TRANSIT FLEET ZERO EMISSION TRANSITION PLAN

CITY OF GREATER SUDBURY

2/6/2025

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EXECUTIVE SUMMARY

The City of Greater Sudbury is committed to reducing energy consumption while fostering a green economy. In response to the Climate Emergency Declaration by the Greater Sudbury City Council in May 2019, the Community Energy and Emission Plan (CEEP) was developed as a long-term strategy aimed at reducing carbon emissions and pollution in Greater Sudbury, with goals of achieving net-zero emissions by 2050.[1]

Transitioning to a zero emission fleet requires more than acquiring new vehicles and fueling systems; it necessitates the integration of new technologies and processes into day-to-day operations. A successful fleet transition plans adopts a comprehensive approach to zero emission mobility, addressing operational requirements, market conditions, infrastructure needs, and associated costs. This Zero Emission Fleet Transition Plan serves as a comprehensive roadmap for GOVA Transit to convert its transit bus fleet to zero emission vehicles by 2035.

This Study utilized energy modelling of battery electric buses (BEBs) using current route data to confirm operational feasibility and develop fleet charging strategies and recommendations for vehicle and charging infrastructure types. The in-depth analysis summarized below provides GOVA Transit with data to guide important decisions involving capital programs and operations necessary to build key partnerships and support transition actions and phases.

This Transition Plan outlines a phased implementation approach that aligns with GOVA's existing fleet replacement schedule and will allow the agency to integrate BEBs into the fleet gradually. GOVA Transit will be able to gain valuable experience with the technology while the market continues to develop and mature. BEBs are impacted by limited range, which can cause difficulties when transitioning as fleet or service modifications may be necessary. As technology advances, batteries will become bigger and lighter, increasing vehicle range and overall availability of a more diverse profile of BEBs. Just as battery and vehicle performance are expected to improve, charging technology and performance are also expected to improve as the technology matures.

Based on today's battery technology, GOVA Transit can electrify a portion of the fleet using depot charging only, but in future years, an expanded fleet or en-route charging would be required to support a full BEB transition. The transition should begin with the installation of the required plug-in depot charging infrastructure and required supporting utility infrastructure at the Greater Sudbury Transit & Fleet Centre located at 1160 Lorne Street. Utility infrastructure should be sized for full buildout to avoid rework and multiple construction phases, but chargers would be installed in phases as the buses are delivered and enter revenue service.

In 2023, GOVA Transit operated a fleet of 59 buses, of which 42 are active operating service and 17 are reserved as spares. GOVA Transit will electrify the fleet in four (4) distinct phases based on fleet and facility requirements, available battery capacity, and potential en-route charging capabilities, shown in the graphic below. During Phase 1, twenty-seven (27) buses will be transitioned to BEBs supported by depot charging only. During Phase 2, nine (9) additional buses will be transitioned to BEBs and en-route charging infrastructure will be installed at the Downtown Hub. During Phase 3, the remaining seven (7) *active* buses will be transitioned to BEBs, and in Phase 4, GOVA Transit will electrify the remaining sixteen (16) *spare* reserve buses to BEBs.

[1] Greater Sudbury Community Energy and Emissions Plan

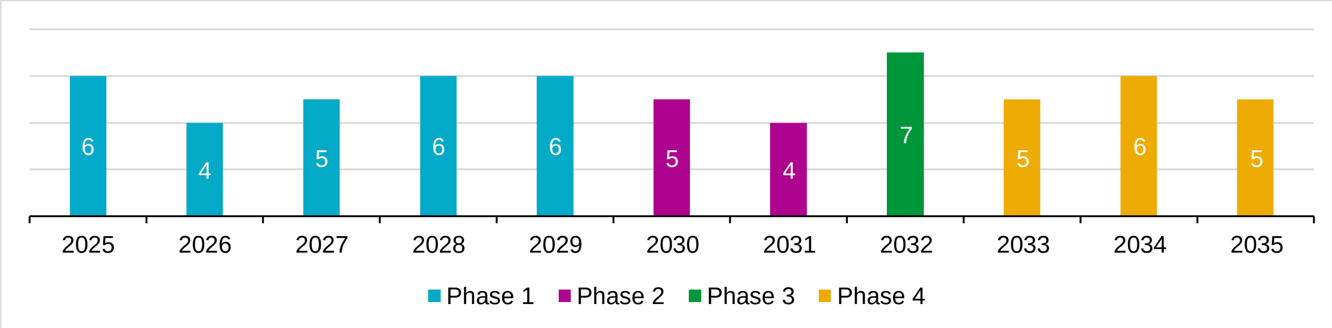

Figure ES-1. Bus Procurement Schedule by Phase, Purchase Year

It is anticipated that a transition of the fleet to BEBs will cost an additional $89.1 million in discounted 2023 dollar terms over the business-as-usual scenario to transition and maintain the fleet and install the necessary charging infrastructure over the 2023-2050 period. The difference in cost is largely due to the capital costs associated with charging infrastructure that otherwise would not be necessary; the next largest contributor to the cost differential is the capital cost premium of purchasing a BEB over a diesel bus. Despite increased capital costs, a significant cost savings is realized on maintenance and fuel expenses, which can help offset the overall net cost to transition the fleet. Operating costs are higher with the BEB fleet due to a higher average number of hours travelled due to bus swaps.

The table below shows the total cost to transition the fleet to BEBs, inclusive of all operating and maintenance expenses and charging infrastructure cost over 2023 to 2050, in discounted 2023 dollar terms. The burdened cost to GOVA Transit could be significantly reduced through available funding streams, such as the Zero Emissions Transit Fund (ZETF), which may provide up to 50% of an applicant's total project capital costs. As the amount and timing of these funds are variable and not guaranteed, they are not included in the analysis.

Table ES-1. Transit Fleet 12-year Lifecycle Cost, Discounted 2023$ millions, 2023-2050

Net Present Value, 2023$	Baseline	BEB	Variance
Bus Purchases	$58.0	$139.3	$81.4
Related Infrastructure	-	$16.8	$16.8
Lifecycle Capital Costs	**$58.0**	**$156.2**	**$98.2**
Operations & Maintenance	$380.1	$388.3	$8.1
Fueling	$51.1	$32.1	-$19.0
Related Infrastructure O&M	-	$1.8	$1.8
Lifecycle O&M	**$431.2**	**$422.1**	**-$9.1**
2023-2050 Total Lifecycle Costs	**$489.2**	**$578.3**	**$89.1**

The lump sum cost per phase for charging infrastructure is shown in the table below, with total costs over the entire 2023-2050 study period include further bus and equipment replacements in later years and are detailed in **Section 7: Financial Planning** and **Appendix C: Budget & Financial Plan**.

Table ES-2. Charging Infrastructure Lump Sum Costing by Phase, 2023$

	Years	Cost	Key Items
Phase 1	2025-2029	$5,217,464	One (1) 2,000 kVA unit substation; (9) 150kW chargers & (27) dispensers
Phase 2	2030-2031	$7,319,188	**Depot:** One (1) 2,000 kVA unit substation; (3) 150kW chargers & (9) dispensers **En-Route:** One (1) 4,000 kVA unit substation; (8) 450 kW pantograph chargers
Phase 3	2032	$1,682,444	(3) 150kW chargers & (9) dispensers
Phase 4	2033-2035	$2,623,969	(5) 150kW chargers & (15) dispensers

Despite increased capital expenses for vehicles and charging infrastructure, as well as increased operating costs attributed to an increase in non-revenue operations to facilitate bus swaps, annual emissions are reduced to achieve CEEP goals.

Over the study period, annual emissions are reduced from approximately 5,600 tonnes of greenhouse gas (GHG) emissions per year to just over 600 tonnes of GHGs per year. Compared to a scenario where the fleet is not transitioned to BEBs, this results in a reduction of approximately 94,300 tonnes of GHGs over the 27-year study period. Residual GHG emissions in the BEB scenario after the fleet is fully transitioned are attributed to the diesel auxiliary heaters installed on the BEBs.

Table ES-3. Total GHG Emissions (CO_2 in Tonnes), Baseline and BEB Scenarios

	2025 Snapshot	2035 Snapshot	2050 Snapshot	Study Period Cumulative Total
Baseline				
Diesel	5,624	5,624	5,624	157,460
BEB	-	-	-	-
Total, Baseline Scenario	**5,624**	**5,624**	**5,624**	**157,460**
BEB Scenario				
Diesel	5,624	1,095	404	59,215
BEB	-	174	203	3,918
Total, BEB Scenario	**5,624**	**1,269**	**607**	**63,133**

1 INTRODUCTION

The City of Greater Sudbury is taking action to reduce energy consumption and greenhouse gas emissions while promoting a green economy. To support this action, the Community Energy and Emissions Plan (CEEP)[2] was developed as a long-term strategy to reduce carbon emissions and pollution in Greater Sudbury. The CEEP was created in response to the Greater Sudbury City Council's Climate Emergency declaration in May 2019, which included a commitment to achieving net-zero emissions by 2050. The goal of achieving a net-zero Greater Sudbury by 2050 will require the combined efforts of many stakeholders in the community, including government, businesses, not-for-profits, and residents.

Greater Sudbury has set 18 sustainability goals to achieve a net-zero Sudbury. These goals outline the actions that the community intends to take to reach net-zero by 2050. Among these goals, four are explicitly focused on low-carbon transportation efforts, and two are explicitly focused on transit; directly impacting GOVA Transit operations. These transportation focused goals include enhancing transit service to increase transit mode share to 25% by 2050, achieving 35% active mobility transportation mode share by 2050, electrifying 100% of the GOVA Transit and Sudbury City fleet by 2035, and ensuring that 100% of new vehicle sales are electric by 2030.

[2] Greater Sudbury Community Energy and Emissions Plan

2 TRANSIT FLEET ZERO EMISSION TRANSITION PLAN

The transition from conventional diesel buses to battery electric buses (BEBs) is a significant undertaking that requires robust planning. The Zero Emission Transit Fund (ZETF) has been established by Housing, Infrastructure, and Communities Canada to support organizations in transitioning their vehicle fleets.[3] In addition to funding planning projects, it has a capital stream that provides opportunities for transit agencies to receive funding for capital projects. To apply for capital funding there are five specific planning elements that applicants must satisfy, and this Fleet Transition Plan has been developed to address those elements:

1. **System Level Planning:** Description of system-level planning undertaken for the project, such as analysis of zero emission bus (ZEB) technologies, energy consumption analysis, and identification of charging/refueling and facility requirements.
2. **Operational Planning & Deployment Strategy:** Outlines a fleet and infrastructure implementation plan that supports innovative and effective ZEB deployments and future operations. This strategy is informed by optimal route selection, service design, and procurement needs.
3. **Financial Planning:** Provides preliminary capital and operating cost estimates, including the anticipated lifecycle cost savings encompassing fuel and maintenance cost savings.
4. **Capacity to Implement the Technology:** Assesses the organization's current resources, skills and training required for the deployment and operation of a new ZEB fleet. It also provides an assessment of potential technological, operational, and system-wide risks associated with the transition and a risk management plan that details mitigation strategies.
5. **Environmental Benefits:** Includes a lifecycle assessment of environmental benefits associated with the transition, including estimates of greenhouse gas (GHG) emissions reduction, noise reduction, and non-GHG pollutant reduction.

This Transit Fleet Zero Emission Transition Plan (Fleet Transition Plan) addresses each of these topics in the following report and the accompanying appendices.

[3] Infrastructure Canada - Zero Emission Transit Fund Applicant Guide

3 SYSTEM LEVEL PLANNING

The foundation of this Fleet Transition Plan begins with the approach to system-level planning. An analysis of BEB technologies was performed to further understand BEB and fueling options on the market for GOVA Transit to consider. An energy consumption analysis was developed for GOVA Transit to create an accurate energy profile, which further works to identify charging, refueling and facility requirements specific to the agency's needs.

3.1 BATTERY ELECTRIC BUSES & CHARGING OPTIONS

BEBs are currently the most popular zero emission bus because they utilize the electric grid as a source of fuel, which is universally available and relatively "easy" to connect to for drawing the required power. One shortfall of BEBs are their limited range compared to conventional diesel buses; for agencies with longer range requirements, BEBs may not be capable of directly replacing conventional diesel buses assigned to long duty cycles at a 1-to-1 replacement ratio. In some cases, it's not possible to adjust the service profile of these longer blocks to accommodate the range capabilities of today's available BEBs. For extended range requirements, either additional vehicles become necessary or en-route charging would be required at layover points along current routes.

En-route charging is an enhancement that can greatly improve the feasibility of BEBs in many situations; it can extend the range of a BEB and facilitate one-to-one replacement of diesel vehicles when routes are conducive to this charging strategy. This is particularly helpful with circular routes where the same en-route charger can be used by a vehicle multiple times throughout the day. En-route charging infrastructure is ideally located at places such as transit centers where buses operating on multiple routes all have scheduled layover time.

3.2 ENERGY CONSUMPTION ANALYSIS

Understanding energy consumption is a key component of fleet transition planning, as it informs the choice of vehicle technology, infrastructure requirements, finances, and fleet replacement strategies. The following sections outline the methodology and key findings.

3.2.1 METHODOLOGY

GOVA Transit's contracted zero emissions consultant, HDR, Inc., provided a comprehensive understanding of the potential impacts BEB technology may have on GOVA Transit's existing service using a proprietary energy consumption model, Zero+. **Figure 1** shows the Zero+ Model inputs, outputs, and process.

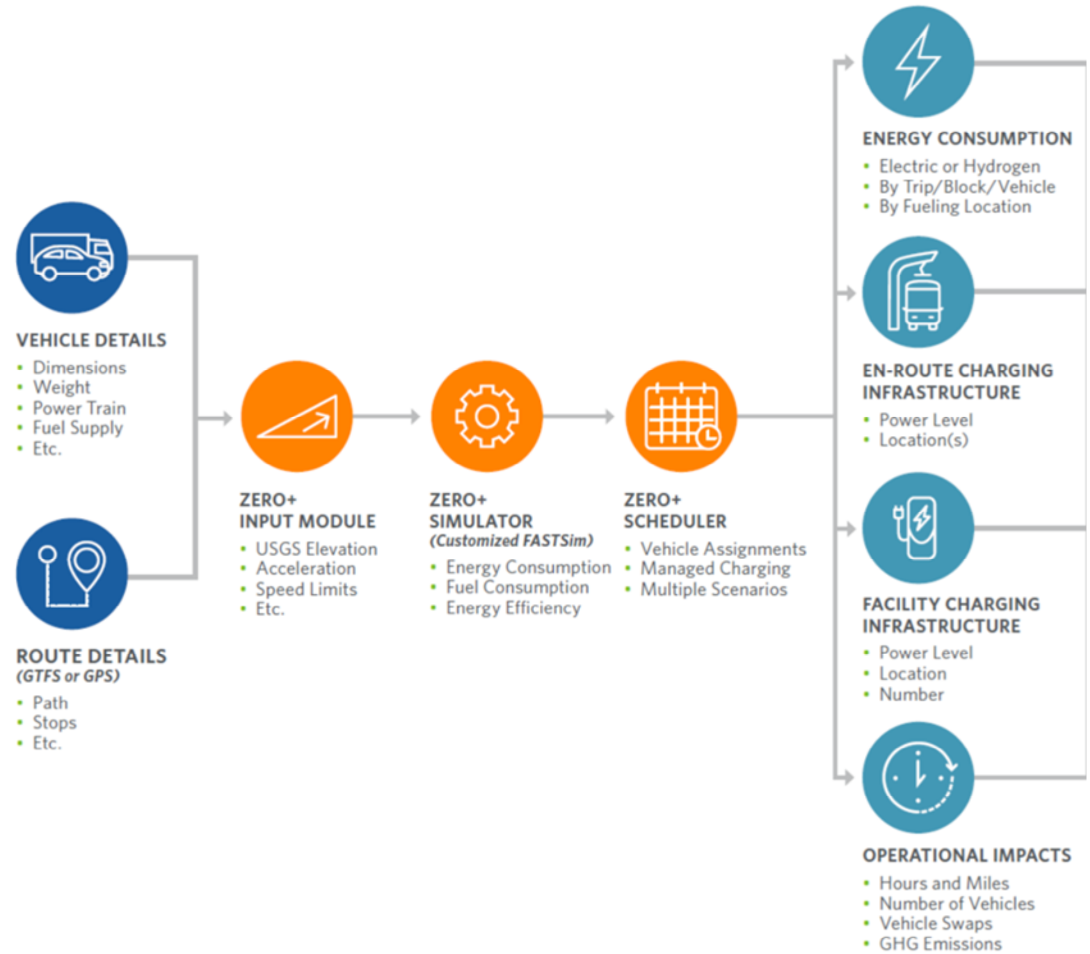

Figure 1. Zero+ Inputs, Outputs, and Modelling Process

Energy consumption is impacted by several factors including slope and grade of the bus routes, number of vehicle stops, anticipated roadway traffic, and ambient temperature. The Zero+ model also analyzes variables known to impact lifetime vehicle performance, like energy density, battery degradation, operating environment, HVAC and auxiliary power loads, as well as the lifecycle of bus batteries. The model is fed by General Transit Feed Specification (GTFS) data, GIS data, and vehicle profile assumptions to create an accurate energy consumption profile unique to GOVA Transit's existing service. Zero+ results include many data variables, yielding the most accurate results possible to influence strong and effective decision making.

The Zero+ model results, combined with discussions with GOVA staff, provide the basis upon which the preferred vehicle technology and refueling strategy will be determined. This modelling evaluated the optimal charging strategy, which nameplate battery capacity and auxiliary heater type is optimal and identifies potential strategies that best complement GOVA Transit's service and fleet plans. Simulations were performed at a granular level so as to inform individual vehicles, routes, and blocks as well as the full GOVA Transit fleet. Examining each vehicle individually drives decisions for the right technology at the system, depot, route, and block levels. This analysis balanced impacts to operations, overall fleet size, and infrastructure requirements, ultimately providing GOVA Transit with the information to support a data-driven determination of the preferred BEB transitional technologies and deployment pace.

3.2.2 MODELLED SCENARIOS

The energy consumption modelling effort included the analysis of five scenarios. Each scenario assumes vehicles are equipped with diesel auxiliary heaters with either a 525 kWh battery or 675 kWh battery used for vehicle propulsion. Electric heaters deplete the battery much faster in the winter, severely reducing the usable range of a vehicle. Given the relative infeasibility of electric heating in northern climates, it is almost always most feasible to install diesel auxiliary heaters on BEBs.

Different battery capacities were modelled to determine if a vehicle with a greater battery capacity would significantly improve the feasibility of a transition to BEBs.

- Baseline (Diesel)
- Full BEB Fleet (525 kWh) with Depot Charging Only
- Full BEB Fleet (675 kWh) with Depot Charging Only
- Full BEB Fleet (525 kWh) with Depot and En-Route Charging
- Full BEB Fleet (675 kWh) with Depot and En-Route Charging

Based on the evaluation and collection of data described above, a baseline diesel scenario was simulated using Fall 2023 GOVA service to validate both the data provided and the functionality of the model, by comparing simulation results to observed GOVA existing diesel operations. This validation provides confidence that the simulations of BEB scenarios are not missing critical data points that influence the transition.

