Supplement 7

Bus Alternative Technology Assessment

DILLON
CONSULTING

CITY OF REGINA

Bus Alternative Technology Assessment

Regina Transit Master Plan

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Acronyms and Definitions

BATA – Bus Alternative Technologies Assessment

BEB – Battery-Electric Bus

Bus Block – a grouping of bus trips into a single continuous piece of work for a bus to undertake

Blocking – the act of creating bus blocks and scheduling bus trips for operation

CIB – Canada Infrastructure Bank

CNG – Compressed Natural Gas

CO_2 – Carbon Dioxide

EV – Electric Vehicle

FCM – Federation of Canadian Municipalities

GHG – Greenhouse Gas

HFC – Hydrogen Fuel Cell buses

ICE – Internal Combustion Engine

ICIP – Investing in Canada Infrastructure Program

kW – Kilowatt

kV – Kilovolt

MW – Megawatt

NRCan – Natural Resources Canada

RNG – Renewable Natural Gas

Termini – locations where buses *terminate*, or end their trips

ZEV – Zero-Emission Vehicle

1.0 Introduction

In October 2018, Regina City Council voted unanimously to direct the City to transition to 100% renewable energy by 2050. This means its annual energy consumption will be equal to or less than the amount of renewable energy generated or sourced in alternative to non-renewable energy sources. This goal is reinforced in the City's Official Community Plan and through the recent commissioning of the development of an Energy and Sustainability Framework for the City.

Regina Transit's diesel-powered bus fleet is one of the most significant consumers of non-renewable energy that is managed and operated by the City. As Regina Transit undertakes a Transit Master Plan update to guide short and long-term decision-making for Regina Transit and Paratransit over the next 25 years, the Bus Alternative Technologies Assessment (BATA) study will help inform future fleet purchase decisions.

As part of Regina's Transit Master Plan, Regina Transit commissioned Dillon Consulting Limited (Dillon) to undertake the BATA study. The study aims to assess the potential implications of transforming Regina Transit's fleet to one of three viable alternative bus propulsion technologies: renewable natural gas, fuel cell electric, and battery electric. The findings of the study will help inform decisions about which alternative bus propulsion technologies could be adopted by Regina Transit in the future.

Section 2 of this report is a high-level summary of the three selected alternative bus technologies. The anticipated impacts of each technology on operations and infrastructure in general, without Regina-specific considerations, are also detailed in this section. As the report aims to compare alternative technology options, diesel has generally not been used as a comparator.

Section 3 outlines the requirements of implementing each alternative fuel technology in Regina, including a high-level implementation plan for each, and forecasts financial implications.

Section 4 summarizes the key elements of each technology, including how they could be implemented in Regina, to provide a succinct comparison between them.

2.0 Summarize Potential Technologies

2.1 Overview of Alternative Technologies

This chapter of the report provides an overview of the three alternative bus technologies being considered as part of the BATA project:

- Battery-electric
- Hydrogen Fuel Cell Electric
- Renewable Natural Gas

Each of these alternative energy systems are discussed in the following sections. For each alternative energy system type, this chapter contains the:

- Defining Features
- Variations
- Availability of Technology and Current Manufacturers
- Existing Implementation Case Studies
- Implications of the Technology on Transit Planning and Operations
- Summary of Implementation Requirements
- Additional Considerations

2.1.1 Battery-Electric

2.1.1.1 Defining Features

Battery-electric buses (BEBs) are powered by electricity stored in batteries. Electric motors are used to propel the bus and the batteries are charged using stationary charging systems located on-route or at the transit garage. As battery capacity is currently limited, BEBs used in cold climates often utilize an on board diesel heater in order to extend range in the winter months.

Battery-electric buses are considered to be zero-emissions vehicles but the source of the electricity may result in some additional GHG emissions if it is not fully-renewable (i.e. hydroelectric, geothermal, solar, etc.).

It is possible to convert diesel buses to battery-electric operation by reusing the existing bus chassis, replacing the ICE with batteries and swapping the transmission with electric motors. However, this practice is not widespread, due to cost and the need for new buses with full lifespans.

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2.1.1.2 Variations

There are two charging methods available for BEBs; garage charging, and on-route charging.

Garage Charging: To facilitate garage charging, buses must return to the garage to recharge. The frequency of this is dictated by the capacity of the onboard batteries and the nature of the routes operated. Generally, low speed, low draw charging technology is used, subject to the number of buses at the garage and the amount of out of service time available. With most buses on the road during the day, charging demand will be concentrated to the garage during low use periods, like overnight.

On-Route Charging: To facilitate on-route charging, infrastructure is required at strategic points along routes instead of being concentrated at a garage. Generally, high speed, high draw charging technology is used to minimize the time stopped on-route, subject to supply limitations. This results in more frequent, smaller charges and requires buses to wait longer at charging stops than would otherwise be required - ideally these are located at termini. Compared to garage charging, these vehicles can stay in service throughout most of the day without needing to return to the garage.

2.1.1.3 Current Bus Types and Manufacturers

Battery-electric buses are available in a variety of sizes. **Table 1** below summarizes the list of existing manufacturers of battery-operated electric buses. In addition to providing the battery storage capacity for a given bus, the manufacturer also provides an estimated range that the bus can travel from 100% charge to 0% charge. Each of their buses have been selected at the maximum storage capacity and range available for the given bus length. There are a number of factors which can negatively affect how far a bus can travel on a single charge including, but not limited to ambient temperature, frequent starting/stopping, road conditions and speed. Range is also reduced over the lifetime of the bus as batteries degrade and lose capacity over time. To account for all of these factors, the range listed in the **Table 1** is 80% of the manufacturer's estimated range. For the purposes of this report, it is assumed that the reliably-usable range of a typical bus battery over its typical 12 year lifespan is 300km.

Table 1: Current Manufacturers of Battery-Electric Buses

Bus Length	Manufacturer	Bus Model	Storage Capacity (kWh)	Range (km/charge)
40ft	Proterra	ZX5MAX	660	423
	NovaBus	LFS e+	594	343
	New Flyer	Xcelsior CHARGE NG	350-525	323
	GreenPower	EV350	400	256
	BYD	K9	324	228
60ft	BYD	K11	578	267
	New Flyer	Xcelsior CHARGE NG	525	197
35ft	Proterra	ZX5 35ft	450	310
	New Flyer	Xcelsior CHARGE NG	350-440	283
	BYD	35ft	266	202
30ft	BYD	30ft	215	203
	GreenPower	EV250	260	180
28ft	Vicinity	Lightning	250	240
26ft	Proterra/Optimal EV	S1LF	113	160
26ft	Lion	LionM	160	192
25ft	GreenPower	EV Star/Star+	118	192

Based on the results of **Table 1** above, it is anticipated that battery 40’-60’ BEBs would have an average range of 314 km per charge and buses 35ft and under would have an average range of 207 km per charge, compared to 800 km per tank for diesel buses.

It is anticipated that the lithium-ion battery systems used in Battery-Electric buses will continue to both reduce in cost and improve in energy density and range, as battery technology continues to improve. That said, it is challenging to predict future battery cost and range, as the technology improvements and availability are dependent on multiple factors, including production limitations, raw materials and mining constraints, and increased demand for battery storage globally.

2.1.1.4 Existing Implementation Examples

<u>Garage Charging:</u>

Toronto Transit Commission (Toronto, ON)

- Currently has the largest pure electric fleet in North America with 60 buses
- Adding an additional 300 electric buses between 2023-2025

Edmonton Transit System

- Currently has 40 electric buses in service, with another 20 electric buses to arrive late 2021/early 2022
- First transit agency in North America to have overhead (pantograph) chargers inside transit facilities, which greatly reduces floor space needed for charging

Société de Transport de Montréal (Montreal, QC)

- Current fleet has six long-range electric buses, seven fast charging electric buses, four 30ft electric minibuses, and one battery-electric paratransit minibus, which debuted in April 2021
- Expecting 24 additional long-range electric buses by the end of winter 2021
- Goal is to only procure electric buses from 2025

Winnipeg Transit

- Four BEB trial is currently underway
- Future procurement of eight more long-range BEBs by 2023

Brampton Transit

- Deployed 8 fast-charging BEBs in May 2021
- Committed to all new and replacement buses to be electric

York Region Transit (ON)

- Two 40-foot electric buses deployed in June 2021, with four more on the way
- Actively transitioning fleet to all BEB

OC Transpo (ON)

- The first four BEBs will arrive in 2021
- 74 BEBs will be added to the fleet by 2023, and by 2036 they aim to have a fully electric fleet

Saskatoon Transit (SK)

- Deployed their first BEBs in 2020, which includes electric heat, and will serve as an model on how an electric bus will perform in very cold winter weather
- Aims to have a fully electric fleet by 2030
- Per bus, per year will have net carbon emission reductions of 50.3T of CO_2 and approximately $27,000 in fuel cost savings

On-route Charging

STM (Montreal, QC)

- Installed quick charging stations at the beginning and end of a dedicated route

Translink (Vancouver, BC)

- Currently has plans to install up to 17 on-route chargers by 2026
- Future plans to purchase 136 40-foot on-route charging buses by 2024

Brampton Transit

- Charging infrastructure also includes for high-powered overhead pantograph on-route charging stations

2.1.1.5 Implications of the Technology on Transit Planning and Operations

- There are a few critical differences when planning transit services using BEBs. Firstly, BEBs have the shortest range of all the alternative technologies, and require more frequent "refuelling" (charging) than conventional diesel buses, which impacts routes and block scheduling. BEBs also have slightly less passenger capacity than diesel buses due to the size and weight of the battery. Both of these limitations mean more buses will be needed to maintain appropriate frequency and service standards, and a well-planned charging strategy must be implemented.
- There is a considerable difference in the mechanics of electric buses to that of diesel. Specialized training for technicians and garage staff will be required to ensure they have the skills to fix and maintain the buses, which will incur additional costs and time for the transit system.
- Electric propulsion in buses is a developing technology and is only recently being implemented on a mass scale. At the moment, North American market BEBs have not been operating long in comparable conditions as Regina, such as extreme cold weather conditions for extended periods of time, so there are some concerns regarding reliability and performance that impact customer satisfaction. We know that cold weather does impact the performance of the battery, however, it is uncertain how this will affect the buses battery over its lifecycle. Consideration will need to be given not only to operating the bus in cold weather, but how buses will be stored and charged when not in service. Keeping buses outside in cold weather conditions can also drain the battery and degrade it over time, requiring more maintenance.
- Careful consideration must be given to the type of charging a transit system would like to implement: In-garage or On-route. On-route charging comes with several advantages, but chargers have to be strategically placed since the infrastructure is fixed. Frequent short duration charging also degrades the battery faster, which means more maintenance may be needed.
- Facility infrastructure upgrades required to operate BEBs include battery chargers, battery charging dispensers, increased electrical supply capacity and backup generation to power the charging equipment. Building expansion to house the chargers and electrical transformation and distribution equipment is also required.

