locked-in" to these vehicles for the duration of their operational life or incur financial loss by retiring the vehicle earlier.
Solutions	It is recommended to have a phased approach towards the replacement of the vehicles in this class with the initial phase involving the continued use of existing greenhouse gas technologies until 2030. The second phase of this transition will involve the replacement of these greenhouse gas technology vehicles with zero-emission variants which are expected to be commercially available and technologically mature by that point. It is expected that the vehicles of lower classes can be transitioned to zero-emission variants earlier than this class. This timeline will ensure that the City is also able to learn more from the experience of other municipalities that had successfully navigated towards a zero-emission fleet comprising vehicles of this class.

6.1.5 Class 6, 7 & 8 Propulsion Technologies (Heavy-Duty Truck Platforms)

The City of Saint John's fleet comprises of 32, Class 6-8 heavy duty truck platforms distributed across various user groups. These vehicles are currently used for heavy-duty applications and constitute approximately 13% of the City's fleet. While there have been commercial variants based on CNG and hybrid diesel/gas-electric technology available since the mid-2010s, the advent of battery-electric variants has been recent with many battery-electric and some hydrogen fuel cell variants being currently in the development pipeline of various OEMs.

Given that there are limited commercially available options for zero-emission vehicles in this category, the following analysis is relevant to all the departments for this class of vehicles.

Table 6.7: Future State Considerations for Class 6,7 & 8 Vehicles for all City Departments

Class 6, 7 & 8 Propulsion	All City Departments

Technologies (Heavy-Duty Truck Platform)	
Opportunities	Plug-in hybrid and CNG variants of these vehicles are currently commercially available with battery-electric variants being currently in the developmental pipeline while hydrogen fuel cell-based vehicles still in a nascent stage. This presents an opportunity to significantly reduce the GHG emission footprint by transitioning the existing fleet to the available low-emission variants. The procurement schedule has also identified several scheduled procurements for vehicles of this class from 2024 onwards, which will be an opportunity to initiate this transition early and thus enable a faster GHG emissions decline. The City has already achieved a considerable reduction in their GHG emission levels from 2015 which provides the flexibility in terms of timeline for making the transition to zero-emission vehicles.
Constraints	Currently there are no existing battery electric or hydrogen variants of the Class 6-8 vehicles commercially available in North America, although some battery-electric variants are currently in the pipeline. The lack of municipal deployments of vehicles of this class across Canada was identified as a key constraint along with the concerns of the existing variants meeting the operational requirements. Long operational deployment of around 20 hours for heavy duty trucks presents a significant challenge for any alternative technology. The downtime windows, that can be availed for charging, are of limited durations (30 minutes). A particular constraint with procuring transitional technology vehicles is futureproofing as they are expected to be soon replaced by zero-emission vehicles.
Risks	Given the developmental stage of the battery-electric and nascent stage of hydrogen-fuel cell variants of these vehicles, there is a risk of supply chain and spares availability. The severe operational deployment contributes to the prominent risk of vehicles being unable to find sufficient time for charging or poses significant financial risk of needing fast charging equipment. Given the high capital costs for these vehicles, there is a significant concern of never being able to achieve break even for these trucks. Hybrid electric vehicles and CNG vehicles are currently commercially available but will continue to have a carbon footprint. This continued carbon footprint may lead to financial burden when the carbon tax comes into effect. Given that there are several zero-emission variants currently under development, any procurement of transitional technologies (CNG, hybrid electric) will lead to the City being "locked-in" to these vehicles for the duration of their operational life or incur financial loss by retiring the vehicle earlier.
Solutions	The challenges associated with heavy duty operational requirements, limited spare vehicles due to high capital costs for replacement, the lack of commercially available zero emission variants, and the potential risk of being "locked" in transitional technologies present a considerable barrier. Given that the City is well on track to achieve its emission reduction goals, a phased approach towards vehicle replacement is recommended. The first phase of this approach will involve continuing with the existing GHG based

	conventional propulsion-based vehicles for heavy operational use with gradual induction of CNG vehicles for relatively lesser operational requirements and for getting staff to get hands-on training. The subsequent phase will initiate with the next round of procurement and will involve the procurement of zero-emission technology variants as it is expected that the zero-emission variants will be commercially available by them. This solution fits well with the scheduled procurements 2024 onwards. It is expected that the vehicles of lower classes can be transitioned to zero-emission variants earlier than this class. There is also a need to learn more from the experience of other municipalities that have successfully navigated towards a low/zero-emission fleet in managing the transition of vehicles of this class.

6.1.6 Class 7 Propulsion Technologies (Streetsweepers)

The fleet of 2, Class 7, street sweepers used by the Public Works Department for the sweeping and cleaning of the City's roadways are a critical component of the City's fleet. The cleaning operations are heavy duty as these streetsweepers can collect tonnes of dust per minute and, therefore, these vehicles have significant auxiliary power requirements.

The following table presents an analysis of the transition dynamics associated with these streetsweepers.

Table 6.8: Future State Considerations for Class 7 Vehicles (Streetsweepers)

Class 7 Propulsion Technologies (Streetsweeper)	Public Works Department
Opportunities	Streetsweeper form a critical component of any municipal fleet. Given the nature of operations of these vehicles, they have extensive auxiliary energy requirements and therefore, transitioning them to zero- and lower-emissions variants will result in significant carbon footprint decline. Battery electric, plug-in hybrid and CNG variants of streetsweepers are currently in the advanced stage of development with commercial availability expected to occur by 2022. The hydrogen fuel cell-based streetsweeper is still under development. City of Saint John has already achieved considerable decline in their GHG emission levels from 2015 which provides the flexibility in terms of timeline for making the transition to zero-emission vehicles.
Constraints	The heavy-duty operational and auxiliary energy requirements of the streetsweeper will put forward reliability challenges for zero-emission technologies especially the battery electric and plug-in hybrid variants. The lack of earlier municipal deployment presents another barrier of lack of municipal familiarity with the operation. High financial costs will present themselves as a constraint to acquiring multiple vehicles as backups. A particular constraint with procuring transitional technology vehicles is futureproofing as they are expected to be soon replaced by zero-emission vehicles. The next rounds of replacements are scheduled to happen this year in 2022 and 2029.
	The key risk with the zero-emission variants is with respect to reliability issues in supporting heavy-duty operation and the associated high costs.

Risks	The high costs create a financial risk in terms of procuring the vehicles (inclusive of replacements) with unverified operational capabilities. Given that the zero-emission variants are expected to be commercially available soon, the procurement of transitional technologies will lead to the City being "locked-in" to use transitional technology vehicles till the end of their operational life or incur financial loss by retiring the vehicles earlier.
Solutions	The challenges associated with heavy duty operational requirements, high financial burden due to high capital costs, the lack of commercially available variants and the potential risk of being "locked" in transitional technologies present a considerable barrier for streetsweeper fleet transition. Given that the City is well on track to achieve its emission reduction goals, a phased approach towards vehicle replacement is recommended. The first phase of this approach will involve continuing with the existing GHG based conventional propulsion-based vehicles for heavy operational use up until 2024. This will be followed by induction of batter electric variant in the subsequent phase 2025 onwards as it is expected that the zero-emission variants will be commercially available by then at a lower price. There is also a need to learn more from the experience of other municipalities that have successfully navigated towards a low/zero-emission fleet in managing the transition of vehicles of this class.

6.1.7 Class 8 Propulsion Technologies (Refuse Truck)

Refuse Trucks form a significant portion of any City's fleet. They are characterized by frequent start-stop operations which results in heavy duty power and energy requirements. There are transitional technology variants (CNG, and hybrid-electric) currently commercially available with battery-electric vehicles currently in the pipeline and expected to arrive in 2022.

As the Refuse Trucks are used by the Public Works Department for the purpose of solid waste collection the following analysis is catered to this user group.

Table 6.9: Future State Analysis of Class 8 Vehicles (Refuse Trucks)

Class 7 Propulsion Technologies (Refuse Truck)	Public Works Department
Opportunities	Given the operating attributes of refuse trucks (high power and energy requirements, low average speed, low mileage, frequent start-stops), converting these vehicles to zero-emissions will result in extensive carbon emission reduction. This vehicle group has a variety of commercially available transitional technologies, including both battery electric and hydrogen fuel-cell variants. currently in development. The City has already achieved a considerable decline in their GHG emission levels from 2015 which provides the flexibility in terms of timeline for making the transition to zero-emission vehicles.

Constraints	The heavy-duty operational requirements of the Refuse Trucks will pose power draw challenges for zero-emission technologies especially the battery electric variants. This will require the need for higher battery capacity which will add weight. A particular constraint with procuring transitional technology vehicles is futureproofing as they are expected to be soon replaced by zero-emission vehicles. Current equipment has been recently procured and replacements are scheduled out to 2040.
Risks	Given the heavy-duty operational requirements of the Refuse Trucks, any failure in supporting the operations will have severe impact. Relatively high procurement costs for the Refuse Trucks also restricts municipalities from having high spare ratios. Given that the zero-emission variants are expected to be commercially available soon, the procurement of transitional technologies will lead to the City being "locked-in" to use transitional technology vehicles till the end of their operational life or incur financial loss by retiring the vehicles earlier.
Solutions	The challenges associated with heavy duty operational requirements, limited spare vehicles due to high capital costs, the lack of commercially available variants and the potential risk of being "locked" in transitional technologies present a considerable barrier. Given that the City is well on track to achieve its emission reduction goals, it is recommended to continue with the existing GHG based conventional propulsion-based systems until the next round of procurement is due. It is expected that the zero-emission variants will be commercially available by then.

6.1.8 Class 8 Propulsion Technologies (Pumper Fire Truck)

The Pumper Fire Truck group consist of pumpers, ladders, and tanker trucks, which are used by the Fire Department at the City. The Fire trucks can be required to deploy at sites for long durations and have extensive auxiliary energy requirements to support ongoing operations.

Table 6.10: Future State Considerations for Class 8 Vehicles (Pumper Fire Truck)

Class 8 Propulsion Technologies (Pumper Fire Truck)	Fire and Police Departments
Opportunities	Pumper Fire Trucks form a small yet essential component of a City's fire fleet. Given the size of these vehicles, they have extensive energy requirements and therefore, transitioning them to zero- and lower-emissions variants will result in significant carbon footprint decline. Battery electric and plug-in hybrid variants of electric pumper truck are currently in the advanced stage of development with several municipal orders lined up at the manufacturers. The hydrogen fuel cell-based pumper trucks are still under development. The CNG variants have been commercially available since 2019. The City has already achieved a considerable decline in their GHG emission levels from 2015 which provides the flexibility in terms of timeline for making the transition to zero-emission vehicles.

Constraints	The heavy-duty operational and auxiliary energy requirements of the Pumper Fire Trucks will put forward reliability challenges for zero-emission technologies especially the battery electric variants. This will require the need for higher battery capacity which will add weight. A particular constraint with procuring transitional technology vehicles is futureproofing as they are expected to be soon replaced by zero-emission vehicles. Current equipment has been recently procured and the next round of replacements are scheduled out to 2040.
Risks	The key risk with the zero-emission variants is with respect to reliability issues in supporting heavy-duty operation and the associated high costs. The high costs create a financial risk in terms of procuring the vehicles (inclusive of replacements) with limited operational capabilities. Given that the zero-emission variants are expected to be commercially available soon, the procurement of transitional technologies will lead to the City being "locked-in" to use transitional technology vehicles till the end of their operational life or incur financial loss by retiring the vehicles earlier.
Solutions	The challenges associated with heavy duty operational requirements, high financial burden due to high capital costs, the need for replacement vehicles to add resiliency against operational limitations, the lack of commercially available variants and the potential risk of being "locked" in transitional technologies present a considerable barrier for pumper fleet transition. Given that the City is well on track to achieve its emission reduction goals, a phased approach towards vehicle replacement is recommended. The first phase of this approach will involve continuing with the existing GHG based conventional propulsion-based vehicles for heavy operational use up until 2030. This will be followed by gradual induction of zero-emission vehicles in the subsequent phase in the next round of procurement as it is expected that the zero-emission variants will be commercially available by then at a lower price. There is also a need to learn more from the experience of other municipalities that have successfully navigated towards a low/zero-emission fleet in managing the transition of vehicles of this class.

6.2 Future State Considerations- Transit Vehicles

6.2.1 Transit Propulsion Technologies

Saint John Transit has a mixed fleet of 47 diesel and gasoline transit buses. Transit buses have a heavy operational duty cycle due to the frequent start-stops, kneeling and raising, and opening & closing of the entrance and exit doors. All of which will result in additional energy draws. Based on these operational characteristics and the available alternatives, highlighted in Section 4, the following analysis highlights the key aspects associated with the transition of the 28-foot and 40-foot buses.

Table 6.11: Future State Considerations for Public Transit Buses

Transit Propulsion Technologies (35-40 foot)	Saint John Transit

Opportunities	Public transit fleets serve a critical requirement of providing mobility services with a significant focus on the social equity aspect. There have been several deployments of zero-emission buses across different jurisdictions across the world. Given, the high operational requirements of the public transit fleet and high energy requirements, transitioning this fleet to zero-emission variants provides the greatest benefit in terms of emission reduction. Zero-emission bus variants have reduced operational costs due to the lower cost of energy compared to diesel fuel, along with reduced maintenance requirements because of lesser moving parts which equates to an overall reduction in the lifecycle cost of the zero-emission buses. Based on the existing procurement schedule, 4-5 transit buses are expected to be added to the fleet each year, thus providing an opportunity to initiate this transition early on. There are other transitional technologies currently available in market such as plug-in hybrid and CNG at lower capital costs. Other options include hydrogen fuel cell buses which are more expensive than battery electric buses but have the advantage of operational ranges that exceed performance values of existing diesel technologies. While the zero-emission buses are presently expensive, the battery costs are experiencing a fast decline and there is more government funding and financing available to support the transition of the public transit buses to zero-emission alternatives.
Constraints	Zero-emission buses have significantly higher capital costs as compared to the conventional diesel buses leading to a substantial upfront financial burden on the municipal agency. In addition, shifting to battery electric buses will require a complete shift in the energy and power infrastructure. This will present itself as an additional financial burden on the City. In addition, the deployment of these new battery electric buses is greatly dependent on the battery capacity, and charger size and location which are additional variables for the City to consider and ultimately manage. Given that the zero-emission buses are available the procurement of transitional technologies will lead to the City being "locked-in" to use transitional technology vehicles until the end of their operational life or incur financial loss by retiring the vehicles earlier.
Risks	The biggest risk associated with transitioning the existing greenhouse technology based transit fleet to a zero-emission fleet is the financial cost and complexity of shifting the entire transportation-energy matrix from the existing diesel and natural gas systems, and supply chain to an electric or hydrogen one. Additional risks include inadequate planning resulting in non-optimal distribution of charging/refuelling locations and non-optimal deployment of the buses. This could result in a failure in route completion, high utility bills and unexpected utility infrastructure modification requirements. Given that the zero-emission variants are commercially available, the procurement of transitional technologies will lead to the City being "locked-in" to use transitional technology vehicles till the end of their operational life or incur financial loss by retiring the vehicles earlier.
Solutions	In comparison among the zero-emission bus alternatives, battery electric buses are found to have an advantage of lower capital costs along with a

	more reliable and lower energy supply costs. Battery electric buses have also undergone multiple deployments across Canada and there are currently ongoing funding and financing programs from the Government of Canada that partially offsets the cost associated with these buses and charging solutions. Given that the local utility Saint John Energy and power generator NB Power are working to reduce the carbon intensity of the grid to zero by 2035, it presents as the most suited solution where multiple local partners can engage in the planning and deployment of the chargers and the buses. Early utility consultation and engagement will also lead to new business models that might have utility playing an active role in maintaining and installing the chargers.

6.3 Electrical Utility Consultations

The Province of New Brunswick has NB Power as its vertically integrated utility provider that covers all aspects of generation and transmission. On the distribution end, NB Power supplies power to residential and industrial units across all jurisdictions except Saint John, Edmundston, and Perth-Andover, each of which being served by local electrical utilities. The utility provider responsible for the power distribution in Saint John is Saint John Energy. Multiple rounds of consultation were conducted with Saint John Energy to develop this section.

Table 6.12: Future State Consideration for Electrical Utility

	Electrical Utility Consultations
Opportunities	The Government of Canada has identified 2050 to be the deadline for achieving decarbonization. However, there are indications from the federal government and industry that suggest that a more ambitious target may be mandated soon. Recently, Environment and Climate Change Canada has initiated a consultation process to achieve a net-zero emission grid by 2035. Both NB Power and Saint John Energy are working towards identifying cleaner alternatives as the Belledune facility, that produces 18% of New Brunswick’s electricity is expected to be closed by 2030. Apart from renewable energy options, such as solar and wind, that are being explored, NB Power is also exploring Small Modular Reactor (SMR) technology. A number of renewable energy projects have been identified in the province and are set to become operational by 2030. Additional benefits in partnering with the local utility include joint procurement and management of utility-sized batteries that can assist in peak-shaving, demand management and two-way energy flow. This will also assist in installing resiliency measures in the community along with cost sharing and lesser burden on the respective organizations. An additional benefit could be the establishment of a business model in which installation and maintenance (preventative and corrective) of charging stations can be managed by the local utility.

Constraints	Currently, the grid in New Brunswick, comparatively, has a higher footprint than the Canadian average. This essentially means that even with zero-tailpipe emission technologies like battery electric and fuel cell variants, there will still be a carbon footprint associated which might be a barrier to achieve net carbon zero goal. The consultation process to achieve a clean, net-zero grid has only recently been initiated and the conclusion of the process along with and timeline is not guaranteed. Another potential constraint from the utility side could be the capacity of existing utility infrastructure to meet the requirements for charging in the case of electric vehicle or plug-in hybrid vehicles.
Risks	The grid carbon intensity remains a key risk factor that can impact the net-zero target by 2040. Given that the consultation process among the stakeholders has been initiated by the Federal Government, the process to address this risk has begun. The utilities in New Brunswick are considering various renewable and other options (including SMR) as alternatives to existing coal-based stations in the province. There exists a risk in having the required suitable renewable energy and non-carbon-based replacements before 2030. There is a financial risk of low uptake of electric vehicles or plug-in hybrid vehicles after investing in the upgradation of the grid although this risk is small as the Federal Government has established deadlines for making the transition.
Solutions	The drive towards electrification at the Federal level and for the purpose of this study, 2035 will be considered as the grid decarbonization deadline based on the received inputs from the City and the utility providers. Based on the guidance provided by Saint John Energy, emission values of 270 grams of CO_2e per kWh will be adopted in the methodology. Given these targets, the GFP will assume a linear decarbonization of the electrical grid from the existing levels achieving zero-emissions by 2035. A methodology can be identified in terms of identifying the trigger points that require the utility infrastructure expansion. EV friendly charging policies are recommended to be pursued by the City with Saint John Energy for lower rates for overnight charging and lower demand charges to benefit infrastructure scaling.

6.4 Hydrogen Provider Consultations

Two locally based gas utilities – Charbone and Liberties – were consulted with respect to the current and future availability of Hydrogen in Saint John. In addition, discussions were also carried with the Port of Saint John to discuss potential upcoming anchor loads in the region to ensure faster scale up to achieve feasibility. The price of hydrogen was provided by two Gas Utilities, Liberties and Charbone. Notably, the price of green hydrogen is expected to be much higher in the short term and is only expected to reach the anticipated price of $8 per kg using large scale production methods and access to cheap energy. Charbone estimated the unit price of hydrogen to be closer to $12 per kg early in the adoption. The uncertainty in price will pose a risk to the City should a hydrogen strategy be selected, though industry partnerships may be available to mitigate exposure to high prices.