Depot charging only was modelled first to establish a baseline feasibility. This scenario allows the Zero+ Model to identify which existing service blocks can be electrified without an increase in peak vehicle requirements, the need for en-route charging, or the need for schedule modifications, to achieve the same level of service. In the depot charging only scenario, the model indicates how many additional vehicles would be required to maintain the same level of service, without the use of en-route charging.

The model also included the analysis of a scenario where GOVA Transit implements a combination of depot and en-route charging. Layover times in the existing schedule were used to identify the most ideal locations for en-route chargers, with three existing transit centers identified as having a significant amount of layover time available for charging.

3.2.3 KEY TAKEAWAYS

In the depot charging only scenarios, approximately half of the fleet (27 of 59 buses) can be transitioned to BEBs at a 1-to-1 replacement ratio before an increase in active fleet size or the installation of en-route charging would be required.

Ultimately, based on modelling results, the recommendation is that GOVA Transit's transition scenario is toward a full fleet of 675 kWh buses, supported by depot charging and en-route charging at the GOVA Transit Downtown Hub. The detailed results of the route modelling analysis for the baseline, depot charging only, and en-route charging scenarios, can be found in **Appendix A: Energy Modelling Analysis.**

4 OPERATIONAL PLANNING & DEPLOYMENT

The following sections highlight critical fleet and infrastructure implementation needs, including actions that will be taken to effectively deploy BEBs and ensure efficient future operations. The fleet deployment plan highlights each phase of the plan, offering a purchase schedule and insight into the phased deployment effort. The facility and infrastructure plan for the depot facility is also provided, covering existing conditions and facility infrastructure implementation. The feasibility of en-route charging is also considered, with potential locations that may be beneficial for GOVA Transit to assess in the future.

4.1 FLEET DEPLOYMENT PLAN

GOVA Transit does not currently operate any BEBs. To achieve goals of the CEEP, diesel buses that have reached the end of their life cycle will be considered for replacement with BEBs beginning in 2025. The fleet will be electrified in phases based on the facilities necessary to maintain existing service levels, number of vehicles, available vehicle battery capacity, and potential en-route charging capabilities. The vehicle battery capacity of each bus remains constant at 675 kWh across all phases, with plug-in depot charger capacity to be 150 kW, with three dispensers each. **Table 1** depicts recommended BEBs purchased during each phase, while **Figure 2** shows the transition phases in graphic form.

Phase 1: BEBs purchased will be one-to-one replacements with 675 kWh buses; vehicle charging will be supported by plug-in chargers at the depot that are powered by a 2,000 kVA unit substation to be installed in 2025.

Phase 2: BEBs purchased will be one-to-one replacements with 675 kWh buses; vehicle charging will be supported by plug-in chargers at the depot and en-route charging infrastructure that would be installed at the Downtown Hub. All en-route charging infrastructure will be installed in 2030. Additional depot chargers will be powered by a second 2,000 kVA unit substation, to be installed in 2030.

Phase 3: BEBs purchased will be 675 kWh buses; vehicle charging will be supported by plug-in chargers at the depot and existing en-route charging infrastructure at the Downtown Hub. Depot chargers will be powered by the existing substation referred to in Phase 2. At the conclusion of Phase 3, the active fleet will be 100% BEB.

Phase 4: BEBs purchased will be 675 kWh buses; vehicle charging will be supported by plug-in chargers at the depot and existing en-route charging infrastructure at the Downtown location. At the conclusion of this phase, the full fleet (active + spares) will be 100% BEB.

Table 1 below shows the number of BEBs purchased in each phase of the transition alongside the cumulative BEB fleet count and the years each phase spans. The BEB purchase schedule and fleet composition are further broken down by year in **Figure 2** and **Figure 3**, respectively. This phased deployment plan allows GOVA Transit to procure a 100% BEB fleet by 2035.

Table 1. Phased Fleet Deployment Plan

Phase	Purchased BEBs	Cumulative BEBs	Purchase Year(s)
Phase 1	27	27	2025 – 2029
Phase 2	9	36	2030 – 2031
Phase 3	7	43	2032
Phase 4	16	59	2033 – 2035

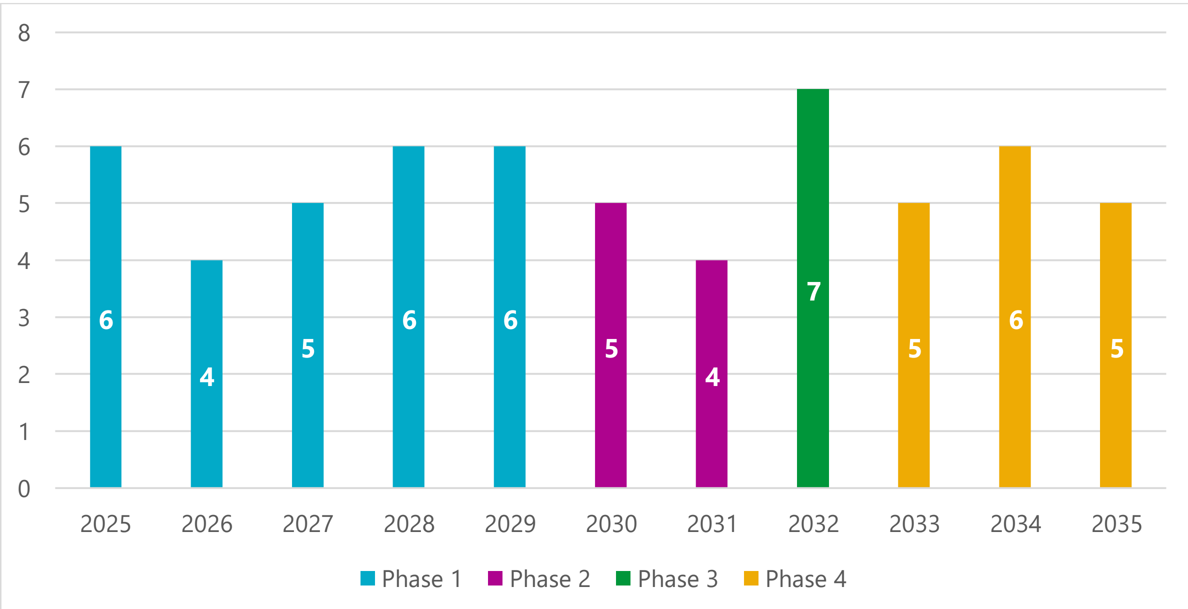

Figure 2. BEB Fleet Procurement Schedule (2025 - 2035)

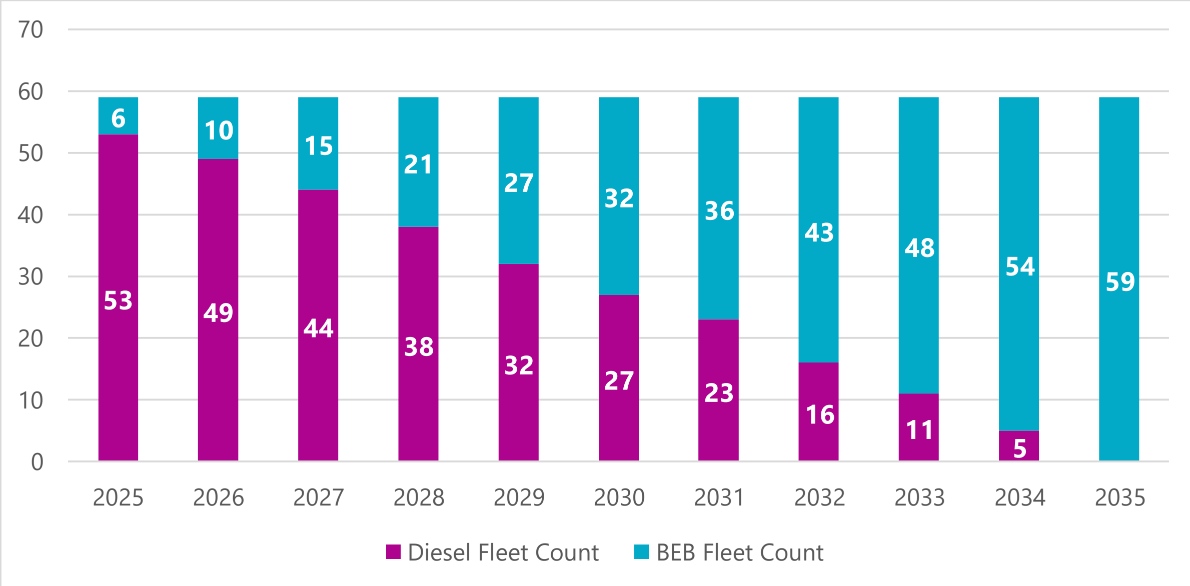

Figure 3. Fleet Composition (2025 - 2035)

Figure 4 shows the charger installation per year to match bus procurement as well as the installation of unit substations, shown in lighter shades, in 2025 and 2030 at the depot facility. GOVA Transit will consolidate charger installation prior to receiving buses and plans to install adequate capacity for growth during each phase. For example, the unit substation installed in 2025 would be adequate to support all nine Phase 1 chargers and conduit would be planned and designed to avoid major modifications and equipment downtime when constructing subsequent phases.

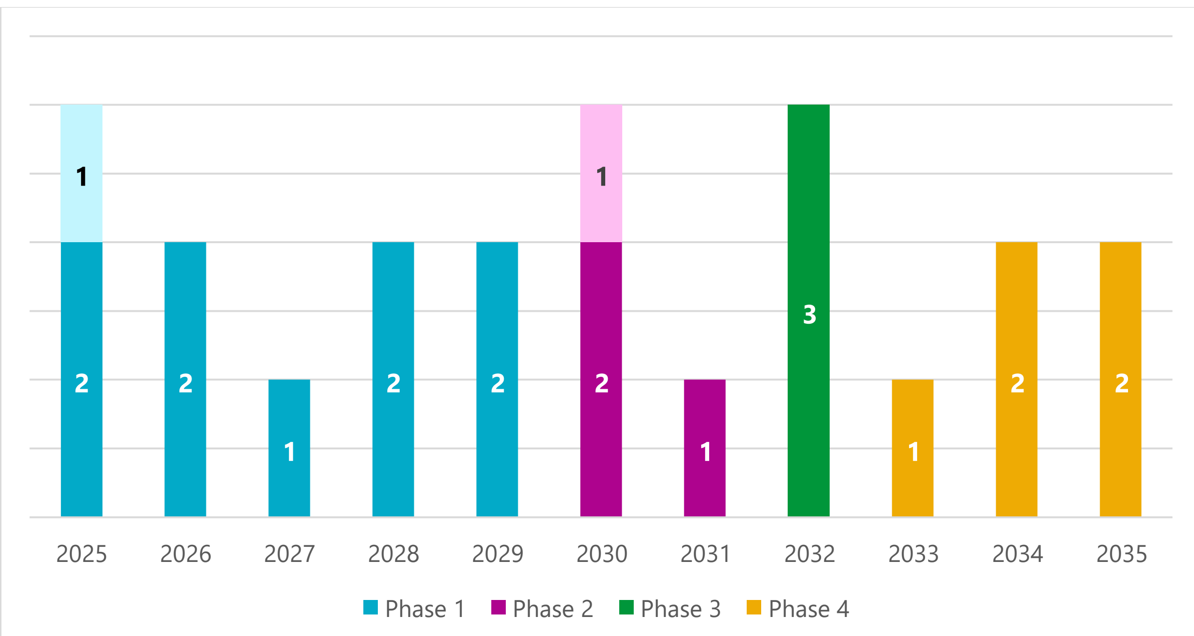

Figure 4. Phased Depot Charging Infrastructure Implementation (2025 - 2035)

4.1.1 FUTURE SERVICE CRITERIA

GOVA Transit will begin by electrifying the fleet and operate service without increasing the fleet size in Phases 1 and 2, adding en-route charging infrastructure at the Downtown Transit Hub in Phase 2. In Phases 3 and 4, GOVA will continue to electrify the fleet at a greater than one-to-one replacement ratio; this will include electrification of routes that do not layover at the Downtown Transit Hub and can't utilize en-route charging at this location. In September 2024, GOVA Transit expanded service and may further expand in the future. Because the nature of the service was unknown, the exact vehicle requirement to support this new, expanded service could not be predicted. **Table 2** outlines the feasibility criteria for expanded service; the feasible distance for a one-to-one conversion is the maximum duty cycle, or block, distance a 675 kWh BEB can complete without the need for bus swaps or en-route charging.

Table 2. Expanded Service Feasibility Criteria

	Easiest Route	Average Route	Hardest Route
Average Vehicle Efficiency	1.23 kWh/km	1.52 kWh/km	1.82 kWh/km
Feasible Distance for 1:1 Conversion	Up to 307 km	Up to 248 km	Up to 207 km

In the table above, "easiest" refers to the most energy efficient route (i.e., least number of stops, flattest terrain, etc.), while "hardest" refers to the least energy efficient route (i.e., many stops, difficult/steeper terrain, etc.). If expanded service exceeds 307 km, either en-route charging or additional vehicles to facilitate bus swaps would be required. In a scenario where extended service does not layover at a location with en-route charging, the duty cycle could be as long at 614 km at best and 414 km at worst with only one bus swap required.

4.1.2 SOFTWARE SYSTEMS

Introducing BEBs into GOVA Transit's fleet will increase the number and types of systems the agency will need to monitor, such as dynamic vehicle scheduling, vehicle battery health, charger health and energy management. There are several software packages available for transit agencies to monitor vehicles and chargers, both live and retroactively. Some may be available from OEMs, and others are third party software packages that would be acquired separate from vehicle or charger procurements.

- **Vehicle Monitoring Systems –** This software will provide constant monitoring and logging of all vehicle data transmitted by BEBs. This information will be critical to quickly identify mechanical component or hardware failures and expedite maintenance repairs. Some OEMs offer this software as part of the rolling stock procurement, but other third-party vendors may be preferred as they are typically manufacturer agnostic which allows the agency to view all vehicles in the same interface regardless of bus manufacturer. GOVA Transit's vehicle monitoring interface will include vehicle telematics information including energy consumption, battery state of charge, and vehicle propulsion efficiency that can all be used to evaluate vehicle performance for future procurements.

- **Charging and Energy Management Systems –** This software will be utilized to schedule and manage charge sessions between different vehicles which may provide a significant operational cost savings through demand peak shaving. This optimizes costs where utility rates are priced in a time of use utility rate structure. Some providers offer options with additional functionality like management of other energy resources like battery energy storage and solar generation, which GOVA transit will explore.

- **Digital Yard Management Systems –** This software will help staff know which buses are ready or not ready for service. Tools are now available that allow staff to know the real time location and status of vehicles in the yard. Some solutions can also help by providing parking information for the vehicle depending on the status and state of charge (SOC) of the vehicle. For example, a digital sign at the entrance of the facility can let drivers know, based on vehicle information, to park vehicles in designated areas, whether they are scheduled for maintenance, or have a high SOC or low SOC. This tool will also be shared with operations to let them know where vehicles are parked in the yard, whether a given vehicle is ready for service and/or if a substitution needs to be made.

- **Scheduling Software –** This software can be particularly helpful with BEB fleets to ensure vehicles assigned to routes are fully charged by the time they are due to pull out of the garage for revenue service. In many cases, this software can be tied into charge management and digital yard management system interfaces so that dispatchers can see the current vehicle state of charge when assigning vehicles to service blocks. In some cases, this can also provide an operational safeguard if a dispatcher attempts to assign a BEB to a block that exceeds the vehicle's capable range, reducing the probability of needing to do in-service bus swaps.

4.2 FACILITY AND INFRASTRUCTURE PLAN

This section discusses the three locations, or types of locations, GOVA Transit will implement or explore implementing BEB charging infrastructure. The Greater Sudbury Transit and Fleet Centre will be used for depot charging; the GOVA Transit Downtown Hub will be used for en-route charging; and future mobility hub locations will be considered for alternative or additional en-route charging.

4.2.1 GREATER SUDBURY TRANSIT & FLEET CENTRE

GOVA Transit's primary facility is located at 1160 Lorne Street in the City of Greater Sudbury. This facility has multiple maintenance bays and indoor parking for all 59 fixed route 40-foot diesel transit buses; a number of non-revenue and municipal vehicles are also maintained and housed here. The garage currently has two existing Level 2 chargers, located near the bus wash, that are powered by the existing building utility infrastructure for use by non-revenue transit BEVs.

All transit buses will be charged overnight using Direct-Current Fast Chargers (DCFCs), and transit non-revenue vehicles will likely be charged by a mix of Level 2 chargers and DCFCs. Though the implementation of BEBs and charging infrastructure will be phased, it is important that charger placement is designed for a full buildout to limit interruptions to service when installing additional chargers in future phases. **Figure 5** shows a conceptual charger layout to illustrate what an electrified garage could look like when factoring in space requirements for different functions in alignment with planned phasing.

The vehicles will use the existing parking arrangement with remote charging dispensers installed in vehicle storage while the power cabinets will be located in a room to the south of the building. Placing the chargers indoors will provide easier maintenance and longer life than if they were exposed to harsh outdoor winter conditions. All chargers are assumed to be 150 kW DCFCs with three dispensers each, capable of charging three buses simultaneously at 50 kW per bus.

Phase 1 primarily accommodates twenty-seven (27) BEBs capable of daily service using depot charging only (27 total). During Phase 2, nine (9) additional buses will be converted to coincide with the downtown en-route charging facility (36 total). Phase 3 will include seven (7) additional BEBs to complete conversion of the active fleet (43 total), and Phase 4 will include the conversion of the sixteen (16) spare vehicles (59 total). Because the indoor parking space is maxed out, the property would not allow for any additional expansion beyond the Phase 4 service without facility modifications or purchase of additional property.