2.1.1.6 Additional Considerations

- On-Route chargers have been considered aesthetically unattractive in some cities and may not fit with the urban design goals of the city, and there may be push back by residents on installing them in their neighbourhoods.
- BEBs are near to silent when in operation and provide a smooth driving experience. Yet the absence of noise has been a concern for many pedestrians who are used to hearing an approaching vehicle, which studies have shown have contributed to an increase of electric vehicle-pedestrian collisions. To mitigate this risk, audible systems have been added to some EVs (electric vehicles).

- The Canadian government has several funding opportunities through Natural Resources Canada (NRCan) and Infrastructure Canada (INFC) that provide grants or loans to assist municipalities in transitioning to zero-emission transit systems, including the procurement of vehicles and the modification of transit facilities to accommodate the charging equipment and increased power supply levels required. These funding opportunities include:
    - The *Zero Emission Vehicle Awareness Initiative* and *Zero Emission Vehicle Infrastructure Program* (NRCan) contribute up to $300,000 toward zero-emission vehicle (ZEV) technology awareness and education activities, and up to 50% of total project costs for installing chargers, up to $75K per charger, and a maximum of $5M per project. Second wave of applicants will open in 2022;
    - The *Investing in Canada Infrastructure Program* (INFC) cost-shares up to 40% of the eligible project costs for public transit projects
    - *Canada Community-Building Fund* (formally *Gas Tax Fund*) (INFC) is a permanent fund that supports municipalities' strategic infrastructure investments
    - Canada Infrastructure Bank's three-year Growth Plan has committed to funding zero-emission buses and associated infrastructure
    - Infrastructure Canada will also be launching a permanent public transit fund in 2026
- The Federation of Canadian Municipalities also provides funding and resources for projects that reduce emissions and encourage non-car forms of travel through their *Green Municipal Fund* and *Climate Innovation Program,* respectively.
- Roadway and pavement damage generally increases with vehicle weight and speed. Battery-electric bus weight largely depends on the number of batteries are onboard. Typically, BEBs are significantly heavier than diesel buses (up to 6,000 lbs more), which will lead to a faster rate of pavement distress and damage than conventional buses.
- Noise pollution from road traffic impacts the health and well-being of people, and has been associated with an increased risk of health problems, such as Alzheimer's. The electric motors in BEBs are relatively quiet (52dB) compared to ICE and CNG buses (80-95dB) since they do not have internal combustion.
- Battery-electric buses are considered zero-emission vehicles, meaning they do not produce greenhouse gas emissions and other air pollutants that harm our environment, unlike conventional and natural gas buses. Compared to a conventional bus, a zero-emission bus can eliminate over 1,600 tonnes of CO_2, 10 tonnes of nitogren oxides (a GHG 300 times more powerful than CO_2), and 350 lbs of diesel particulate matter (particles known to cause adverse health effects). However, heating and cooling on BEBs is often powered by a small gas or diesel combustion engine which produces some emissions.

2.1.2 Hydrogen Fuel Cell (HFC)

2.1.2.1 Defining Features

Hydrogen Fuel Cell (HFCs) buses are essentially battery-electric buses (BEBs) that utilize a hydrogen fuel cell that acts as a range extender. A fuel cell is an electrochemical cell that converts continuously supplied fuel to electricity. Unlike a traditional battery, fuel cells do not discharge or require recharging as long as fuel is supplied.

Hydrogen fuel cells are fuel cells that use hydrogen as the fuel source. In the vast majority of cases today, fuel cells vehicles - both cars and buses - run on hydrogen fuel. When hydrogen is used as the fuel source for a fuel cell, the only by-products of the chemical reaction are electricity, water, and heat, making it a zero-emission producer of electricity. Therefore, with the exception of **Section 2.2.2**, fuel cell buses are used interchangeably with hydrogen fuel cell buses to mean the same thing - buses that use hydrogen as the fuel for the fuel cells.

A fuel cell bus contains a fuel cell and a tank for pure hydrogen gas, which must be refilled like an ICE engine vehicle. The propulsion system of a fuel cell bus is similar to that of electric vehicles, but instead of storing energy solely in batteries, hydrogen in the tank is converted to electricity by reacting with oxygen in the fuel cell. A smaller bank of batteries is utilized as a buffer storage system on fuel cell buses.

HFC buses are new to the North America market, but hydrogen has been used in industry for decades and is well regulated in regards to handling, distribution, and dispensing. Hydrogen gas is odourless, colourless and is deemed flammable with a lower explosive limit (LEL) of 4% by volume. The application of the appropriate codes and standards including NFPA 2 and the Canadian Electrical Code, make hydrogen just as safe as more commonly-used fuels such as gasoline and natural gas.

Safety features on board the vehicles and in facilities where the vehicles are stored or maintained are required with a primary focus on preventing situations where hydrogen levels can exceed the LEL and ignition sources are present. This includes systems that vent hydrogen to atmosphere, sensors to detect leaks and anomalies in pressure and temperature, shut-off valves to fuel sources, use of specific electrical equipment in designated areas and properly designed ventilation systems.

2.1.2.2 Variations

Fuel cells can use a wide range of fuels, however, most vehicles currently available on the market run on hydrogen. The most common type of hydrogen fuel cell for vehicle application is a polymer electrolyte membrane (PEM) fuel cell, which provides high power density and lower weight and volume compared to other fuel cells.

Fuel cells work like batteries, but will continue working as long as they are supplied with fuel: hydrogen, oxygen (from the air), and water. Hydrogen fuel cells are a zero-carbon technology that emit only water and heat.

The most commonly used hydrogen is "blue hydrogen". Blue hydrogen is produced using fossil fuels, such as natural gas, in a thermal process called steam methane reforming (SMR). This uses steam at extreme temperatures to produce hydrogen from the methane found in natural gas, and the remaining GHGs are captured to mitigate their environmental impacts. SMR is currently the most cost-effective way to produce hydrogen.[1]

Other types of hydrogen include green hydrogen, which uses electrolysis powered by renewable energy to split water into hydrogen and oxygen. Less common variations of hydrogen include grey hydrogen (same production as blue hydrogen but emits CO^2), pink hydrogen (nuclear energy), and yellow hydrogen (electrolysis powered by solar panels).

Taking into consideration the type (or production) of hydrogen used in fuel cells is important for a city to remain transparent with their sustainability goals and reduce global GHG emissions. Only green hydrogen is considered to be zero-emission. This report assumes that Regina Transit will generate its own hydrogen by electrolysis, allowing it to create green hydrogen if renewable electricity is supplied to the garage.

2.1.2.3 Current Bus Types and Manufacturers

Hydrogen fuel cell buses are available for a range of sizes. **Table 2** below summarizes the list of existing manufacturers of hydrogen fuel cell buses.

Table 2: Current Manufacturers of Hydrogen Fuel Cell Buses

Bus Length	Manufacturer	Bus Model	Range (km/ tank)
40ft	New Flyer	Xcelsior CHARGE H2	450
	ENC	Axess FC	334
60ft	New Flyer	Xcelsior CHARGE H2	377
35ft	ENC	Axess FC	334

Based on the results of **Table 2** above, it is anticipated that hydrogen fuel cell buses would have an average range of 387 km per tank, compared to approximately 800 km per tank for diesel buses.

2.1.2.4 Existing Implementation Examples

MiWay Mississauga Transit (Mississauga, ON)

- Launched Canada's first HFC bus pilot project in April 2021
- Pilot has two phases; first is a feasibility study (estimated completion date of April 2022), and second will secure funding for 10 HFC buses

Stark Area Regional Transit Authority (SARTA) (Canton, OH)

- Began investing in HFC buses in 2014 and had 19 HFC buses in 2021

1 https://www.energy.gov/eere/fuelcells/hydrogen-fuel-basics

- First hydrogen-powered paratransit bus as of 2019

Winnipeg Transit (MB)

- Undertook a limited trial in 2004
- Deploying a test fleet of 8 HFC buses between 2022-23

SunLine Transit Agency (Riverside County, CA)

- Entire fleet is made up of alternative propulsion methods to diesel, including 16 HFC buses
- First transit agency in the United States to convert their fleet to alternative fuel in 1994
- Began investing in HFC buses in 2000

2.1.2.5 Implications of the Technology on Transit Planning and Operations

- The range, power, and passenger capacity of HFC buses is comparable to conventional diesel buses operating in Regina, therefore HFCs can directly replace conventional buses. For decades, HFC bus technology has been used in transit systems around the world on a small scale, but the technology is still developing and only recently being implemented on a large scale in differing conditions and environments.
- The lack of long-term data collected on HFCs makes it difficult to predict the reliability of HFC buses and their performance in similar weather conditions to Regina. The City of Winnipeg recently launched their HFC bus trial which will provide valuable information for the City of Regina to consider. Nevertheless, HFC buses have proven to perform better than BEBs in colder weather conditions.
- Operating HFC buses is similar to conventional diesel buses for drivers, but provides a smoother and quieter driving experience. In fact, a 2019 study found that drivers rated HFC buses to be at the same or better performance than diesel buses for handling, acceleration, braking and overall ride quality.[2] However, absence in noise from quiet vehicle technologies has been shown to increase the risk of vehicle-pedestrian collisions due to pedestrians not being able to hear the vehicle approaching. [3] [4]
- There is a considerable difference in the maintenance of HFC buses than diesel buses, which will require specialized training for technicians and garage staff to ensure they have the skills to fix and maintain the buses safely. Transit system facilities will also need to be modified to accommodate hydrogen by installing fueling/defueling systems, providing proper ventilation and monitoring, and integrating additional safety measures.
- Facility infrastructure upgrades required to operate hydrogen fuel buses include water service upgrades, hydrogen electrolyser equipment (to produce green hydrogen), compression

2 https://journals.sagepub.com/doi/abs/10.3141/2502-06

3 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7558663/

4 These studies focused on EVs and HEVs, but HFCs also have very little noise and are difficult to hear approaching.

equipment, hydrogen storage infrastructure, increased electrical capacity and backup generation to power the hydrogen production equipment, and dedicated hydrogen fuelling infrastructure.