Table 6.13: Future State Consideration for Hydrogen Utility

	Gas Utility Consultations about Hydrogen
Opportunities	Hydrogen provides a zero-emission alternative to existing fuels and a potential advantage better meeting range constraint. Similar facility modifications are required to safely accommodate CNG and hydrogen fuel-cell vehicles. This could lead to a pathway where CNG naturally transitions to hydrogen fuel-cell vehicles. Hydrogen refuelling can be completed in minutes just like the gas/diesel refuelling process. The scaling up of hydrogen fuel utilization is much easier on the infrastructure part when compared to battery electric vehicles. Both Charbone and Liberty have highlighted their plans to develop green hydrogen. There is a project currently under-development in Quebec that will be able to produce up to 200 kgs/day within next 18 months and will be scaled up thereafter. The availability of other potential hydrogen consumers in the region especially in the Atlantic Hydrogen Alliance provides an opportunity for hydrogen exports, thus establishing anchor loads to ensure scaling up to achieve feasibility. A large-scale hydrogen adoption by the City could potentially lead to hydrogen producers exploring to lease land within the city to establish hydrogen production centres which can create additional revenue opportunities and long-term hydrogen availability, thus easing any hydrogen supply chain anxieties leading to community-wide hydrogen uptake in the future.
Constraints	Hydrogen costs are the biggest constraint. At present, the hydrogen delivery cost has been identified to be $16/kg and is expected to range in the future between $8-$12/kg with $8/kg being the optimistic case and $12/kg expected to be a more reasonable cost. Hydrogen vehicles in general are more expensive than battery electric vehicles. Another constraint for the hydrogen technology is that the hydrogen refueling stations are more centrally located and the vehicles might have to travel significant distances for refueling.
Risks	The hydrogen fuel pricing presents the greatest risk as it significantly depends upon the production scale and thus relies massively on the anchor loads and consumption uptake. A 50% difference in the hydrogen costs per kg between the optimistic and reasonable scenarios presents a significant financial risk for the City. For this study, the optimistic assumption of hydrogen cost of $8/kg is compared against the conservative estimates of the BEV scenario. While evaluating the findings of this study, it needs to be considered that all hydrogen related outputs are based on the optimistic assumption of hydrogen prices.
Solutions	For the purpose of this study, the optimistic assumption of hydrogen cost of $8/kg is incorporated in the belief that future investments in hydrogen production will be made through cooperation with Atlantic Hydrogen Alliance.

7.0 Green Fleet Plan

7.1 Purpose of Green Fleet Plan

In the context of the City's Low-Carbon Migration Strategy, the Green Fleet Plan (GFP) considers a series of potential scenarios for the City Fleets to transition to green alternatives. These scenarios forecast the capital expenditures (CAPEX), operational expenditures (OPEX), and environmental impacts of operating different fleet mixes. The City will inform its decision of which technologies it wishes to pursue using these key performance metrics. After combining these findings with non-quantitative opportunities and risks, the recommended green fleet scenario will be used by the City to create a roadmap outlining the Low-Carbon Migration Strategy pathway. A roadmap for which the City will develop a detailed implementation plan and financial budgeting strategy.

The goal of the Green Fleet Plan is to serve as a like-for-like comparison of the different fleet technologies for informing the direction of the City's Low-Carbon Migration Strategy.

The GFP was created such that all scenarios satisfied the City's zero-emission sustainability goals. The two (2) applicable targets are a commitment to reducing City emissions 30% below 2015 levels by 2025, followed by achieving carbon neutrality by 2040. As indicated in the current state section of this report, the 2025 goal has already been met for City's transportation assets. Without a significant increase in fleet size or service miles. neither of which is currently planned by the City, no additional action was required by the GFP to meet this requirement (such as the early retirement of existing fleet assets or the incorporation of renewable fuels). Therefore, the 2040 target for carbon neutrality was the required target that all GFP scenarios had to satisfy.

To serve as a quantitative comparison between various implementations of fleet alternatives, the GFP aimed to provide the following information:

- Show the magnitude of investment required for each scenario.
- Show the operating costs associated with each scenario.
- Show the scale and rate of decarbonization with each scenario.
- Compare overall results to determine the best performing scenario.

7.1.1 Inclusions and Exclusions of the Green Fleet Plan

The GFP focused on on-road transportation assets that made up the active portion of the City's fleet. This included the eight (8) public fleet vehicle groups defined Section 4.2.2.

Table 7.1 GFP Public Fleet Vehicle Groups

Vehicle Group #	Public Vehicle Group Name
1	Class 1 – General Purpose
2	Class 1 – Police Cruiser
3	Class 2 – Light Duty Pickup Truck
4	Class 3, 4, & 5 – Heavy Duty Pickup Truck
5	Class 6, 7, & 8 – Heavy Duty Truck Platform
6	Class 7 – Streetsweeper

7	Class 8 – Pumper Fire truck
8	Class 8 – Refuse Truck

Two groups of transit fleet Vehicles were included in the GFP based on Saint John Transit's active fleet, which are listed below. Please note that the current transit fleet roster also includes 60' articulated joint buses, which would normally require an additional vehicle group, however these assets are not active and are planned for retirement without renewal.

Table 7.2 GFP Transit Fleet Vehicle Groups

Vehicle Group #	Transit Vehicle Group Name
9	40' Conventional Transit Bus
10	28' Specialized Transit Bus

The transportation assets that were not included in the GFP are presented in the figure below. Generally, excluded assets were either not on-road assets, such as tools, equipment, and generators. The excluded on-road assets were historic/museum vehicles that are not used to deliver City services and not planned for renewal. Similarly, other exclusions included hyper-specialized assets, such as an armoured vehicle that was received as a gift. These vehicles do not see regular service and are not planned for renewal.

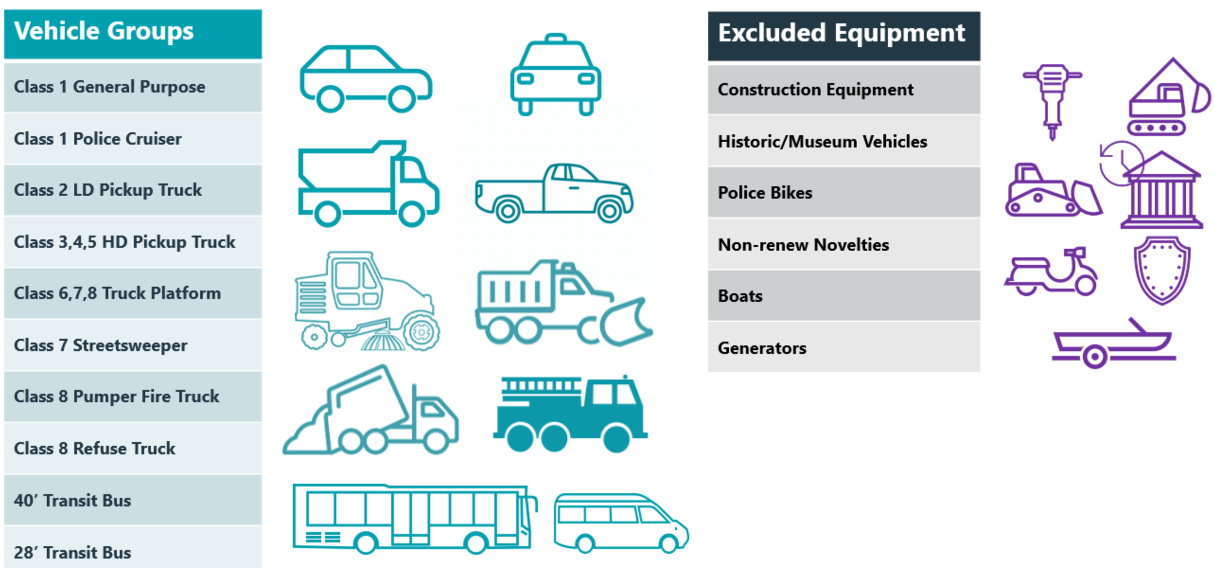


Figure 8 GFP: Included and Excluded Vehicles and Equipment

Figure 9 presents the proportion of the emissions produced in 2021 by assets included and exclude in the GFP. It is important to note that the capital costs, operational costs, and environmental impacts listed in the GFP does not include the excluded assets. Ultimately, transitioning the excluded assets to zero-emission alternatives will be necessary for the City to meet its environmental target of zero emissions by 2040. Plans for when and how to address these excluded assets will be included as part of the Low-Carbon Migration Strategy roadmap and implementation plan.

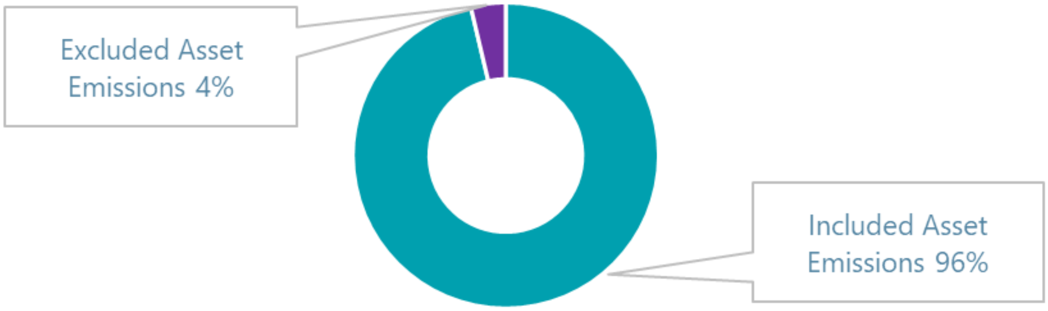


Figure 9 GFP: Proportions of Emissions between Included and Excluded Vehicles and Equipment

7.1.2 Comparative Scenarios of the GFP

7.1.2.1 Scenario 1: Business-as-Usual (BAU)

When comparing the performance of various fleet technologies, it can be helpful to present results in terms of the City's current operations. For this reason, Scenario 1 in the GFP is the BAU which models the continued procurement of GHG (diesel and gasoline) technologies. This means that each time a vehicle is retired at the end of its useful life, it will be replaced like-for-like with the existing GHG technology. No fleet expansions are anticipated up to 2040, meaning that all fleet purchases are limited to renewals. The capital and operating costs as well as the emissions will remain static, with the exception of increasing carbon tax and the impact of financial analysis factors (inflation and discount rates).

7.1.2.2 GFP Green Scenarios (2, 3, and 4)

The BAU scenario was compared with three (3) green fleet Scenarios (#2, #3, and #4). Each of the green scenarios modelled a different technology path for the City to reach its zero-emission goals. The primary mechanism for each transition is to replace vehicles with available technologies as they naturally reach the end of their expected useful lives. Early in the transition plan, replacements will be served with the current GHG (diesel or gasoline) technologies unless an effective hybrid vehicle is available. As the green technologies mature, it is expected that future replacements will involve procuring alternative technologies dependent on the scenario being modelled.

In the first green scenario, Scenario 2 – BEV, battery electric vehicles will be the primary technology used to reach zero emissions. The primary fuel used will be energy purchased from Saint John Energy and will require the deployment of significant EV charging equipment and expansions to the electrical infrastructure.

In Scenario 3 – FCEV, hydrogen fuel-cell vehicles will be the primary technology used to reach the zero-emission goal. The primary fuel used will be hydrogen purchased from a private gas utility (or utilities) and will require the deployment of a hydrogen refuelling station at the City's depot. The hydrogen fuelling partner(s) will deliver green hydrogen to site such that no emissions are attributed to City operations. Additionally, the depot will need significant modifications to safely accommodate the hydrogen vehicles.

Scenario 4 – CNG to BEV involves a deployment of CNG vehicles for the Class 6, 7, and 8 Truck Platform vehicle group. This vehicle group was identified for the opportunity as few green alternatives exist that can meet the service needs of the group, meaning that a CNG deployment may be worthwhile in lowering emissions and costs as green technologies are developed. This will involve the deployment of a CNG refuelling station and facility modifications to safely accommodate the CNG deployment. Ultimately the CNG vehicles need to be phased out and replaced with battery electric technologies to reach the City's zero-emission goals. The remaining vehicle groups will transition to battery electric vehicles as planned in Scenario 2.

7.1.2.3 Green Public Fleet Procurment/Renewal Plan

In general, light duty vehicles will begin being replaced with hybrids (PHEV and HEV) until green vehicles (BEV or FCEV) begin implementation in 2023, 2025, and 2030. Streetsweepers and Refuse Trucks will continue to be replaced with GHG vehicles until 2025, when green technologies will begin being adopted. The remaining heavy-duty vehicles will continue to be replaced with GHG vehicles until 2030, at which point they will begin to be replaced with green alternatives. Notably in Scenario 4, the Class 6, 7, 8 Truck Platform vehicle group is expected to be replaced with CNG technologies beginning in 2024 up until 2030, at which point the vehicle group will begin to be replaced with green alternatives.

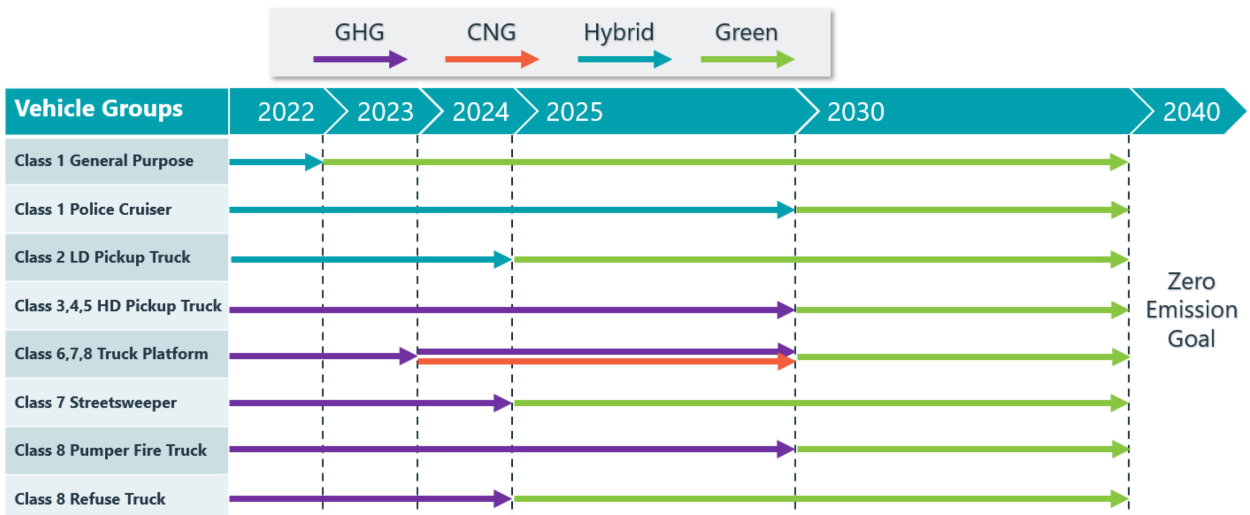


Figure 10 Expected Procurement Technology for the Public fleet

The expected useful life (EUL) of each vehicle group was developed collaboratively using historic replacement frequencies. This was supplemented with information regarding historic lifespans, identifying vehicles that were purchased “used” rather than “new”. The City’s expectation of future asset EUL was also incorporated in the final values used in the GFP. The final EUL values for each public fleet vehicle group are presented in Table 7.3.

Table 7.3 GFP Expected Useful Lives for Public Fleet Assets

Vehicle Group #	Public Vehicle Group Name	Expected Useful Life (Years)
1	Class 1 – General Purpose	10
2	Class 1 – Police Cruiser	6
3	Class 2 – Light Duty Pickup Truck	10
4	Class 3, 4, & 5 – Heavy Duty Pickup Truck	6
5	Class 6, 7, & 8 – Heavy Duty Truck Platform	10
6	Class 7 – Streetsweeper	12
7	Class 8 – Pumper Fire truck	10

8	Class 8 – Refuse Truck	13

No scenario in the GFP involves retiring assets before using them for the extent of their EUL. The timelines presented above refer to the points in time when the replacement technology will be applied to scheduled replacements. The planned procurements for the public fleet and resulting transition from GHG to Green technologies is graphically presented in Figure 11.

Figure 11 Public Fleet Procurements and Technology Mix

7.1.2.4 Green Transit Fleet Procurment/Renewal Plan

The GFP scenarios for Transit are more straightforward as Green alternatives exist that can be implemented in the short term. This means that Transit can transition its fleet into using battery-electric or hydrogen fuel-cell beginning with its next round of procurements, scheduled for 2023. To maintain the like-for-like comparison between the green technologies, the FCEV model predicts procuring hydrogen technologies for the 28' Transit Buses. This is a risk as because unlike 40' Transit Buses, FCEVs have yet to be launched commercially. This means that if the FCEV scenario was selected, some short-term adjustments to the City's procurement plan will be required to accommodate the launch of these vehicles.

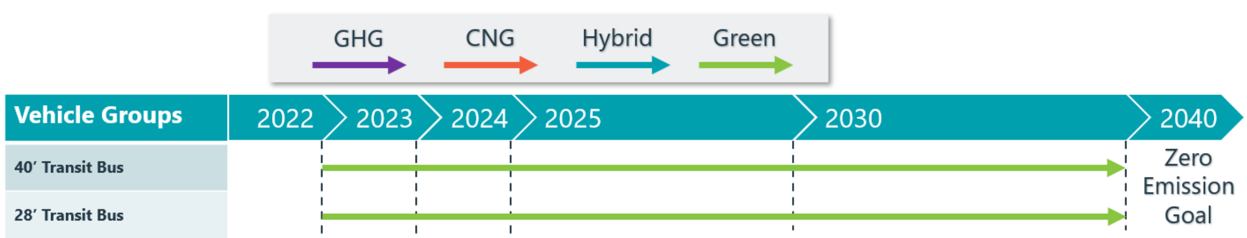


Figure 12 Expected Procurement Technology for the Transit Fleet

Similar to the public fleet assets, the expected useful lives of each transit vehicle group were developed collaboratively using the historic replacement frequencies of vehicles as a reference. This was supplemented based on the City's expectation of how future assets are expected to perform.

Table 7.4 GFP Expected Useful Lives for Public fleet Assets

Vehicle Group #	Public Vehicle Group Name	Expected Useful Life (Years)
9	40' Conventional Transit Bus	12
10	28' Specialized Transit Bus	8

The GFP modelled transit services as if they were to continue as they organised today, however it should be acknowledged that alternative modes of delivery could be implemented between now and 2040. At the time of writing, Saint John Transit is evaluating new types of service that would allow it to downsize its fleet. Specifically, some regular service fixed routes may be transitioned to on-demand transit in the future, which may be better served by 28' Transit vehicles. The result is that some 40' buses may be renewed as 28' buses. No detailed transition has been developed as the feasibility study and pilot of the new on-demand service are on-going. For the GFP, the procurements will follow the existing rate of renewal under the assumption that no changes are made to transit service delivery (fleet size mix, annual mileage, fuel consumption).

Figure 13 Transit Fleet Procurements and Technology Mix

7.1.3 GFP Inputs and Assumptions

7.1.3.1 Financial Modelling Factors

The GFP model used the City of Saint John's standard inflation rate and discount factor. The inflation rate was applied to all scenarios to express values in real dollars, whereas the discount factor was reserved to net present value (NPV) calculations.

The Technology Discount Factor was an additional discount factor applied to the capital cost of procuring zero-emission technologies (BEV and FCEV). This rate was provided to de-escalate the cost of procuring zero-emission technologies as they're production techniques mature, competition between OEMs increases, and economies of scale are realized.