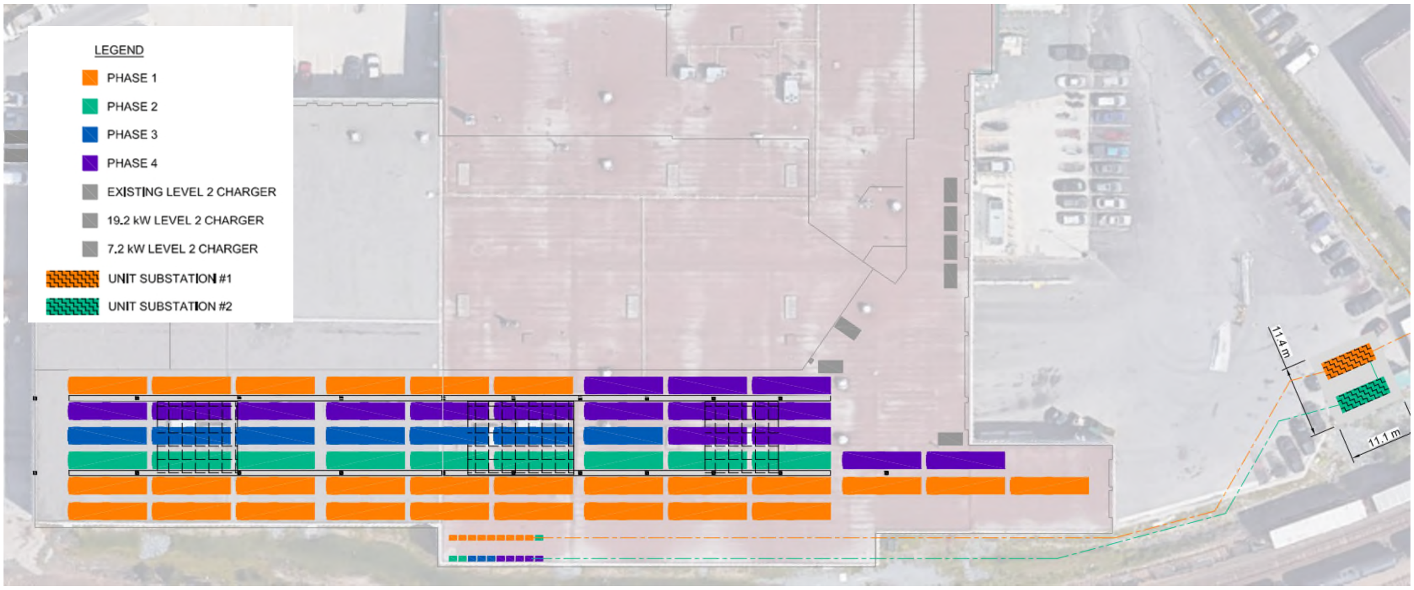

Figure 5. Greater Sudbury Transit & Fleet Centre Conceptual Site Plan

4.2.1.1 Depot Charging Considerations

GOVA Transit will avoid ground mounting of the dispensers where possible due to space constraints. Aligning with indoor bus storage, dispensers could either be ceiling mounted pantographs or retractable cable reels for plug-in charging; based on cost and ease of implementation, GOVA Transit plans to utilize retractable cable reels. With the current facility plan, the charging modules are located indoors and are designated to specific areas. GOVA Transit will ensure that the chargers meet code requirements and fit within the existing space, and placement and selection of dispenser type is subject to a detailed design and structural analysis.

4.2.2 FUTURE EN-ROUTE CHARGING LOCATIONS

In Phase 1, GOVA Transit will begin electrifying the fleet with depot charging only. Buses will be assigned where they can be replaced at a one-to-one replacement ratio, without the need for extra vehicles or en-route charging, to maintain existing levels of service. In Phase 2, en-route charging infrastructure becomes necessary to maintain the same level of service as current operations without a significant increase to the overall fleet size.

En-route charging is typically installed at terminus locations (hubs) where vehicles layover between runs and already have time built into the schedule to charge. Transit stops are often located at public streets or on properties that are owned by third parties. GOVA Transit is committed to finding appropriate locations for en-route charging and will seek to locate en-route charging where the agency already owns property or where property owners are amenable to the installation of en-route chargers.

Through this study, GOVA Transit evaluated the potential benefits of installing en-route chargers at the Downtown Transit Hub. This location is ideal because of the scheduled layover times and the number of routes that share the same layover point, but other alternative sites may provide the same benefits in place of or in addition to the Downtown Transit Hub. As part of GOVA Transit's ongoing Mobility Hubs Study, additional suitable sites may be identified, although further modelling analysis would be needed to determine exact requirements and feasibility.

4.2.2.1 GOVA Transit Downtown Hub

The existing GOVA Transit Downtown Hub has been identified as the primary location for en-route charging; this location is ideal because 17 fixed routes layover here. Located at 9 Elm Street, buses enter the Transit Hub and park at gates in a sawtooth pattern depending on route assignment as shown in **Figure 6**.

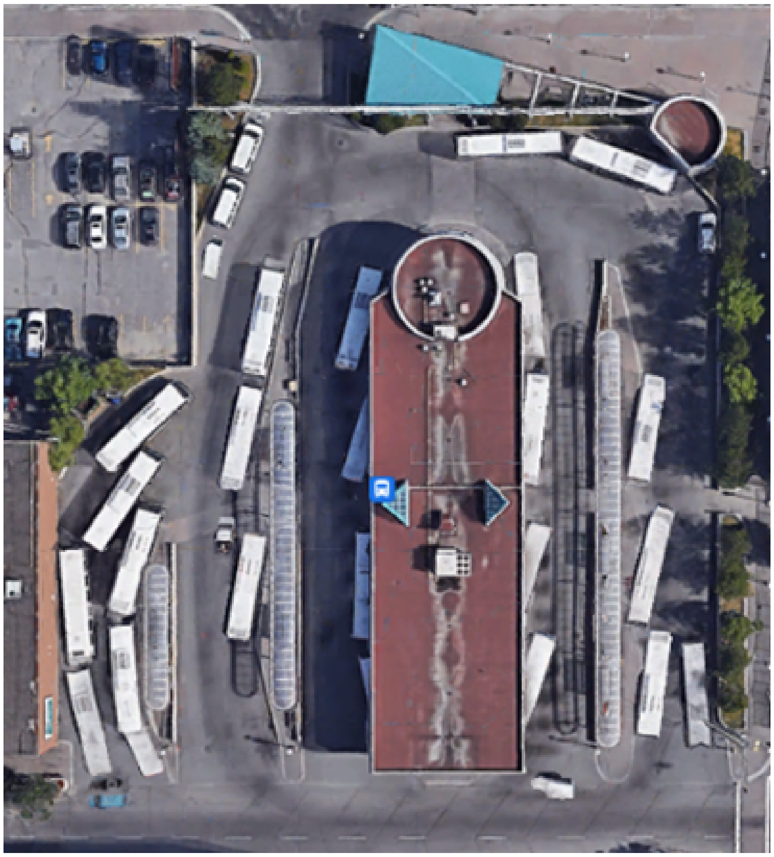

Figure 6. GOVA Transit Downtown Hub Aerial View

Figure 7 and **Figure 8** illustrate two potential charger layouts to accommodate the 8 pantograph chargers that would be required at this location to support en-route charging of the entire fleet.

Conceptual charging infrastructure layouts for the GOVA Transit Downtown Hub have not been confirmed or refined through a site assessment; GOVA Transit will coordinate with the electric utility to determine appropriate placement of the infrastructure. If the utility is not able to bring power to this location to support charging, or if chargers cannot be installed without interfering with existing traffic flow, alternate locations for en-route charging infrastructure will be evaluated. This may also create a need for service modifications to accommodate the required layover times for vehicles at the alternate en-route charging location(s) chosen.

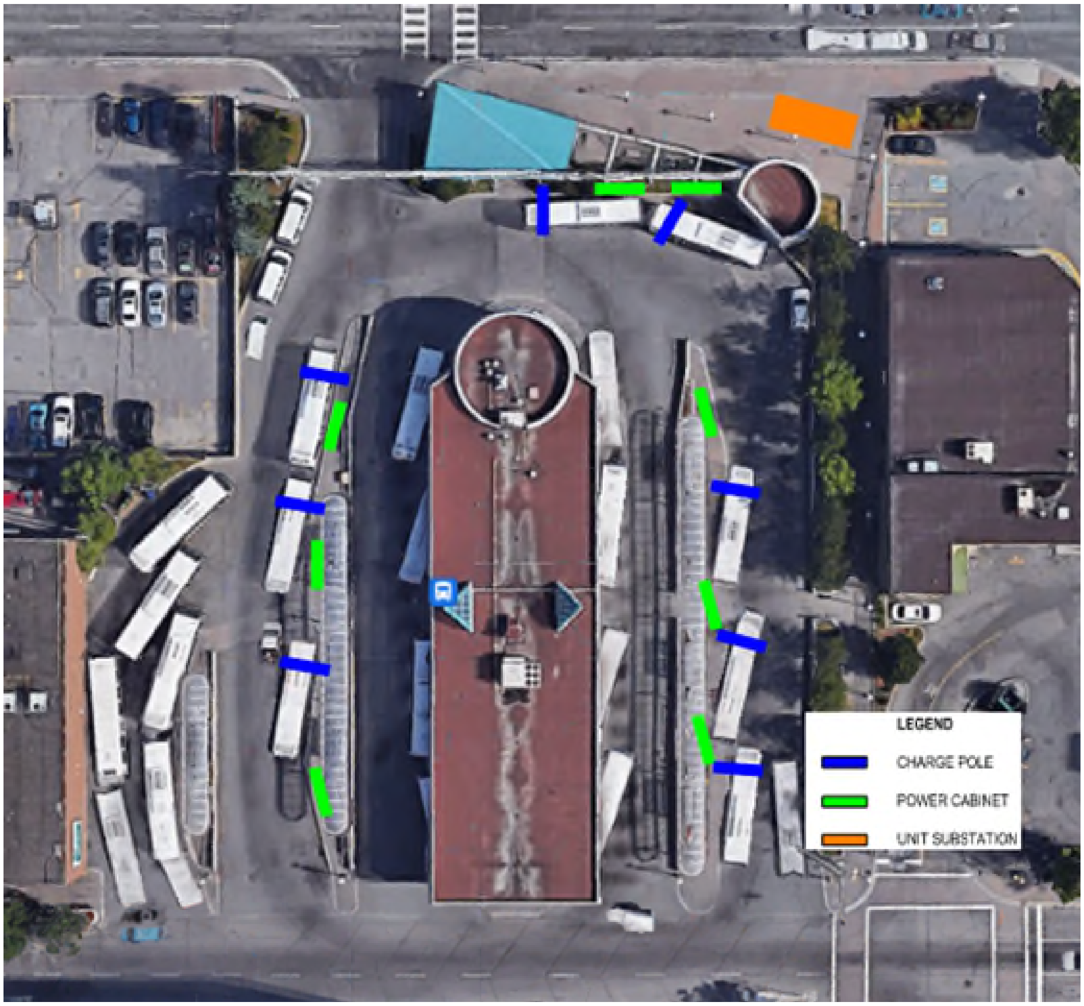

Figure 7. GOVA Transit Downtown Hub Conceptual Charger Layout Option 1

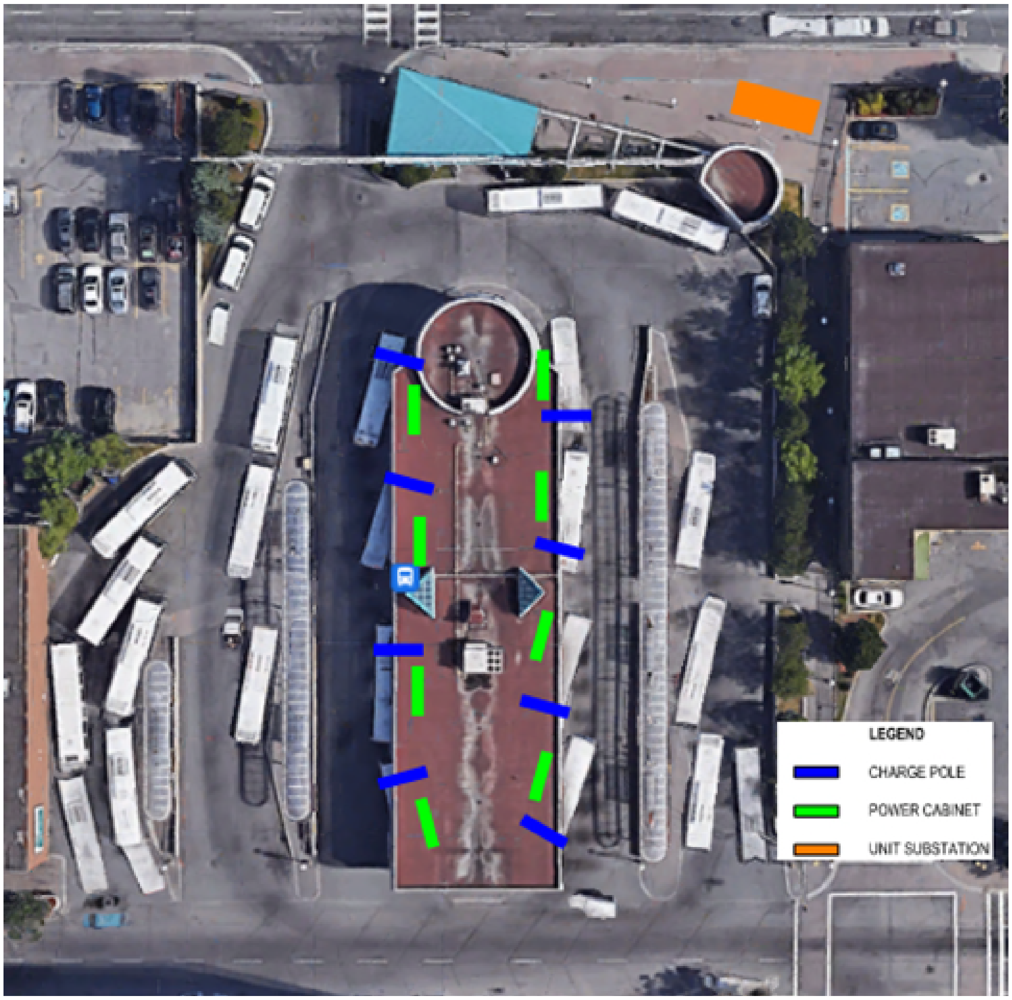

Figure 8. GOVA Transit Downtown Hub Conceptual Charger Layout Option 2

4.2.2.2 Future Mobility Hubs

The City of Greater Sudbury will evaluate en-route charging at Mobility Hubs in the future based on operational need and financial feasibility. This evaluation may include the existing Mobility Hubs included in this study, or future Mobility Hubs being evaluated as part of an ongoing, parallel study. Future expansion of the transit system may require additional infrastructure.

5 CAPACITY TO IMPLEMENT THE TECHNOLOGY

In this section of the plan, GOVA Transit's current resources, skills and training required for the deployment and operation of a new BEB fleet are evaluated to develop a staffing and training plan which will meet the agency's needs. An assessment of potential technological, operational, and system-wide risks associated with the transition and a risk management plan that details mitigation strategies is also provided.

5.1 STAFFING & TRAINING PLAN

With the introduction of battery electric technology to GOVA Transit's fleet, proper training on bus systems and subcomponents unique to BEBs is critical to ensure safe, efficient operation and maintenance of the transitioned fleet. GOVA Transit will work with internal and external training programs while in close coordination with OEMs and neighboring transit agencies to acclimate the existing workforce to the new technology, avoiding any displacement of the existing workforce.

This section will address the necessary steps to evaluate the skills of the existing workforce, identify skill gaps on an individual basis, and develop a plan to build and implement an effective training program for bus operators and bus maintenance personnel. In addition to the further development of the existing workforce, this chapter describes a workforce growth strategy for attracting new employees, retaining new and current employees, and funding opportunities to sponsor the required growth.

5.1.1 SAFE WORKPLACE LEGISLATION AND STANDARDS

In Ontario, employers have a legal obligation through the Occupational Health and Safety Act, R.S.O. 1990 (OHSA) to develop and implement a workplace safety program that ensures the health and safety of their workers. This includes a written policy, hazard identification and control, worker training, worker involvement in program development, procedures for accidents and illness, and regular review and updates. Failure to comply with OHSA can result in harm to workers and penalties for the employer.

The Canadian Standards Association (CSA) developed CSA Z462:21, an electrical safety standard for Canadian workplaces to prevent electrical injuries and fatalities. It provides guidelines and requirements for identifying and assessing electrical hazards, selecting and using personal protective equipment (PPE), establishing safe work procedures, and training workers. CSA Z462:21 is updated periodically to reflect changes in technology, regulations, and best practices. The standard is widely adopted in Canada by a variety of industries where electrical hazards exist, including manufacturing, construction, and utilities.

CSA Z462:21 is largely based on its American counterpart, developed by the National Fire Protection Association (NFPA), called NFPA 70E. Both standards are focused on fixed electrical infrastructure (such as charging infrastructure) and do not directly address "mobile" high-voltage systems, such as the battery drivetrains in battery electric vehicles. Transit agencies are identifying principles from these standards to apply to battery electric workplaces, and it is possible that updated versions of the standards will include consideration of battery electric vehicles.

5.1.1.1 Personal Protective Equipment (PPE)

Personal Protective Equipment (PPE) is designed to protect users from health and safety hazards. It should be considered the last line of defense against hazards and not a preventative measure to stop accidents from occurring. PPE must be implemented when elimination, substitution, engineering and administrative controls fail to reduce or remove hazards.[4] Canadian and Ontarian law requires employers to provide PPE and employees to wear said PPE to maintain safe working conditions. The following policies and standards related to PPE are applicable:

Canada Labour Code (R.S.C., 1995, c. L-2)

- Section 122.2 states that "Preventive measures should consist first of the elimination of hazards, then the reduction of hazards and finally, the provision of personal protective equipment, clothing, devices, or materials, all with the goal of ensuring the health and safety of the employees."
- Section 125 (l) requires the employer to provide the prescribed safety materials, equipment, devices, and clothing and Section 126 (1) requires employees to use safety materials, equipment, devices, and clothing intended for their protection.

Occupational Health and Safety Act, R. S. O. 1990

- Section 25 of the Act outlines the duties of the employer requiring them to provide equipment, materials and protective devices in good condition ensuring safety measures and procedures are enforced in the workplace.
- Section 27 of the Act outlines the duties of the supervisor to ensure that protective devices, measures and procedures are conducted and that they wear equipment, protective devices or clothing required by the employer.
- Section 28 outlines the duties of the worker to work within the provisions of the Act and use or wear equipment, protective devices or clothing required by the employer.

Battery electric buses are classified as high voltage systems, and as such, require specialized tools and PPE that may not be necessary when working on the typical 12/24 V systems found in diesel buses. Examples of additional PPE that may be required for working on high voltage systems are offered by the International Transportation Learning Center (ITLC). The ITLC[5] provides a list of typical tools and PPE that are needed to work on BEBs, shown in **Table 3** and **Table 4**.