2.1.2.6 Additional Considerations

- The Canadian government has several funding opportunities through Natural Resources Canada (NRCan) and Infrastructure Canada (INFC) that provide grants or loans to assist municipalities in transitioning to zero-emission transit systems, including the procurement of HFC vehicles and the modification of transit facilities to accommodate fueling equipment and hydrogen storage. These funding opportunities include:
    - The *Zero Emission Vehicle Awareness Initiative* and *Zero Emission Vehicle Infrastructure Program* (NRCan) contribute up to $300,000 toward zero-emission vehicle (ZEV) technology awareness and education activities, and up to 50% of total project costs for installing chargers, up to $1M per site and $5M per project;
    - The *Investing in Canada Infrastructure Program* (INFC) cost-shares up to 40% of the eligible project costs for public transit projects
    - *Canada Community-Building Fund* (formally *Gas Tax Fund*) (INFC) that supports municipalities' strategic infrastructure investments
    - Canada Infrastructure Bank's three-year Growth Plan has committed to funding zero-emission buses and associated infrastructure
    - Infrastructure Canada will also be launching a permanent public transit fund in 2026
- The Federation of Canadian Municipalities also provides funding and resources for projects that reduce emissions and encourage non-car forms of travel through their *Green Municipal Fund* and *Climate Innovation Program,* respectively.
- The creation of green hydrogen has some limitations to consider. Hydrogen production via electrolysis is somewhat inefficient, with losses of up to 30% through the electrolysing process. Therefore, more electricity will be needed to produce a unit of energy through green hydrogen than if electricity was directly used as the fuel, like in BEBs. The source of the electricity is not ideal for reducing GHGs, since over 80% of electricity in Saskatchewan is produced from fossil fuels. Electricity generated from renewable sources would reduce its associated GHG footprint.
- Roadway and pavement damage generally increases with vehicle weight and speed. Hydrogen fuel cell buses are significantly heavier than diesel buses (up to 10,000 lbs more), which will lead to a faster rate of pavement distress and damage than conventional buses.
- Noise pollution from road traffic has been associated with an increased risk of health problems, such as dementia, and negatively impacts quality of life. The electric motors in HFCs are relatively quiet (52dB) compared to ICE and CNG buses (80-95dB) since they do not have internal combustion.
- Hydrogen fuel cell buses are considered zero-emission vehicles, meaning they do not produce greenhouse gas emissions and other air pollutants that harm our environment, unlike

conventional and natural gas buses. When in operation, an HFC bus only produces water. However, heating and cooling on HFC buses is often powered by a small gas or diesel combustion engine which produces some emissions.

2.1.3 Renewable Natural Gas

2.1.3.1 Defining Features

Renewable natural gas (RNG) is a cost-effective alternative to diesel fuel. It is derived from biogas (a mixture of gases made up primarily of methane and carbon dioxide) that is captured from sources such as organic waste, agricultural production, and wastewater treatment and repurposed into RNG.

RNG is often considered to be a renewable source of energy since the biogas is naturally generated and would have been produced regardless, as opposed to being extracted from the environment like conventional natural gas. As a result, RNG can be considered a carbon neutral energy source because it does not contribute any net carbon dioxide into the atmosphere. However, other local vehicle emissions including nitrogen oxides, carbon monoxide, volatile organic compounds, sulfur dioxide, and particulate matter are still released as a result of RNG combustion.

2.1.3.2 Variations

Natural gas is a naturally occurring hydrocarbon gas mixture that is composed primarily of methane. To be used as fuel, natural gas is compressed to a small fraction of its original volume.

Conventional natural gas - often referred to as compressed natural gas (CNG) - is extracted from deep underground rock formations or other hydrocarbon reservoirs. Though it is a fossil fuel, CNG is considered “cleaner” than other internal combustion engine (ICE) propulsion fuels, such as diesel or gasoline, because it produces fewer greenhouse gas and tailpipe emissions.

RNG is a carbon neutral variant of CNG. Although the sources of RNG and CNG differ, RNG is functionally the same as CNG and can be used interchangeably in CNG vehicles.

2.1.3.3 Current Buses and Manufacturers

Natural gas-powered buses (using either CNG or RNG) are available for a range of sizes. **Table 3** below summarizes the list of existing manufacturers of natural gas-powered buses.

Table 3: Current Manufacturers of Natural Gas Buses

Bus Length	Manufacturer	Bus Model	Range (km/charge)
40ft	Nova Bus	LFS CNG	Unknown
	New Flyer	Xcelsior CNG	450
60ft	New Flyer	Xcelsior CNG	450
35ft	New Flyer	Xcelsior CNG	450
	Vicinity	Classic Vi35	Unknown
30ft	Vicinity	Classic Vi30	Unknown

Based on the results of **Table 3** above, it is anticipated that natural gas buses would have an average range of 450 km or more per tank, compared to 800 km per tank for diesel buses.

2.1.3.4 Existing Implementation Examples

Calgary Transit

- Calgary Transit is home to the largest indoor CNG bus fueling facility in North America, and plans to fuel buses with RNG once a source is secured. The system opened the Stoney CNG Transit Garage in 2019 with capacity for over 425 buses.
- As of 2021, Calgary Transit has 114 CNG buses (15% of their fleet) with another 25 on order. They plan to only purchase CNG buses in the future.

BC Transit

- BC Transit, which provides buses to transit systems in BC, began deploying CNG buses to Kamloops and Nanaimo in 2014, to Whistler in 2017 and Langford in 2020.
- In 2020 they also added 60 CNG buses to the Victoria Regional Transit System, with goals to use RNG fuel in the future.

Hamilton Street Railway (HSR)

- HSR has historically operated a fleet mix that contains CNG buses and is the first city in Ontario to use RNG in their buses. A CNG fuelling station exists at the Upper James Operations Centre
- Currently, about 120 CNG buses are part of HSR's fleet
- In March 2021, HSR launched the first bus operating on RNG fuel from the StormFisher Organics facility (London, ON) provided by Enbridge Gas Inc.

2.1.3.5 Implications of the Technology on Transit Planning and Operations

- Compressed Natural Gas technology (which is compatible with renewable natural gas) is a proven and reliable technology used on a large scale in Canada and worldwide. Its established use has made it a low risk technology which means a reduced possibility of issues during operations that can negatively impact customers. Additionally, its similar nature to conventional transit operations and infrastructure reduce challenges of incorporating it into existing operations.
- CNG buses operate much like conventional buses with an internal combustion engine that has been slightly modified for CNG use. Therefore, few adjustments to existing operations and scheduling need to be made to integrate CNG buses into the fleet. Since most of the interior mechanics and operation of the vehicle is similar to that of a diesel bus, staff will not need to be trained on a whole new system like with electric buses. The main difference will be comprehensive safety training for the technicians to ensure they have the skills necessary to perform their jobs safely and accurately.

- CNG vehicles are also similar to gasoline and diesel vehicles with regards to their power and performance. Their comparable range and fueling time results in similar scheduling demands as conventional buses since additional time to refuel does not need to be incorporated. CNG buses are also just as efficient as diesel buses in winter, unlike BEBs which have reduced range and performance in cold weather conditions.[5] This is particularly important in Regina which experiences average winter temperatures below -10°C.
- Although CNG/RNG technology and operations are similar to the existing fleet, its adoption comes with some challenges for transit planning and operations. Adopting CNG/RNG has high upfront costs for the installation of fueling infrastructure, depot safety modifications, procurement of vehicles, and speciality maintenance training.
- Another challenge is access to RNG since public infrastructure for its production is currently sparse. However, access could improve over the next few years as companies like Enbridge Gas Inc. and FortisBC are beginning to develop a number of RNG projects across Canada. Therefore, integrating CNG buses into the fleet now can help reduce emissions earlier on than waiting for RNG availability to improve, and once RNG sources become more readily available, those CNG buses can be switched to RNG fuel.
- Facility infrastructure upgrades required to operate CNG/RNG buses include incoming gas service capacity upgrades, compression equipment to increase the gas pressure from the utility to the service pressures required by CNG buses, increased electrical capacity and backup generation to power the compression equipment, and dedicated CNG fuelling infrastructure. The storage and maintenance facilities will also require modifications to ensure sufficient ventilation and monitoring is in place for the natural gas vehicles.

2.1.3.6 Additional Considerations

- The price of CNG buses is considerably less expensive than HFC and BEBs. However Renewable Natural Gas has been modeled to have the highest fuel cost compared to battery electric and hydrogen.
- The Federation of Canadian municipalities’ Green Municipal Fund provides two sources of funding for RNG projects. Their *Signature Initiative* provides up to $500,000 to cover up to 50% of eligible costs for municipal projects that reduce GHG emissions. FCM also offers grants and loans for capital projects that reduce or avoid fossil fuels and GHGs in municipal fleets (all classes of vehicles are eligible). This includes the installation of alternative fueling infrastructure, the procurement of buses, and alternative fuel fleet conversion.
- The Canadian government has also been working on the Clean Fuel Standard (CFS) which would mandate fuel distributors to lower the emission intensity of their products and create tradable

5 https://ebigaznaturel.com/en/an-assessment-of-compressed-natural-gas-vehicle-performance-in-winter/

credits by 2023. The CFS will promote innovation and adoption of cleaner fuels which will impact RNG's price and availability.

- Roadway and pavement damage generally increases with vehicle weight and speed. CNG buses being around 3,000lb heavier than diesel equivalents due to their heavy gas tanks. This means the rate of pavement distress and damage will be similar to conventional diesel buses or slightly increased.
- CNG buses have a similar noise level to ICE buses (80-95dB), which contributes to the increase of noise pollution in urban areas. Higher levels of noise pollution impacts the health and well-being of people, and has been associated with an increased risk of health problems, such as Alzheimer's.
- Natural gas buses emit 10-25% less local GHG pollution than conventional diesel or gasoline buses. However, they have the potential to emit a large number of fine particle pollution and ammonia, which is linked to serious health issues including cancer, Alzheimer's, and cardiovascular and respiratory illnesses, particularly during urban driving.

2.2 Renewability and Sustainability of Alternative Technologies

Using alternative technologies in place of conventional fuels helps conserve energy and lower vehicle emissions. All three technologies listed in **Section 2.1** would help reduce the local carbon footprint, however, consideration should be given to the life cycle emissions for these technologies, including the source of production.