Table 7.5 GFP Financial Modelling Factors

Financial Input	Value
Inflation Rate	2.2%
Discount Factor	3.0%
Technology Discount Factor	2.5%

7.1.3.2 External Funding

The City of Saint John expects to access external funding resources to assist the procurement of green fleet assets. This funding could be provided from a variety of institutions and programs such as the federal government through the Canadian Infrastructure Bank (CIB) and the provincial government through the

Federation of Canadian Municipalities (FCM). These funds are modelled using the expected external funding contribution as a proportion of green vehicle capital costs procured during the time that these funds will be available. These expectations are listed for the Public Fleet and for the Transit Fleet in Table 7.6. Which funds the City should access for which deployments is a topic reserved for the implementation plan discussed in Section 8.0.

Table 7.6 GFP External Funding Factors

External Funding Input	Public Fleet Value	Transit Fleet Value
External Funding Proportion	15%	50%
External Funding Availability	2022-2030	2022-2027

7.1.3.3 Procurement Prices

The procurement prices for each vehicle group are an average of what a vehicle in that group will cost to replace once existing assets reach the end of their useful lives. Procurement prices for alternatively fuelled vehicles were sourced from the market scan findings and supplemented with direct OEM inquiries. Where no pricing information was available, similar cost ratios between similar alternative technologies and GHG prices were used to estimate procurement costs.

Table 7.7 GFP Procurement Prices

Vehicle Group Prices	GHG ($)	BEV ($)	FCEV ($)	Hybrid/CNG ($)
Class 1 General Purpose	28,000	38,198	62,750	35,682
Class 1 Police Cruiser	61,000	67,590	77,750	66,502
Class 2 LD Pickup Truck	55,000	68,000	81,600	55,000
Class 3,4,5 HD Pickup Truck	88,000	120,000	144,000	NA
Class 6,7,8 Truck Platform	425,000	633,000	735,600	510,000
Class 7 Streetsweeper	300,000	860,000	1,032,000	NA
Class 8 Pumper Fire Truck	675,000	2,125,000	2,550,000	NA
Class 8 Refuse Truck	330,000	1,000,000	1,200,000	396,000
Conventional Buses (35'-40')	550,000	1,000,000	1,250,000	NA
Specialized Buses (26'-30')	200,000	500,000	900,000	NA

7.1.3.4 Fuel Economy

The fuel economies for the GHG vehicles were compiled based on historic data from the City's fleet telematic system. Where fleet data was not available, fuel economies were generated using OEM specifications for similar vehicle classes. The same process was applied to alternative technologies that the City did not operate at time of writing. Some vehicle groups have yet to have commercial hydrogen fuel-cell product launches, in which case estimations were derived from other hydrogen vehicles of similar size.

Table 7.8 GFP Fuel Economy

Vehicle Group Prices	GHG ($)	BEV ($)	FCEV ($)	Hybrid/CNG ($)
Class 1 General Purpose	0.095	0.208	0.0087	0.220 (kWh/km)
Class 1 Police Cruiser	0.098	0.223	0.0087	0.098 (L/km)
Class 2 LD Pickup Truck	0.183	0.532	0.0250	0.064 (L/km)
Class 3,4,5 HD Pickup Truck	0.269	0.588	0.0250	NA
Class 6,7,8 Truck Platform	0.622	1.629	0.1000	0.250 (kg/km)
Class 7 Streetsweeper	0.385	1.643	0.1000	NA
Class 8 Pumper Fire Truck	0.713	1.629	0.1000	NA
Class 8 Refuse Truck	0.814	1.623	0.1250	0.250 (kg/km)
Conventional Buses (35'-40')	0.512	1.140	0.067	NA
Specialized Buses (26'-30')	0.305	0.800	0.035	NA

7.1.3.5 Maintenance Cost Expectations

The annual maintenance cost of the GHG vehicles were calculated using historical data for each vehicle group, this formed the baseline maintenance cost for GHG vehicles. Using maintenance cost savings expectations available from industry and academic reports, BEV and FCEV factors were produced to forecast costs in relation to the GHG baseline.

Table 7.9 GFP Annual Vehicle Maintenance Cost

Vehicle Group Annual Maintenance	GHG ($) (Baseline)	BEV Factor	BEV ($)	FCEV Factor	FCEV ($)
Class 1 General Purpose	1,274	60%	764	65%	828
Class 1 Police Cruiser	4,134	60%	2,481	65%	2,687
Class 2 LD Pickup Truck	3,365	60%	2,019	65%	2,187
Class 3,4,5 HD Pickup Truck	6,488	60%	3,893	65%	4,217
Class 6,7,8 Truck Platform	20,486	70%	14,340	75%	15,364
Class 7 Streetsweeper	33,969	70%	23,779	75%	25,477
Class 8 Pumper Fire Truck	14,573	70%	10,201	75%	10,930
Class 8 Refuse Truck	23,206	70%	16,244	75%	17,404
Conventional Buses (35'-40')	29,298	75%	21,974	75%	21,974
Specialized Buses (26'-30')	8,268	75%	6,201	75%	6,201

7.1.3.6 Fuel and Electricity Prices

The listed prices for gasoline and diesel were provided by the City based on its historic and expected rates. The Price of CNG was provided through a sample of Canadian and US prices. The price of hydrogen was provided by two Gas Utilities, Liberties and Charbone. Notably, the price of green hydrogen is expected to be much higher in the short term and is only expected to reach the anticipated price of $8 per kg using large scale production methods and access to cheap energy. Charbone estimated the unit price of hydrogen to be closer to $12 per kg early in the adoption. The uncertainty in price will pose a risk to the City should a hydrogen strategy be selected, though industry partnerships may be available to mitigate exposure to high prices.

The energy rates were provided by Saint John Energy. These rates are variable based on the monthly peak power demand (100kWh/kW). For example, if the peak power load was 100kW, the first 10,000kWh would be priced at the first rate of $0.107, with the remaining energy consumed that month being priced at $0.0759.

Table 7.10 GFP Fuel Costs

Unit Cost of Fuel and Electricity	Fuel Unit	Cost ($)
Gasoline	Litre (L)	1.3241
Diesel	Litre (L)	1.3561
CNG	Kilogram (Kg)	1.0600
Hydrogen	Kilogram (Kg)	8.0000
Electricity/Energy (First 100kWh/kW)	Kilowatt-hour (kWh)	0.1070
Electricity/Energy (After 100kWh)	Kilowatt-hour (kWh)	0.0759

As is common for electrical utilities, in addition to paying for the energy consumed, Saint John energy also charges a fee for the service connection (the "Service Charge"), as well as a Demand Charge which is calculated based on the monthly power consumption peak. For example, should the monthly peak reach 100kW, the Demand Charge for that month would be $592.00 and the Service Charge would be $16.55. This calculation is then repeated for each month of the year to generate the total Utility Cost. Note that the energy cost for buying electricity is included in the GFP's "Fleet Fuel Cost" output, despite technically being a fee charged by the Utility. This decision is aligned with categorizing CNG and Hydrogen as a fuel cost rather than a Gas Utility fee, as it enables the like-for-like comparison of fuel/energy consumption and cost between various vehicle technologies.

Table 7.11 GFP Utility Fees

Additional Utility Fees	Interval	Cost ($)
Service Charge	Monthly	16.55
Demand Charge	Monthly	5.92 per kW

7.1.3.7 Fuel and Electricity Emission Factors

The fuel emission factors were sourced from the City's 2015 baseline to ensure that any fuel reductions would be compared equivalently to the City's emission target baseline. This is important for the like-for-like comparison as previous calculations used an average emission factor, when in reality different exhaust systems impact the mix of emissions produced by the consumption of fuel. This leads to different CO_2e emissions based on the vehicle being used, which wasn't considered in the baseline. Hydrogen is a new addition to the 2015 fuel list. Any hydrogen purchased by the City is expected to be Green Hydrogen, meaning that would have no emissions associated with its production or consumption.

Table 7.12 GFP Fuel Emissions Factors

Fuel Emission Factors	Fuel Unit	Emissions (CO_2e)
Gasoline	Litre (L)	0.002440
Diesel	Litre (L)	0.002683
CNG	Kilogram (Kg)	0.003022
Hydrogen	Kilogram (Kg)	0.000000

The emissions generated from the use of energy in a BEV is different than the use of the fuels listed above in that there is no "downstream" or "tailpipe" emissions. Rather the emissions are produced by the electrical grid as the energy is consumed by the grid to recharge batteries. This means that the carbon footprint from using electrical energy as a fuel is determined by the grid's carbon intensity, a measure of how much CO_2e is generated per unit of electrical energy produced. This can be measured in two ways, as a carbon intensity for "generation" or a carbon intensity for "consumption". The latter of which includes losses in efficiency and electrical distribution.

The 2015 baseline used the carbon intensity for "production"; however, Saint John Energy has advised that since energy is purchased from NB Power the "consumption" carbon intensity should be used. For this comparison, the 2015 baseline does not need to be adjusted as there no electrical energy consumed by transportation assets. The most recently published figures for New Brunswick were included in Canada's 2021 National Inventories Report to the United Nations Framework Convention on Climate Change (UNFCCC). This shows a consumption intensity of 270 grams (or 0,00027 Tonnes) of CO_2e per kWh. This value shows progress in the decarbonization of New Brunswick's electrical grid, with each year showing a lower carbon intensity.

The current legislative target provided by Saint John Energy indicates that electrical utilities are required to reach net-zero emissions by 2050. However, indications from the federal government and industry suggest that a more ambitious target may be mandated in the near future. The Liberal party has outlined their plan for a "Cleaner, Greener Future" which includes the following statement:

Canadian Target: Introduce a Clean Electricity Standard to achieve a 100% net-zero emitting electricity system by 2035 and build a prosperous net-zero economy by 2050

These initiatives mirror targets set by the United States which aim decarbonize their power sector by 2035 and achieve a net-zero economy later than 2050.

American Target: To create a carbon pollution-free power sector by 2035 and net zero emissions economy by no later than 2050.

Given these targets, the GFP will assume a linear decarbonization of the electrical grid, achieving zero-emissions by 2035. However, it should be acknowledged that despite consultations being launched regarding the implementation of these target, no formal legislation has been adopted to mandate the 2035 target. The 2035 target was chosen as the preferred forecast for electrical grid decarbonization through consultation with the City project committee.

Figure 14 GFP Electrical Emissions

7.1.3.8 Carbon Tax

In 2019, the Canadian Federal Government implemented Carbon pollution pricing systems across Canada. In this model any province or territory can design its own pricing system tailored to local needs and compliant to the federal benchmark or can choose the federal pricing system. New Brunswick's Output-Based Pricing System meets federal benchmark and stringency requirements as is expected to evolve in step with the federal benchmarks increasing carbon price. The implication for carbon pricing is that the minimum benchmark price of $50 per tonne of CO_2e in 2022 is expected to increase by $15 per year up to a high of 170 per tonne in 2030. How this is implemented in the province of New Brunswick may vary based on the implementation of the provincial system, however in lieu of specifics, the GFP will use the federal minimum as its carbon tax pricing forecast.

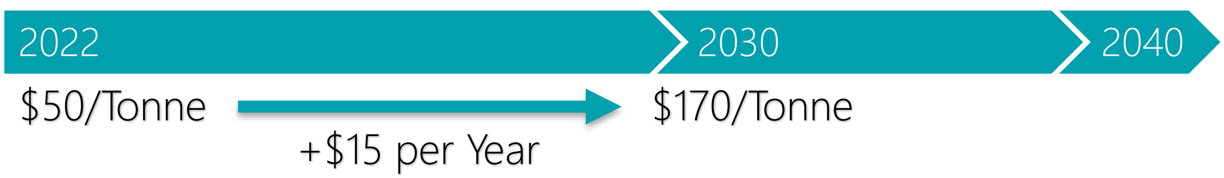


Figure 15 Federal Carbon Tax Escalation

7.1.3.9 Infrastructure Investments

The amount and type of infrastructure required to support the deployment of the different technologies varies between scenarios. For this reason, the magnitude and timing of infrastructure investment varies as well.

Beginning with Scenario 1 – BAU, no infrastructure investment is forecasted.

For Scenario 2 – BEV, the facility will require modification to accommodate the size and storage of electric vehicles and the scale deployment will require electrical utility upgrades. These costs are summarized in Table 7.3 below. Note that the cost estimates for the switchboard upgrades were estimated to accommodate 8MW of power, while the predicted requirement was refined to 3MW over the course of the analysis. It is likely that the cost to provided sufficient infrastructure will be lower than the values used in the GFP.

Table 7.13 Scenario 2 Infrastructure Investments

Scenario 2 - BEV	Cost ($)
General Facility Modifications	$30,000
Bayside Substation Circuit Upgrade	$500,000
Switchboard Upgrades	$2,000,000
(2x) 2MW Transformer	$500,000

Total	$3,030,000

For Scenario 3 – FCEV, the facility will require significant modification to safely accommodate vehicles powered by hydrogen gas due to the combustible nature of gaseous fuels. The heavy-duty vehicles in the transit and public fleets are expected to be refuelled using slow-fill dispensers located in dedicated parking locations. A fast-fill dispensing station is planned to serve the light duty fleet as well as heavy duty vehicles that will not be stationed at the McDonald Street depot, namely firefighting apparatus. Note that fast-filling a light duty vehicle with hydrogen is expected to take marginally longer than the time expected to fill a gasoline or diesel tank. An example would be 15 minutes to fill a hydrogen tank compared to less than 10 minutes to fill a gasoline vehicle.

Table 7.14 Scenario 3 Infrastructure Investments

Scenario 3 - FCEV	Cost ($)
General Facility Modifications	$800,000
Hydrogen Refuelling Station	$11,905,000
Total	$12,705,000

For Scenario 4 – CNG to BEV, the infrastructure investments are very similar to Scenario 2 as the only difference is that CNG vehicles will be employed as a transitional technology before implementing a 100% BEV fleet. This means that the facility will require all the same investments as Scenario 2 in addition to facility modifications to accommodate CNG vehicles (due to the combustible nature of gaseous fuels) and a CNG refuelling station. The refuelling strategy is to slow fill the vehicles overnight with slow-fill posts installed in designated parking stalls. To add resiliency to fleet operations, one fast-fill post will provide quick refuelling as is required. With regard to refuelling time, a CNG fast-fill location will take 50% longer to refuel than from using diesel refuelling stations. However, the actual time to fill depends on the configuration of the fast-fill post, cheaper posts are slower, whereas more expensive posts can match the diesel fuel time.

Table 7.15 Scenario 4 Infrastructure Investments

Scenario 4 – CNG to BEV	Cost ($)
General Facility Modifications (for CNG)	$800,000
CNG Refuelling Station	$835,000
All Scenario 2 Infrastructure Investment	$3,030,000
Total	$4,665,000

7.1.3.10 Refuelling Station Operating Costs

The maintenance and personnel component includes the considered a conservative estimate of routine maintenance/inspections costs including compressor overhauls. The electricity component is based on the compression equipment selected plus an additional 10% for ancillaries. The electricity cost to operate this equipment was included following electricity rates in New Brunswick.

Table 7.16 Annual Refuelling Station Operating Costs

Annual Refuelling Station OPEX	CNG	Hydrogen
Maintenance and Personnel	$11,370	$178,400
Electricity	$6,200	$97,000
Training	$4,360	$4,360
Total	$21,930	$277,230

7.1.3.11 Charging Equipment

The fees to install charging equipment was calculated on a per unit basis including the equipment and installation costs. The equipment cost represented the physical system purchased, while the installation cost included the necessary wiring and connections necessary for the equipment to function. It is possible that the City may find savings regarding installation fees through bulk purchases and a phasing plan that includes future proofing infrastructure to more readily except future equipment installations.

Table 7.17 Charging Equipment and Installation Costs

Charger Prices	7.2kW (AC)	50kW (DCFC)	150kW (DCFC)
Equipment	$1,500	$7,500	$135,000
Installation	$150	$3,000	$15,000
Total	$1,650	$10,500	$150,000

This charging equipment will need to be managed across the facility to ensure that the maximum power draw does not exceed infrastructure tolerance. Further benefits to management software are the allowance to lower the peak load (reducing utility fees), prioritize the charging of vehicles, and to incorporate other energy storage/generation assets. The connection fee listed by OEMs is in the range of $150 per charger per year. Additional fees would be applicable for more robust charge management software. The installed chargers will also require both preventive and corrective maintenance. These services are expected to be contracted to a third party at the cost of $1,500 per charger per year.

7.1.3.12 Staff Safety, Tooling, and Training

The existing transportation budget for staff safety, tooling, and training is $30,550 per year. This includes items provided by the City, such as coveralls, gloves, visors, and other personal protective equipment (PPE). The training includes additional safety sessions, and conference fees for all relevant staff. Mechanic tooling refers to the tools allowance provided to each mechanic in order for them to maintain their toolbox, replacing tools as they are damaged.

Table 7.18 Existing Staff Safety, Tooling, and Training Costs

Staff Safety, Tooling, and Training	Annual Cost ($)
Personal Protective Equipment (PPE)	$14,750
Training (Including Conferences)	$5,000
Mechanic Tooling (Per Mechanic)	(24x) $450
Total	$30,550

When forecasting the cost of transitioning to alternative technologies it is understood that additional funding will be required in all categories. Electric vehicles are a good example for this as they will require new static free tools, non-conductive clothing and PPE, as well as training to enable City staff to perform new maintenance activities. Further, the risk of high voltage systems associated with BEVs requires that all staff, from service cleaners, to operators, to mechanics and welders will need safety training to be aware of high-voltage risks. Similar additional costs are associated with other fuel types, including electric hybrids (HEV), plug-in electric hybrids (PHEV), Compressed Natural Gas (CNG), and hydrogen fuel-cell (FCEV). Additional maintenance equipment can be phased in as the portion of new vehicle technologies grow and the maintenance team performs more service activities in-house. Therefore, the additional cost of each scenario was estimated as a factor of the existing budget. For the BEV and FCEV scenarios, some light duty hybrids are expected followed by a single fuel type, leading to an increase of 50%. For Scenario 4, the increase was estimated at 100% due to the further inclusion of CNG fuelled vehicles. These increases are summarized in Table 7.19.

Table 7.19 Charging Equipment and Installation Costs

Scenario Staff Costs	Scenario 2 (BEV)	Scenario 3 (FCEV)	Scenario 4 (CNG to BEV)
Factor	+50%	+50%	+100%
Total	$45,825	$45,825	$61,000

7.1.3.13 Additional GFP Considerations

The primary output of the GFP is the capital cost, operational cost, and environmental emissions associated with each pathway to zero emissions. Once a preferred approach is selected, additional opportunities may be identified to further optimize the transition. This may include bundled procurements, the award of additional external funds, innovative practices such as charging as a service (CaaS), and changes in service delivery such as implementing on-demand transit.

These quantitative outputs can be helpful in determining a preferred roadmap, however additional consideration is required for qualitative factors. In particular, the risks and opportunities explored in

Section 0 should be used as a reference in understanding how successful various technologies are in meeting the needs of the city.

These items are considered alongside the results of the GFP in Section 7.3, which conclude in a final recommendation for planning the City's Carbon Migration Plan. The implementation opportunities and risks for the recommended scenario are explored in detail in Section 0.

7.2 GFP Results

7.2.1 Net Present Value Comparison

The gross cost comparison of the GFP scenario is a summation of all modelled costs over the 18-year period from 2022 to 2040. The net present value comparison uses the inflation rate and the discount rate to evaluate the costs in the context of 2022 Canadian dollars, reflective of the time value of money. Using the business-as-usual scenario as a baseline, scenarios 2 and 4 perform similarly well, with both being approximately 5% less expensive than the BAU. Conversely scenario 3 shows an increase of 18% above the cost of the BAU.