Table 3. Recommended Insulated Tools

Tool	Recommended Quantity
CAT III rated digital multimeter(s) (rated up to 1000 VDC)	1 for each BEB technician
Insulated hand tools that follow ASTM F1505-01 and IEC 900 standards and compliance with OSHA 1910.333 (c)(2) and NFPA 70E standards (as recommended by the OEM)	1 set for each BEB technician that could be working on a BEB at any given time

[4] https://www.ccohs.ca/oshanswers/hsprograms/hazard/hierarchy_controls.pdf
[5] ITLC_ZEB_Report_Final_2-11-2022.pdf (transportcenter.org)

Table 4. Recommended PPE for BEB Maintenance

Tool	Recommended Quantity	Notes
ASTM Class 0 insulated gloves with red label	1 pair, properly sized for each technician	Insulated gloves need to be tested and replaced at specified intervals.
Leather gloves to be worn over ASTM insulated gloves	1 pair, properly sized for each technician	
Insulated EH Rated Safety Shoes	1 pair, properly sized for each technician	
NRR 33 rated ear plugs	Ample supply for each technician that could be working on a BEB at any given time	
NRR 331 rated (overhead) earmuffs	Ample supply for each technician that could be working on a BEB at any given time	Combining NRR 33 rated ear plugs with NRR 31 ear muffs can provide a NRR protection level of 36.
Arc flash suits	Ample supply for each technician that could be working on a BEB at any given time	
Combination arc flash shield and hardhat	Ample supply for each technician that could be working on a BEB at any given time	
Arc flash hoods	Ample supply for each BEB technician that could be working on a BEB at any given time	Arc flash shield, hardhat and hood may be procured as one integrated item depending on manufacturer and agency preference.
Insulated electrical rescue hook(s) (Sheppard's Hook) sized for use on BEBs	1 set for each BEB technician that could be working on a BEB at any given time (certain HV operations require a second worker to be available to extricate primary worker in an emergency)	

5.1.2 EXISTING TRAINING PROGRAMS

GOVA Transit currently has two in-house driving instructors and provides a 3-week Driver Certification Program (DCP) which consists of in-class and 36 hours of in-vehicle instruction. The DCP provides bus operators with commercial licensing (B, C, D, and Z) as needed. GOVA Transit also provides Corporate Health & Safety Training consisting of customer service, Accessibility for Ontarians with Disabilities Act, and health and safety topics. GOVA Transit does not currently have in-house maintenance training programs and instead contracts with an outside maintenance training provider.

In early 2021, The Ontario Public Transportation Authority (OPTA) recommended the establishment of a Zero Emission Bus (ZEB) Committee to allow members to learn from one another as revenue and non-revenue fleets are transitioned to zero emission technology. The OPTA ZEB Committee's mandate is to establish and maintain a forum for OPTA members to develop and share best practices, lessons learned, standard documentation, and key metrics for the implementation of zero emission vehicle technology. This forum is defined by three Workstreams:

- WS1 - Operations and Maintenance Work Plan
  - WS1A – ZEB Planning, Scheduling, and Operations

  - WS1B – ZEB Safety, Training, and Maintenance
  - WS1C – ZEB Performance, Monitoring, and Reporting
- WS2 - Engineering Work Plan
  - WS2A – ZEB Light & Heavy Duty Vehicle Requirements
  - WS2B – ZEB Infrastructure Requirements
  - WS2C – NA Technical Working Group
- WS3 - Procurement and Vendor Engagement Work Plan
  - WS3A – Engage Vendor Community
  - WS3B – Commercial Bus Management
  - WS3C – Paratransit EV Commercial Management
  - WS3D – Non-Revenue Vehicle Commercial Management

5.1.3 TRAINING CURRICULUM

BEBs contain high voltage batteries, requiring all maintenance technicians to be certified to work on high voltage (HV) systems. GOVA Transit is aware of the development of zero emission bus maintenance training curriculum by the OPTA ZEB Committee in conjunction with other transit agencies in Ontario and anticipates implementing these training resources for GOVA Transit staff when they are available. The OPTA ZEB Committee's training curriculum development program aims to establish and maintain safe work conditions for bus operations and maintenance personnel serving Ontario's fleet of BEBs.

5.1.3.1 Training Progression

Training for maintenance and repair work on ZEBs should focus first on electric/electronic principles, then progress to general ZEB familiarization, and finally end with OEM-specific trainings relevant to ZEB models within an agency's fleet. **Figure 9** from the ITLC illustrates this recommended training progression.

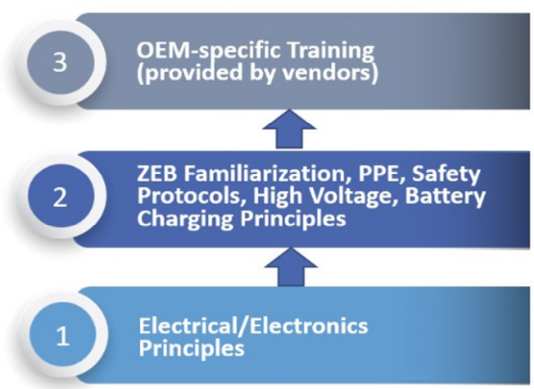

Figure 9. Recommended ZEM Training Progression for Vehicle Maintenance and Repair Staff

5.1.3.2 OPTA Workstream Training Curriculum

The Ontario Public Transit Association (OPTA) is currently working with several Ontario public transit agencies on a peer resources initiative to develop shared curriculum to reduce cost and create uniformity in the training mechanics receive across the province. GOVA Transit intends to review opportunities to participate in the OPTA Workstream Training Curriculum.

5.1.3.3 OEM Training Curriculum

The City of Greater Sudbury currently contracts with an external maintenance training provider. GOVA Transit will look for opportunities to purchase additional OEM training modules with the addition of BEBs to its fleet. As a part of the initial OEM training, GOVA Transit's selected BEB OEM can be anticipated to provide training modules such as Operator Orientation, Maintenance Mechanic Training, and Towing and Emergency Responder Training.

5.1.4 SKILLS ASSESSMENT, CATEGORIZATION, AND GAP IDENTIFICATION

This section outlines workplace hierarchy, authorized responsibilities based on qualifications, skill level requirements, and training guidelines. Operational staff can be grouped into the following four categories:

- **Operations Support**: Staff in this category would include those who are critical to bus operations but do not directly interact with the buses.
- **Bus Operations**: Staff in this category would include operational staff who directly interact with the buses but do not perform any vehicle maintenance.
- **Bus Maintenance Support**: Staff in this category include operational staff who directly interact with the buses and are responsible for the assignment and oversight of maintenance functions.
- **Bus Maintenance**: Staff in this category include operational staff who directly interact with the buses and perform routine and unplanned maintenance functions.

Operations Support staff will require minimal training and should be provided a high-level overview of the technology and its capabilities. For example, it's important for dispatchers to understand the operational range of the vehicles to avoid assigning vehicles to unsuitable routes. Depending upon fleet conversion goals and timelines, route design methodology may need to be updated to consider ZEB capabilities. Route design may also need to accommodate en-route charging or consider variations in performance due to extreme weather. Training for control center staff can help to clarify ZEB capabilities and align expectations with actual performance abilities, which can help reduce state of charge challenges during unexpected service disruptions.

Bus Operations staff will require more training than Operations Support staff given their direct interaction with the vehicles. For example, bus operators must be familiar with all dash indicator lights, the operation of doors and wheelchair access, and safety procedures. Acclimating bus operators to the regenerative braking system will likely be the largest operational difference between ZEBs and conventional diesel buses. On days with extreme weather conditions (hot or cold), bus operators will need to monitor the battery state of charge to ensure that vehicles can complete routes and return to depot. Overall, completing the recommended trainings from the ZEB OEM is expected to address operator skill gaps and adequately prepare operators to drive ZEBs.

Bus Maintenance Support staff include key personnel responsible for the assignment and oversight of maintenance work, both preventative and corrective, and are responsible for troubleshooting and dispatching vehicle road calls. Staff in this category will receive the same training as bus maintenance personnel as their roles include making "game time" decisions that require full familiarity with all vehicle systems and mechanical components.

Bus Maintenance personnel require the most training as they have the most frequent and in-depth interaction with the vehicles. Bus maintenance personnel will be individually assessed on current skills and assigned to training modules as necessary, ensuring that bus maintenance personnel receive all training required without duplicating efforts. For example, maintenance personnel who can demonstrate proficient multiplexing skills will not be assigned to multiplexing courses. Staff will need to perform routine inspections on insulated tools and PPE to ensure equipment can provide adequate protection against electrical hazards.

Table 5 shows the composition of GOVA Transit's existing operations and maintenance staff, including the number of employees, number of authorized positions, union affiliation, and role categorization with respect to the zero emission transition.

Table 5. GOVA Transit Current Maintenance and Operations Staff

Job Title	Role Category	Part Time/ Full Time	# of Employees	# of Authorized Positions	Union Affiliation	CDL Required?
Dir, Transit Services	Operations Support	FT	1	1	NON-REP	No
Mgr, Transit Operations	Operations Support	FT	1	1	NON-REP	No
Supervisor of Transit Assets and Services	Operations Support	FT	1	1	NON-REP	No
Transit Services Supvsr/Plan	Operations Support	FT	1	1	NON-REP	No
Supervisor of Transit Admin	Operations Support	FT	1	1	NON-REP	No
Cashier (Transit)	Operations Support	FT	1	1	CUPE Local 4705	No
Transit Administration Clerk	Operations Support	FT	3	3	CUPE Local 4705	No
Transit Operations Supervisor	Operations Support	FT	3	3	NON-REP	No
Transit Operations Supervisor	Operations Support	PT	6	3	NON-REP	No
Dispatcher	Operations Support	FT	2	2	CUPE Local 4705	No
Administration	Operations Support	FT	1	1	CUPE Local 4705	No
Driving Instructors	Operations Support	FT	2	2	NON-REP	Yes
Supervisor	Operations Support	FT	1	1	NON-REP	Yes
Bus Operator	Bus Operations	FT	78	79	CUPE Local 4705	Yes
Bus Operator	Bus Operations	PT	58	61	CUPE Local 4705	Yes
Transit Night Leader	Bus Operations	FT	1	1	CUPE Local 4705	No
Transit Serviceperson	Bus Operations	FT	4	4	CUPE Local 4705	No
Transit Serviceperson	Bus Operations	PT	4	4	CUPE Local 4705	No
Maintenance - Parts	Bus Maintenance Support	FT	1	1	CUPE Local 4705	No
Maintenance Supervisor/Foreman	Bus Maintenance	FT	2	2	NON-REP	Yes
Auto Body Repairer	Bus Maintenance	FT	3	3	CUPE Local 4705	No
Mechanic Apprentice	Bus Maintenance	FT- Temp	2	2	CUPE Local 4705	Yes
Mechanic	Bus Maintenance	FT	9	11	CUPE Local 4705	Yes

5.1.5 TRAINING PROGRAM IMPLEMENTATION

GOVA Transit's current technical training approach will continuously evolve. As older buses are retired, replacement buses and onboard systems are integrated into the fleet and new OEM training modules will be procured in order to provide a comprehensive curriculum on all vehicle systems, subsystems, and components. GOVA Transit's outside contracted maintenance program is specialized to provide up-to-date information on new and existing equipment, including modern electronic and mechanical bus systems, OEM changes that impact maintenance practices, and refresher training when necessary.

GOVA Transit plans to take a phased approach to implement ZEB-specific training. As the number of zero emission vehicles in the fleet increases, more mechanics will complete zero emission maintenance training. GOVA Transit will look for opportunities to develop a core group of subject matter experts to serve as BEB fleet specialists. This approach will proactively develop qualified fleet specialists through hands-on experience and learning. In turn, this will influence the transition to an entirely zero emission certified workforce on a timeline that aligns with the integration of new BEBs into the fleet.

5.1.6 FLEET APPRENTICESHIP PROGRAM

City of Greater Sudbury Fleet sponsors an apprenticeship program with CUPE Local 4705 and the Ministry of Skilled Trades (Ontario) and Industry. Applicants must apply through the City of Greater Sudbury, must have completed the academic standard prescribed by the regulations for the trade or must have an Ontario Secondary School Diploma or its educational equivalent, and must successfully pass the agency's regular employment requirements, including testing. The City of Greater Sudbury will give preference to any internal applicants to the Fleet Apprenticeship Program over external applicants.

This program is designed to provide practical training for apprentices, which complements their classroom instruction.[6] The program aims to provide on-the-job (OTJ) training and help individuals become Certified 310T truck and coach mechanical technicians. To achieve this, apprentices must complete 6,000 hours of reasonably continuous employment and 720 hours of in-class instruction, which is divided into three levels/semesters, namely Basic, Intermediate, and Advanced. One of the occupational objectives under this program is to train individuals to become 310T truck and coach mechanical technicians.

5.1.6.1 Academic Training

Program participants are required as a condition of apprenticeship to receive and attend classroom instruction at a technical, trade, or similar school. Credit for time spent in academic training is given in the calculation of the hours of apprenticeship served and are applied against the period total.

As hybrid and battery electric technology becomes more prevalent in the automotive industry, automotive programs will begin to expand course curriculum to include these new systems. GOVA Transit will continue to promote classes offered by local technical and trade schools and are working on partnerships with these institutions to build a workforce that has the technical competency to service zero emission vehicles as they are phased into the fleet.

5.1.6.2 Completion of Apprenticeship

An employee's apprenticeship period begins upon registration with the Ministry of Labour, Immigration, Training and Skills Development (MLITSD) and will be completed when the institution has formally acknowledged that the

[6] Skilled Trades Ontario

apprentice has met all requirements of the program. Apprentices must be in good standing with the educational institution throughout their apprenticeship regarding academic standing and attendance and must provide proof of a passing grade at the completion of each semester. The academic program is 3 semesters long and includes Basic Level 1, Intermediate Level 2, and Advanced Level 3; each semester is 240 hours.

Upon completion of the apprenticeship, the GOVA Transit will recommend to the institution that a certificate of completion be issued to the apprentice. After completion of the Apprenticeship Program, apprentices must successfully write the provincial exam for Journeyperson/Tradesperson status within six months to be reclassified as a Mechanic.

5.1.6.3 Job Postings

While enrolled in the Apprenticeship Program, apprentices are not eligible to apply for posted positions. Additionally, for a period of five years following the completion of their apprenticeship, they are ineligible to apply for posted positions unless they agree to pay back the full amount of the supplementary benefit (i.e., top-up), 50% of the tuition paid by the GOVA Transit, and 50% of any tool allowances provided. The GOVA Transit invests significantly in each apprentice by supporting them through employment while in class, covering the cost of tools and tuition, and providing a top-up of employment insurance benefits following completion of the apprenticeship program. Therefore, the GOVA Transit expects to recoup its investment through each apprentice's commitment to employment.

5.1.7 WORKFORCE RIGHTSIZING

The City of Greater Sudbury Fleet employs nine (9) Tech II bus maintenance mechanics, one (1) Maintenance Supervisor, one (1) Equipment Part Expeditor, and two (2) full-time temporary apprentices to meet current needs. As GOVA Transit transitions to a zero emissions fleet, it will re-evaluate its staffing needs on a rolling basis, based on overall fleet growth. If necessary, it will recommend additional Apprentice Mechanic and Mechanic positions to ensure the smooth functioning of the fleet.

Due to a shortage of qualified BEB OEM training resources, GOVA Transit will look for opportunities to collaborate with other regional transit agencies to optimize limited OEM training resources. This includes exploring partnerships with local agencies and trade schools to maximize class sizes and send mechanics to participate in scheduled training sessions or reserving a centrally located training location or college to host an OEM session. This coordination has received overwhelming endorsement and is a key strategic initiative through OPTA's ZEB Committee Workstreams surrounding Safety and Training. The Committee's other foundational goals include developing and sharing training programs and content, lobbying, and working with colleges to expand battery electric bus training program availability and certifications.

GOVA Transit may leverage local resources such as Cambrian College's Industrial Battery Electric Vehicle Maintenance Certificate Program, which prepares technicians for the maintenance of electric buses. This program can support the development of a skilled workforce capable of addressing the unique challenges of BEB maintenance. enhancing local job readiness and supporting future staffing requirements. .[7]

GOVA Transit currently posts job openings on the CGS website, as well as on job search sites, such as Indeed, and in local newspapers. Priority is given to internal candidates pursuant to the applicable Collective Bargaining Agreement. All City of Greater Sudbury employees have the opportunity to apply to the Apprenticeship Program. Whenever there are available mechanic vacancies, GOVA Transit will first evaluate whether any apprentices are

[7] Battery Electric Vehicle Maintenance certificate program | Cambrian College

nearing program completion. If the position cannot be filled internally, GOVA Transit will then post the vacancy externally in partnership with local trade schools. GOVA Transit offers various job positions, including maintenance positions, Transit Supervisors, and Bus Operators.

As post-pandemic service levels have begun increasing, the GOVA Transit is actively hiring Bus Operators. Applicants with a high school diploma, valid "G" driver's license and a clean driver's record can apply for the job; it is not mandatory to possess a commercial driver's license. Through the Driver Certification Program, GOVA Transit provides a three-week training program to all new operators.

GOVA Transit does not have specific plans at this time to hire additional zero emissions-specific staff but acknowledges that specialty skills will be required to support the agency’s transition to a zero emission fleet. GOVA Transit will continue to monitor and assess the need for specific zero emissions staff as the fleet transition proceeds and will approve and post dedicated positions as necessary.

5.1.8 FUNDING OPPORTUNITIES

The expenses associated with workforce training are expected to vary, influenced by the widespread adoption of BEBs. Funding is projected to emanate from a number of sources, encompassing procurement, where training costs are incorporated into the allocated budget for vehicle or infrastructure procurement, as well as existing funding streams dedicated to training. Additionally, financial support is anticipated from federal, provincial, and local funding allocations.

While the cost of the training itself is one item to consider, the labor cost to train bus maintenance personnel is anticipated to be high. As highlighted by the International Transportation Learning Center, the following costs will be considered when budgeting for workforce training:

- Classroom training hours
- Instructor hours (instruction and prep)
- Instructor hourly wages and benefits
- Instructor costs per class
- Instructor cost per trainee
- OTJ training hours
- Mentor hours
- Mentor hourly cost
- Mentor cost per trainee
- Facilities costs
- Training materials/mock-ups/software/simulation cost

GOVA Transit will continually work to identify funding sources for worker training and re-training and utilize the training funding offered through federal grants to support the agency’s zero emission workforce training.

6 FINANCIAL PLANNING

When undertaking any major transit technology and infrastructure project, the cost to implement can be a major concern. This section of the report compares GOVA Transit's existing diesel fleet to proposed BEB alternatives to identify the best value alternative for the City of Greater Sudbury to reach 100% BEB by 2035. A high-level summary is provided below, while a comprehensive breakdown of the financial analysis assumptions and results can be found in **Appendix C: Budget & Financial Plan**.

6.1 FLEET TRANSITION SCENARIOS

The financial analysis considers two scenarios for GOVA Transit's fleet transition: baseline and a transition to 675 kWh BEB. The modelled scenario for the 675 kWh fleet demonstrated that 40 buses could be purchased before requiring en-route charging, and no overall fleet expansion is required if en-route chargers are implemented at the Downtown Hub. This was selected as a feasible replacement scenario and compared against the Baseline Scenario. Each scenario evaluates the capital, operating, maintenance, and fuel/electricity costs over the 2023-2050 study period. The assumptions used are detailed further below. The two scenarios evaluated reflect the following:

- **Baseline (Business as Usual) Scenario:** Reflects the scenario where no transition to BEBs occurs. All replacements of the current diesel fleet are with new diesel buses.
- **BEB Transition Scenario:** Reflects the full transition of GOVA Transit's fleet to BEBs with 675 kWh batteries, and enroute chargers as part of a phased transition beginning in 2025.