SaskPower, who would supply the electricity for BEBs and the electrolyser for HFCs, produces approximately 83% of its electricity from fossil fuels - 43% from natural gas and 40% from coal - and 17% of its electricity from renewables, primarily hydroelectricity. This means that, although BEBs and HFC buses will have limited emissions at a local level, the generation of the electricity is linked to significant emissions. The proposed *Energy and Sustainability Framework* will provide a pathway to improve the cleanliness of Regina Transit's electricity supply.

Hydrogen Fuel Cell buses also require the local production of hydrogen through an electrolyser since a hydrogen supplier is not available in Saskatchewan. This process is significantly more water intensive than gasoline or diesel production, and requires a vast amount of electricity. Due to the nature of SaskPower's electricity generation, the hydrogen would not be considered "green hydrogen" since the electrolyser is not powered by a renewable source. To off-set some of the impact on water resources, the grey water produced during the process could be used for washing buses or in washroom facilities.

SaskPower is gradually transitioning to less carbon intensity in its electricity. However, it is anticipated that at their current rate of transition, they are unlikely to accomplish the province's goal of 100% renewable energy by 2050. Regina may wish to consider additional renewable power options to supplement some of the electricity supply for BEBs and HFCs electrolyser to reduce the emissions associated with the buses.

On the other hand, natural gas is a fossil fuel that is considered “cleaner” than coal or oil because its emissions are less carbon intensive. However, its production greatly impacts the land it's extracted from, surrounding waterways, and emits harmful air pollutants. Plus, it emits more than carbon dioxide; natural gas production has been linked to methane emissions, which is up to 84 times worse for the environment than carbon dioxide.

Although there is no fully renewable-powered bus option at the moment, the next 30 years will see a rapid advancement in these technologies and a greater shift towards more renewable energy and fuel sources.

3.0 Implementation in Regina

This section takes all of the information defined in **Section 2.0** and identifies the requirements and costs associated with implementing each of the technologies in the Regina context.

3.1 Energy Supply

This section addresses local electricity and natural gas utilities to determine if their networks have the capacity to provide the required energy and, if they do not, identify the approximate costs associated with upgrading the networks to meet the needs. The availability of green hydrogen (generated by renewable energy) or blue hydrogen (produced using fossil fuels) in the Regina area will also be established to determine if there is already a local supply, or if electrolysing equipment to generate hydrogen would be required. The approximate costs of supplying or manufacturing hydrogen, along with the requirements for each approach, would be determined.

3.1.1 Battery-Electric

To provide sufficient charging for Regina Transit's anticipated 2046 fleet over the course of a day, sixty (60) 150kW chargers are recommended. This requires a peak demand of 9MW of power during the day. SaskPower provides customer-owned transformations at 25kV, 72kV and higher at two different rates; Power Time-of-Use Rate and Power Standard Rate. Power Time-of-Use Rate incorporates on-peak and off-peak rates as described below in **Table 4**, whereas Power Standard Rate has a standard energy rate as described below in **Table 5** SaskPower defines on-peak hours as 07:00 - 22:00.

To provide the required 9MW of power, a SaskPower provided 25kV dedicated express line, 9MW of customer-owned transformation, switchgear, sixty (60) 150kW chargers, and 180 dispensers would be required. Due to the electrical constraints on the switchgear, the 9 MW of power would be separated into 3 - 3 MW transformers and switchgear lineups, which would each feed 20 chargers.

Table 4: SaskPower Power Time-Of-Use Rate at 25kV

Time-Of-Use Rate Type	Rate Price
Basic Monthly Charge	$6,188.90
Monthly Demand Charge (per kVA)	$10.906
On-Peak Energy Charge (per kWh)	$0.07475
Off-Peak Energy Charge (per kWh)	$0.06475
Federal Carbon Charge (per kWh)	$0.006065

Table 5: SaskPower Power Standard Rate at 25kV

Power Standard Rate Type	Rate Price
Basic Monthly Charge	$6,188.90
Monthly Demand Charge (per kVA)	$10.906
Energy Charge (per kWh)	$0.06902
Federal Carbon Charge (per kWh)	$0.006065

As the BEBs would not have sufficient range to last an entire day, some charging during peak hours will be required regardless of the selected rate. Given that the majority of charging can be done off-peak it would be recommended to use Power Time-Of-Use rates.

In discussions with SaskPower, the existing utility feeders at the Transit Operations Centre cannot support 9 MW of additional load. As a result, the utility would need to install a new 25kV express line from the substation. This has been estimated at a cost of $2.2M.

3.1.2 Hydrogen Fuel Cell

The infrastructure required to produce, compress, store and dispense hydrogen for the 2046 fleet has an anticipated peak demand of 16.6 MW of power during the day. As noted above, SaskPower provides customer owned transformations at 25kV, 72kV and higher at two different rates; Power Time-Of-Use Rate and Power Standard Rate. 25 kV service is anticipated for the infrastructure. The production of hydrogen would occur throughout the day at a steady rate. It can be scheduled to ensure that the off peak hours are used to meet the production demand, with the peak time frame used as needed.

3.1.3 Renewable Natural Gas

Currently, there is no existing source of renewable natural gas available through SaskEnergy. The options explored will have renewable natural gas availability by 2026. However, since CNG technology is compatible with RNG fuel, CNG buses can be integrated into the fleet to help reduce emissions earlier on and once RNG sources become more readily available, the fuel can be switched to RNG.

To accommodate compressed natural gas, a new utility connection to the utility natural gas will be required for refuelling of the fleet. A connection at higher pressures, 100 - 250 psi, is preferred to keep the capital and operating costs down for the compressors required for the refuelling equipment. In discussions with SaskEnergy, the estimated cost for the new high pressure gas service would be $4M. The annual gas consumption for the refuelling would put the facility in the “Small Industrial” category with SaskEnergy. Current rates for natural gas with SaskEnergy are provided in **Table 6.** A 2500 amp, 575V electrical supply is required for the natural compressors. It is unlikely that the existing facility will have sufficient power available and an upgrade will be required.

Table 6: SaskEnergy Service Charge for Small Industrial Clients

Natural Gas Rate Type	Rate Price
Basic Monthly Charge	$216.00
Delivery Charge	First 40,000 m3/month $0.0442 per m3
Remaining Volumes	$0.381 per m3

It is important to note that while it would likely not apply to RNG Fuel, Canada has imposed a Carbon Tax on carbon emitting fuels such as natural gas. The cost of Carbon is to reach $170/tonne by 2030. This would increase the cost of natural gas by $0.32 per m3 and the cost of diesel fuel by $0.46 per liter by 2030.

3.2 Energy Distribution & Fueling

The focus of this section is on the Transit Storage and Maintenance Facility site and what must be done to receive the required energy and distribute it within the site. A description, along with approximate costs, will be developed for each of the technology options.

For battery-electric buses, this would likely require:

- The development of a substation on the site
- An upgraded distribution network
- Increased or enhanced electrical rooms; and
- Pedestal and/or overhead charging infrastructure

For hydrogen fuel cell buses, this would likely require:

- Either equipment to receive the product from external sources or a facility expansion for electrolysing equipment
- Piping between receiving/generation infrastructure
- Fuelling infrastructure

For compressed/renewable natural gas buses, this would likely require:

- Equipment to receive the gas from the main
- Facility expansion for the compression and storage
- Fueling infrastructure

3.2.1 Battery-Electric

Based on the Transit Master Plan's network and services, a bus would need to travel approximately 400km per day of service. Given that the assumed bus range is 300km, charging during the day will be required. It is important to note that manufacturers are continually improving bus and battery technology, thereby improving range. By the time this project is implemented, there may be electric buses available which would have sufficient range to not require day charging. This would reduce the bus fleet to peak requirements and allow charging to be fully optimized for off-peak utility rates.

For Main and Local routes in 2046, 161 buses are required during peak hours. Due to the need for day charging and the peak/off-peak bus ratio, it would be beneficial to 'group' buses into three separate groups for most routes.

Given a range of 300km, it is possible for a bus to run from the start of AM peak to the end of PM peak. However, this would nearly deplete the bus's charge and would require the bus to be fully charged at the start of AM peak and return to the garage to charge at the end of PM peak. This would work for one group. To meet the required number of buses during off-peak hours before AM peak and after PM peak, the other two groups would both be required to run during this time, meaning they would both be required to charge between the AM and PM peaks while "group A" runs. They could split the 6 hours between peaks and each have 3 hours to return to the garage and charge. This would allow these two groups sufficient charge to fulfill the required number of buses for the remainder of the day.

For example, for Route 4, each group would represent 6 buses. This would allow for 12 buses off-peak, 18 buses on-peak, and 6 buses during late hours.

The typical day charging plan is described in **Table 7**, where green represents a group of buses on route and orange represents buses in the garage charging.

Table 7: Proposed BEB Charging Plan

Time	Group A	Group B	Group C
5:30			
6:00			
6:30			
7:00			
7:30			
8:00			
8:30			
9:00			
9:30			
10:00			
10:30			
11:00			
11:30			
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18:30			
19:00			
19:30			
20:00			
20:30			
21:00			
21:30			
22:00			
22:30			
23:00			
23:30			
0:00			
0:30			

Using this scheme, it is estimated that 172 buses would be required for a given weekday. At any given time between peak hours, it is estimated that a maximum of 60 buses would be charging at a single time, each using 150kW for a total power consumption of 9MW. With a fleet of at least 172 buses running each day and 60 buses charging at a time, a charger/bus ratio of 3:1 can be used with each charger having three dispensers. This would allow for staged charging overnight in off-peak hours.

Given the nature of the bus storage garage, which has multiple rows of buses tightly packed, overhead pantograph chargers would need to be utilized as there is insufficient space for standard dispensers and walking room for drivers to exit the area. Note that the current garage does not have sufficient storage capacity for the anticipated fleet in 2046, and will need to be expanded. The pantograph chargers would be mounted from the ceiling which would add significant weight. A review of the building and roof structure would be necessary to determine required structural upgrades, if any, to support the pantograph chargers. Using a 3:1 pantograph-charger ratio, buses could be simultaneously charged along rows, with pantographs connected to the same charger being in adjacent rows. This would allow a full row of buses to charge simultaneously, and deploy to their given routes at the same time. This can be seen visualized in **Table 8**, with pantographs connected to the same charger outlined in black, with each individual pantograph coloured in blue, green and orange to indicate staggered charging, with simultaneous charging in common rows.