Table 7.20 GFP Net Present Value Comparison

City of Saint John Green Fleet Strategy	Scenario Results (NPV)			
Scenario Summary [Gross Costs]	**Saint John BAU**	**BEV**	**FCEV**	**CNG to BEV**
Model Duration	2022-2040	2022-2040	2022-2040	2022-2040
Total	**225,845,226**	**213,886,615**	**267,798,511**	**214,746,589**
NPV GHG Comparison	**100.0%**	**94.7%**	**118.6%**	**95.1%**
NPV Difference		**-5.3%**	**18.6%**	**-4.9%**

7.2.2 Real Cost Comparison

Reals costs are calculated by expanding the nominal cost by the inflation rate. This represents the inflation adjusted price of procurements between 2022 and 2040. Scenarios 2 and 4 show total gross costs of approximately $284 million, while the BAU is higher near $293 million, and scenario 3 is the most expensive at $357 million. The summary breakdown of gross costs is presented for each scenario in Table 7.21.

Notably the expected external funding amounts to $12.5 million based on the funding expectation inputs. It is expected that the external funding contribution will exceed this amount by strategically timing procurement to occur when funding is available, rather than uniformly each year. Further external funds would be available if the City is successful in securing additional external funding sources, such as the Zero Emission Transit Fund (ZETF).

Table 7.21 GFP Gross Cost Comparison

City of Saint John Green Fleet Strategy	Scenario Results (Real)			
Scenario Summary [Gross Costs]	**Saint John BAU**	**BEV**	**FCEV**	**CNG to BEV**
Model Duration	2022-2040	2022-2040	2022-2040	2022-2040
CAPEX - Public Fleet				
Gross Fleet Renewal Cost	81,043,400	100,943,581	117,557,827	102,428,147
Gross External Funding	-	(1,920,050)	(2,425,530)	(1,920,050)
Gross Infrastructure Cost	-	4,510,663	7,368,900	5,506,916
Sub-total	**81,043,400**	**103,534,194**	**122,501,197**	**106,015,013**
OPEX - Public Fleet				
Gross Fleet maintenance Cost	41,493,963	34,541,052	35,562,493	33,985,699
Gross Fleet Fuel Cost	54,114,632	29,352,185	44,246,760	26,382,838
Gross Fleet Charging Utility Cost	-	1,500,631	-	1,489,365
Gross Fleet Infrastrucutre and Staff Operations Costs	455,611	2,565,543	4,425,905	3,262,566
Gross Fleet Carbon Tax	7,877,366	3,083,844	3,087,020	2,948,480
Sub-total	**103,941,572**	**71,043,255**	**87,322,177**	**68,068,947**
CAPEX - Transit Fleet				
Gross Fleet Renewal Cost	46,028,460	80,331,343	105,321,072	80,331,343
Gross External Funding	-	(10,639,565)	(13,979,669)	(10,639,565)
Gross Infrastructure Cost	-	3,275,508	5,893,830	4,178,665
Sub-total	**46,028,460**	**72,967,285**	**97,235,233**	**73,870,443**
OPEX - Transit Fleet				
Gross Fleet maintenance Cost	28,623,650	23,463,209	23,463,209	23,463,209
Gross Fleet Fuel Cost	25,415,959	9,854,157	21,391,566	9,854,157
Gross Fleet Charging Utility Cost	-	1,151,935	-	1,151,935
Gross Fleet Infrastrucutre and Staff Operations Costs	371,820	969,866	3,267,808	1,155,777
Gross Fleet Carbon Tax	7,496,744	1,488,025	1,488,025	1,488,025
Sub-total	**61,908,174**	**36,927,192**	**49,610,609**	**37,113,102**
Fleet Totals				
Gross Public Fleet	184,984,973	174,577,449	209,823,375	174,083,960
Gross Transit Fleet	107,936,634	109,894,478	146,845,842	110,983,545
Total	**292,921,607**	**284,471,927**	**356,669,216**	**285,067,505**

7.2.3 Environmental Emission Comparison

When comparing the environmental emissions of each green scenario, all scenarios perform similarly in reducing 50% or more emissions between 2022 and 2040. This amounts to a reduction in close to 40,000 tonnes of CO_2e. The difference in reduction is due to the progressive decarbonization of the electrical grid, whereas green hydrogen is carbon neutral beginning in 2022. Scenario 4 shows additional emission reductions through inclusion of CNG. Notably each green scenario reaches zero emissions by 2040.

Table 7.22 GFP Gross Emission Comparison

City of Saint John Green Fleet Strategy	Scenario Results (Real)			
Scenario Summary [Gross Emissions]	**Saint John BAU**	**BEV**	**FCEV**	**CNG to BEV**
Gross Public Fleet Emissions [Tonne CO2]	32,689	22,845	22,766	22,113
Gross Transit Fleet Emissions [Tonne CO2]	42,040	13,737	13,299	13,737
Total	**74,729**	**36,582**	**36,065**	**35,850**
Sub-totals	**100.0%**	**49.0%**	**48.3%**	**48.0%**
Difference		**-51.0%**	**-51.7%**	**-52.0%**

7.2.4 GFP Year 2040 Indicators

When planning future vehicle deployments, an insight that can provide additional value is forecasted scenario performance for the last year of the model. This shows that the GFP predicts no emissions for any green scenario. Regarding predicted costs, the year 2040 involves many renewals which shows that capital costs remain higher for green scenarios, particularly for transit vehicles. The inverse is true for the operational cost where significant savings are anticipated for all green scenarios.

Table 7.23 GFP Year 2040 Forecast

City of Saint John Green Fleet Strategy	Scenario Results (Real)			
Scenario Summary [2040 Indicators]	**Saint John BAU**	**BEV**	**FCEV**	**CNG to BEV**
CAPEX - 2040				
Public Fleet	5,713,844	6,222,587	7,468,856	6,222,587
Transit Fleet	2,737,082	5,663,406	7,070,394	5,675,223
OPEX - 2040				
Public Fleet	2,637,599	1,749,806	1,881,686	1,749,806
Transit Fleet	4,015,227	1,794,708	2,833,836	1,806,525
Total	**15,103,752**	**15,430,507**	**19,254,772**	**15,454,142**
Envm - 2040				
Public Fleet	2,325	-	-	-
Transit Fleet	2,213	-	-	-
Total	**4,538**	**-**	**-**	**-**

7.2.5 Scenario Capital Cost Figures (CAPEX)

7.2.5.1 Public Fleet CAPEX

The following figures (Figure 16 to Figure 19) show the anticipated capital cost for each scenario based on expected public fleet renewals. The values are provided in inflation-adjusted real dollars and compared with the budget for public fleet renewal. The replacements follow a strict replacement schedule which leads to some years exceeding the budget, with other years falling well below. This is expected due to the high price to renew heavier and more specialized vehicles (Ex: fire trucks), leading to alternating years of high expenses. The City is able to carry surplus budget in its fleet fund from one year to the next, meaning that this procurement outline is tenable.

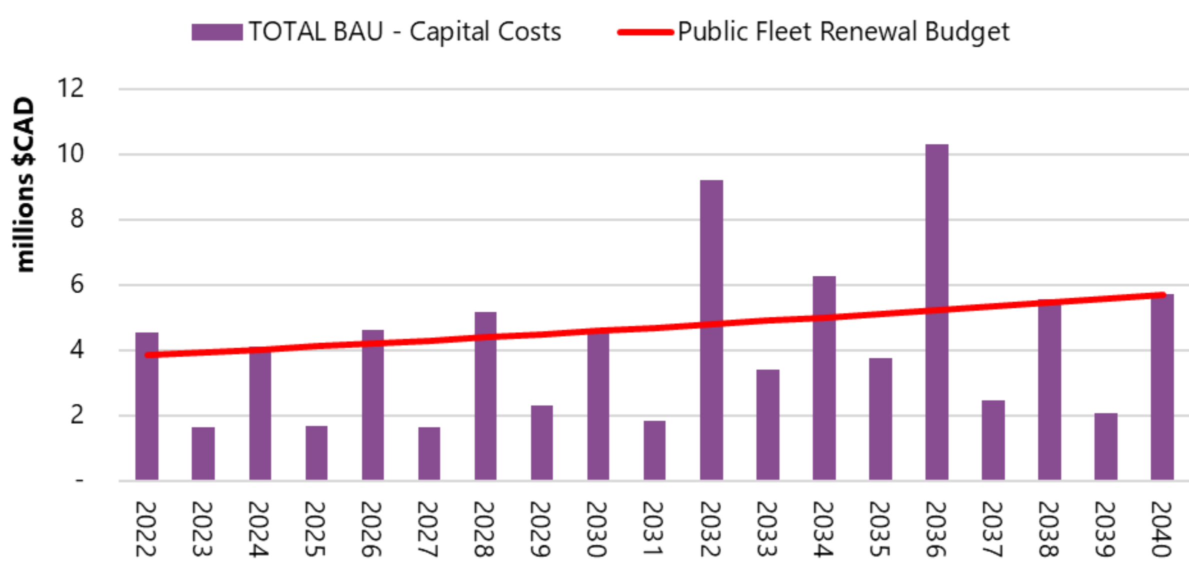


Figure 16 GFP Public Fleet CAPEX Scenario 1 – BAU

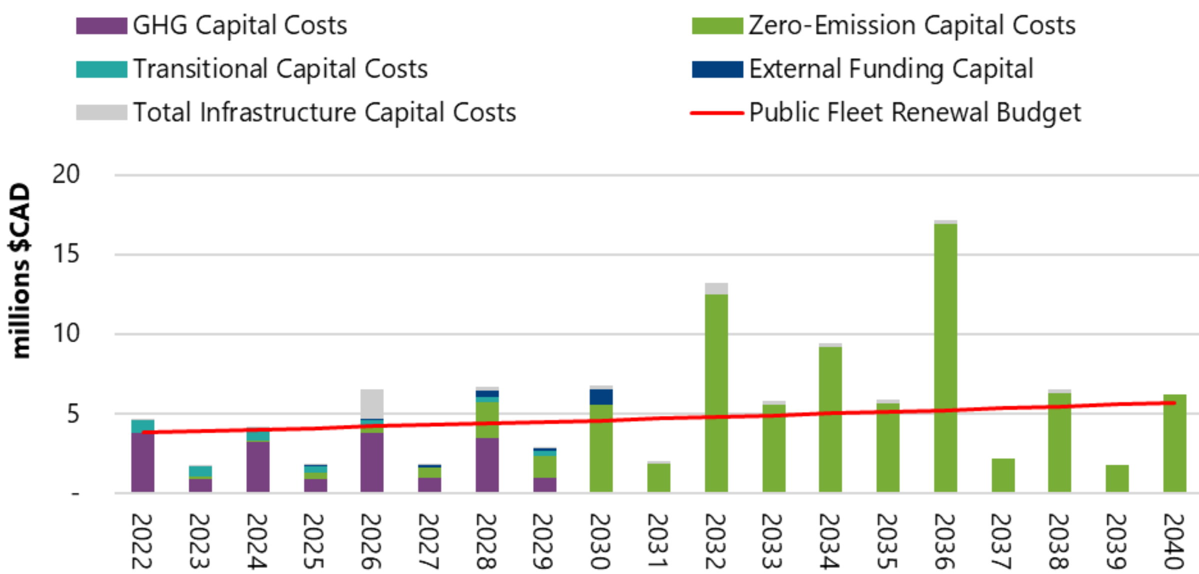


Figure 17 GFP Public Fleet CAPEX Scenario 2 – BEV

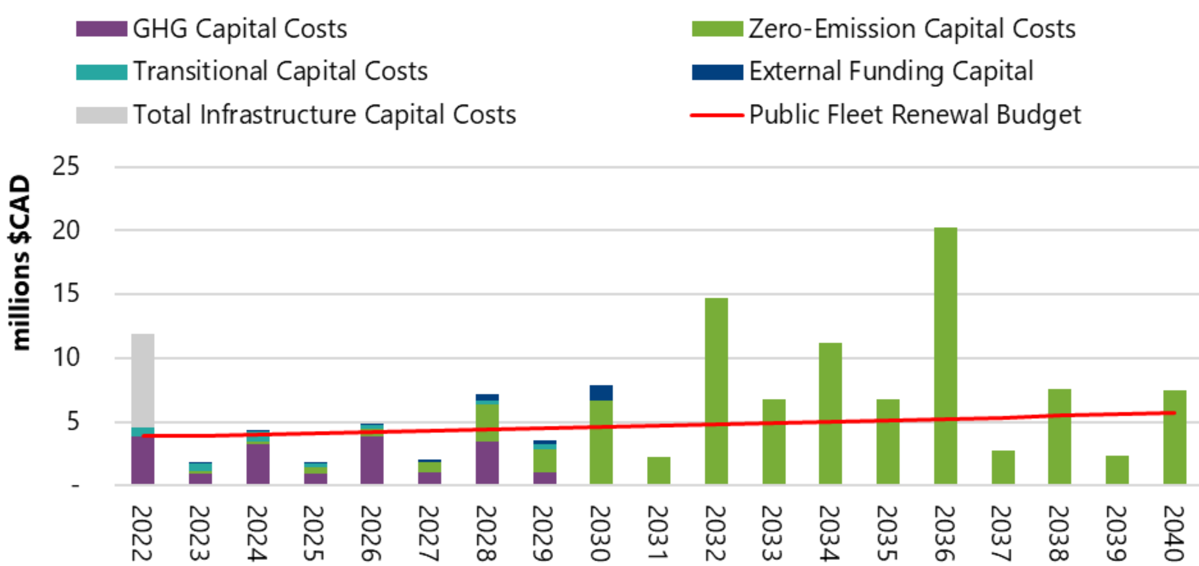


Figure 18 GFP Public Fleet CAPEX Scenario 3 – FCEV

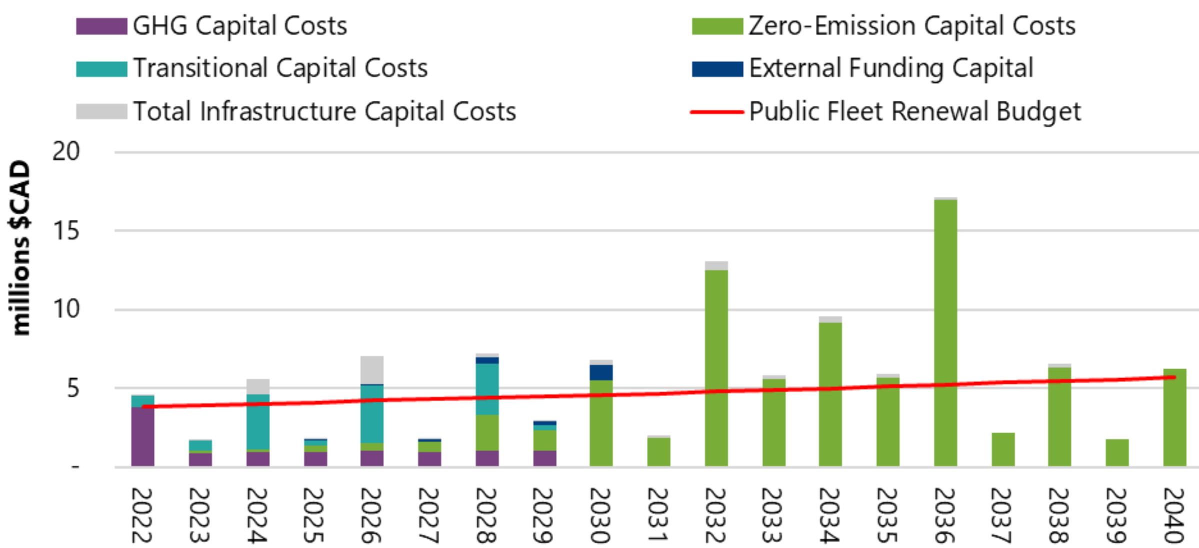


Figure 19 GFP Public Fleet CAPEX Scenario 4 – CNG to BEV

7.2.5.2 Transit Fleet CAPEX

The following figures (Figure 20 to Figure 23) show the anticipated capital cost for each scenario based on expected transit fleet renewals. The values are provided in inflation-adjusted real dollars and compared with the budget for public fleet renewal.