6.2 LIFECYCLE COST ANALYSIS

The lifecycle cost analysis compares the discounted lifecycle cost of implementing each scenario described above. A nominal discount rate of 8% was applied to all costs back to the initial year of 2023 to account for the "time value of money": the principle that a dollar today is worth more than a dollar tomorrow. A nominal discount rate of 8% was selected based on a high-level estimate of municipal borrowing costs of 5% and a 3% general inflation rate. A general 3% escalation rate was applied to estimate future capital expenditures, based on the Bank of Canada's long term inflation target of 1-3%.[8] The upper bound of that range was selected for this analysis as a conservative rate for estimating future cost escalation. The study period for the analysis was selected to be 27 years, from 2023-2050 as this aligns with the federal government's current guidance on reaching net-zero emission targets.[9] While GOVA Transit's technology transition goal ends in 2035, ending the study period in that year excludes operating cost savings for BEBs purchased in the later years of the fleet transition.

6.2.1 CAPITAL COST ASSUMPTIONS

Capital costs include bus unit costs, mid-life rehabilitation costs, and BEB charging equipment and required electric servicing upgrades. Cost estimates were based on recent price data provided by the City of Greater Sudbury, procurement data from other transit agencies, and third-party databases of infrastructure costs for BEB charging infrastructure. **Table 6** contains the capital cost assumptions used in the lifecycle cost analysis.

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8 Our commitment to 2% inflation - Bank of Canada

9 Net-zero emissions by 2050 - Canada.ca

Table 6. Capital Cost Assumptions, 2023$

Conventional Fleet Capital Assumptions	
Diesel Bus Cost	$780,000
Battery Electric Bus Cost (675 kWh)	$1,874,287
Plug-In Depot Charger (150 kW)	$133,900
Plug-In Depot Cable Dispenser	$44,596
Pantograph Charger (450 kW)	$312,455

In addition to the per unit capital costs above, depot charging infrastructure phasing costs are shown in **Table 7**. Lump sum infrastructure costs were developed in 2024 dollar terms and adjusted to 2023 dollars to be consistent with other costs used in the financial analysis. Lump sum phasing costs include budgetary pricing provided by electrical infrastructure OEMs for unit substations, an estimate of construction materials, and a labor markup. The per-phase costs also factor in a 4% engineering design and a 20% contingency based on concept plan details.

Table 7. Charging Infrastructure Lump Sum Costing by Phase, 2023$

	Years	Cost	Key Items
Transit Phase 1	2025-2029	$5,217,464	One (1) 2,000 kVA unit substation; (9) 150kW chargers & (27) dispensers
Transit Phase 2	2030-2031	$7,319,188	**Depot:** One (1) 2,000 kVA unit substation; (3) 150kW chargers & (9) dispensers **En-Route:** One (1) 4,000 kVA unit substation; (8) 450 kW pantograph chargers
Transit Phase 3	2032	$1,682,444	(3) 150kW chargers & (9) dispensers
Transit Phase 4	2033-2035	$2,623,969	(5) 150kW chargers & (15) dispensers

Table 8 displays a comparison between the capital costs under each scenario. The incremental capital cost of transitioning the fleet to BEBs relative to the Baseline scenario is $98.2 million in discounted terms. This is largely driven by the higher capital costs of BEBs, and the additional electrification infrastructure required.

Table 8. Capital Cost Comparison, Millions of Discounted 2023$

	Baseline	BEB	Variance
Diesel	$58.0	-	-$58.0
BEB	-	$139.3	$139.3
Additional Infrastructure	-	$16.8	$16.8
Total	**$58.0**	**$156.2**	**$98.2**

6.2.2 OPERATING & MAINTENANCE COSTS

Operations and Maintenance (O&M) costs associated with the transition to BEBs considered the regular expenses required to maintain GOVA Transit's conventional diesel fleet, as well as any incremental maintenance costs for new BEB infrastructure. O&M costs for the buses were calculated using historical GOVA Transit operating and maintenance cost data. Operating and maintenance costs represent the hourly labor costs and parts associated with operating and maintaining the transit fleet and were calculated from the City of Greater Sudbury's 2023 dollar per revenue hour operating cost. Fuel costs for the buses were excluded from the per-hour O&M cost to avoid overstating fuel costs. The per-revenue hour cost was adjusted to a per-total hour (including revenue and non-revenue hours) to reflect the outputs of the Zero+ modelling. Annualized O&M costs for BEB charging equipment were estimated from a published service level agreement of representative in-depot, and pantograph chargers. A more detailed discussion regarding these estimates is included in the Budget and Financial Plan Memo attached as an appendix. **Table 9** contains the key O&M assumptions in the analysis.

Table 9. O&M Cost Assumptions

Conventional Fleet Operating Assumptions	Diesel	BEB
Operating & Maintenance Costs ($/hr)*	$132.00	$132.00
Enroute Charger Maintenance Cost ($/year)	-	$12,000
In-Depot Charger Maintenance Cost ($/year)	-	$5,958
Charger Efficiency	-	95%
Average Useful Life of New Bus	12	12
Bus Fuel Efficiency (L/100 km)	48.4	-
Spare Bus Ratio (Peak Fleet/Total Fleet)	29%	27%
Average BEB:Diesel Transition Ratio	-	1.0

**- Operating and maintenance costs exclude fuel costs to avoid double counting*

Table 10 displays the comparison of O&M lifecycle costs between the different scenarios. The costs are higher under the BEB Scenario due to combined O&M costs on a per hour basis and additional hours driven due to swaps. Spending on diesel bus O&M is lower in the BEB Scenario, but this spending is replaced by O&M spending on BEBs. Notable differences include the incremental maintenance costs between the Baseline Scenario and BEB Scenario due to additional infrastructure.

Table 10. O&M Lifecycle Cost Comparison, Millions of Discounted 2023$

	Baseline	BEB	Variance
Diesel O&M	$380.1	$178.5	-$201.7
BEB O&M	-	$209.8	$209.8
Related Infrastructure O&M Costs	-	$1.8	$1.8
2023-2050 Total	**$380.1**	**$390.1**	**$10.0**

Fuel and electricity costs associated with the transition include the propulsion of diesel and BEBs, and diesel fuel to operate electric heaters on board BEBs. Diesel fuel costs were estimated using wholesale diesel fuel prices per litre for the City of Greater Sudbury, and escalated to include federal and provincial HST, as well as the federal carbon tax (**Table 11**). The average price of diesel fuel per litre was applied to total diesel consumption. Estimated electricity costs are based on GOVA Transit's average per kilowatt-hour and per kilowatt charges, combined with 2023 year to date Ontario electricity prices. These charges were applied to the total kilowatt-hours and kilowatts to be consumed, respectively.

Table 11. Fuel and Electricity Cost Assumptions

Conventional Fleet Fuel Assumptions	
Diesel fuel cost (2023$/L)	$1.48
Electricity Consumption cost (2023$/kWh)	$0.11
Peak Demand Charge (2023$/kW)	$13.38

In the Baseline Scenario, fuel costs are more expensive due to the increasing price of diesel, driven in part by escalating carbon taxes, and costs $19.0 million more than the BEB Scenario (**Table 12**).

Table 12. Fuel and Electricity Lifecycle Cost Comparison, Millions of Discounted 2023$

	Baseline	BEB	Variance
Diesel Costs	$51.1	$25.2	-$25.9
Electricity Costs	-	$6.9	$6.9
2023-2050 Total	**$51.1**	**$32.1**	**-$19.0**

6.2.3 LIFECYCLE COST COMPARISON

Table 13 below shows the overall lifecycle cost comparison between the Baseline and BEB Scenarios. It is anticipated that the cost of transitioning to BEBs will be $89.1 million over the Baseline in discounted 2023 dollar terms. Additionally, the analysis assumes that capital costs will not be offset by grant or incentive funding; including additional funding sources, such as ZETF, may affect the results of the analysis.

Table 13. Overall Lifecycle Cost Comparison, Millions of Discounted 2023$, 2023-2050

Net Present Value, 2023$	Baseline	BEB	Variance
Bus Purchases	$58.0	$139.3	$81.4
Related Infrastructure	-	$16.8	$16.8
Lifecycle Capital Costs	**$58.0**	**$156.2**	**$98.2**
Operations & Maintenance	$380.1	$388.3	$8.1
Fueling	$51.1	$32.1	-$19.0
Related Infrastructure O&M	-	$1.8	$1.8
Lifecycle O&M	**$431.2**	**$422.1**	**-$9.1**
2023-2050 Total Lifecycle Costs	**$489.2**	**$578.3**	**$89.1**

6.3 FUNDING PLAN

There are several financing opportunities available to GOVA Transit to secure funding for their zero emission fleet transition. The primary funding sources are the Canadian Permanent Transit Fund (CPTF), the Infrastructure for Housing Initiative, and the Zero Emission Transit Fund (ZETF). Funding from these programs can be used to offset capital outlays for buses, chargers, and other infrastructure. The amount funded will vary by program; ZETF provides up to 50% of eligible capital costs in grants, while the Infrastructure for Housing Initiative will offer variable amounts, depending on the loan terms arranged with CIB.

The ZETF is administered by Infrastructure Canada, and targets projects that enable or implement transit fleet electrification. The ZETF offers flexible financing solutions, including grants and loans to applicants. ZETF funding decisions are determined by project viability, estimated operational savings, and estimated GHG emission reduction. Approximately $2.75 billion in funding is earmarked for the ZETF program to support the numerous municipal transit agencies that may apply for that funding.

Funding from either program may be used to offset planning, capital, and operating costs associated with transitioning diesel fleets to BEBs or alternative fuel technologies. As the timing and delivery of this funding varies, it is not included in this analysis.

In March 2024, Canada Infrastructure Bank (CIB) announced the Infrastructure for Housing Initiative, a $6 billion fund dedicated to "housing enabling infrastructure," which includes public transit.[10] CIB primarily invests in revenue-generating assets. Interested applicants work with CIB to secure a mix of public and private funding. Smaller municipalities are eligible for access to lower borrowing rates, without access to capital markets or federal borrowing programs.

Finally, the Canadian Permanent Transit Fund plans to begin disbursing funds in 2026.[11] This fund is allocated $3 billion annually over the next 10 years. It includes a funding stream specific to fleet electrification, along with funding that can flow from the federal government to provinces or municipalities. The program has begun accepting intake for Metro-Region and Baseline funding agreements. The majority of funding will be through the Metro-Region Agreements stream, which is accessed through collaboration with the provincial government.

With a clear understanding of capital, O&M, and fuel/electricity costs associated with a zero-emission bus transition, GOVA Transit can begin to incorporate these costs into future operating and capital budgets. Federal and provincial funding will be essential in helping GOVA Transit meet the ambitious goal of reaching their zero emission targets by 2035. GOVA Transit will use this information to apply for funding from relevant programs at the local, regional, provincial, and federal level such as the ZETF.

10 Infrastructure for Housing Initiative | Canada Infrastructure Bank (CIB) (cib-bic.ca)

11 The largest public transit investment in Canadian history | Prime Minister of Canada (pm.gc.ca)

7 ENVIRONMENTAL BENEFITS

Greenhouse gas (GHG) emissions reduction is a significant benefit of transitioning from a diesel fleet to BEBs. This section helps quantify the impacts that a conversion to BEBs may have on GHG emissions relative to the baseline diesel scenario; results do not consider GHG emissions associated with fabrication and construction of new BEB infrastructure or with resource extraction for the vehicles.

7.1 ASSUMPTIONS & METHODOLOGY

The analysis quantified GHG impacts based on estimates of diesel fuel and electricity usage by transit buses over the 2023-2050 study period. The following assumptions were used to quantify emissions based on litres of fuel and kWh of electricity consumed. GOVA Transit's current fleet consumes diesel fuel, and the emission factor selected reflects this.

The emission rate for diesel fuel is 2.681 kilograms (kgs) of carbon dioxide (CO2) per litre of fuel. This value was obtained from the Canadian National Inventory Report, 2023. The emission rate was multiplied by the annual litres of fuel consumed per year by GOVA conventional transit, to calculate the annual kgs of CO2 emitted. To quantify the impact of electricity usage on GHG emissions, the total kWh of electricity used per year was multiplied by the corresponding Electricity Emission Intensity factor for Ontario from 2023 to 2050. This factor represents the kg of CO2 per kWh based on the average electricity grid mix for the province. The intensity factor declines over time due to anticipated introduction of new renewable power generation sources. The Electricity Emission Intensity Factor was obtained from the Average Grid Electricity Emission Intensities table in the ZETF GHG+ Guidance Modules, Annex C.

7.2 GHG EMISSION REDUCTION IMPACTS

Based on the assumptions above, the greenhouse gas (GHG) emissions from BEB operations are summarized in **Table 14** and **Figure 10**. Over the study period, annual emissions are reduced from approximately 5,600 tonnes of greenhouse gas GHG emissions per year to just over 600 tonnes of GHG emissions per year; this translates to approximately 157 tonnes of CO_2 saved per year, per bus. Compared to a scenario where the fleet is not transitioned to BEBs, this results in a reduction of approximately 94,300 tonnes of GHGs over the 27 year study period. Residual GHG emissions in the BEB scenario after the fleet is fully transitioned are attributed to the diesel auxiliary heaters installed on the BEBs.

Table 14. Total GHG Emissions (CO_2 in Tonnes), Baseline and BEB Scenarios

	2025 Snapshot	2035 Snapshot	2050 Snapshot	Study Period Cumulative Total
Baseline				
Diesel	5,624	5,624	5,624	157,460
BEB	-	-	-	-
Total, Baseline Scenario	**5,624**	**5,624**	**5,624**	**157,460**
BEB Scenario				
Diesel	5,624	1,095	404	59,215
BEB	-	174	203	3,918
Total, BEB Scenario	**5,624**	**1,269**	**607**	**63,133**

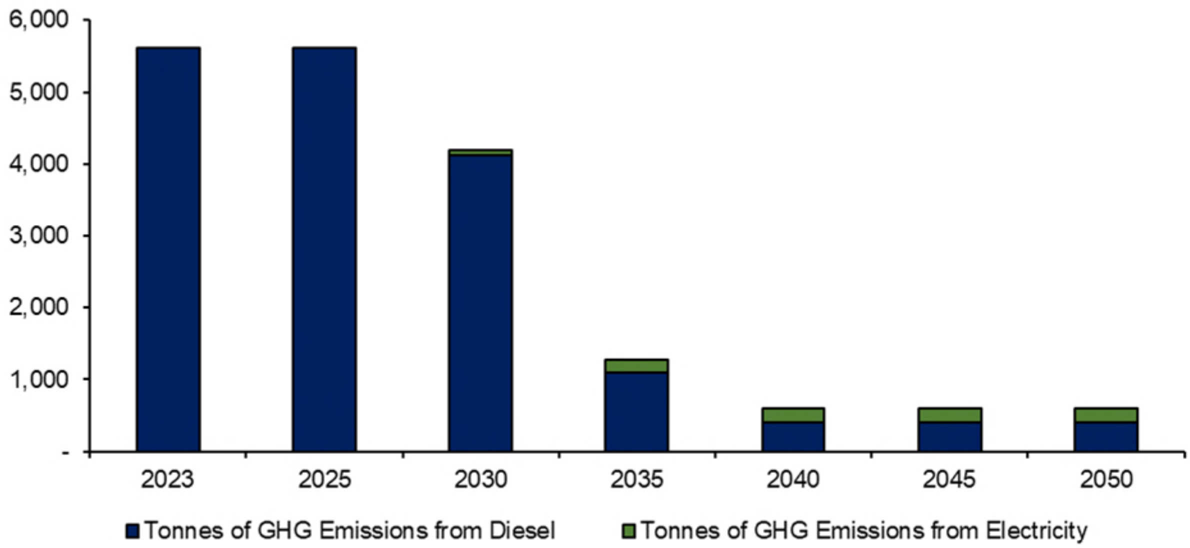


Figure 10. Annual GHG Emissions (CO_2 in Tonnes), BEB Scenario

The cumulative reduction in GHG emissions is shown in **Figure 11**. The annual reduction in emission grows substantially over time as the diesel fleet is converted to BEBs. By the end of the transition to BEBs, emissions are reduced by approximately 89%.

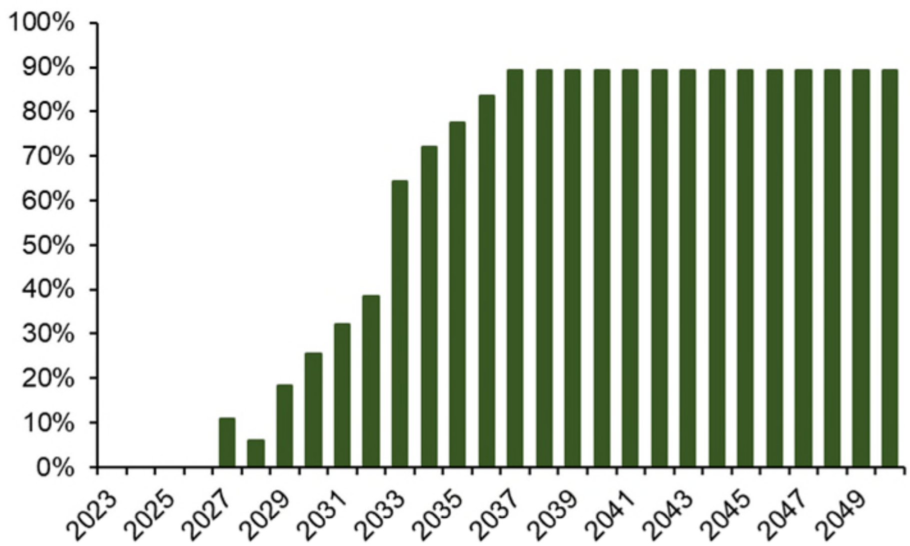


Figure 11. Cumulative Percent GHG Reductions from Baseline in BEB Scenario

8 PROJECT RISKS & MITIGATION

There are risks associated with transitioning GOVA Transit's fleet to a new technology and fuel source. The table below highlights potential areas of risk associated with implementation and operation of BEBs into GOVA Transit's fleet and the proposed response or countermeasure for each risk. It should be noted that risk exposure is subjective by nature and the plan's risk exposure will continuously evolve throughout the transition.