Table 8: Pantograph Charger Stalls

	Stall 10	Stall 9	Stall 8	Stall 7	Stall 6	Stall 5	Stall 4	Stall 3	Stall 2	Stall 1
Row 1										
Row 2										
Row 3										
Row 4										
Row 5										
Row 6										
Row 7										
Row 8										
Row 9										
Row 10										
Row 11										
Row 12										
Row 13										
Row 14										
Row 15										
Row 16										
Row 17										
Row 18										

To provide the required 9MW of power, a 25kV dedicated express line, 9MW of customer-owned transformation, switchgear, sixty (60) 150kW chargers, and 180 dispensers would be required. Due to the electrical constraints on the switchgear, the 9 MW of power would be separated into 3 - 3 MW transformers and switchgear lineups, which would each feed 20 chargers.

If located indoors, the service entrance 25kV switchgear would require a room with a footprint of approximately 6m x 7m. The customer owned transformation and distribution switchgear would require a room with a footprint of approximately 11 x 15m. Given the storage arrangement of buses, the chargers would need to be located in a centralized room rather than next to the buses. The 150kW chargers are approximately 1.25m x 2m in dimension each. To locate the chargers in one room, with adequate spacing for ventilation would require an area of approximately 19m x 27m. To save on building space, the 25kV switchgear and transformers could be located outdoors if desired.

The building expansion would also incur new electrical loads including lighting, cooling and heating to the existing building utility. A review of the existing electrical capacity would need to be completed to determine if there is sufficient capacity. A potential location for this expansion is shown in

Figure 1.

The total electrical requirements and costs for the proposed BEB fleet are articulated in **Table 9** and **Table 10**. **Table 11** summarises the required electrical charging equipment and shows anticipated costs.

Table 9: Daily Utility Requirements

Year	Electricity (kWh)
2026	34,965
2046	59,598

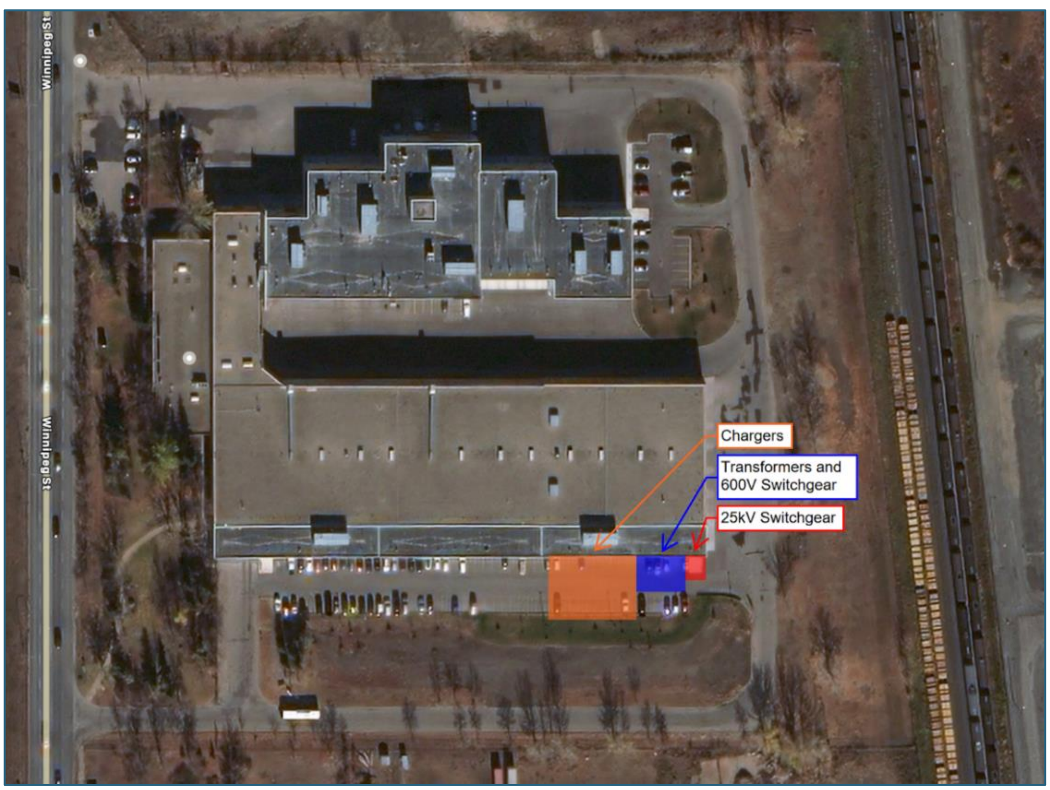
Table 10: 2046 Weekday Electricity Fuel Cost

KMs Travelled	42,570.00
Cost of Electricity	$0.06902/kWh
Daily Charger Consumption	59,598 kWh
Daily Cost of Fuel	$4,113

Table 11: Electric Charging Equipment List

Equipment	Quantity	Description	Cost
25kV Express Line and Service Termination Switchgear	1	New 25kV service dedicated to providing power to bus charging infrastructure	$2,200,000
Customer Owned Transformation	3	3 MVA 25kV:600V step down transformers	$500,000
600V Switchgear	3	600V, 3000A rated switchgear with main breaker, metering, 20 breakers for chargers	$1,200,000
Chargers	60	150kW 600V charger	$9,000,000
Dispensers	180	Overhead pantograph chargers rated for 150kW charging at 600V	$4,500,000
Structural Upgrades to Existing Facility		Upgrade structural roof trusses to accommodate pantograph chargers	$1,000,000
Building Expansion	1	720m^2 building expansion for electrical transformation and distribution equipment	$2,000,000
Backup Power	6	1.5MW Outdoor Generators, ATS, Reinforced Concrete Pad, Cabling	$6,000,000
TOTAL			**$26,400,000**

Figure 1: Aerial photo of garage with proposed equipment location



3.2.2 Hydrogen Fuel Cell

There is currently no large supply of hydrogen to service a fleet for Regina, nor are any of sufficient size expected in the coming years. On-site production of hydrogen would be required to support fleet operations including infrastructure to produce, compress, store, and dispense gaseous green hydrogen. Based on project routes, the following supply of hydrogen would be required:

Table 12: Daily Hydrogen Requirements

Year	Daily Hydrogen Requirements (kg)
2026	2,073
2046	3,533

For the purposes of this study and to achieve the required emission reductions, only electrolysis will be reviewed for production.

Saskatchewan has adopted the Canadian Hydrogen Installation Code CAN/BNQ 1784-000. This code sets the installation requirements for hydrogen generation equipment, hydrogen utilization equipment, hydrogen dispensing equipment, hydrogen storage containers, hydrogen piping systems and their related accessories. The code sets minimum clearances from the hydrogen infrastructure to different exposures including adjacent buildings and public sidewalks. Of particular importance to this site when considering potential locations for the installation is the requirement to maintain a clearance of 4.6m from public sidewalks and parked vehicles and 15.2m from HVAC inlets, building openings and flammable liquid storage.

The hydrogen electrolysers require a source of potable water and electricity to produce hydrogen. Typical commercial electrolysers are provided with a water treatment skid to treat the municipal water to the levels required. It is estimated that 1.5 L to 2 L of potable water will produce 1 L of pure process water, which produces 1 normal cubic metre (Nm^3) of hydrogen. The anticipated utility requirements are summarized in **Table 13**, and the anticipated cost of hydrogen in **Table 14**.

The electrolyser equipment requires a sanitary drainage connection for equipment and process drainage. As this water is generally of a quality to meet grey water standards, reuse can be considered, such as for irrigation or vehicle washing.

To meet the 2046 demand, a total of 16.6 MW of power is anticipated, and new 25kV service would be required. The electrolyser equipment can receive power at 25 kV and is provided with the necessary equipment to transform the service down to supply all of the auxiliary equipment loads.

Hydrogen is typically produced at a pressure of 30 bar, but vehicle dispensing is required at 350 bar. On site storage is typically in the range of 450 bar requiring onsite compressors. A minimum of two reciprocating compressors would need to be installed for redundancy. Pressure vessels specifically designed for high pressure hydrogen storage are required to meet ASME UPV Code Section VIII Division 1. The installation of the storage equipment can be phased over time as additional buses come online.

The on-site storage provides a source of fuel in the event of maintenance or utility downtimes, along with buffer capacity for increased periods of refuelling. A typical storage volume of two (2) days has been used by other transit authorities or fleets. Additional storage can be considered, but the high pressure vessels have a high capital cost and large footprint.

Based on a fueling time of 6-10 minutes for a 40' bus, typical fleets estimate one dispenser can service 24 buses within an acceptable refuelling time. Initially 5 dispensers would be required for the 2026 fleet, with space provisions for an additional 2 in 2046. A potential location for this expansion is shown in **Figure 2.**

Commercial electrolyser and hydrogen compression equipment is provided with weather enclosures to facilitate operation down to -40°C and all safety equipment as required by CAN/BNQ for their specific equipment. The equipment would be installed in separate enclosures as they are generally provided by separate manufacturers. The existing site would require grading and new reinforced concrete slabs for all equipment. The anticipated total footprint for the hydrogen infrastructure is approximately 20 m x 45 m. This includes all equipment to produce, compress, store, and dispense fuel for the 2046 fleet with two days of storage capacity. It does not include vehicle access and turnarounds.

It is recommended that hydrogen production infrastructure consider the full 2046 requirements for total electrical demand and space during the initial installation. **Table 15** summarises the required electrical charging equipment and shows anticipated costs.

Table 13: Utility Requirements

Year	Daily Potable Water (L)	Daily Electricity (kWh)
2026	46,096	109,098
2046	78,571	185,958

Table 14: 2046 Weekday Hydrogen Fuel Cost

KMs Travelled	42,570.00
Cost of Electricity	$0.06902/kWh
H2 Daily Station Consumption	185,958 kWh
Cost of Water	$2.10/m3
H2 Daily Station Consumption	78.57 m3
Daily Cost of Fuel	$13,000

Table 15: Hydrogen Equipment List

Equipment	Quantity	Description	Cost
25kV Express Line and Service Termination Switchgear	1	• New 25kV service dedicated to providing power to bus charging infrastructure	$2,200,000
Customer Owned Transformation	6	• 3 MVA 25kV:600V step down transformers	$1,000,000
Electrolyser	1	• PEM Electrolyser c/w weather container or building capable of producing 4,000 kg hydrogen / day at 10.25 MW peak power • Electrical and controls to support electrolyser • Water purification system • All process drying and cooling requirements	$12,600,000
Compressors	2	• Hydrogen compressors capable of compressing hydrogen from 30 bar to 450 bar • 4,000 kg/day capacity • Buffer tank with 30 bar pressure rating	$4,000,000
High Pressure Storage Containers	3 banks	• 450 bar hydrogen storage tanks • 7,000 kg capacity	$4,000,000
PLC Control System	1	• Station control system capable of remote access for monitoring station	$500,000
Dispensers	7	• Seven 350 bar heavy duty fueling dispensers c/w user interface	$3,000,000
Backup Power	2	• Paired 1.5MW Outdoor Generators, ATS, Reinforced Concrete Pad, Cabling	$4,000,000
TOTAL			**$31,300,000**

Figure 2: Aerial photo of garage with proposed equipment location

3.2.3 Compressed Natural Gas

The compressed natural gas station would receive fuel from the local utility, SaskEnergy. A high pressure utility connection of 100 psi - 250 psi is preferred to reduce the size and cost of the compressors. Additional compression to 3,600 psi is required for the buffer storage and vehicle fills.