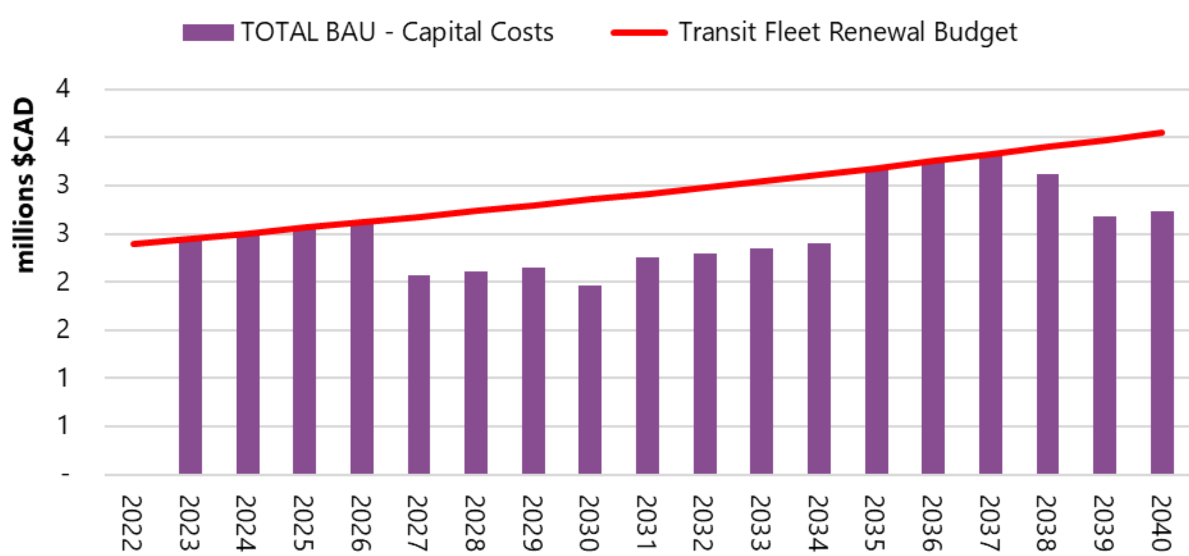


Figure 20 GFP Transit Fleet CAPEX Scenario 1 – BAU

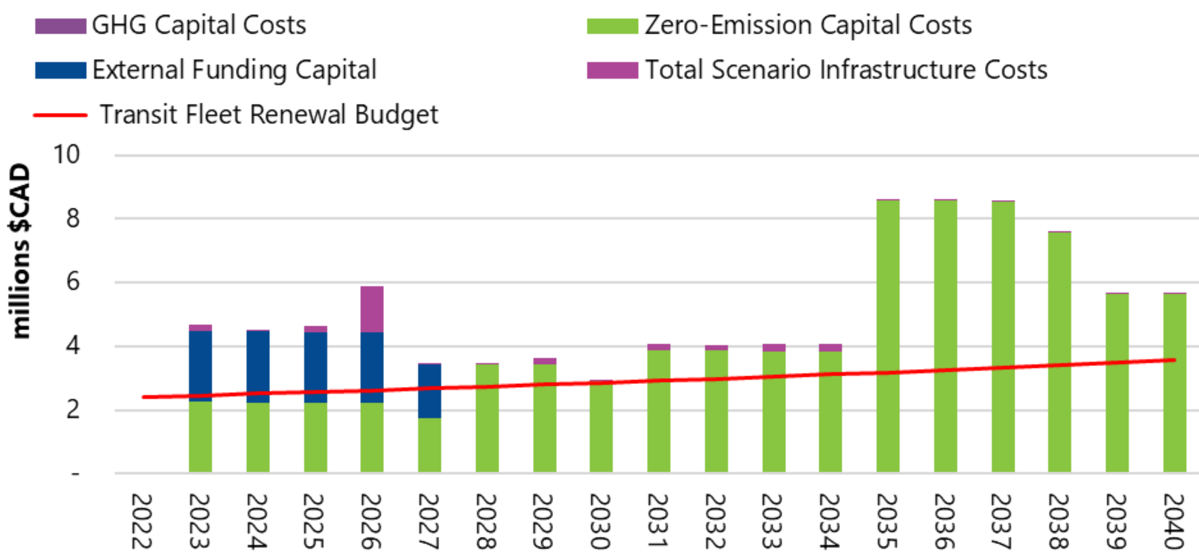


Figure 21 GFP Transit Fleet CAPEX Scenario 2 – BEV

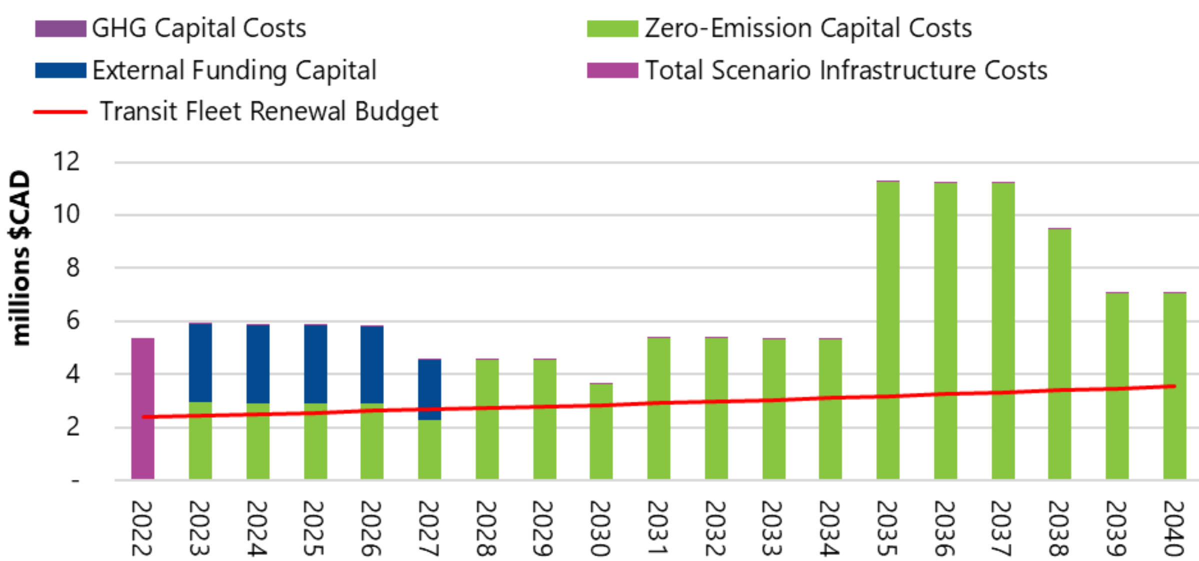


Figure 22 GFP Transit Fleet CAPEX Scenario 3 – FCEV

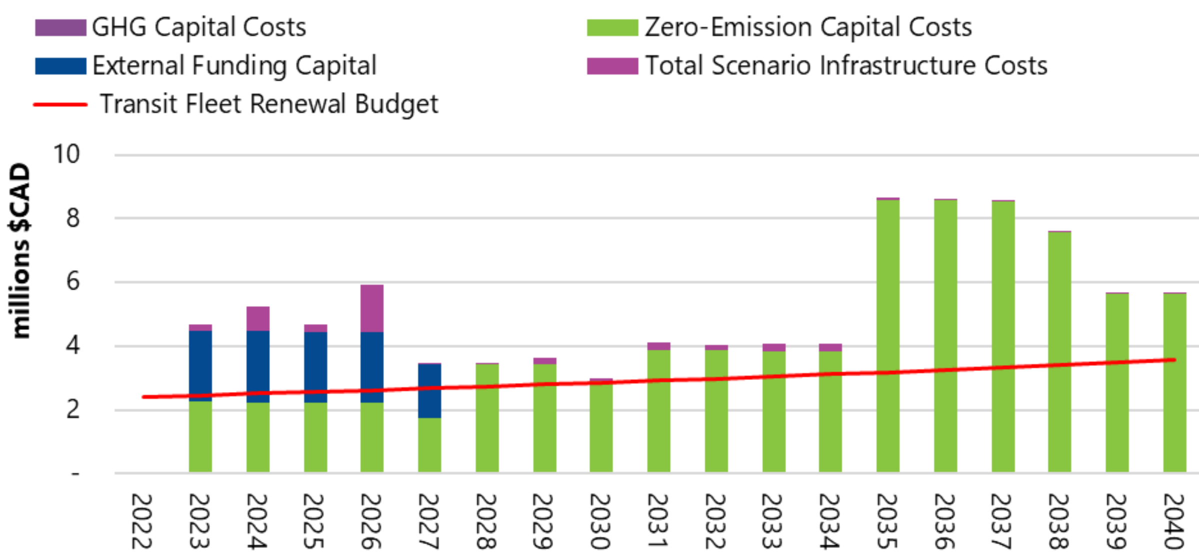


Figure 23 GFP Transit Fleet CAPEX Scenario 4 – CNG to BEV

7.2.6 Scenario Operational Cost Figures (OPEX)

7.2.6.1 Public Fleet OPEX

The following figures (Figure 24 to Figure 26) show the anticipated operational cost for each scenario based on performing service miles with each type of vehicle technology. The values are provided in inflation-adjusted real dollars and are compared with the BAU cost estimate.

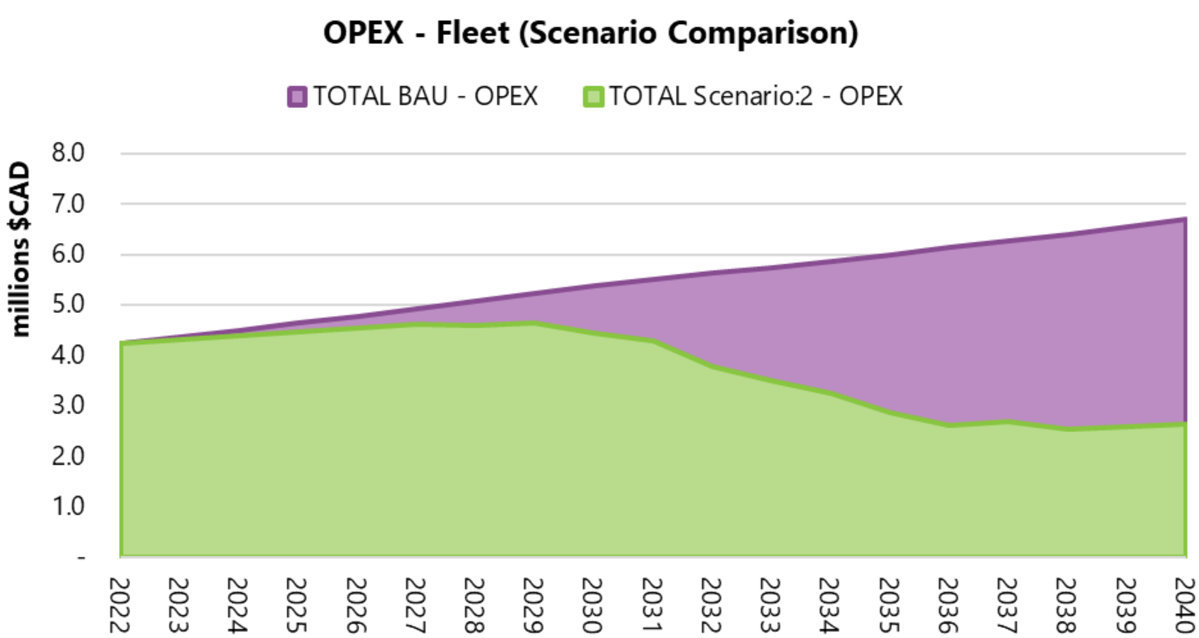


Figure 24 GFP Public Fleet OPEX Scenario 2 – BEV

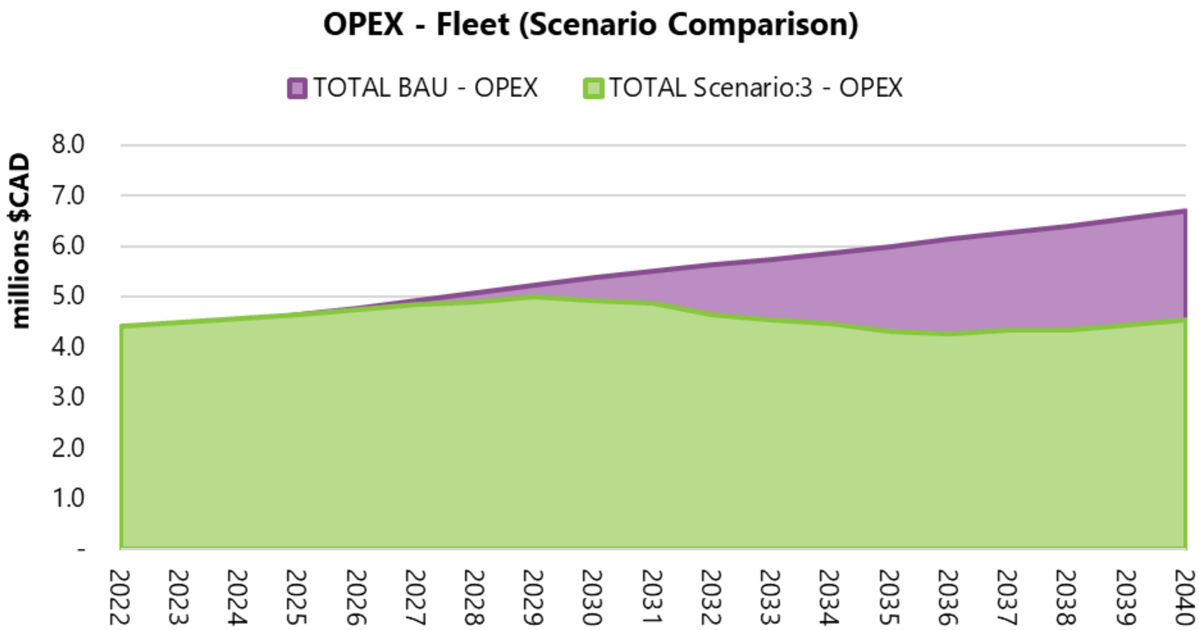


Figure 25 GFP Public Fleet OPEX Scenario 3 – FCEV

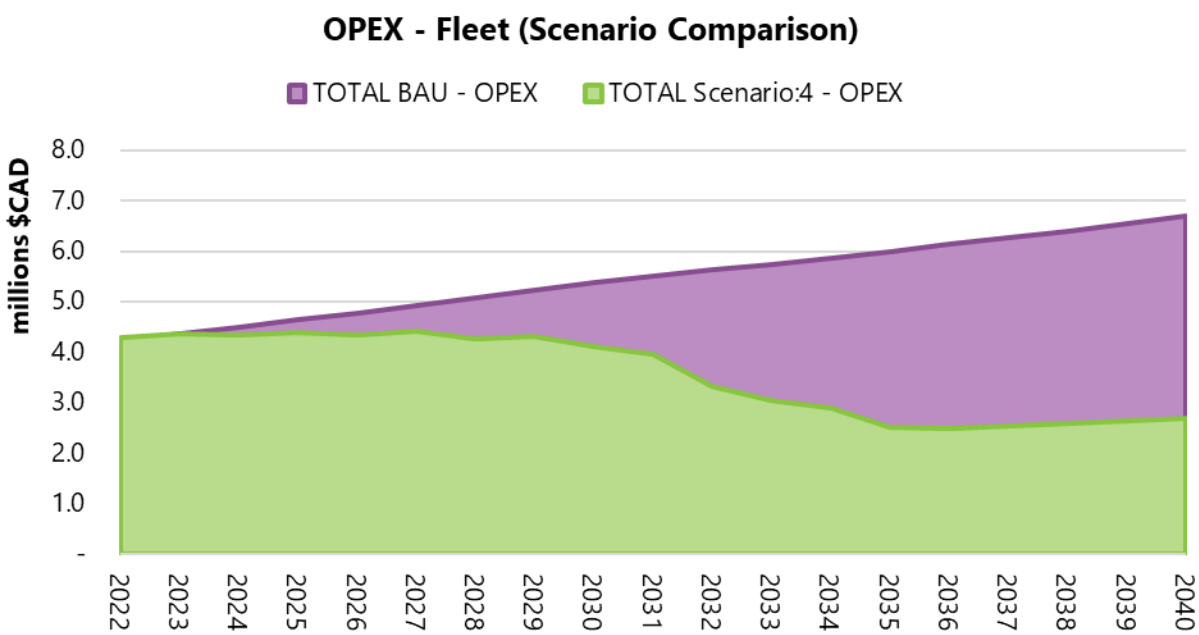


Figure 26 GFP Public Fleet OPEX Scenario 4 – CNG to BEV

7.2.6.2 Transit Fleet OPEX

The following figures (Figure 27 to Figure 29) show the anticipated operational cost for each scenario based on performing service miles with each type of vehicle technology. The values are provided in inflation-adjusted real dollars and are compared with the BAU cost estimate.

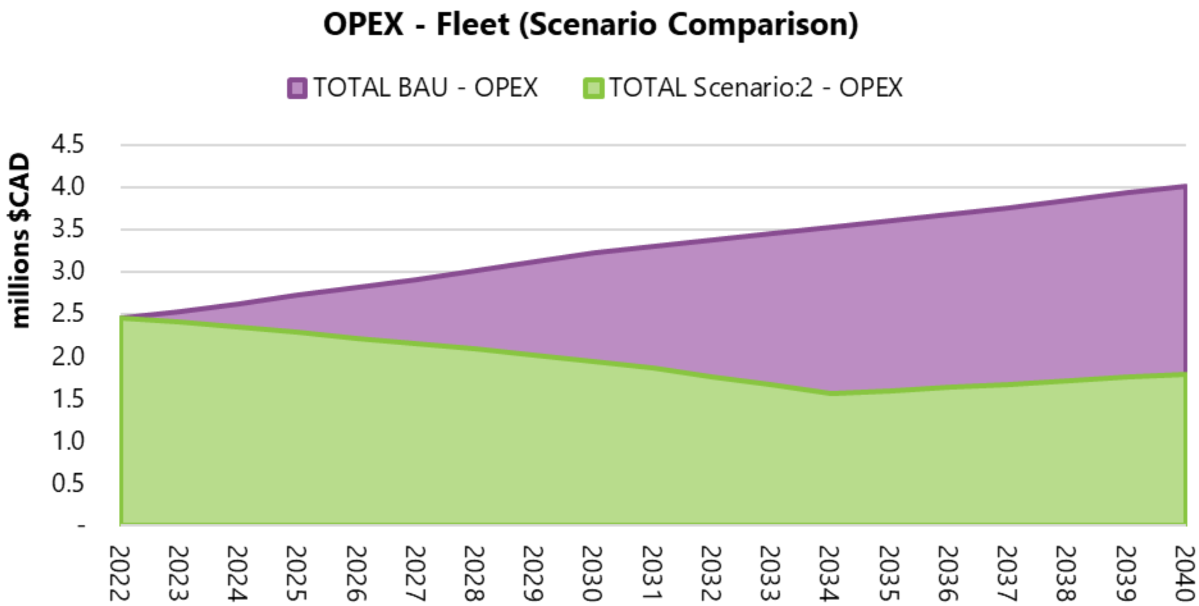


Figure 27 GFP Transit Fleet OPEX Scenario 2 – BEV

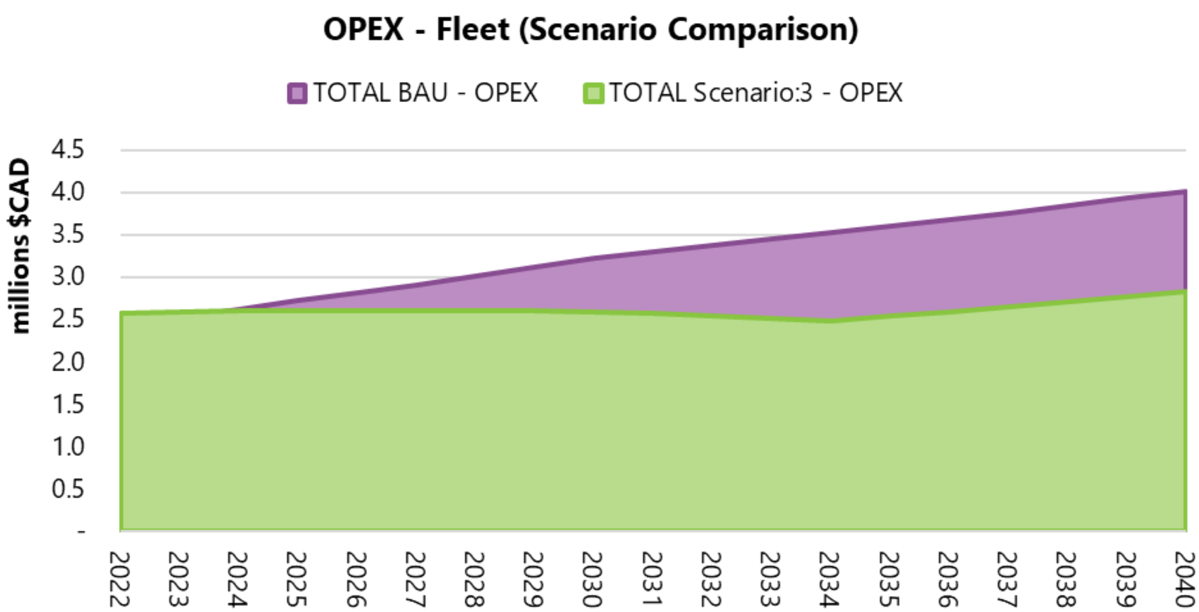


Figure 28 GFP Transit Fleet OPEX Scenario 3 – FCEV

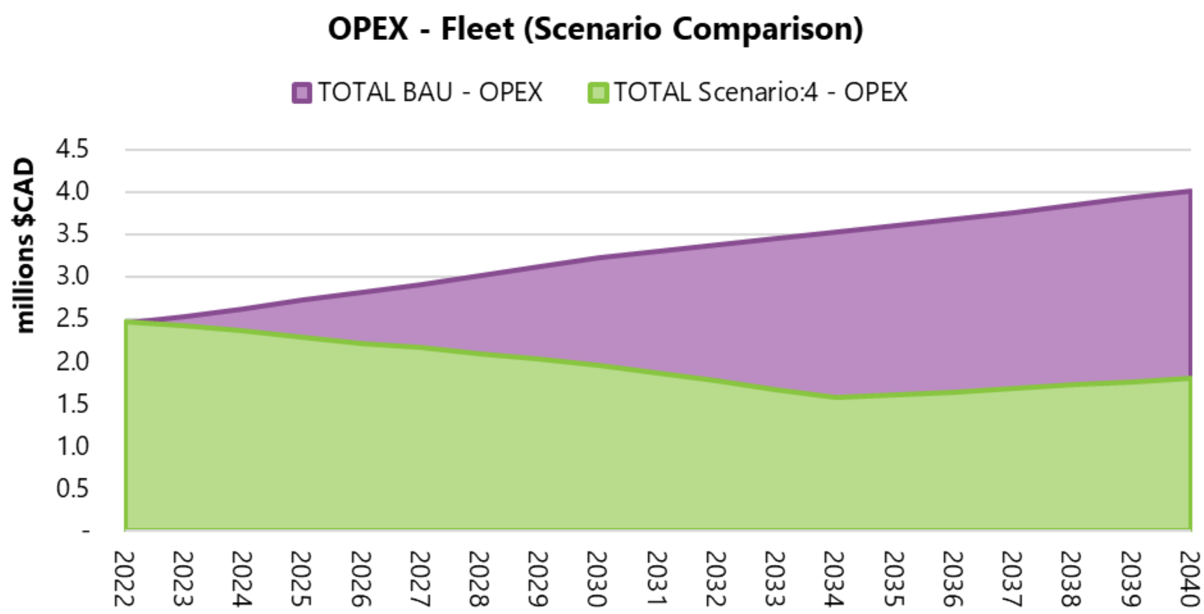


Figure 29 GFP Transit Fleet OPEX Scenario 4 – CNG to BEV

7.2.7 Scenario Environmental Emission Figures

7.2.7.1 Public Fleet Environmental Emissions

The following figures (Figure 30 to Figure 32) show the anticipated environmental emissions for each scenario based on performing service miles with each type of vehicle technology. The values are provided in tonnes of CO_2 equivalent (CO_2e) emissions and are compared with the BAU cost estimate.