Risk	Risk Description	Risk Response
Infrastructure Transition	As BEBs are introduced to the fleet, it is essential that the necessary infrastructure is in place to enable their integration into the service. Coordination with third parties, such as local utilities and infrastructure manufacturers, can often result in lengthy timeframes and disruptions to current operations.	Initiate planning for infrastructure and ensure construction considerations are made while maintaining current operations. See that infrastructure upgrades are completed at least six months in advance of vehicles arriving. Following infrastructure installation, it is critical to conduct comprehensive testing and commissioning before placing vehicles and infrastructure into active service.
Internal Resource Availability to Support Implementation	The implementation of BEBs will require program management and operational support and may result in resource limitations, additional costs, and delays.	Identify key personnel for the management of procuring the vehicles and infrastructure upgrades as a coordinated program. See that existing resources are supplemented by hiring new roles to address gaps that have been identified. Engage consultants as necessary to offer support during project delivery to support the procurement process, construction, delivery and commissioning. Continue to leverage the Metrolinx TPI Group Purchasing program for procurement and contract administration for BEB and required charging infrastructure.
Service Planning and Scheduling	The BEB fleet will introduce new variables and processes into service planning and scheduling. Adjusting to these new requirements may take additional time and resources, which could result in an increased cost of service delivery and potential delays in implementation. It is important for service planning and scheduling to be flexible to the changes brought about by the new fleet to ensure smooth and efficient operations.	Initiate service planning adjustments at an early stage to gain insights into the attributes and operational limitations of BEBs using data from the Transition Plan. Ensure staff to identify necessary information and tools, assist them in acquiring additional capabilities, and support optimization of schedules with BEBs to maximize fleet utilization and minimize operating costs. Collaborate with BEB OEM on monthly business review calls to address any reliability and performance issues. This includes bench-marking Mean-Distance-Between-Failures (MDBF) data with other transit agencies and, in comparison, to conventional diesel bus fleet.

Risk	Risk Description	Risk Response
Revenue Operations Assumptions	The modelling forecasts the fleet size required to maintain current operations considering operator hours and associated operating costs. However, the underlying assumptions may not consider the full range of operations which may underestimate operational costs.	Initiate the adjustment of service planning practices to align with the characteristics and operational constraints of BEBs using insights from the Transition Plan. This approach aims to minimize the chance of adverse impacts. Additionally, start early and engage in a constructive dialogue with unions to mitigate the impact of any deviations from expected models. The use of on-board AVL / Electric Bus Telematics Software has been critical in creating critical alerts around battery state of charge and operating metrics.
Supply Chain Disruptions	The ongoing global shortage of electrical subcomponents, replacement parts, and heightened production demand due to the increased funding available for zero-emissions bus fleets may result in shortages of parts and tooling which would increase costs and delay procurement. Delays in vehicle procurement and delivery would also result in increased maintenance requirements for the current diesel fleets.	Consider supply chain disruptions, as they are applicable to both buses and fixed electrical infrastructure. Plan for adequate lead time to account for potential manufacturing and delivery delays. Ensure that enough local spare parts are maintained either through contracts or storage at the transit facility. Lists of types and quantities of critical spare parts should be provided by both vehicle and charging system suppliers. Strategies to address some of these challenges have been built into the Metrolinx TPI procurement contract (e.g. late delivery penalties, parts availability, etc.).
Resiliency	Utility blackouts, primary and secondary infrastructure failures, as well as natural disasters or extreme weather events, have the potential to significantly disrupt operations.	Assess the impact and frequency of power outages to evaluate mitigation options that will meet the organization's risk tolerance. Consider the options provided in the facilities report to determine what level of resiliency is required. Having a plan to replace major critical electrical components with long lead times, such as transformers, should be evaluated.
Insufficient Grid Capacity	The planned fleet will require significant power demand which may not be available with current infrastructure and require additional costs to install new transmission lines or substations.	Begin constructive engagement with local utilities to ensure necessary infrastructure upgrades are in place in time to support the charging equipment in the early stages. Engagement was done as part of the facilities assessment and currently, there are not expected to be capacity constraints to support the required electric upgrades at the sites identified. Upgrades will also need to consider impacts from other facility related electrification.

Risk	Risk Description	Risk Response
Technology Interoperability	Potential incompatibility between buses and chargers from different manufacturers may be discovered during testing and commissioning which would result in additional costs and delays.	Thoroughly inquire and assess the compatibility of the equipment to be purchased during the procurement phase. Ensure contracts include testing and commissioning of vehicles with any equipment that is expected to be used. Plan would be to standardize on infrastructure provider and develop Service Level Agreement.
Technology Obsolescence	The technology for EVs is quickly evolving and older generation vehicles and chargers may not be compatible with newer ones. These changes can be driven by updates to charging standards, advancements in battery technology, or changes in design principles. As a result, retrofitting older models with the latest technology	Prior to the procurement of additional vehicles and infrastructure, regular and periodic market scans of the current state of the industry are recommended. Vehicle and charging manufacturers should be expected to maintain spare components for the expected lifespan of vehicles. Additionally, a sufficient supply of spare components should be purchased to ensure equipment is able to be kept serviceable. Leverage Metrolinx TPI Group Purchasing contracts to assist with contract administration as well as obsolescence and parts availability throughout the life of the contract. Evaluate alternative delivery options to lease / finance infrastructure through the utility or another 3rd party.
Software Issues	The smart charging software available in modern chargers is subject to minor malfunctions, such as software “bugs”, and disruptions which would negatively impact operations.	Ensure thorough testing and commissioning are carried out after installation of new infrastructure servicing BEBs and that timely support is available for software that is essential to operations. Leverage Metrolinx TPI Group Purchasing contracts to assist with contract administration and language surrounding obsolescence, reliability and parts availability throughout the life of the contract. Utilize charge-management software to pro-actively alert any charging faults, etc. Review option to have the utility manage charging infrastructure under a service contract.

Risk	Risk Description	Risk Response
Software Adoption	Delays or failure to adopt necessary software tools for electrification, such as smart charging, dispatch, and control, planning and scheduling, depot management, and fleet telematics, may cause implementation delays for electrification.	Before procuring new infrastructure for BEBs, conduct a comprehensive assessment of software and data needs. Once installed, thoroughly test and commission the new infrastructure. Leverage Metrolinx to share ideas and best practices around software deployment. (i.e. use of ChargePoint, etc.) This should also tie into Municipal Zero Emission Fleet Plans and Infrastructure Planning.

APPENDIX A

ENERGY MODELLING ANALYSIS

APPENDIX A: ENERGY MODELLING ANALYSIS

The service data used was based on GTFS data for service in Fall 2023, which is representative of current (post-COVID) service conditions. Four BEB scenarios were modelled with a fleet of either 525kWh or 675kWh BEBs: baseline, depot charging only, depot and en-route charging at Downtown only location, and depot and en-route charging at three. All of the scenarios are detailed below.

KEY ASSUMPTIONS

To develop a model relevant for GOVA Transit's fleet and operations, a set of assumptions and variables were identified and displayed in **Table 15**. It is noted that the assumptions regarding vehicle Original Equipment Manufacturer (OEM) attributes, represent a typical, commercially available BEB model. Subsequent procurement following this analysis, may result in vehicle OEM specifications which differ from these assumptions, which may impact the results of this analysis. Additional energy consumption modelling, based on the selected OEM, should be conducted to confirm energy and infrastructure requirements.

Table 15. BEB Simulation Assumptions

Variable	Input
Service Data	Fall 2023
Battery Capacity	525 kWh (Existing vehicle battery size) 675 kWh (Expected future vehicle battery size)
End-of-Life Battery State of Health	80% (max battery degradation)
Energy Reserve	20% state of charge (SOC)
Heating	Diesel Auxiliary Heat
Ambient Temperature	-27C (Cold weather, 10th percentile) +29C (Hot weather, 90th percentile)
Passenger Capacity	100% seated capacity
Depot Charger Power	150 kW @ 95% Efficiency
En-route Charger Power	450 kW (Vehicle Limited) @ 95% Efficiency

BASELINE SCENARIO

The first modelled scenario assumes depot charging is allowed all day with no modifications to block schedules. Buses are reused if a vehicle has a minimum state-of-charge (SOC) of 60% or higher. In this scenario, if a short block is completed and the bus has at least 60% SOC, then the vehicle is used again in the same day to start another block that it can complete. This gives an indication of how feasible the blocks will be based on how GOVA Transit currently operates. The results of the baseline scenario indicate that both 525kWh and 675kWh vehicles were not able to complete several of the blocks, so this scenario was discounted as it is not a viable option.

DEPOT CHARGING ONLY SCENARIOS

This scenario evaluated a fleet of either 525kWh or 675kWh BEBs with on-board diesel auxiliary heaters that would utilize plug-in depot chargers. It was assumed that buses would be swapped out part way through the block with a fully charged vehicle when the first vehicle reaches 20% SOC. From a scheduling perspective, this would be done by swapping the buses, so they run in shorter blocks that are conducive to BEB capabilities.

The model also assumes that when swaps occur, the bus that would normally stay in service would return to the depot, and another bus and operator would drive from the depot to take its place. This has impacts both on fleet size required (peak vehicle requirement) as well as operational costs due to the increased amount of deadhead miles incurred (non-revenue hours and kilometres between the depot and the first/last stop).

MODEL RESULTS: 525 KWH BATTERY CAPACITY

Below is a review of the main components of the transit service and operations that are likely to change and should be considered when transitioning to a 525kWh BEB fleet using depot charging only. **Figure 12** shows an estimate of the increase in non-revenue hours and kilometres as well as the estimated number of vehicles required to continue the current transit service.

- Revenue hours and kilometres remain the same
- Non-revenue hours: **86 to 126 hours (47% increase)**
- Non-revenue kilometres: **4,398 to 6,508 km (48% increase)**
- Peak Vehicle Requirement: **40 to 60 vehicles (50% increase)**
- 8 depot chargers will be required:
  - (8) 150 kW plug-in chargers
- (26) 525kWh BEBs can be deployed before an increase in fleet size is required

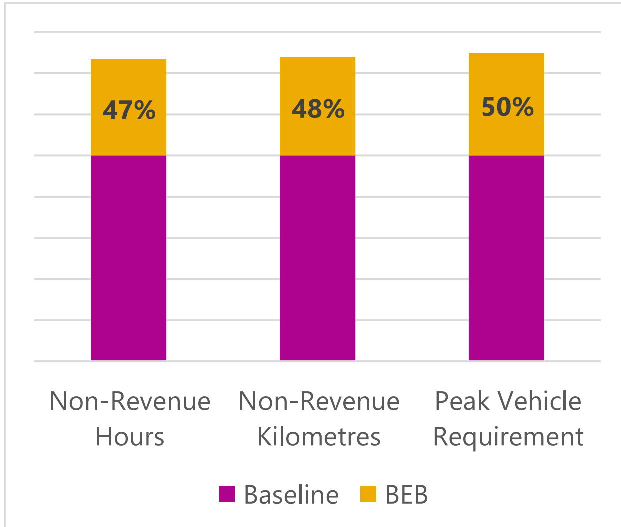


Figure 12. 525kWh BEB Depot Charging Only Model Outputs

The vehicle battery states of charge on each block during weekday service are shown in **Figure 13**. Weekend service was also modelled, but fleet and charging requirements are driven by weekday service which illustrates the most demanding operations for GOVA.

Each block is represented by a line on the chart with the color of the line corresponding to the state of charge of the vehicle (**Figure 13)**. The color changes from green to yellow to red to black as the state of charge drops from 100 to 0 percent. Bus swaps (shown in blue) are introduced only between trips to minimize service impacts. Bus swaps are also inserted in locations shown in blue to guarantee the minimum SOC does not dip below the required 20 percent reserve capacity, including the energy needed to return the vehicle to the depot when a swap is needed. Whenever a vehicle is swapped out, it is replaced with a BEB that has a fully charged battery. Swapping buses is only helpful when the bus either stays near the depot all day or returns within a close distance to the depot at multiple points throughout the day. If a block is scheduled to travel a long distance away from the depot, then there is no convenient opportunity for a swap.

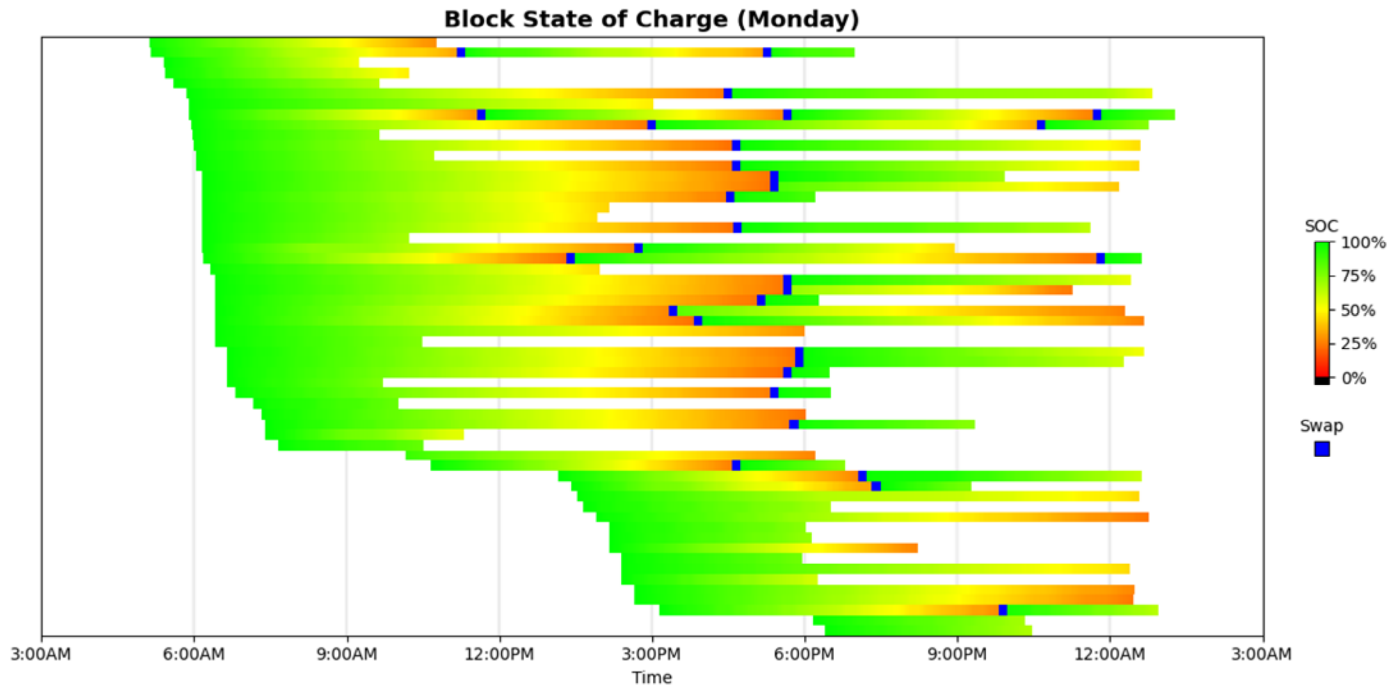


Figure 13. 525kWh BEB Depot Charging Only - Weekday Service Block SOC Heatmap

The modelling reveals which existing service blocks are feasible without the need for en-route charging or a bus swap to complete service**.** A total of 32 blocks (55%) can be replaced with BEBs at a 1-to-1 ratio without the need for en-route charging. The remaining 26 blocks (45%) would require either en-route charging or a bus swap to complete service.

Power Requirements

Figure 14 shows the daily power demand profile for 525kWh BEBs at the depot facility if GOVA elects to continue with depot charging only. The demand is greatest in the evenings and overnight, peaking at 1,200 kW. When buses return to the depot facility and are all plugged in, there are peaks between 5pm to 11pm and 1am to 6am, and demand is relatively low between 6am to 3pm.

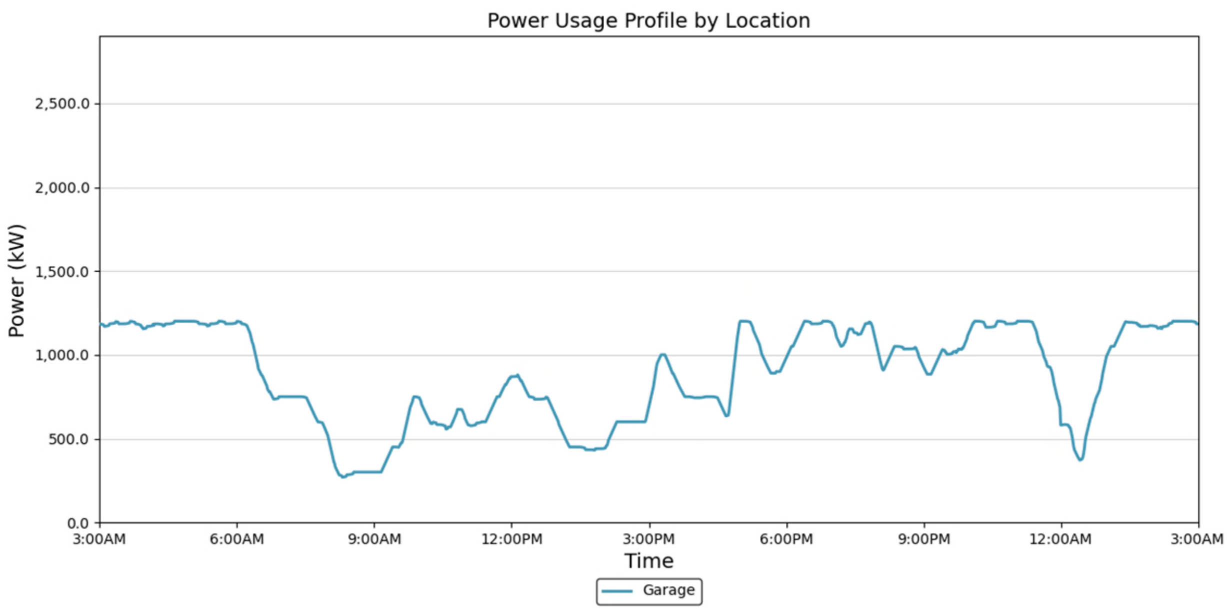


Figure 14. 525kWh BEB Depot Charging Only Maximum Daily Power Profile at Depot Facility

Vehicle Battery Capacities

Figure 15 shows what percentage of GOVA's service becomes feasible without en-route charging by battery size, where the pink area shows feasibility as battery capacity is greater than 525 kWh. With 525 kWh buses, 55% (32 blocks) of weekday services blocks can be replaced one-to-one without en-route charging. Increasing to 675 kWh, feasibility increases to 64%

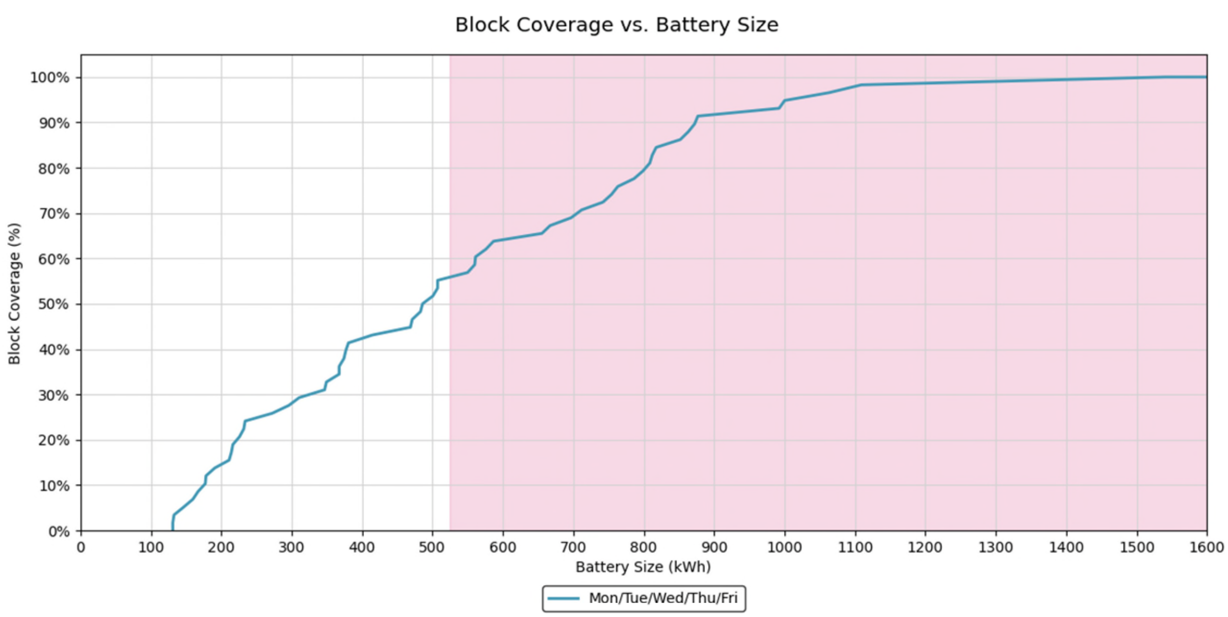


Figure 15. Block Feasibility by Required Vehicle Battery Size

MODEL RESULTS: 675 KWH BATTERY CAPACITY

Below is a review of the main components of the transit service and operations that are likely to change and should be considered when transitioning to a 675kWh BEB fleet using depot charging only. **Figure 16** shows an estimate of the increase in non-revenue hours and kilometres as well as the estimated number of vehicles required to continue the current transit service.