A CNG Time-Fill station, a fueling station used to fill multiple vehicles over a longer fueling window (like overnight), is typically used for transit fleets as the equipment is better suited for large vehicle numbers with high volumes over long fuelling periods (hours). They utilize less storage and fill directly from the compressors, reducing the capital cost and equipment sizing. Less on-site storage is required with a Time-Fill station.

The station infrastructure includes three (3) reciprocating compressors, a dryer for the incoming natural gas, filtration equipment downstream of the compressors, buffer tank storage, and fuel dispensers. The compressors are sized at 50% of the load to allow for better operation at smaller loads and to provide redundancy in the system for utility downtime and maintenance. Electric driven compressors have been largely utilized over natural gas drives for transit and fleet operations. The buffer tanks are sized to accommodate multiple simultaneous fills, but not long term storage. The fill time is similar to that of diesel buses. A potential location for this infrastructure is shown in **Figure 3**.

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The available gas pressure from the utility has an impact on the station design and cost. As the amount of compression required increases, the compressors and associated equipment subsequently increase along with the operating costs. For a large-scale facility such as this, high-pressure (greater than 100 psig) is preferred. The total gas requirements and costs for the proposed fleet are articulated in **Table 16** and **Table 17**. **Table 18** summarises the required equipment and shows anticipated costs.

Table 16: Daily Natural Gas Requirements

Year	Daily Natural Gas Requirements (m3)
2026	30,411
2046	51,836

Table 17: 2046 Weekday RNG Fuel Cost

RNG Cost	$10/GJ - $0.400/m3
KMs Travelled	42,570.00
Daily Gas Consumption	51,836 m3
Cost of Electricity	$0.06902/kWh
CNG Station Electrical Consumption	23,040 kWh
Daily Cost of Fuel	$22,324

Table 18: CNG Equipment Requirements

Equipment	Quantity	Description	Cost
Upgrade to existing Incoming gas service	1	• Upgrade gas line to accommodate 100-205psig Gas supply for daily requirement described above)	$4,000,000
Customer Owned Transformation	1	• 3 MVA 25kV:600V step down transformers	$200,000
Natural Gas Compression Station		• 1x Gas Dryer • 4x Gas Compressors (1 redundant) • 9x Cylinders of CNG Storage • 1x Gas Control Panel • 3x Dual Hose Gas Dispensers • 2x Motor Starter Panel	$8,720,000
Backup Power		• Paired 1.5MW Outdoor Generators, ATS, Reinforced Concrete Pad, Cabling	$2,000,000
TOTAL			$16,920,000

Figure 3: Aerial photo of garage with proposed equipment location

3.3 Energy Storage & Back-up

This section will focus on determining the approximate size of potential natural gas and hydrogen storage vessels and identifying the approximate costs for these. It will also identify how much battery storage capacity might be appropriate for the battery-electric option in order to provide an offset to drawing from the electricity grid during peak rate times, and to provide for back-up in case of an electricity grid outage. Appropriately sized electricity generation capability for each of the technology options will also be identified in order to provide reasonable back-up power resiliency for all options. Approximate costs for all of these options will be developed.

3.3.1 Battery-Electric

To provide backup power for the charging infrastructure, diesel or natural gas generators and automatic transfer switches (ATS) connected in parallel with the 3MVA transformer feeds are recommended. During the day and at night, all sixty (60) 150kW chargers may be needed simultaneously. Therefore, to provide adequate backup, 9MW of generation would be required. To accommodate for scenarios in which not all chargers would be in use, an array of smaller generators would be recommended. For each 3MVA 600V switchgear, two 1.5MVA generators could be used, staged to turn on as needed, for a total of 6 1.5MVA generators.

Each generator would require an outdoor enclosure and a reinforced concrete pad. For each 600V switchgear lineup, an additional section approximately 1m in width would be required to incorporate the ATS.

3.3.2 Hydrogen Fuel Cell

Two days of storage is recommended for the hydrogen refuelling station. This allows for equipment maintenance downtime and interruptions in utility supplies. Additional storage can be accommodated, but the high pressure hydrogen storage tanks have a high capital cost and a large footprint. Back-up power for the electrolysis is not recommended if the onsite storage can accommodate most anticipated utility disruptions. A smaller source of back-up power is required for the electrolyser cooling, control, and dispensing equipment to ensure refuelling can continue. An on-site generator can be used.

As storage for the produced hydrogen is included, there would be no need for back-up power for the electrolysis equipment. The equipment to dispense the hydrogen and maintain the station operation would be required to be connected to an emergency power supply to ensure refuelling can occur during utility downtimes. The anticipated load needed for emergency power is not expected to exceed 6 MW.

All hydrogen production facilities will require a maintenance program in accordance with codes and regulations. Maintenance activities can be provided by equipment suppliers under contracts or transit staff can be trained to perform all scheduled maintenance activities. Annual costs for maintenance contracts are anticipated to be $200,000. Another $80,000 is expected for routine replacement parts.

3.3.3 Compressed Natural Gas

As time-fill stations typically don’t utilize large amounts of storage, interruptions to the electrical power supply would disrupt refuelling operations. A backup supply of electrical power for the compressors is recommended to maintain operations.

Similar to the hydrogen production facility, the compressed natural gas station will require a maintenance program to ensure proper operation of the compressors, high pressure piping, storage vessels and dispensers. Annual costs for maintenance contracts are anticipated to be $120,000. Another $50,000 is expected for routine replacement parts.

3.4 Other Facility Needs

In addition to the energy related requirements for the transit storage and maintenance facility for each of the technology options, there are likely to be additional upgrades and changes required at the facility. These could include:

- Hoist upgrades recently made to the facility will accommodate all three bus technologies - no hoist upgrades required
- Partial diesel decommissioning
- Structural upgrades to accommodate overhead charging equipment
- Shop and service bay renovations to accommodate different tools and technology
- Shop and service bay renovations to accommodate access to overhead chargers, etc; (costs)
- Ventilation system and gas monitoring changes to accommodate different requirements and costs
- These and any other relevant requirements will be identified and appropriate cost allowances will be developed
- Environmental

Maintenance garages designed for conventional diesel fleets will need upgrades to the ventilation systems to accommodate the additional exhaust rates required by code for hydrogen or natural gas/methane. Hydrogen or natural gas detection equipment including alarms is also required.

3.5 Operational Impacts

Each potential technology has its own operational constraints that will impact how Regina Transit may use the new vehicles and systems. This task will identify these differences and analyse how existing blocking may be operated by each technology.

The main operational limitations, number of existing blocks that can be operated, and recommended operational changes will be detailed for each technology.

3.5.1 Cost of Fleet

The cost of standard 40' buses and the cost to replace the whole fleet is summarized in **Table 19**. It is assumed, however, that Regina Transit will not retire diesel buses before they reach the end of their lifespan (usually 15 years). All costs are in 2021 Canadian dollars.

Table 19: Bus and Fleet Costs

Technology	Average cost per bus	Cost of fleet replacement
Compressed Natural Gas	$700-$850K	$158-191M
Hydrogen Fuel Cell	$1.2-$1.5M	$234-$292M
Battery-electric	$1.3M	$304M

3.5.2 Bus Range & Blocks

The range of each bus technology differs depending on several factors, including but not limited to the manufacturer and bus model, external temperature, storage capacity, and the number of people on the bus (additional weight). For context, existing diesel buses have a range of approximately 820km. The ranges used and discussed are based on conservative estimates:

Table 20: Bus Range by Fuel Type

Bus Technology	Average bus range (km) on full tank/charge
Compressed Natural Gas	450+
Hydrogen Fuel Cell	400
Battery-electric	300

Based on Regina Transit's typical schedule and blocking plan, the anticipated operating ranges would allow the CNG and HFC buses to operate on all 40' bus blocks, and BEBs to operate on approximately 80% of the 40' bus blocks. This accounts for the length of the block falling within the vehicle range.

It should be noted that HFC buses and BEBs use diesel heaters to meet cabin heating demands and allow the buses to achieve the same range across the spectrum of Regina's weather conditions.

3.5.3 Fleet Requirements

The fleet requirements for all three technologies are summarized in **Table 21, Figure 4** and **Figure 5.**

Fleet requirements were based on Regina Transit's forecast typical weekday schedule and blocking plan. The following assumptions were applied:

- A fleet-wide spare bus ratio of 25%
- CNG and HFC buses can replace diesel buses 1:1
- Due to range limitations, BEB would need additional buses to cover Regina's typical bus blocks

It is anticipated that 204 CNG or HFC buses, or 215 BEBs would be needed by 2046 for the fleet to operate the same level of service compared to diesel buses. This accounts for the maximum number of buses needed during peak times, as well as additional buses needed for maintenance.