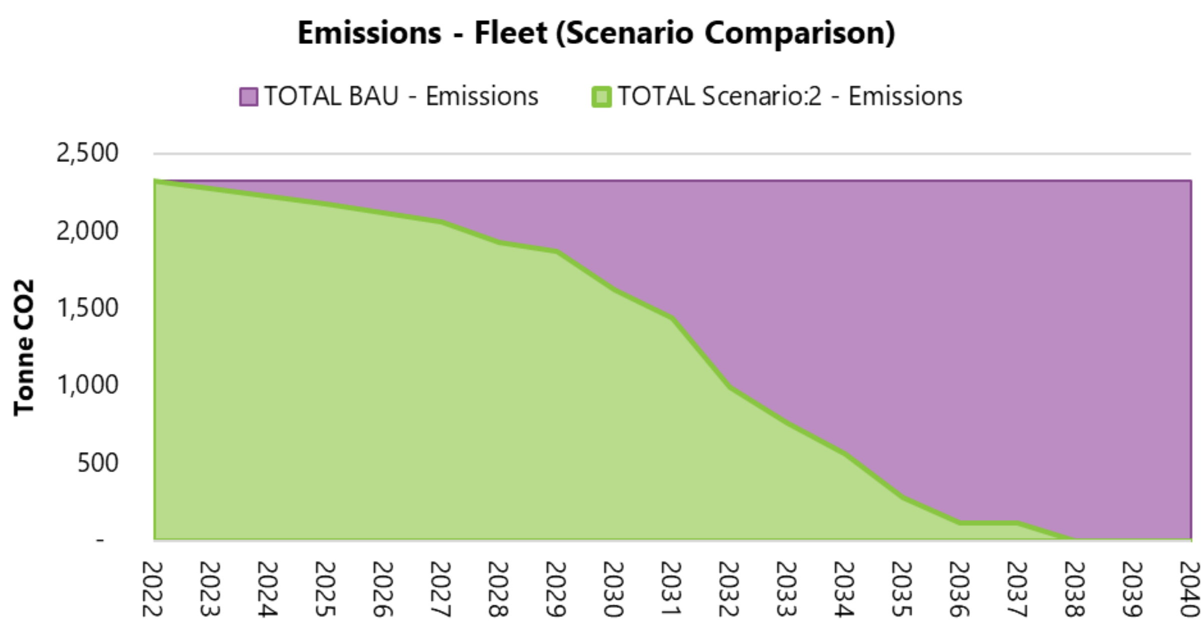


Figure 30 GFP Public Fleet Environmental Emission Scenario 2 – BEV

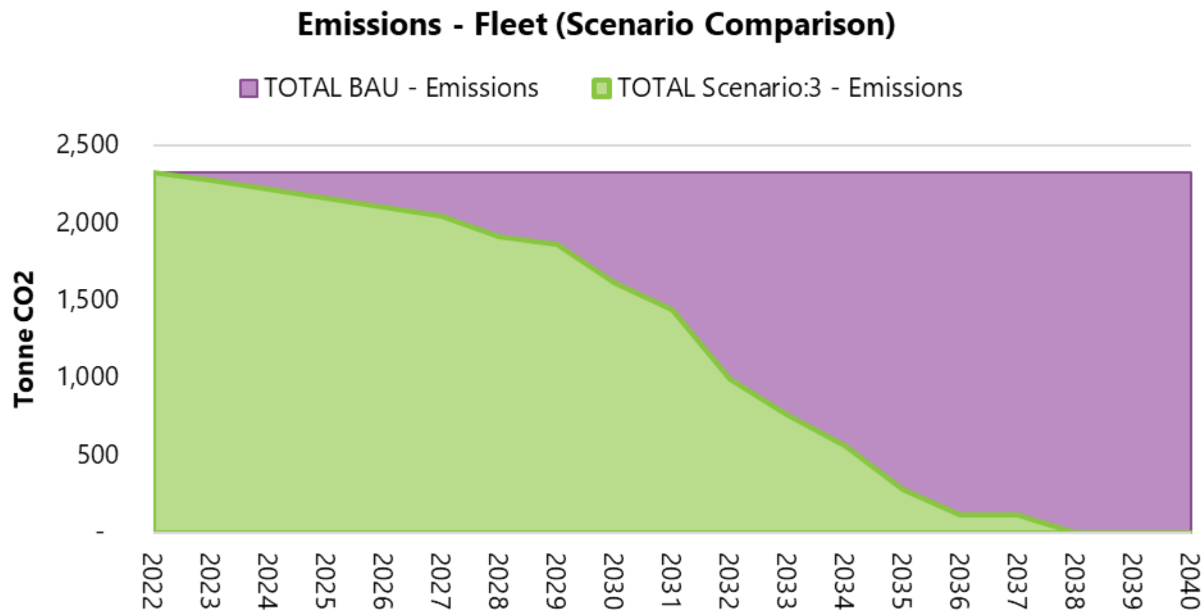


Figure 31 GFP Public Fleet Environmental Emission Scenario 3 – FCEV

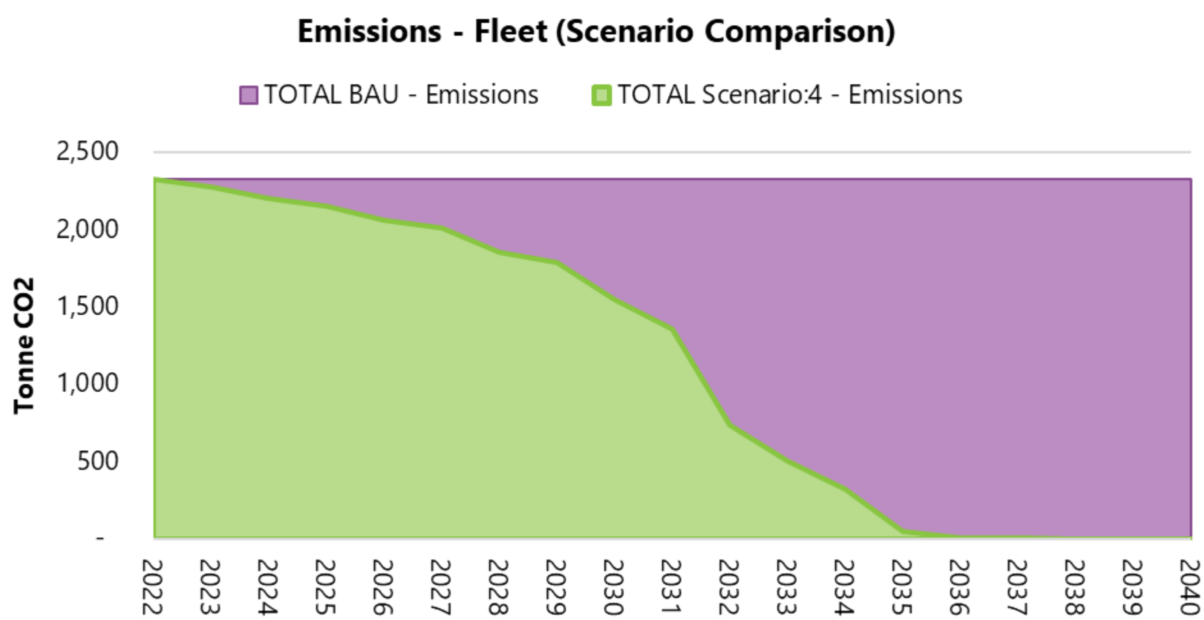


Figure 32 GFP Public Fleet Environmental Emission Scenario 4 – CNG to BEV

7.2.7.2 Transit Fleet Environmental Emissions

The following figures (Figure 33 to Figure 35) show the anticipated environmental emissions for each scenario based on performing service miles with each type of vehicle technology. The values are provided in tonnes of CO_2 equivalent (CO_2e) emissions and are compared with the BAU cost estimate.

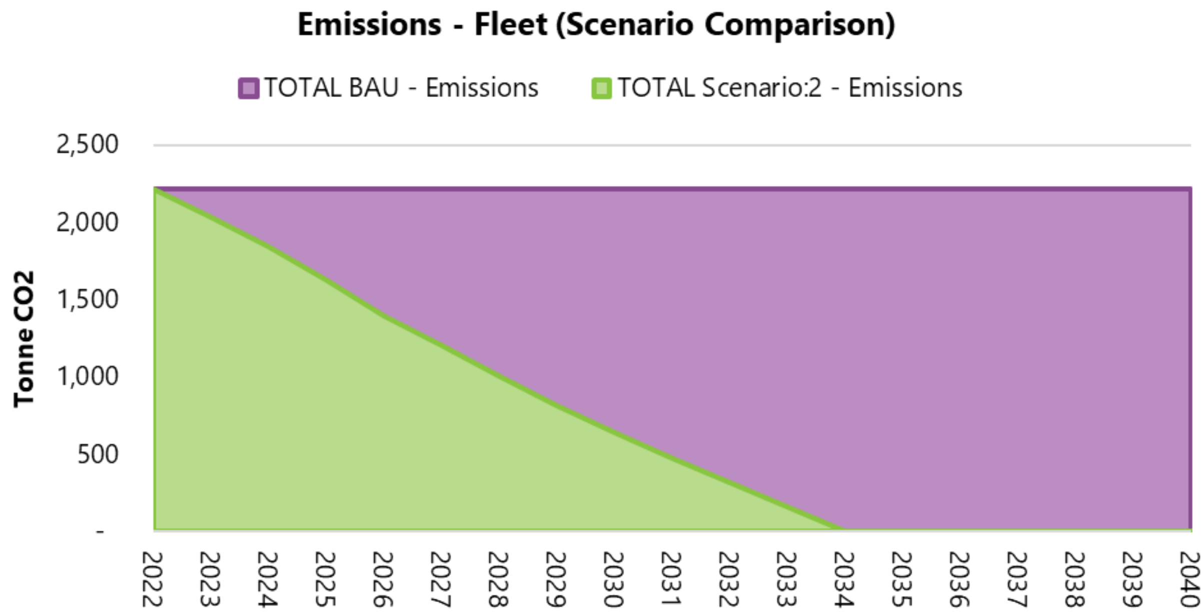


Figure 33 GFP Transit Fleet Environmental Emission Scenario 2 – BEV

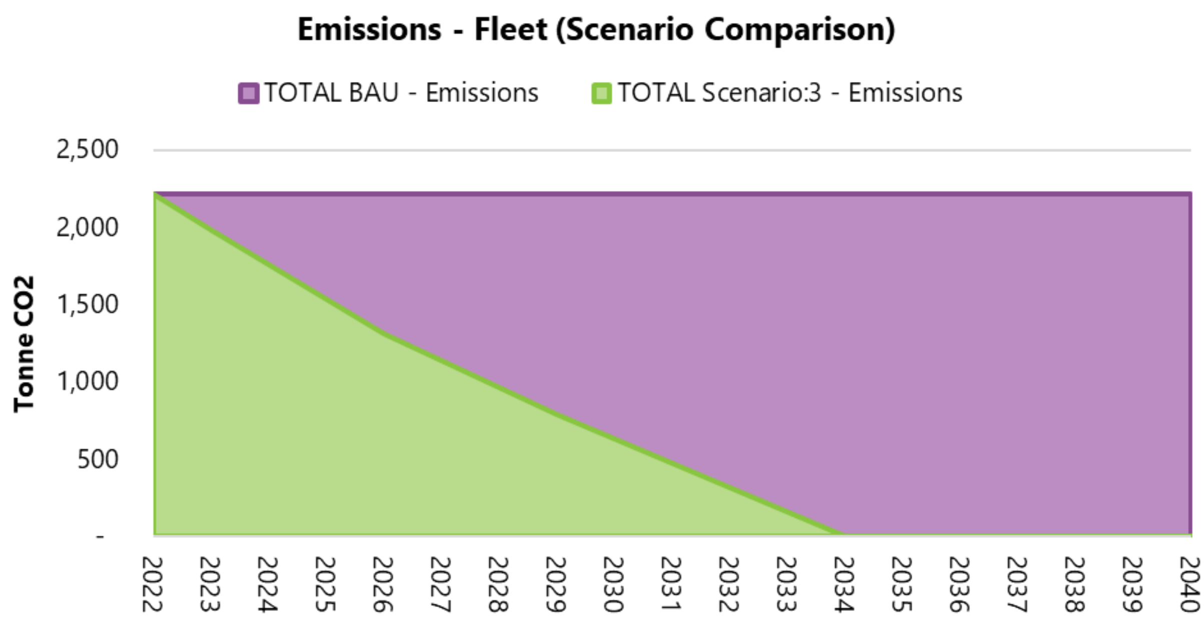


Figure 34 GFP Transit Fleet Environmental Emission Scenario 3 – FCEV

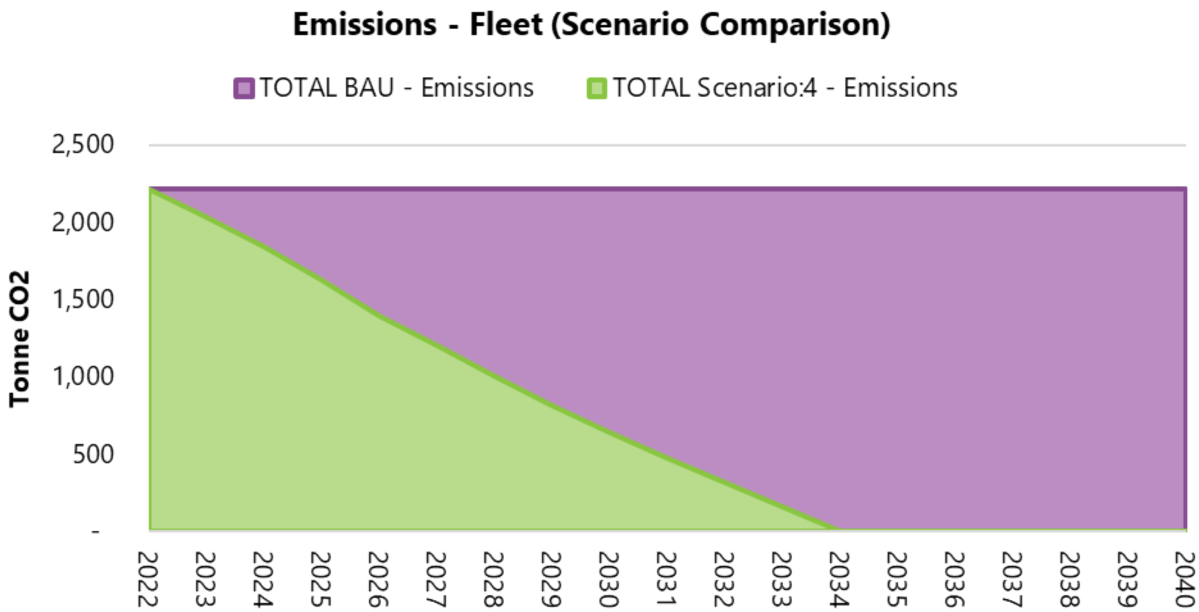


Figure 35 GFP Transit Fleet Environmental Emission Scenario 4 – CNG to BEV

7.3 GFP Conclusion

7.3.1 Overall Results

The primary finding from the GFP is that a battery-electric focused transition would be less costly than a transition to hydrogen fuel-cell. The battery-electric scenarios are so competitive that they are less costly than continuing to operate existing diesel and gasoline technologies. In terms of emissions, all scenarios are similarly effective in reducing emitted tonnes CO_2e by 50% or more between 2022 and 2040, while meeting the City's 2025 and 2040 emission targets.

Note it is the opinion of the analysts that the BEV scenarios are generally conservative regarding costs, whereas the FCEV scenario represents a more optimistic forecast of the nascent technology.

- Examples of conservative estimates for the BEV scenario include the pricing of electricity and electrical infrastructure upgrades. The existing electricity rates have no incentives for off peak use or electric vehicles which are being explored nationwide (including in New Brunswick). Further, the infrastructure investment was calculated based on preliminary requirements and were sized for 8MW of demand, rather than the refined estimate of 3MW which may results in a significantly reduced cost.
- Examples of optimistic estimates for the FCEV scenario include the hydrogen fuel itself, which was assumed to be green hydrogen available as required at a delivered rate of $8 per kg. This $8 cost is the optimistic range of scaled production costs, with the high-end estimate being 12$ per kg. It is possible that green hydrogen reliable availability of hydrogen be lower than expected while the current price remains high. Current prices are approximately $16 per kg that rate and are only expected to decrease as the market grows. The optimistic estimate was chosen under the assumption that significant private investment will be available to bridge the gap, facilitated by groups such as the Atlantic Hydrogen Alliance.

The BEV scenario outperformed the FCEV scenario despite a being a conservative estimate compared to optimistic outlook. This allows us to confidently say that a battery electric pathway to zero emissions is preferable following current technology trends.

7.3.2 CNG to be Excluded

The cost of incorporating CNG class 5,6, and 7 truck platforms is very similar to continuing to operate diesel vehicles until battery electric products become available. When comparing scenario performance, incorporating CNG slightly more expensive, with an increase of 0.4% NPV, while reducing net emissions by 1%. This close result means that qualitative factors and the City's strategic intent should be referred to when deciding which approach is preferable.

When assessed through a qualitative lens, the preferred approach is to not incorporate CNG technologies in the fleet. The reason for which is explained in the following themes:

- **Long Term Commitment**: A CNG deployment requires significant capital investment ($1.6 to $2.0 Million) which mostly recuperated over 15 years through operational savings. If pursued, the City will have less flexibility in changing to a new technology type, should green technologies mature more quickly than expected. Should green technologies mature more slowly, than the added benefit would be limited by the need to be net-zero by 2040.
- **Limited Piloting Period**: the opportunity to operate CNG vehicles begins in 2024 as the next group of Class 5, 6, 7 Truck Platforms are expected to be renewed. Before CNG vehicles can by deployed, facility modifications and refuelling infrastructure need to be constructed, in addition to equipping and training staff to operate and maintain the vehicles. The first five (5) CNG vehicles are expected in 2024, increasing to a peak of 16 by 2028. This will leave little time to properly pilot the vehicles to understand their performance in serving the variety of functions performed by the vehicle group.
- **Limited Procurement Period**: The expected useful life of the CNG vehicles is 10 years meaning that the phase-out period must begin in 2030, as new purchases would still be in operation past the carbon-neutral date of 2040. Based on forecasted procurements, this results in the CNG vehicles being retired between 2034 and 2037. Should CNG vehicles be procured after 2030, they would need to be retired early, leading to increased capital costs.
- **Multiple Technology Transitions**: Guiding two technology migrations for the City may limit staff buy-in, particularly if challenges arise when accommodation the CNG technology. If vehicles fail to meet staff expectations, it may lead to increased hesitation or resistance when asked to transition again, this time to green vehicles.