- Revenue hours and kilometres remain the same
- Non-revenue hours: **86 to 127 hours (49% increase)**
- Non-revenue kilometres: **4,398 to 6,598 km (50% increase)**
- Peak Vehicle Requirement: **40 to 50 vehicles (25% increase)**
- 11 depot chargers will be required:
    - (11) 150 kW plug-in chargers
- (27) 675kWh BEBs can be deployed before an increase in fleet size is required

With the increased battery capacity of 675kWh BEBs, 5 additional blocks (+9%) become feasible without swaps, in addition to a reduction in peak vehicle requirement. The vehicle battery states of charge on each block during weekday service are shown in **Figure 17**.

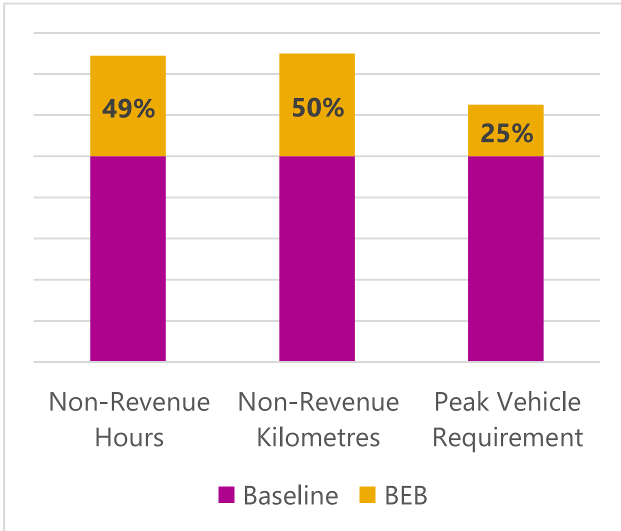


Figure 16. 675kWh BEB Depot Charging Only Model Outputs

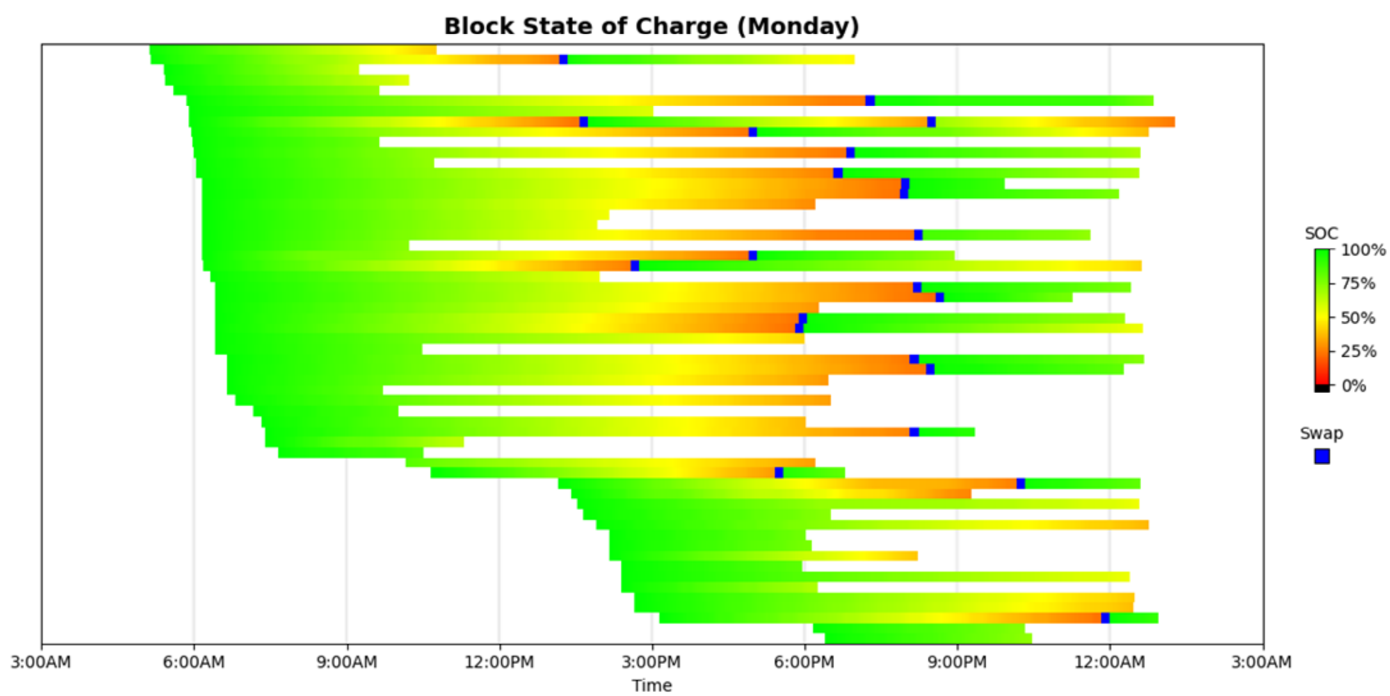


Figure 17. 675kWh BEB Depot Charging Only - Weekday Service Block SOC Heatmap

Table 16 shows which service blocks are feasible with 675 kWh buses and infeasible, respectively. A total of 37 blocks (64%) can be replaced with BEBs at a 1-to-1 ratio without the need for en-route charging. The remaining 21 blocks (36%) would require either en-route charging or bus swaps to complete service.

Table 16. Summary of Feasible Service Blocks without Swap for 675 kWh BEB

Feasible with 675 kWh Bus			Infeasible with 675 kWh Bus	
24024	24015	24004	24007	24037
24033	24034	24011	24008	24045
24038	24046	24047	24009	24029
24039	24006	24016	24012	24043
24040	24032	24017	24026	24049
24041	24013	24014	24027	24028
24042	24030	24002	24023	24035
24052	23995	24018	24025	23998
24051	24000	23996	23999	
24020	24019	24001	24044	
24021	24036	24048	24031	
24022	24010		24005	
24050	23997		24003	

Power Requirements

Figure 18 shows the daily power demand profile for 675kWh BEBs at the depot facility within a depot charging only scenario. The demand is greatest overnight, peaking at 1,650 kW, when buses return to the depot facility. There is a peak between 1am to 4am, and demand is relatively low between 9am to 6pm.

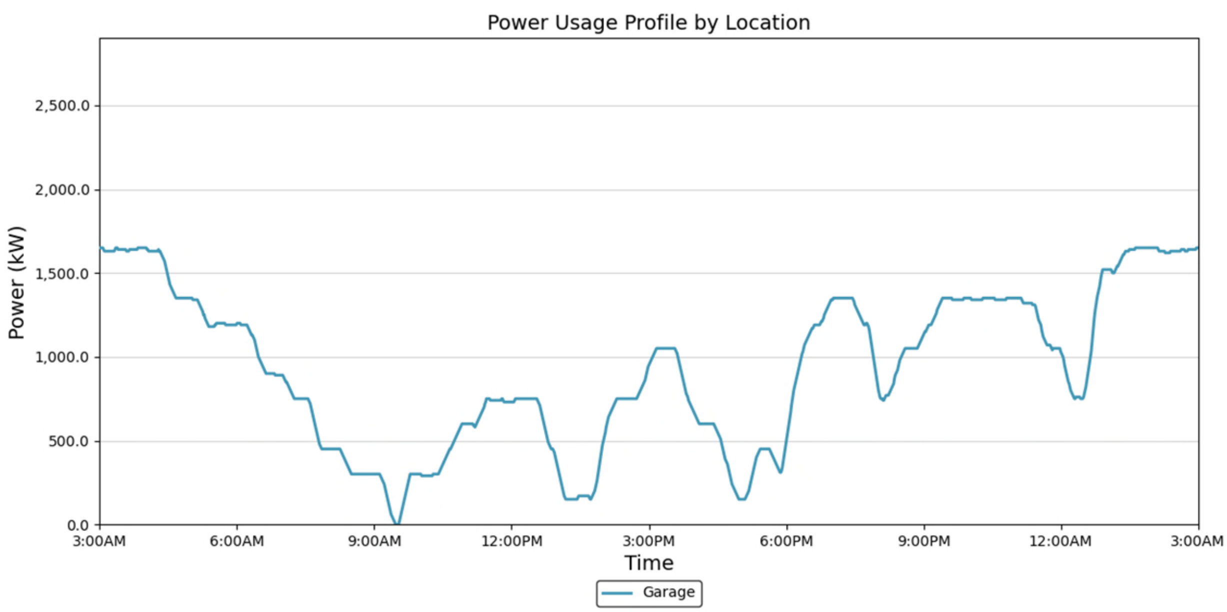


Figure 18. 675kWh BEB Depot Charging Only Maximum Daily Power Profile at Depot Facility

DEPOT & EN-ROUTE CHARGING SCENARIOS

These scenarios evaluated a fleet of either 525kWh or 675kWh BEBs with diesel auxiliary heaters that would utilize plug-in depot chargers and overhead pantograph chargers en-route positioned at either the Downtown Transit Hub only or at the Downtown Transit Hub plus two additional sites. Layover times in the existing schedule were used to identify the most ideal locations for en-route chargers. A total of three locations were identified as having a significant amount of layover time available for buses to charge. While a scenario with en-route charging at three locations was initially modelled for feasibility, this scenario was not ultimately selected but details are included in this appendix for completeness.

The review of the en-route charging locations does not consider the complexity associated with property ownership, access, existing utilities, and other site constraints that may limit or be prohibitive for these activities. This illustrative exercise would require additional study prior to committing to this work.

MODEL RESULTS: 525 KWH BATTERY CAPACITY; DOWNTOWN LOCATION ONLY

Below is a review of the main components of the transit service and operations that are likely to change and should be considered when transitioning to a 525kWh BEB fleet utilizing enroute charging at the Downtown location in addition to depot charging. **Figure 19** shows an estimate of the increase in non-revenue hours and kilometres as well as the estimated number of vehicles required to continue the current transit service.

- Revenue hours and kilometres remain the same
- Non-revenue hours: **20% increase**
- Non-revenue kilometres: **20% increase**
- Peak Vehicle Requirement: **10% increase**
- 8 en-route chargers will be required:
  - (8) 450 kW pantograph chargers at Downtown Transit Terminal
- (38) 525kWh BEBs can be deployed before an increase in fleet size is required

With the introduction of en-route chargers at Downtown Transit Terminal, there are operational improvements in GOVA's service as the 525kWh BEB can service 19 (+33%) more blocks without a swap when compared to depot only charging. The vehicle battery states of charge on each block during weekday service are shown in **Figure 20.**

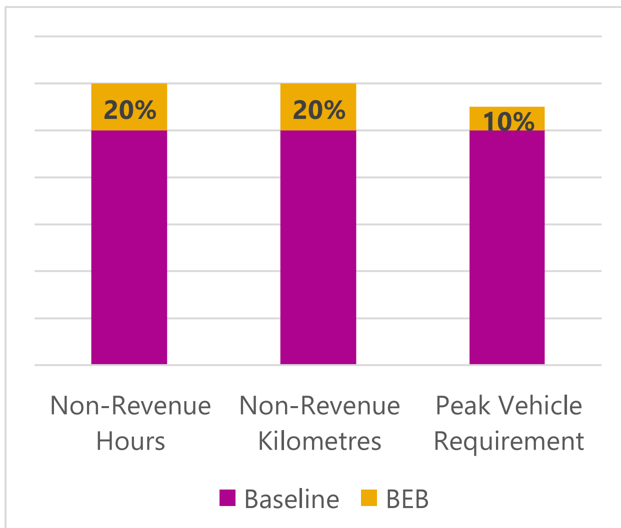


Figure 19. 525kWh BEB Depot and En-Route Charging Model (Downtown Location Only)

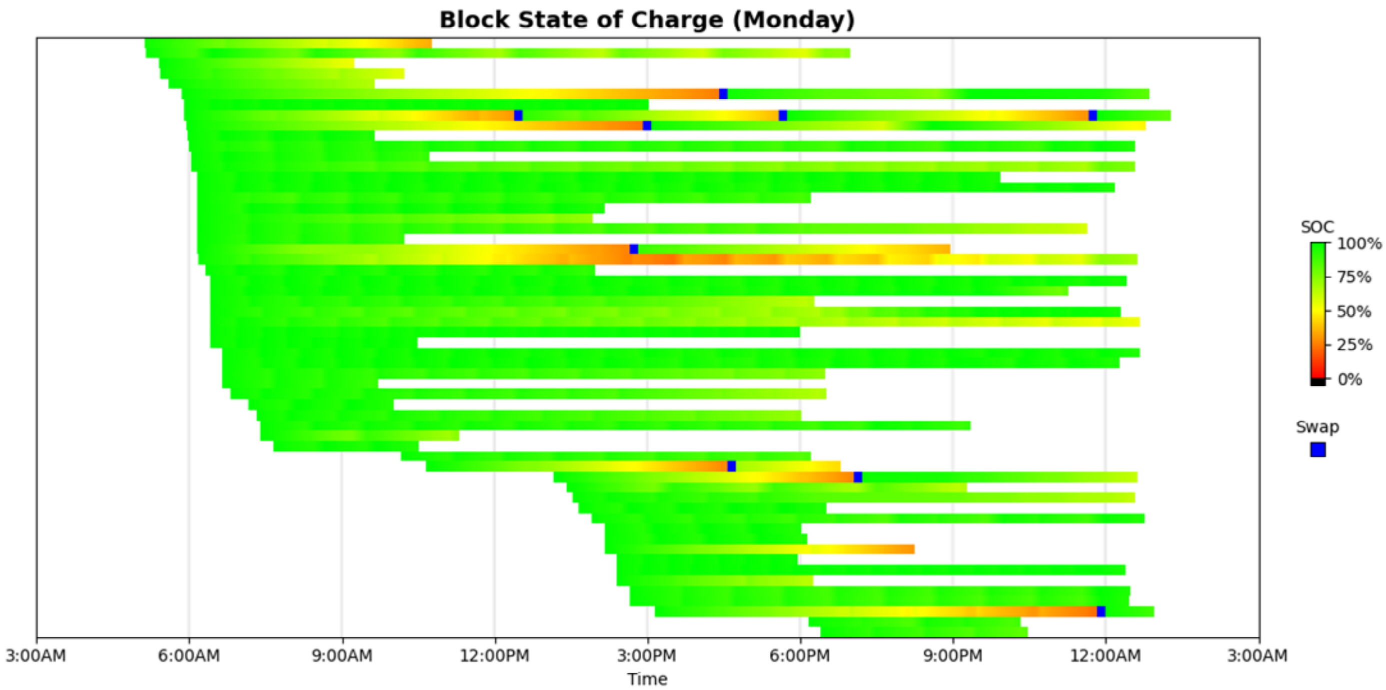


Figure 20. 525kWh BEB Depot and En-Route Charging (Downtown Location Only)- Weekday Service Block SOC Heatmap

Power Requirements

Figure 21 shows the daily power demand profile at the depot facility, peaking at 600 kW, if GOVA elects to deploy en-route chargers only at the Downtown location with 525kWh BEBs in the future. The overnight peak demand is reduced and the demand during the day is lower and more uniform in nature than in the depot charging only scenario.

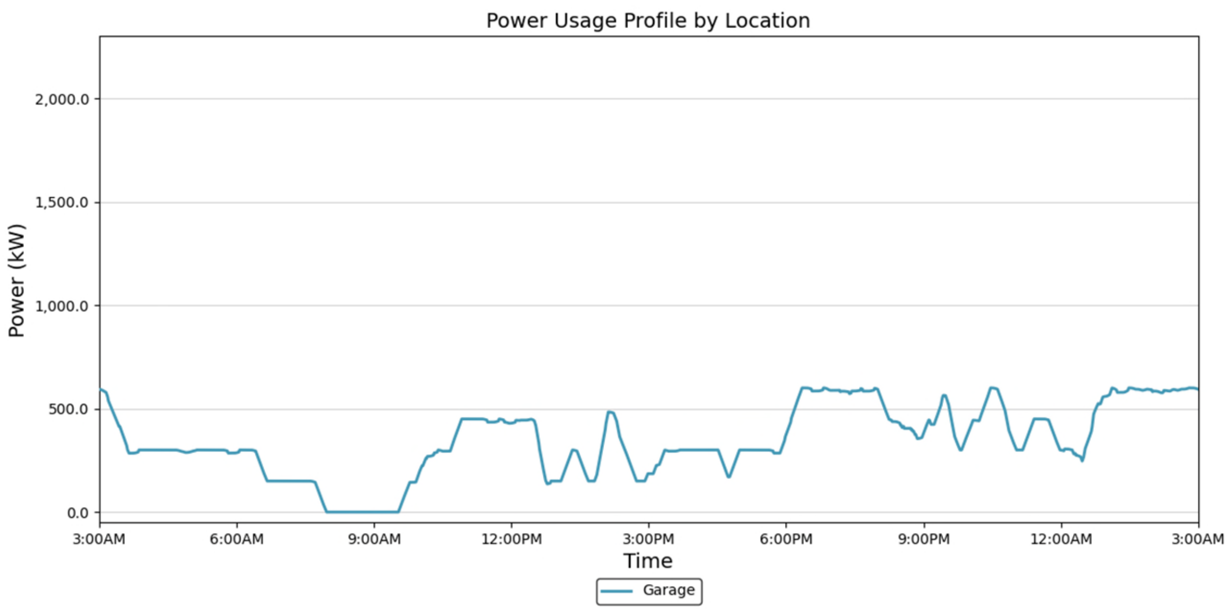


Figure 21. Depot and En-Route Charging (Downtown Only Location) Maximum Daily Power Profile at Depot Facility with 525kWh BEB

MODEL RESULTS: 525 KWH BATTERY CAPACITY; THREE LOCATIONS

Below is a review of the main components of the transit service and operations that are likely to change and should be considered when transitioning to a 525kWh BEB fleet utilizing depot charging and enroute charging at three locations. **Figure 22** shows the estimated increase in non-revenue hours, kilometres, and the estimated total number of vehicles required to provide the examined transit service.