Table 21: Fleet Requirements by 2046

Technology	Fleet Requirements by 2046
Compressed Natural Gas	204
Hydrogen Fuel Cell	204
Battery-electric	215

Figure 4: Battery-Electric Fleet Composition to 2046

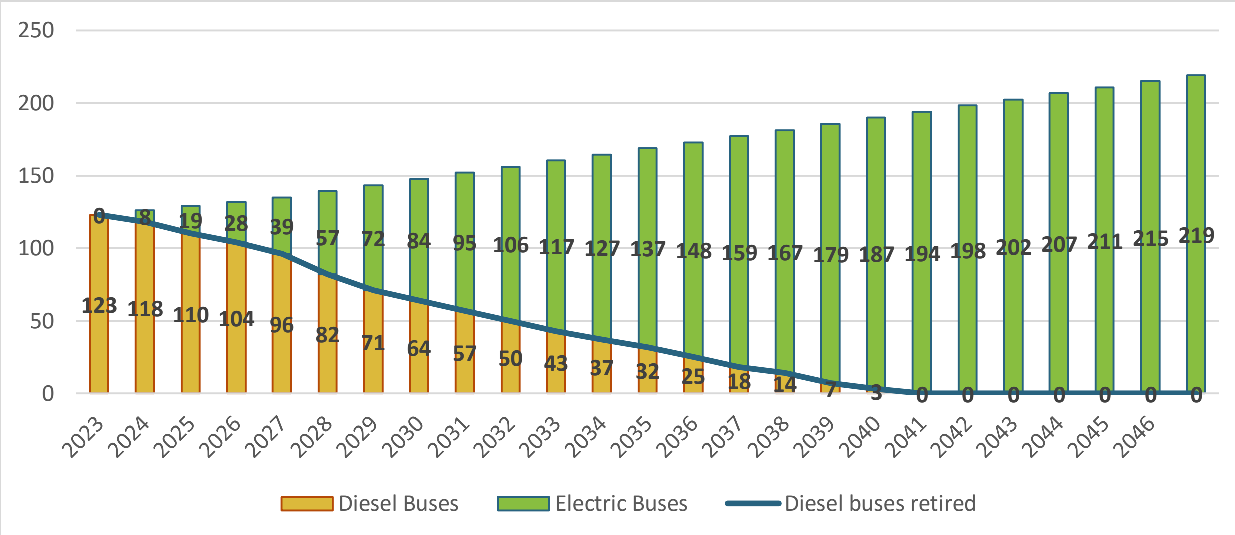
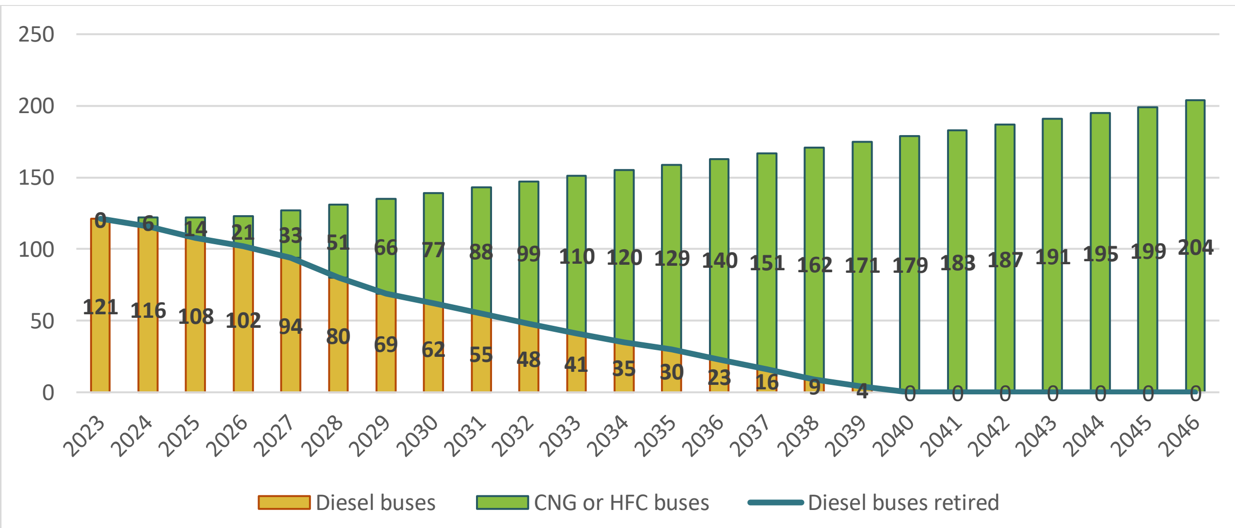


Figure 5: CNG or Hydrogen Fuel Cell Fleet Composition to 2046



3.5.4 Operational Impacts

Assuming Regina Transit would keep the same block patterns and lengths as present day, the same scheduling can be used for CNG and HFC buses since their ranges can cover all the blocks. Only BEB scheduling will be affected due to shorter ranges. Selecting BEBs would require an additional 20% of buses to cover the blocks and operational restructuring and schedule adjustments to top-up some buses' charges mid-day. It is recommended to avoid any charging during the PM peak.

Changes to make existing blocks shorter and maximize charging opportunities may improve the number of blocks that can be operated by the BEBs; however, with limited range and relatively slow charge times, additional buses would be required to operate the same level of service compared to existing diesel buses. It should be noted that, within the transit industry, it is widely-expected that BEB range will be a primary field of improvement over the coming years, which would reduce operational constraints of future bus purchases.

It should also be noted that HFCs will have a slightly longer fueling time than diesel (6-10 minutes), and the availability of parts for maintenance may impact downtime.

3.6 Staffing and Training Needs

The transformation of Regina Transit's system will also have significant impacts on staff – both in terms of the size of Regina Transit's staff and the training required for them. Introducing a new propulsion technology will require staff to be trained at various levels, depending on their role in the organization. The new technology may also require more or less staff, depending on the technology and the assumptions associated with it. This task will identify the general requirements in these areas for each of the technologies, including the time and cost implications.

3.6.1 Staffing Requirements

Each staffing category was forecast as functions of the system metrics, shown in **Table 22** below. The projected Regina Transit staffing needs to 2046 are assumed to be similar for CNG and HFC buses since they will be able to cover the same blocks as diesel buses and therefore more staff are not required. It is also assumed that current maintenance staff will be trained on the new technology, which is discussed in the following section. Staffing needs will change if BEBs are selected since more buses will be needed. The projected staffing to 2046 will be outlined in the following report.

Staff are categorized based on the classification used in the annual Canadian Urban Transit Association (CUTA) Conventional System Factbook.

Table 22: Staff Requirement Forecasting Assumptions

	Staff Category	Function of
Conventional Fleet Staff	**Operators**	Fleet Size
	Other Transport Operators	Fleet Size
	Vehicle Mechanics	Fleet Size
	Other Vehicles Mechanics	Fleet Size
	Plant and Other Maintenance	Fleet Size
	General and Administration	Service Hours

3.6.2 Training

The training schedule is based on the training requirements and assumptions for a battery-electric fleet in the comprehensive [6]*2021 Winnipeg Transit: Transition to Zero-Emission Technical Evaluation Report*. Although very different technologies, the training requirements are being generally applied to all three technologies at this stage in the report writing since training will include similar elements: general staff

6 *https://winnipegtransit.com/assets/2788/Transition_to_Zero_Emission_Technology_Report_-_Rev1.pdf*

familiarization, safety awareness and work procedures, fuel handling/energy charging, emergency training, and advanced training for those working on buses. More specific training schedules will be recommended later on.

Similar to the Winnipeg Transit report, Regina Transit staff are recommended to be divided up into one of five training levels based on their role and exposure to high voltage. The training levels and the staff groups recommended for each level are summarized in **Table 23**. Assumptions for the table can be found in the footnotes under the table. Note that staff are classified according to the CUTA Factbook staffing categories introduced in **Table 22**.

Table 23: Battery-electric Training Categories

Training Category	Eligibility	Training Components	Conventional Staff Receiving this Training
Level 1	All Staff	• 1 hr of in-house training[1]	• 50% of "General and Administration"
Level 2	Staff working in areas where buses or chargers are operated	• Level 1 training • Additional 3 hrs of in-house training[1] covering bus familiarization, basic high voltage safety awareness vehicle hazard identification and precautions, operations safety training, safe work procedures	• 100% of "Operators" • 50% of "General and Administration"
Level 3	Staff directly servicing buses or chargers	• Level 1 and 2 training • Additional 12 hours of in-house or manufacturer-offered[2] training covering: ○ Advanced safe work procedures for servicing buses and chargers ○ Advance vehicle service safety training ○ Facilities emergency response procedures for service and parking garages ○ Tools and equipment for electric bus service ○ Basic Personal Protective Equipment instruction and training	• 100% of "Other Transport Operators"

Training Category	Eligibility	Training Components	Conventional Staff Receiving this Training
Level 4	Staff directly involved in maintenance, repairs, or overhauls of buses, chargers, or service equipment	• Level 1, 2, and 3 training • Arc Flash training • First Aid Training • External training[3] for: ○ Advanced safe work procedures for bus maintenance and repair ○ Advances vehicle maintenance safety training ○ Advances PPE instruction and training ○ Tools and equipment for electric bus maintenances ○ Facilities emergency response procedures for maintenance garage	• 100% of Plant and Other Maintenance • 95% of Vehicle Mechanics • 95% of Other Vehicle Mechanics
Level 5	Staff directly involved in diagnostics, repair, or troubleshooting of bus propulsion or electrical systems	• Level 1, 2, 3, and 4 training • External training[3] for: ○ Advanced diagnostics and troubleshooting of vehicles ○ Advanced diagnostics and troubleshooting of facilities and equipment	• 5% of Vehicle Mechanics • 5% of Other Vehicle Mechanics

[1] Assumed that Regina Transit will develop internal basic training modules for staff
[2] Assumed that manufacturers will offer advanced training, based on conversations with vendors and manufacturers
[3] Winnipeg Transit included external training from the "Introduction to Electric Vehicles" program at Red River College in Winnipeg. Modules 1 and 2 were included for Level 4 and Modules 1, 2, and 3 were included for Level 5. It is assumed that Regina Transit would be able to find similar training at a local partner institution

3.7 Paratransit/Demand Responsive Buses

Regina Paratransit buses are used to deliver Regina Transit's current specialized transit and future Demand Responsive services. These vehicles currently use gas propulsion technology.

The results of the industry scan have shown that alternative energy technologies for Paratransit vehicles are not as advanced as conventional vehicles and have not been extensively tested in real operating conditions. The vehicles available on the market are also relatively few in number. Today, there are no large-scale implementations of alternative energy specialized bus fleets. Though some technologies exist, they are largely untested in regular service conditions. Based on this consideration, it is recommended that the purchase of proven technologies, like gas powered vehicles, be undertaken for the next few years, until alternative fueled paratransit vehicles have gained experience.

Since paratransit buses typically have a lifespan of approximately five to six years, and small low floor gas buses six to eight years, the purchase of alternative technology vehicles in the next few years could still allow Regina Transit to meet its sustainability goals. The next round of gas-powered vehicles purchased over the next five years will be retired well ahead of the City's 2050 goal. Future investigations can flag changes or improvements in the availability of alternative energy technologies for Paratransit vehicles over time. This would inform Regina Transit's purchase decisions for the following Paratransit fleet replacement cycle and ensure that reliable and proven vehicles are provided for riders.