7.3.3 Acknowlogement of Long-term Planning Uncertainties

It is important to note that these results are contingent on the model inputs which have been forecasted using information currently available. As the City moves through its 18-year transition, technologies may develop differently than our contemporary forecasts. This may lead to hydrogen, or an entirely different technology, becoming more effective and less costly. Similarly, fuel and energy prices may significantly depart from what is experienced today, further changing the results of the financial analysis. Therefore, with the acknowledgement of the unknows inherent with long-term forecasting, the GFP represents an educated projection of the City's expected costs and emissions.

Using the GFP, the City aims to forge a path to a carbon-free future, rather than waiting to react to what the future holds.

8.0 Recommended Roadmap & Implementation Plan

8.1 Recommended Green Fleet Plan

The City of Saint John has already achieved its short-term targets and now needs to focus on its long-term transition. From the time of writing, the City has 18 years to transition its entire fleet to a new low-carbon technology. The analysis of today's technologies revealed that battery-electric is preferred, as it outperformed hydrogen fuel-cell technologies in terms of financials, opportunities, and risks. The roadmap lists actions necessary to make the transition a reality. Implementation recommendations are presented to add context to the City's next steps and opportunities that have the potential to improve the adoption of battery-electric technologies are explored.

Flexibility is also a key component of the plan. Depending on how innovative technologies like hydrogen fuel-cell vehicles mature over the next 18 years, the City's future fleet may comprise of a mix of green technologies. For this reason, the plan includes the reassessment of hydrogen fuel-cell technologies to ensure that the City can confidently move forward with the technology that best serves its needs. A summary of factors that are indicative of why the BEV scenario is recommended to the City of Saint John is presented below:

- Lowest overall cost: Net Present Value (NPV) shows the BEV scenario is 5% less expensive than continued operations with gasoline and diesel vehicles. Additional savings may be realized by leveraging implementation opportunities.
- Similar reduction in lifetime emissions compared to other green scenarios, resulting in a 50% reduction of emissions between 2022 and 2040, and carbon neutrality by 2040.
- Many pilot deployments are currently underway for both the public and transit fleet vehicles. This means that lessons learned from other cities throughout North America will be available to Saint John in time for their green fleet adoption.

8.2 Carbon Migration Strategy Roadmap

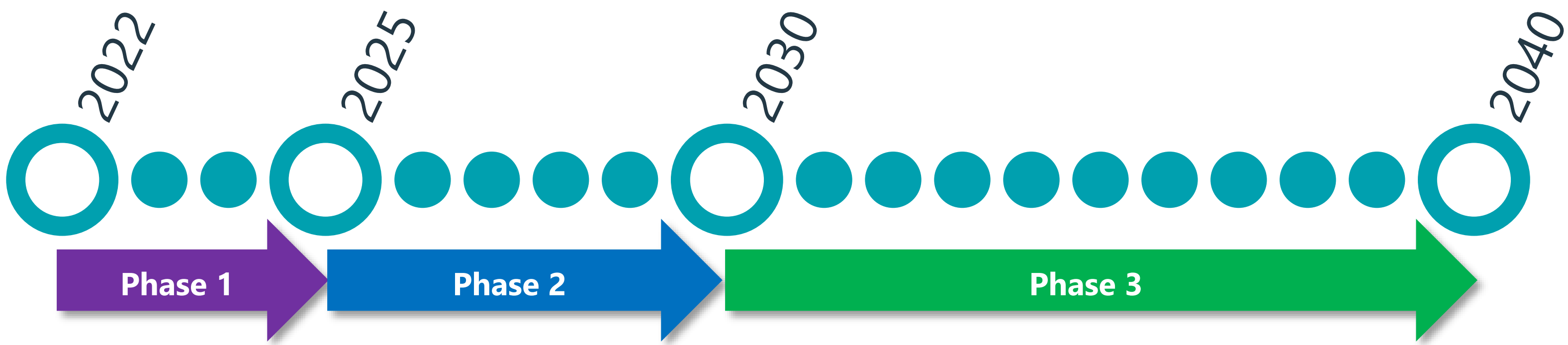
The roadmap developed for Low-Carbon Migration Strategy outlines the timeline of activities to be performed by the City between 2022 and 2040. It is divided into three phases, corresponding to short-, medium-, and long-term activities.

Phase 1 is the shortest of the three phases with a 3-year duration, beginning in 2022 with anticipated completion by 2025. Phase 1 serves as a launching point to explore funding programs, partnerships, and leverage implementation opportunities. "Easy win" battery electric vehicles will begin to be adopted to introduce the new technology to City staff. Pilot programs will begin for the vehicles planned for adoption in Phase 2. During this time the City will work with hydrogen producers and the Atlantic Hydrogen Alliance to explore partnerships that could potentially make fuel-cell technologies more competitive.

Phase 2 is five (5) years long from 2025 to 2030. During this time the next vehicle groups will begin their transition to battery electric alternatives, with the next round of pilots launching for vehicles identified for Phase 3. During this time the City's charging needs will exceed the available capacity at its fleet depot, necessitating electrical infrastructure upgrades. This significant investment should be sized accordingly to the portion of the fleet being electrified and any additional hydrogen fuel cell analysis should be completed before proceeding with any major infrastructure upgrades.

Phase 3 is ten (10) years long from 2030 to 2040. During this time all remaining assets (vehicular and equipment) will need to be transitioned to zero-emission technologies. Actual progress should be compared to planned progress to understand any shortfall in meeting the 2040 net-zero emission goal. In particular, the rate at which the electrical grid decarbonizes will have the largest impact on reducing emissions.

8.2.1 Recommended Carbon Migration Strategy Roadmap (Phases 1, 2, and 3)



Phase 1	Phase 2	Phase 3
• Begin grant/funding applications. • Implement PHEV and BEV for General Purpose Vehicles. Implement HEV for Police and HD Vehicles. Implement BEV for the transit fleet. • Pilot BEV light-duty trucks, street sweepers, and refuse trucks. • Explore green fleet transition opportunities (public charging, on-demand transit, community targets). • Explore external partnerships and investments that would make FCEV technologies competitive with BEV.	• Review/update migration plan to review the competitiveness of hydrogen technologies. • Implement electrical utility upgrades/expansions. • Implement BEV for light-duty trucks, street sweepers, and refuse trucks. • Pilot BEV for remaining vehicles classes. • Expand market scan to remaining assets (equipment/construction/off-road).	• Review/update migration plan to review planned vs actual progress of the migration plan. • Implement additional electrical utility upgrades/expansions. • Implement BEV for remaining vehicles classes. • Implement zero-emission solutions for City equipment, construction, and off-road assets. • Review the progress of electrical grid decarbonization. Consider options to offset carbon should the grid fail to achieve carbon neutrality by 2035.

8.3 Implementation Opportunities

8.3.1 Continuous Improvements

Continuous improvement in the context of the City's Low-Carbon Migration Strategy is a mechanism to leverage opportunities, manage progress, and retain agility. It is understood that technologies and the City's services will evolve over the course of the plan, and adaptations should be expected. This will lead to a more sophisticated and financially viable action plan, representative of the future technology landscape.

The first mechanism for accomplishing this is to update the plan with the status of the transition compared to the planned progress. This should be performed for each activity listed on the roadmap, and subsequent subtasks developed in future implementation plans. An annual high-level assessment should be conducted, with a more detailed assessment at the end of each phase (in 2025 and 2030) and whenever a development arises that will significantly impact the execution of the plan. The high-level assessment should be aimed to monitor progress and identify solutions to problems that arise, while the more detailed assessment should be seen as opportunities to change the City's pathway more fundamentally towards net-zero emissions. Key questions to answer during each progress review include:

- Green Technology Adoption
    - Have green technologies been incorporated in the City's procurement plans?
        - Are there any outstanding vehicles in a vehicle group that face challenges being replaced? What alternative options exist for these vehicles?
    - Have vehicle pilot programmes failed to determine a viability zero-emission product to be incorporated into the fleet?
        - Are the piloted vehicles meeting the needs of the user groups? If not, what alternative technologies can be leveraged to make the implementation more feasible (Generators, larger batteries, alternative propulsion technology, larger fleet size, etc.)?
- Technological Progress
    - Is the pace of commercial deployments of green technologies keeping up with the City's forecasts in terms of meeting user group needs?
        - If the technology is behind, how does it impact other milestones and what risks does it pose to achieving the City's goals?
        - If the technology is ahead, should the City accelerate adoption and achieve net-zero emissions earlier than forecasted? How would an accelerated adoption impact other milestones?
    - Are alternative technology types, such as hydrogen fuel-cell, more competitive than forecasted?
        - What benefits and risks would be realized should the City incorporate the alternative technology?
        - How would the adoption impact other milestones and what risks would it pose to achieving the City's goals?
- Financial Performance
    - Are the CAPEX and OPEX projections aligned with the GFP forecasts?
        - If not, why?
            - An implementation opportunity was pursued which involved changes to the financial plan (ex. higher capital investment resulting in lower operating cost).
            - Changes to City services (level of service, vehicle mileage, vehicle count, fuel efficiency, etc.,)

- Alternative technologies were implemented more quickly/slowly
- Predicted procurement prices were above/below expectations
- Predicted fuel/energy prices were above/below expectations
- Infrastructure and equipment costs were above/below expectations
- Maintenance savings were above/below expectations
- Other unexpected costs

Regardless of the current plan, the City will need to continuously update its market scan of green technologies being released to the market. This will help keep the City informed of the development of emerging technologies such that they can be incorporated into procurement policies, particularly the City's "Greening Our Fleet" Policy. This is how the City will identify new products to pilot and how the selection of suitable technologies for vehicle replacement will evolve.

8.3.2 Implementation Opportunities

The implementation opportunities listed in this plan are a list of prospects that could be leveraged to improve the City's transition to green technologies. This includes identifying technical and financial efficiencies, risk mitigation opportunities, and supporting the City's broader goals.

8.3.2.1 Phased Infrastructure Implementation

Proper planning can ensure that preliminary steps are both rationale and scalable, guaranteeing the widespread ability to deploy BEVs on a larger scale on a go-forward basis while minimizing the disruption to operations. This can be accomplished by designing infrastructure to support the complete rollout and phasing in the equipment as necessary. Alternatively, space can be allocated in advance for modular infrastructure upgrades which can be additively incorporated into the City's operations.

The phasing of the infrastructure upgrades should consider the following:

- The infrastructure upgrades should align with the needs of the vehicles being procured.
- Infrastructure should be installed in quantities that benefit from economies of scale, while limiting the upfront cost of expansion.
- Allowances should be made for the infrastructure to be installed in a manner that minimizes disruptions to operations.
- The various impacts on employees during the construction phases should be understood and mitigated. This may include additional interim procedures that maximize safety while minimizing disruption to normal routines, and processes and procedures resulting from noise, dust, workspace encroachment, etc.

Particular attention should be directed to electrical conduit and cable runs that connect charging power control units to dispensers, which in turn charge the vehicles. Regardless of where the conduit and cable runs are located (i.e., trenches in exterior parking lots, floor slabs, or suspended from roof structures), the electrical conduit and cable runs for the charging infrastructure needs to be designed to limit operational impacts whilst allowing for effective maintenance, repairs, and upgrades. In the case of suspended cabling, it is recommended that the necessary reinforcement for the full build-out is performed at the prior to the deployment of vehicles.

8.3.2.2 Phased Tooling Implementation

Maintenance of BEBs requires specialized tools to service the more complex, high voltage electrical systems and components that are not found in conventional fuel vehicles. These systems include battery packs, inverters, electric motors, etc. Due to the high cost of the special tooling, more detailed consideration is warranted to determine the following:

- What is the scope of tooling required to meet the City's in-house maintenance needs?
- What existing tools and systems will need updating or replacement to serve the new vehicle types?
    - For example, hoist adapters may be required to hoist vehicles that don't have axles.
- What quantity of tooling will be required to support the adoption – from the initial adoption up until the City has completely transitioned?
- When will the tooling be required - ensuring that operations support is not negatively impacted?
- What systems will be in place to manage the allocation and control of the tools?
    - Will it begin with a shared pool of tools that transitions into individual tool assignments?
- What calibration and recertification requirements apply to the tools and related staff?

The battery-electric vehicle industry is experiencing short-term production and supply constraints as production lines for this new technology are deployed and ramped up to intended output levels. These constraints extend to spare parts required for vehicle maintenance, thus the City will need to expand its spare parts stocking levels to include parts that are unique to battery-electric vehicles. This will be inclusive of batteries, drive trains, and auxiliary systems. As the scope of the City's in-house maintenance activities evolves, so too will their needs for replacement parts.

8.3.2.3 Procurement Opportunities

As noted in the Green Fleet Analysis, the modelled external funding resources were limited to the funding streams that have already been earmarked for the City. Additional funding opportunities exist that the City should pursue, and if successful will further improve the business case for the transition. Some of these funding programs have windows of eligibility, meaning that only procurements made before a certain year can be claimed for funding. To maximize external contributions, the City may wish to procure replacement vehicles ahead of their planned retirement date, such that their replacement cost is eligible for grant funding. Doing so may also lead to additional benefits as the City will be purchasing vehicles in bulk, giving more leverage to negotiate for lower prices and secure production line build schedules.

As the City of Saint John is not the only municipality embarking on a transition to green vehicles there is an opportunity to partner with other municipalities in developing procurement agreements. This could take the form of an electric vehicle hub for municipalities to leverage their buying power and advocate for agreements that meet their needs, reduce costs, negotiate cost sharing agreements, and reduce risks through improved warranty terms.

In the short term, the battery electric vehicle industry is expected to continue experiencing production and supply constraints which have led to increased lead times between ordering and receiving a vehicle. The City should work with OEMs to understand the expected delay for various products and secure build slots on the manufacturer's production schedule to ensure vehicles are delivered as per schedule. When following a tendered procurement process, the City will need to be aware that delivery timeline will be a factor for comparing proponents.

The City will also need to update its "Greening our Fleet" policy, which includes the procurement of rental and leased vehicles. The emission reduction elements of the policy are limited to reducing idling and long-hauling. This policy should be expanded to explicitly evaluate technology type when renting or leasing. In the short term, the policy could prioritize renting hybrid vehicles so long as they meet the duty-cycle requirements. In the long term, the City should prioritize zero-emission vehicles as they become available for rentals and leases, so long as they meet user group performance requirements. Beginning in 2040, the policy should require that all rental and leased equipment are zero-emission.

The City will need to review its other policies and documents to align them with new considerations relevant to battery electric vehicles. The library of standard vehicle and equipment assets specifications is one such example. This library retains a database of general specifications to identify the basic common items required for each class of vehicle and equipment assets. As new technology groups are incorporated into the fleet the library will need to be updated – with obsolete items being phased out.

If possible, the City should begin its battery electric deployment with plug-in hybrid (PHEV) models. These will help introduce battery electric technology as the vehicles operate entirely on an electric drivetrain until the battery is depleted. The benefit to the plug-in hybrid is that staff anxieties regarding range should be mitigated, as once the battery is depleted the gasoline engine is engaged and the PHEV drives much like a conventional hybrid vehicle. This will provide a safe space for staff to experience the strengths and limitations of the new technology. However, it should be noted that many OEMs are discontinuing plug-in hybrid production in favour of pure battery electric products which could result in the City missing an opportunity to procure this vehicle type. Additionally, the City will need to consider the maintenance impacts of procuring a discontinued product. The City should weigh the benefit of introducing staff to the new technology using plug-in hybrids when considering whether or not to proceed with their procurement. Starting in 2023, the green fleet plan prescribes that all new procurements for the Class 1 general purpose vehicles are expected to be battery electric products.

8.3.2.4 Electrical Optimization and Resilience Opportunities

The critical component for reducing the City's electrical utility bill throughout a battery electric vehicle adoption will be minimizing the monthly peak power demand – the maximum rate at which electricity was pulled from the grid. The City's monthly peak power demand incurs a direct monthly fee based on the magnitude of the peak. The City also pays for the energy consumed, the volume of electricity used to operate devices and recharge batteries. However, the rate at which the City is charged for energy increases in relation to the monthly peak power demand. This means that the monthly peak power demand impacts the electrical utility fees directly and indirectly. Beyond the electrical utility fees, the peak power demand will also impact the sizing of the infrastructure required to accept the power from the grid. The impacted infrastructure includes the transformer(s) and switchgear, where the larger the peak power requirements, the larger the capital and maintenance costs.

For all of the reasons above, limiting the peak power demand through optimization will allow the City to reduce its costs while increasing its resiliency.

Starting with optimization, the first and most important piece is to optimize how much charging is being performed at one time. Quickly charging the whole fleet at one time leads to very high peak power demand. Meaning that the City should seek to sequentially charge its fleet over a longer period of time or limit the rate of charge. It is sometimes impractical for fleets to recharge throughout the day, as they are needed on site performing their functions. This means that the window for charging optimization exists between the end of one day's operation and the start of the next. For fleets with well understood duty cycles, like transit, the magnitude of charging can be specified to take advantage of the entire charging window. For more ad-hoc operations, the charging equipment will need to be specified to meet the user group's needs for recharging, which are more difficult to optimize for.

Beyond optimizing the charging scheduling, the City can invest in energy storage and/or generation. The storage of energy is typically accomplished using a battery energy storage system (BESS). The BESS allows the City to withdraw energy from the electrical grid when its power demand is below the monthly peak. Later when the vehicles begin to charge, the energy is dispensed from the BESS, offsetting some demand that would be placed on the grid. This process is referred to as "peak shaving" as the BESS is providing energy at the time that it is needed, lowering the peak demand for charging.

The energy generation component is similar in that electricity is created on-site when it is needed, which helps to lower the peak demand, by an on-site generator which can be fuelled, by diesel, CNG, or other combustibles. If this is chosen as a long-term solution, the City should investigate products that accommodate low- and zero-emission fuels: biodiesel, renewable diesel, renewable natural gas, hydrogen.

Alternatively, the on-site generators may exist in the form of renewables, commonly solar. The limitation of renewables is that energy availability cannot be planned, rather it depends on weather. For solar the problem is more fundamental, as most of the charging will occur overnight when no solar energy is available. For this reason, renewable on-site generation is best paired with a BESS, so that the energy can be stored whenever it is available and can be drawn upon as needed. Solar PV arrays and BESS have their limitations as the power generated with solar PV arrays will likely account for a small portion of the energy requirements of a BEV fleet, and in the case of BESS's once they have been discharged to charge a BEV, they need to be recharged, which typically takes several hours. Relying solely on solar energy during an emergency is impractical.

Installing on-site energy storage and/or generation allows the City to add resiliency to its operations. If there is ever an unexpected interruption in the electrical grid, whether that be from a black-out or an equipment failure with the City's transformer, the City will have alternative energy available to it. Using a generator would allow the City to recharge its most critical vehicles at any time. Similarly, the BESS can hold a reserve amount of energy to be accessed in the case of electrical service interruptions. Depending on the length of the interruption, the City will be able to decide whether to continue normal operations or limit itself to more critical services.

8.3.2.5 Electrical Utility Opportunities

The electrical utility for the City is Saint John Energy (SJE), a subsidiary of the City itself. This creates more avenues for collaboration than many Cities throughout Canada. However, it is important to note that the bulk of the electricity provided by SJE is purchased from NB Power, which limits SJE's ability to alter the rate structure.

The first electrical utility opportunity that may benefit the deployment of battery electric vehicles is the introduction of an EV charging rate. These charging rates have been implemented in a variety of forms throughout Canada and is being explored for implementation in New Brunswick. If an EV charging rate is implemented, it could take many different forms. The most common form is a tariff window, where the price for consuming electricity is reduced for a period of time each day, generally overnight. Other frameworks could be a flat fee reduction based on type of use, or a separate rate class being created to cater to the needs of charging stations.