In terms of emerging alternative technology vehicles for Paratransit, in line with personal automobiles and larger buses, the majority of options are battery electric. The first cutaway vehicles built on electric chassis are becoming available in North America. In addition, start-ups like Lion Electric, as well as experienced diesel bus manufacturers like Vicinity and Arboc, have launched 30ft low floor electric bus models that would also be suitable. As stated above, none of these vehicles have been proven through constant transit use, or in cold climates, for a number of years and, therefore, are considered too immature for adoption by Regina Transit in the short term.

3.7.1 Recommended Paratransit/On Demand Bus Purchase Plan

Regina Transit should continue to purchase gas-powered vehicles similar to its current fleet for replacements and growth over the next five years. Regina Transit should continue to monitor the development of alternative energy vehicles for Paratransit use, with a view to replacing their gas-powered vehicles as they are due to be retired.

In planning for the future Demand Responsive fleet, the Transit Master Plan assumes the following:

- The current Paratransit fleet (35 buses) will grow as On Demand service is introduced and demand for Paratransit service increases over the life of the plan;
- Cutaway vehicles have an assumed 5 year lifespan, while electric 30ft low floor vehicles have a lifespan of up to 10 years;
- Six to eight cutaway vehicles will be replaced each year, based on the current fleet size;
- Electric cutaways cost about $250,000 each; compared to $450,000 for electric 30ft low floor buses.

4.0 Summary Comparison of Technologies

Metrics	Renewable Natural Gas	Hydrogen Fuel Cell	Battery-Electric
VEHICLES			
Number of buses required for full fleet (by 2046)	205	204	215
Cost per bus	$700-850K	$1.2-1.5M	$1-1.3M
Capacity	83 (40 seated)	75 (41 seated)	84 (40 seated)
Storage Capacity (kWh)	N/A	N/A	350-660
Range (km)	650	450	300
Climate impacts on performance	Similar to diesel	May have slightly less range in cold weather, minimized by diesel heaters	May have slightly less range in cold weather, minimized by diesel heaters
Range degradation	Similar to diesel	Less than BEBs, but range will still degrade over time	Range degrades over time (~20% over 12 years) and in colder weather
Cost for replacement of whole fleet	$144-174M	$245 - 306M	$215-280M
Annual Fuel Cost	$8,148,260	$4,745,000	$1,501,411
Canadian Infrastructure Bank Eligible?	✕	✓	✓
FUEL/ENERGY & INFRASTRUCTURE			
Fueling Infrastructure	• Natural gas compressors and fuel dispensers • Power upgrades • New high pressure (100 - 250 psi) natural gas service	• Hydrogen production system including PEM electrolysers • Hydrogen station requirements including high pressure storage, compressors and dispensers • Significant power upgrades	• New dedicated utility service and switchgear • Customer owned transformation • Overhead or plug-in chargers need to be added to garage • Significant power upgrades
Additional Infrastructure	• HVAC System upgrades to manage gas safety	• HVAC System upgrades to manage gas safety	N/A
Source of fuel/energy & production	• SaskEnergy - Renewable Natural Gas project on the longer-term horizon	• Electrolyser-produced hydrogen using electricity from SaskPower electrical Grid: 75% produced thru fossil fuels, 25% produced through renewable sources	• Electricity from SaskPower electrical Grid: 75% produced thru fossil fuels, 25% produced thru renewable sources

Metrics	Renewable Natural Gas	Hydrogen Fuel Cell	Battery-Electric
Average rate cost of fuel/ energy source	• $10/GJ for RNG	• Electricity for electrolyser subject to SaskPower pricing ($6,188.9 base + $10.906 per kVA + $0.060902 per kWh) + $2.10/m3 of water • Additional costs for diesel heaters	• Subject to SaskPower pricing - ($6,188.9 base + $10.906 per kVA + $0.060902 per kWh) • Additional costs for diesel heaters
Cost of fuel/energy infrastructure	$16.9 M	$31.3 M	$26.4M
Future Risks/ Opportunities	• Price of natural gas may fluctuate and will be impacted by carbon taxes • New sources of renewable natural gas are anticipated	• The price and availability of hydrogen is likely to improve in the next 10 years as the technology becomes more common	• Price of electricity may fluctuate
OPERATIONS			
Scheduling	Higher range means that less changes would need to be made to block schedules compared to BEBs	Higher range means that less changes would need to be made to block schedules compared to BEBs	Lower range means some service blocks may require restructuring or an additional vehicle.
Impact to Staff	Training would be required for drivers and maintenance staff	Training would be required for drivers and maintenance staff	Training would be required for drivers and maintenance staff
Fleet size Implications	Fleet size can remain as planned	Fleet size can remain as planned	If blocks remain the same, additional buses will be needed to accommodate blocks 300 km+
Fueling time	Comparable to diesel	6-10 minutes	3-4 hours
Fueling Process	Fueling process similar to diesel	Fueling process similar to diesel	There may be operational adjustments required to charge buses mid-day
Future Risks / Opportunities	Current market for RNG in Saskatchewan is not well established. Possible that it will grow in the future	Vehicle range and fuel cell lifespan may improve as technology improves	Vehicle range and battery degradation may improve as technology improves
LOCAL & ENVIRONMENTAL IMPACTS			
Upstream Emissions	*CNG*: Produced with fossil fuels *RNG*: derived from organic waste material or	Grid supplied electricity produced with a mix of fossil fuels and renewables	Grid supplied electricity produced with a mix of fossil fuels and renewables

Metrics	Renewable Natural Gas	Hydrogen Fuel Cell	Battery-Electric
	degradable carbon sources		
Tailpipe Emissions	Low CO_2 emissions Up to 25% less GHG emissions	No carbon-based tailpipe emissions from operation, but diesel heaters required during colder months	No carbon-based tailpipe emissions from operation, but diesel heaters required during colder months
Noise Pollution (diesel 80-95 dB)	85dB Similar noise levels to diesel buses	52-60dB Significantly quieter than diesel buses	52-60dB Significantly quieter than diesel buses
End of Life Emissions	Unknown	Fuel cell recycling is unproven	Battery recycling is unproven
Air Quality Profile of Fleet	Little improvement - higher greenhouse gas and nitrogen oxide emissions	Significant improvement	Significant improvement
Estimated Vehicle Weight (Diesel bus, Curb weight: 21-33K lb / GVWR: 30K-44K lb)	Curb weight: 31,400 lb GVWR: up to 42,500 lb	Curb weight: 34,000 lb GVWR: up to 43,000 lb	Curb weight: 33,000 lb GVWR: up to 44,000 lb
Pavement damage from Weight	Will impact the pavement at a similar rate as diesel buses	Will potentially damage pavement at a faster rate than diesel buses	Will potentially damage pavement at a faster rate than diesel buses
		FUNDING AVAILABILITY	
Federal	• INFC Canadian Community-Building Fund (formally Gas Tax Fund): up to $14,000 annually • INFC Investing in Canada Infrastructure (ICIP) Public Transit Stream: 40% of eligible project costs for new construction and expansion of transit; 50% of eligible project costs for transit rehabilitation (includes maintenance facilities)	• CIB Zero-emission Bus Initiative: Direct loans that cover the cost difference of ZEBs and their infrastructure vs. buying a diesel bus • INFC Zero Emission Transit Fund: up to fifty percent (50%) of the total eligible costs • INFC Investing in Canada Infrastructure (ICIP) Public Transit Stream & Green Infrastructure Stream: 40% of eligible project costs for new construction and expansion of transit; 50% of eligible project costs for transit rehabilitation (includes maintenance facilities) • FCM's Green Municipal Fund both the Signature	• CIB Zero-emission Bus Initiative: Direct loans that cover the cost difference of ZEBs and their infrastructure vs. buying a diesel bus • INFC Zero Emission Transit Fund: up to fifty percent (50%) of the total eligible costs • INFC Investing in Canada Infrastructure (ICIP) Public Transit Stream & Green Infrastructure Stream: 40% of eligible project costs for new construction and expansion of transit; 50% of eligible project costs for transit rehabilitation (includes maintenance facilities) • FCM's Green Municipal Fund both the Signature

Metrics	Renewable Natural Gas	Hydrogen Fuel Cell	Battery-Electric
		initiative, and the Reduce Fossil Fuel Use in Fleets fund: ○ Pilot project: Grant: Up to $500,000 to cover up to 50% of eligible costs ○ Capital Project: Low-interest loan of up to $10 M and grant worth up to 15% of the loan, covering up to 80% of eligible costs • INFC Canadian Community-Building Fund: up to $14,000 annually • NRCan Zero Emission Vehicle Infrastructure Program will have funding available in 2022 for refuelling stations	initiative, and the Reduce Fossil Fuel Use in Fleets fund: ○ Pilot project: Grant: Up to $500,000 to cover up to 50% of eligible costs ○ Capital Project: Low-interest loan of up to $10 M and grant worth up to 15% of the loan, covering up to 80% of eligible costs • INFC Canadian Community-Building Fund: up to $14,000 annually • NRCan Zero Emission Vehicle Infrastructure Program will have funding available in 2022 for charging stations
Provincial	• INFC Investing in Canada Infrastructure (ICIP) – Public Transit Stream: Provinces will have to cost-share on municipal projects at a minimum of 33.33% of eligible costs Public Transit Stream:	• INFC Investing in Canada Infrastructure (ICIP) – Public Transit Stream & Green Infrastructure Stream: Provinces will have to cost-share on municipal projects at a minimum of 33.33% of eligible costs	• INFC Investing in Canada Infrastructure (ICIP) – Public Transit Stream & Green Infrastructure Stream: Provinces will have to cost-share on municipal projects at a minimum of 33.33% of eligible costs

Appendix A

Assumptions

- All bus purchases, for either growth or replacement purposes, will be of an alternative fuel technology as of 2023, which is the next time a conventional diesel bus will be decommissioned, as planned by Regina Transit;
- All buses (regardless of fuel type) are assumed to have a 15-year lifespan;
- Regina Transit will not retire diesel buses before they reach the end of their lifespan;
- All costs presented in this report are in 2021 Canadian dollars, not accounting for inflation;
- A standard 40’ bus is assumed to cost as follows:
  - Compressed natural gas bus: $700-850K per vehicle
  - Hydrogen fuel cell bus: $1.2-$1.5M per vehicle
  - Battery-electric bus: $1,304,000 per vehicle (based on the data from the ongoing OC Transpo e-bus pilot, which includes $30k per bus for Regina Transit-specific equipment - branding, fare boxes, cameras etc.)
- Bus purchases are made one year before the order is delivered, meaning bus purchases in one year are only reflected in the fleet composition for the following year.

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