Another method to reduce cost could be through entering a charging as a service (CaaS) agreement. This could be done with the utility, or with a private partner. CaaS agreements serve to contract the installation, maintenance, and operation of charging equipment to an external party. This can include capital investment contributions from the CaaS partner, which are recuperated from the service fee. Some fees are charged based on energy consumption, however CaaS arrangements have been explored which would charge fees based on the mileage of the charged vehicles. Regardless of the specifics of a future CaaS agreement, it could limit the City's needs to hire staff that can maintain the specialized charging equipment, while offloading risk to the CaaS partner.

Collaboration with SJE will be critical to understand the long-term forecast for future power needs at City operation and maintenance facilities. This will aim to ensure that the electrical grid's capacity meets the City's electrical infrastructure demands. Communicating the needs of the full buildout will help the utility provider in developing their capital plans including scheduling of infrastructure upgrades.

If the City pursues the deployment of utility grade batteries as part of a BESS, SJE has communicated its interest in accessing the BESS capacity to add resiliency to the wider electrical grid. This would allow SJE to better manage the grid load during peak times. This potentially beneficial as the times in which the City would be best served accessing the BESS capacity is different from the times most beneficial to SJE. Many opportunities for mutual benefit exist depending on how the agreement is structured. For instance, the capacity made available to SJE could also vary with the season based on energy needs of the City's fleet, thus allocating more or less capacity to SJE dependant of the circumstances. An agreement to share BESS capacity with the utility could generate additional revenue for the City while adding resiliency.

8.3.2.6 Fleet Opportunities

There are many benefits to incorporating battery electric vehicles into the City fleet, but the technology is not without weakness. The public fleet's need for fast charging will need to be investigated through pilot deployments to best understand the scale of infrastructure required to operate in the City. This supporting infrastructure will likely take the form of recharging sites throughout the City's service area, however additional charging locations may not satisfy all user group concerns regarding battery electric vehicles.

A notable limitation of battery electric vehicles compared to diesel or gasoline is the difficulty to idle for long periods of time. This may require the City to incorporates new equipment, such as portable generators capable of providing additional energy on-site when long periods of idling are necessary. This could be used to power the ancillary tools and lights or used to recharge the electric vehicles themselves. An alternative to a portable generator could be portable battery, as it could fulfil the same role of providing energy on-site. These generators or battery systems could be integrated into a new class of vehicle that is used to offset the weaknesses of the new technology, without significant fleet expansion.

Other changes may be incorporated at the service delivery level. One such example is the creation of an on-demand micro transit fleet, which would offset the needs of the existing transit fleet. This could allow more energy efficient vehicles to provide the same level of service to the community, which would reduce the overall electrical needs. In the event of a service change, the City will need to re-evaluate its energy needs. In doing so, additional savings may be realized as the refined infrastructure requirements are reduced.

8.3.2.7 Community Emission Goal Opportunities

The infrastructure being deployed for City operations may be leveraged to help the City in achieving its broader climate goals. Once such opportunity would be to make some charging infrastructure available for public use throughout the day. This would support community electric vehicle adoption with limited impact to City operations as the bulk of the charging is likely to be planned for the overnight period. Alternatively, separate chargers could be installed that are dedicated for public use, which could leverage the infrastructure installed for City charging. Again, this opportunity is particularly effective because the City's electrical capacity will generally be planned for overnight periods, when the fleet has returned from its regular operations.

Beyond supporting community electric vehicles, there is also a marketing opportunity to show that the City is a leader in climate change mitigation. Not only in reducing greenhouse gas emissions, but in reducing noise pollution and improving air quality. These improvements can be targeting in communities to improve social and environmental equity. This can be targeted with through the deployment of battery electric vehicles in communities where air and noise pollution, racial, socioeconomic disparities are greatest whist also balancing the challenges of new technology. An example of which would be to allocate electric buses to routes that begin early in the morning or late at night, to reduce the community impact of the noise generated by the diesel alternatives.

8.3.3 Piloting Programs

Piloting vehicles before committing to their deployment can add value by creating familiarity with the technology. This includes understanding how successfully it can perform its required duty cycle, identify opportunities to leverage its strengths, identify weaknesses that need solutions or changes in service delivery, and refine the procurement strategy, rate of conversion and charging options to be implemented to better meet the City's needs moving forward.

Piloting is recommended for all vehicle groups except for Class 1 general purpose, as it is understood that user group needs can be met with existing technologies. This is far less understood for the remaining vehicle groups which have more strenuous duty cycles. For this reason, piloting programs are suggested to evaluate how new products perform when tasked with the City's duty cycles.

This is important as climate conditions can have a significant impact on the performance of battery electric vehicles. Using piloting programs, the City will know the limitations of the products and be able to develop solutions for any identified shortcomings.

8.3.3.1 Key Performance Metrics

The recommended key performance metrics to monitor during pilot testing include:

- Utilization – how many kms are driven
- Availability – number of days ready for service
- Infrastructure availability – number of days ready for use
- Vehicle availability – Mean distance between road calls
- Charger reliability – Number of days unavailable for use – warranty issues
- Cost per km – Energy costs per km driven collated to fuel cost savings
- Environmental Impact – Emissions reduction, value of carbon savings
- Equity and Environmental – Kms driven through these areas

8.3.3.2 Phase 1, 2, and 3 Pilots

The roadmap currently recommends piloting the vehicle groups and equipment in the following phases.

Phase 1	Phase 2	Phase 3
• Class 2 – Light Duty Pickup Truck • Class 7 – Streetsweeper • Class 8 – Refuse Truck	• Class 1 – Police Cruiser • Class 3, 4, & 5 – Heavy Duty Pickup Truck • Class 6, 7, & 8 – Heavy Duty Truck Platform • Class 8 – Pumper Fire truck	• Excluded asset classes: construction equipment, armored vehicles, etc. • Pilot zero-emission tools and equipment (Optional)

8.3.4 Staff Readiness

The next step in preparing City staff for incoming changes is to establish a broad communication strategy, as it is important to get buy-in at all levels – both within the organization and externally.

This should outline stakeholder relationships, and how they should be consulted and informed throughout the transition. Champions for change should be identified in each user group, who can act as a first point of contact in addressing questions from their group.

Discussion with user groups regarding transition and phasing strategies are essential to initial planning, ensuring that all stakeholders within operations (operators, maintenance, facilities, planners, schedulers, and first responders are included in the process.

This can be achieved using engagement (or "outreach") teams to foster a positive environment for change. Some elements to focus on when communicating with stakeholders include:

- Engagement – relationship and trust building

- Outreach – sharing of information, education and awareness through community town halls, social media, in garage pop-ups, and surveys
- Involvement/Collaboration – Engage stakeholders in the engagement sessions, design, planning, roll-out phases
- Input – Seek and evaluate feedback from stakeholders, public, communities

8.3.4.1 Labour Negotiations

A large portion of City staff are members of various unions with which the City will need to include due to the large role they will play in the success of the BEV transition and implementation, and also negotiate to refine job descriptions and classification. This will be a result of necessary alterations to employee roles following the adoption of battery electric vehicles. These alterations extend to all new responsibilities assigned to drivers/operators, mechanics, and service staff, most if not all of which will require adjustments to the existing labour agreements. The following list outlines a range of upcoming changes that will need to be considered by all parties involved in negotiations:

- New necessary certifications
- New staff classifications
- Revised compensation structures
- Changes to standard operating procedures
- Changes to vehicle, equipment, and infrastructure maintenance activities

The City may also enter service agreements with third party contractors to provide operations and maintenance services applicable to battery electric vehicles and their supporting equipment. One example presented in the Implementation Opportunities section is charging as a service (CaaS). Under this arrangement, it is possible that the third party maintain ownership of the charging equipment and be responsible for all related maintenance activities to facilitate an agreed upon level of service.

8.3.4.2 Training Program Development

The City will need to develop multiple training programs to ensure that each staff segment knows the changes that will impact them as battery electric vehicles are adopted. Safety concerns will apply to all staff working in proximity to battery electric vehicles and their associated infrastructure and equipment. Familiarity with battery electric technologies should not be assumed as common knowledge among staff, so it is expected that staff will have many questions about how the technology works and how it will impact their roles.

As a result of these considerations, the following training elements should be incorporated into City training programs.

- All Staff – Electrical Safety
    - High voltage safety procedures
    - Lock Out – Tag Out
    - Casualty rescue – Sheppard's crook
    - Personal Protective Equipment
- Battery Electric Vehicle Operators – Vehicle Orientation
    - Vehicle familiarity – switches, controls, indicator/warning lights gauges, etc.
    - Battery SOC
    - Remaining operating time / estimated range
    - Start up and shut down procedures
    - Driving characteristics (regenerative braking, acceleration, etc.)
    - Depot charging protocols

  - Enroute charging protocols (for applicable vehicles)
- Mechanics/Auto-body/Welders – Knowledge and Skillset Training
  - Preventative Maintenance
  - Electrical/electronic
  - Multiplex system
  - Electric drive/transmission
  - Inverters
  - Batteries and energy management hardware & software
  - High voltage
  - Startup – shutdown procedures
- Service Cleaners
  - Charging and fuelling auxiliary heaters
  - Depot charging protocols
  - Overnight parking configurations and procedures
  - Pressure washing vehicle undersides
- First Responders and Utility Workers – Response Measures
  - In the event of an accident
  - Thermal event
  - High voltage and chemical factors

8.3.5 Facility Modifications

Battery electric vehicles are different from existing technologies in a number of ways that require consideration and potential facility modifications. Unit level differences between vehicle types include added height and weight. The fuelling requirements of battery electric vehicles extends to new specialized infrastructure. These needs should be incorporated into the facility layout, as the act of recharging requires more space time than refilling a gasoline or diesel fuel tank. Furthermore, the added maintenance considerations involve both specialized tooling and spacing requirements that may necessitate new layouts and space allocation/reallocation to limit conflict between workspaces.

8.3.5.1 Vertical Clearances

The increased height of battery electric vehicles is a result of the vehicles being designed to accept overhead charging, necessitating the installation of overhead rails and the full-length fairings for aerodynamics and protection of the roof rails. The roof fairings and charge rail structure add between 10 and 12 inches (25- 30cm) to the height of battery electric vehicle compared to their gasoline of diesel equivalent. Transit buses will the tallest vehicle in the City fleet after receiving overhead rails, meaning that vertical clearances in the depot can be sized accordingly. Accommodating overhead rails on a bus increase the vertical profile from 10’2” to 11’0” (3.1 to 3.4 metres). Currently the garage doors, necessary to access maintenance, servicing, and the facility at large vary in size, with the lower clearance accommodating vehicles with heights up to 13’1” (4.0 metres) which is sufficient for battery electric buses. Furthermore, the doors at the City’s depot have the ability to be adjusted several inches higher to provide even more clearance if desired.

In terms of the main vehicle storage area, the existing clearance between buses and the overhead structure is 5’4”. This is sufficient space to accommodate the additional height of the overhead rails and shroud. Additional investigation will be required to confirm whether overhead pantographs can be mounted overhead, however in the absence of unforeseen engineering constraints, the existing space should be sufficient.

In the and maintenance areas the clearing from the top of vehicles and lowest point of the ceiling structure must consider the height of the vehicle when hoisted. The clearance of existing buses when hoisted is 4'5", which is sufficient to accommodate the added height from the overhead rails and shroud.

Once piece of equipment that will need to be modified for taller vehicles is the City's wash bay. The device washes the exterior of buses each time they return to the depot. The required modifications are twofold. First, the existing overhead clearance will not accommodate the additional height of the vehicles. Second, the washing is limited to side jets, whereas overhead rails required overhead washers to enable proper cleaning. The equipment will need to be modified or replaced such that both of these needs are accommodated.

8.3.5.2 Electrical Infrastructure

Given the high-power requirements for the charging equipment necessary to support battery electric vehicles, the City will need to upgrade its electrical infrastructure. This begins with an upgrade to the existing transformer to accept more power from the grid. Once the power is transformed it will need to be processed through an electrical room with switchgear necessary to accept that increased capacity. This power will then need to be routed to the charger power control units via high-voltage (HV) cabling.

Additional infrastructure will be necessary should the City elect to pursue on-site energy storage and/or generation as the infrastructure will need to accommodate a higher peak power load. These additions are recommended as they will allow the City to employ peak shaving strategies (reducing maximum draw from the electrical grid) and provide resiliency in the case of an electrical service disruption. In the case of fuelled generators, fuel storage will need to be developed on-site to enable their function (existing fuel storage may be repurposed to serve this function).

8.3.5.3 Candidate Power Control Unit Locations

For the purposes of high-level planning, charging equipment can be thought of as having two components. The first is the power control unit (PCU) which accepts energy from the grid and directs it to dispensers. The PCU have flexibility in their location, so long as they can be connected to their dispensers. Generally, the maximum range for this connection is 150 metres. The second component is the dispenser, which uses a connector to physically attach to the vehicle charging port. Depending on the equipment selected, one PCU can power multiple dispensers simultaneously or sequentially.

All the locations where dispensers are installed will nearby PCUs to supply the energy This charging infrastructure should be in areas which limit risk of vehicle collision and other damage, while remaining accessible to maintenance staff. Furthermore, the systems release a large amount of thermal energy when in use which requires excess heat be vented or repurposed for use elsewhere in and around the facility.

An ideal location for centralized PCUs at the City's depot is the mezzanine above the mechanic offices and lunchroom. The underutilized location is set adjacent to both the vehicle storage and maintenance area. The modifications necessary to use this location includes strengthening the mezzanine to bear the increased load, and to connect the location to the electrical room. Following the ceiling and parking lanes from this location, the distance to the furthest corner of the storage area is 100 metres, enough to accommodate the connection between PCU and dispenser.

An alternate location for centralized PCUs is the mezzanine above the tire storage area. The underutilized location is less ideally located to serve the vehicle storage area but is adjacent to several maintenance bays. Similar to the location above, the modifications necessary to use this location includes strengthening the mezzanine to bear the increased load, and to connect the location to the electrical room.

8.3.5.4 Primary Dispenser Locations

The primary location for charging activities will be the vehicle storage area, such that the fleet can benefit from overnight charging. In the vehicle storage area, plug-in dispensers installed for charging will occupy space that would otherwise be available for vehicle storage and circulation. Beyond their footprint, dispensers also have access requirements as staff will need to attach dispenser connectors with vehicle charging ports to begin refuelling. Dedicating storage space for charging infrastructure and its use will result in lower vehicle storage capacity. The amount of floor space required for charging infrastructure, and allowing access to it, can be reduced by opting to use overhead infrastructure such as pantograph charging equipment or the overhead storage of plug-in charging dispenser units. Both ground level and overhead storage approaches will require high-voltage (HV) cabling to connect dispensers with their chargers, however placing the dispensers and HV cabling overhead can mitigate the inherent safety risks in placing them at ground level with circulating staff and vehicles.

The degree to which overhead charging infrastructure can be implemented will depend on the existing structural capacity to support the increased load and whether structural upgrades can be employed to meet any capacity shortfall.

Lanes dedicated to charging should alternate with flow through lanes to allow vehicles to access charging as required. The charging dispensers should be rated for 150kW to meet the needs of larger vehicle classes. Early in the transition this will be limited to buses, however it will expand to include truck platforms and other heavy apparatus.

An overhead fast charger should be considered to provide the City with more operational flexibility. This could be located in the wash lane or in an exterior area that will not conflict with storage area circulation.

8.3.5.5 Auxiliary Dispenser Locations

Charging dispensers should also be installed in maintenance and service bays to ensure that vehicles do not find themselves stranded with depleted batteries. The charging equipment in these areas can be much smaller than those in the primary charging area as the vehicles only need to be able to maintain functionality – rather than needing a full state of charge to operate their entire duty cycle.

The location and number of chargers suggested are as follows:

- Body Shop: two (2) to three (3) dispensers.
- Pit Bay: two (2) to three (3) dispensers.
- Repair Bays: three (3) to six (6) dispensers.

The variance in the number of dispensers is a function of whether they can be shared between bays and whether they are AC level 2 or DC fast chargers. Using AC level 2 chargers would warrant a one-to-one deployment of dispensers to bays, whereas DC fast charging dispensers have enough power to sustain multiple bays. Whether one dispenser can serve multiple bays will depend on the specific layout of the equipment and the charging port location of procured vehicles. An additional consideration for these auxiliary locations is that they may require standalone PCUs if cable runs from the primary PCU area are too long.

8.3.5.6 Static Free Workplaces and Storage

Maintenance of some electric vehicle components require that they be conducted in a static free environment. In particular the batteries, the costliest vehicle component, can be significantly damaged by undesired electrical discharges. Static free precautions must be inclusive of the maintenance tools and equipment as well as the spaces dedicated to their storage.

Currently the City's depot does not include any static free workspaces or equipment meaning that existing space dedicated to vehicle maintenance will need to be adapted. One such adaptation will need to be the inclusion of an electronic repair lab where electronic diagnostics and repairs can be conducted. This should be inclusive of all repair processes from component disassembly to reassembly. A potential location for this is the engine rebuild room that could be repurposed as diesel engines are phased out of the fleet. The extent to which these locations are required will be dependent on the scope of maintenance activities that the City decides to perform in-house.

The storage of sensitive electrical components is similar in that the space needs to be controlled such that the items are protected from unplanned electrical discharge. One approach to this need is just-in-time delivery for batteries rather than stocking them in inventory. This can be accomplished through service-level agreements with OEMs which make them responsible for maintaining the inventory and providing a timely delivery pipeline.

8.3.5.7 Staff Spaces

A dedicated training room for the maintenance staff may be considered in the project to build more office space in advance of the public fleet's relocation to this facility. This could be served with additional multipurpose spaces throughout the facility. These multipurpose spaces may primarily be used for training purposes, but their flexible nature provides the City with flexibility in how to operate. One example would be to repurpose the room to function as a lunchroom should Covid restrictions be reintroduced as this would provide space for social distancing: 6 feet between individuals, limited seating per table, etc.

The City will need to determine how many staff members will be relocated to the depot, as a significant migration of staff may necessitate more significant expansion than initially planned.

Staff spaces extends to the areas dedicated to personal storage. The existing locker room is currently limited in space for the existing staff. Should the staff count be expanded and/or staff need to maintain multiple sets of PPE for working on a fleet of mixed technologies the personal storage space may need to be relocated and expanded.

8.3.5.8 Additional Modifications

The maintenance of battery electric buses requires that mechanics be able to access the roof of the vehicle to perform certain maintenance activities. This could be accomplished at the City's depot in two ways. First a portable or fixed maintenance gantry platform could be acquired. This would allow mechanics to ascend stairs onto an overhead platform, from which they would have access to the roof of the vehicle. When using a portable or fixed gantry it must span the length of the bus plus on both sides to effectively mitigate the risk of staff falling from the roof.

An alternative approach would be to use the City's existing one (1) mobile platform and three (3) triangular 3-point platform ladders. The mobile platforms and ladders will require the City to install an overhead fall-arrest system to ensure that staff are safe working at height.

As zero-emission alternatives are incorporated into the fleet, there will be fewer diesel and gasoline vehicles. Equipment designed to support the gasoline and diesels will become less necessary up until they become obsolete. Throughout this process the City will be able to phase out old equipment. This includes exhaust hoses (located in the pit bay and paint booth), as well as the oil and lubricant dispensers located in the pit bay.

Appendix A

Green Fleet Plan Outputs

Appendix B

Transit Route Modelling
ZES Simulator Output

Appendix C

Site Visit Photos