- Revenue hours and kilometres remain the same
- Non-revenue hours: **16% increase**
- Non-revenue kilometres: **19% increase**
- Peak Vehicle Requirement: **5% increase**
- 11 en-route chargers will be required:
    - (8) 450 kW pantograph chargers at Downtown Transit Terminal
    - (2) 450 kW pantograph chargers at New Sudbury Transit Hub
    - (1) 450 kW pantograph chargers at South End Transit Hub
- (40) 525kWh BEBs can be deployed before an increase in fleet size is required

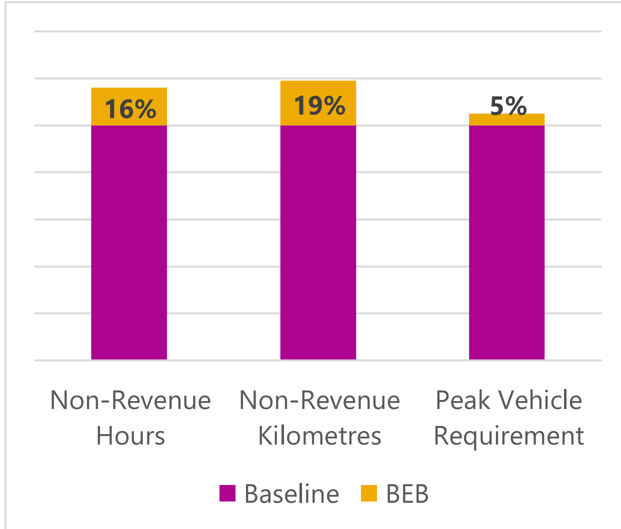


Figure 22. 525kWh BEB Depot and En-Route Charging Model (Three Locations)

With the introduction of en-route chargers at three locations, there are operational improvements in GOVA's service as the 525kWh BEB can service 24 (+42%) more blocks without a swap when compared to depot only charging. The vehicle battery states of charge on each block during weekday service are shown in **Figure 23.**

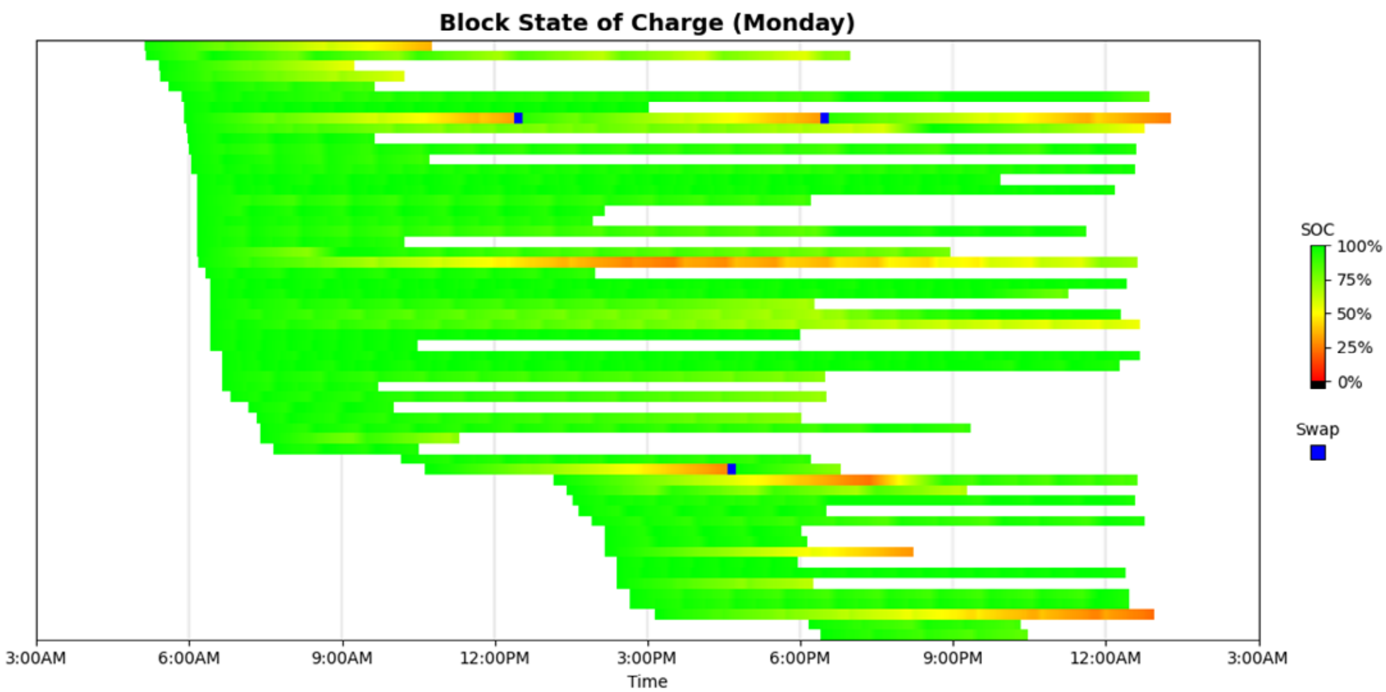


Figure 23. 525kWh BEB Depot and En-Route Charging (Three Locations)- Weekday Service Block SOC Heatmap

Power Requirements

Figure 24 shows the daily power demand profile at the depot facility, peaking at 450 kW, if GOVA elects to deploy en-route chargers at three locations with 525kWh BEBs in the future. The overnight peak demand is further reduced and the demand during the day is lower, and more uniform in nature, than in the depot charging only scenario.

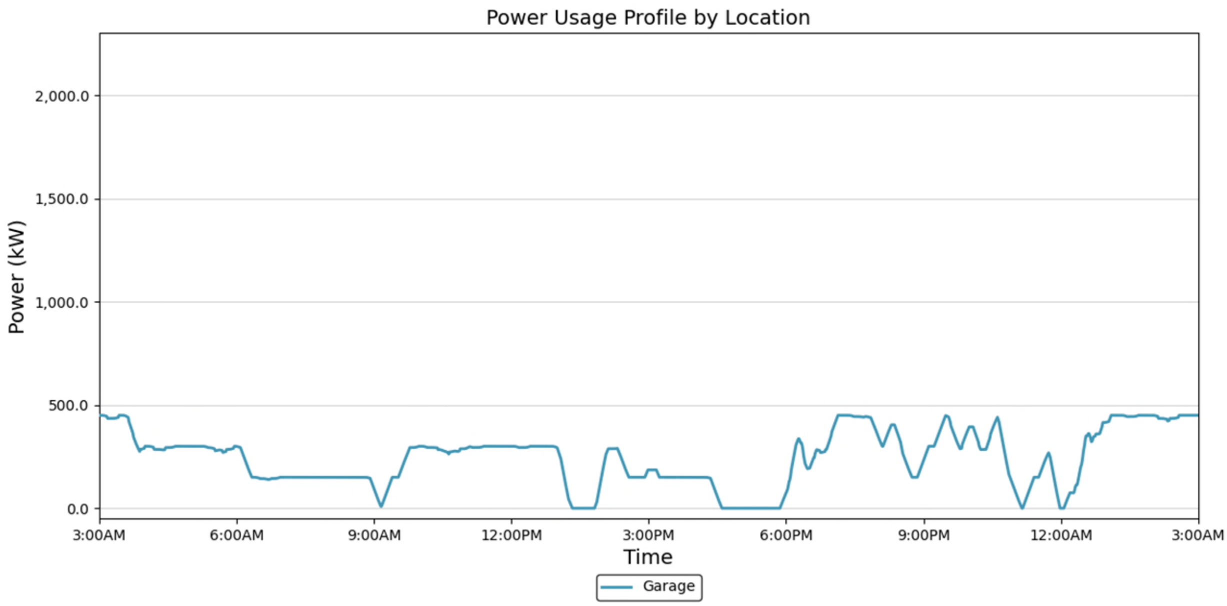


Figure 24. Depot and En-Route Charging (Three Locations) Maximum Daily Power Profile at Depot Facility with 525kWh BEB

MODEL RESULTS: 675 KWH BATTERY CAPACITY; DOWNTOWN LOCATION ONLY

Below is a review of the main components of the transit service and operations that are likely to change and should be considered when transitioning to a 675kWh BEB fleet utilizing enroute charging at the Downtown location in addition to depot charging. **Figure 25** shows the estimated increase in non-revenue hours, kilometres, and estimated total number of vehicles required to provide the examined transit service.

- Revenue hours and kilometres remain the same
- Non-revenue hours: **27% increase**
- Non-revenue kilometres: **30% increase**
- Peak Vehicle Requirement: **7% increase**
- 8 en-route chargers will be required:
    - o (8) 450 kW pantograph chargers at Downtown Transit Terminal
- (36) 675kWh BEBs can be deployed before an increase in fleet size is required

With the introduction of en-route chargers at the Downtown Transit Terminal, there are operational improvements in GOVA's service, as the 675kWh BEB can service 15 (+26%) more blocks without a swap, when compared to depot only charging. The vehicle battery states of charge on each block during weekday service are shown in **Figure 26**.

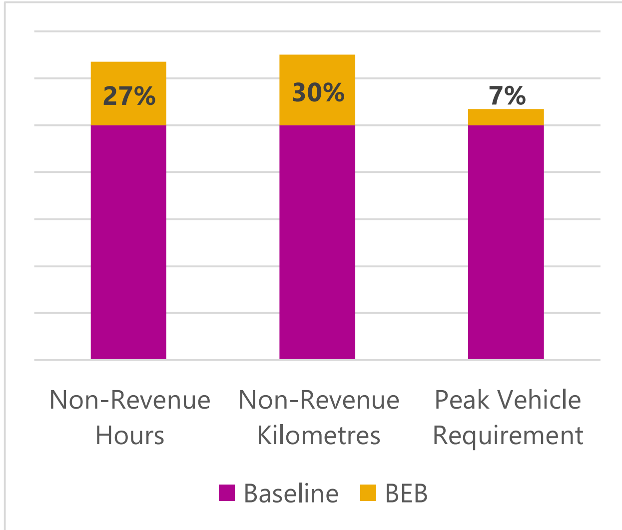


Figure 25. 675kWh BEB Depot and En-Route Charging Model (Downtown Location Only)

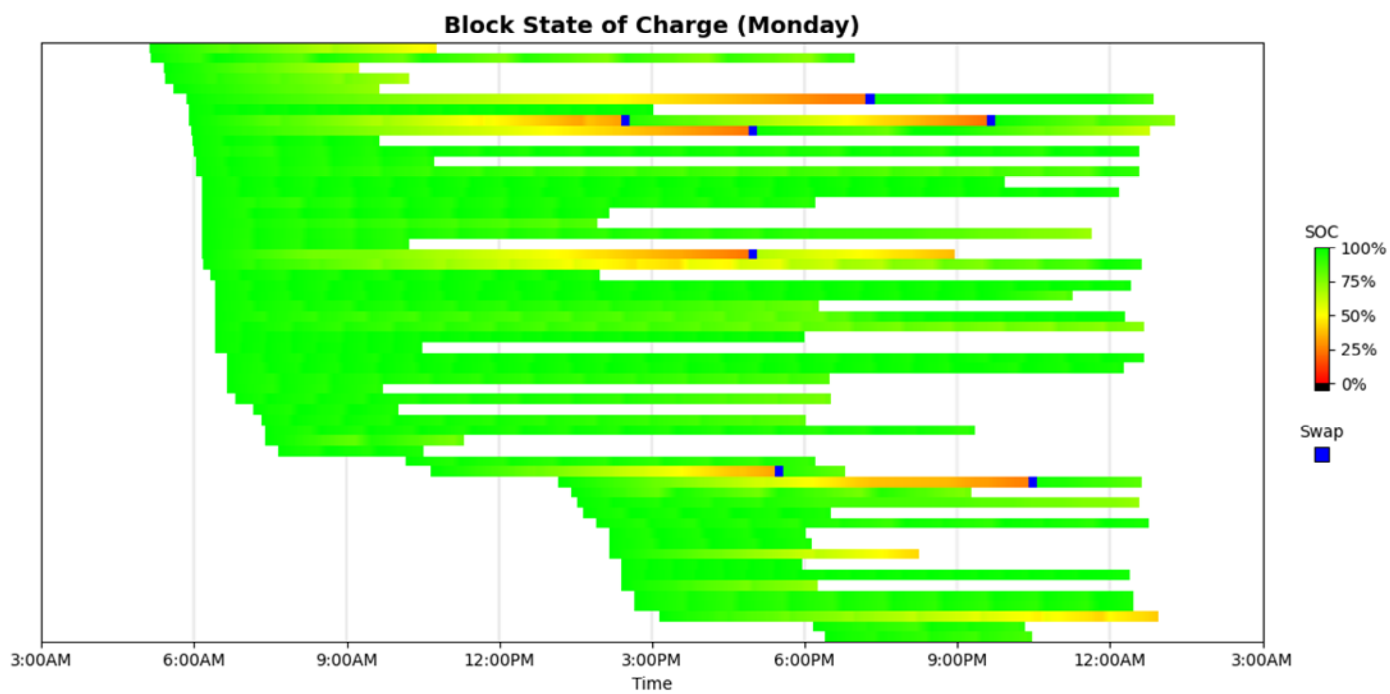


Figure 26. 675kWh BEB Depot and En-Route Charging (Downtown Location Only)- Weekday Service Block SOC Heatmap

Power Requirements

Figure 27 shows the daily power demand profile at the depot facility, peaking at 600 kW, if GOVA elects to deploy en-route chargers only at the Downtown location with 675kWh BEBs in the future. The overnight peak demand is reduced and the demand during the day is lower and more uniform in nature than in the depot charging only scenario.

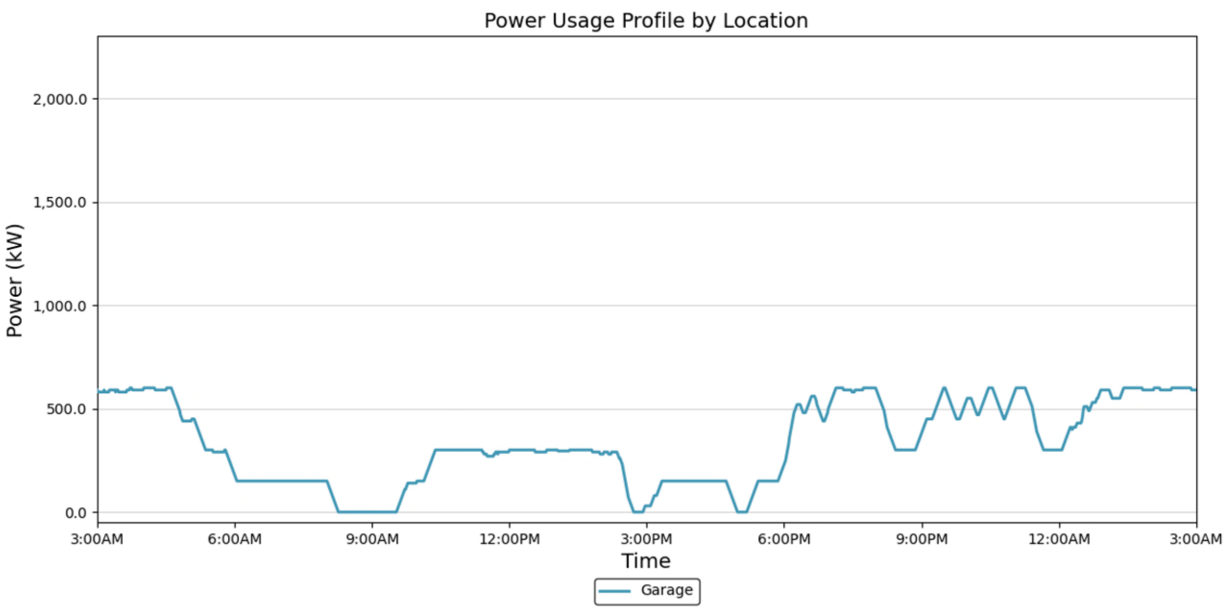


Figure 27. Depot and En-Route Charging (Downtown Only Location) Maximum Daily Power Profile at Depot Facility with 675kWh BEB

MODEL RESULTS: 675 KWH BATTERY CAPACITY; THREE LOCATIONS

Below is a review of the main components of the transit service and operations that are likely to change and should be considered when transitioning to a 675kWh BEB fleet utilizing enroute charging at three locations in addition to depot charging. **Figure 28** shows an estimate of the increase in non-revenue hours and kilometres as well as the estimated number of vehicles required to continue the current transit service.

- Revenue hours and kilometres remain the same
- Non-revenue hours: **16% increase**
- Non-revenue kilometres: **19% increase**
- Peak Vehicle Requirement: **5% increase**
- At least 10 en-route chargers will be required:
    - (7) 450 kW pantograph chargers at Downtown Transit Terminal
    - (2) 450 kW pantograph chargers at New Sudbury Transit Hub
    - (1) 450 kW pantograph chargers at South End Transit Hub
- (40) 675kWh BEBs can be deployed before an increase in fleet size is required

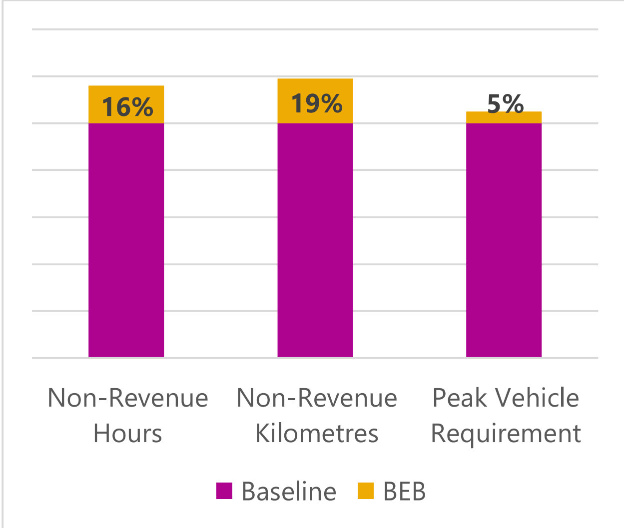


Figure 28. 675kWh BEB Depot and En-Route Charging Model (Three Locations)

With the introduction of en-route chargers at three locations, there are operational improvements in GOVA's service as the 675kWh BEB can service 19 (+33%) more blocks without a swap when compared to depot only charging. The vehicle battery states of charge on each block during weekday service are shown in **Figure 29.**

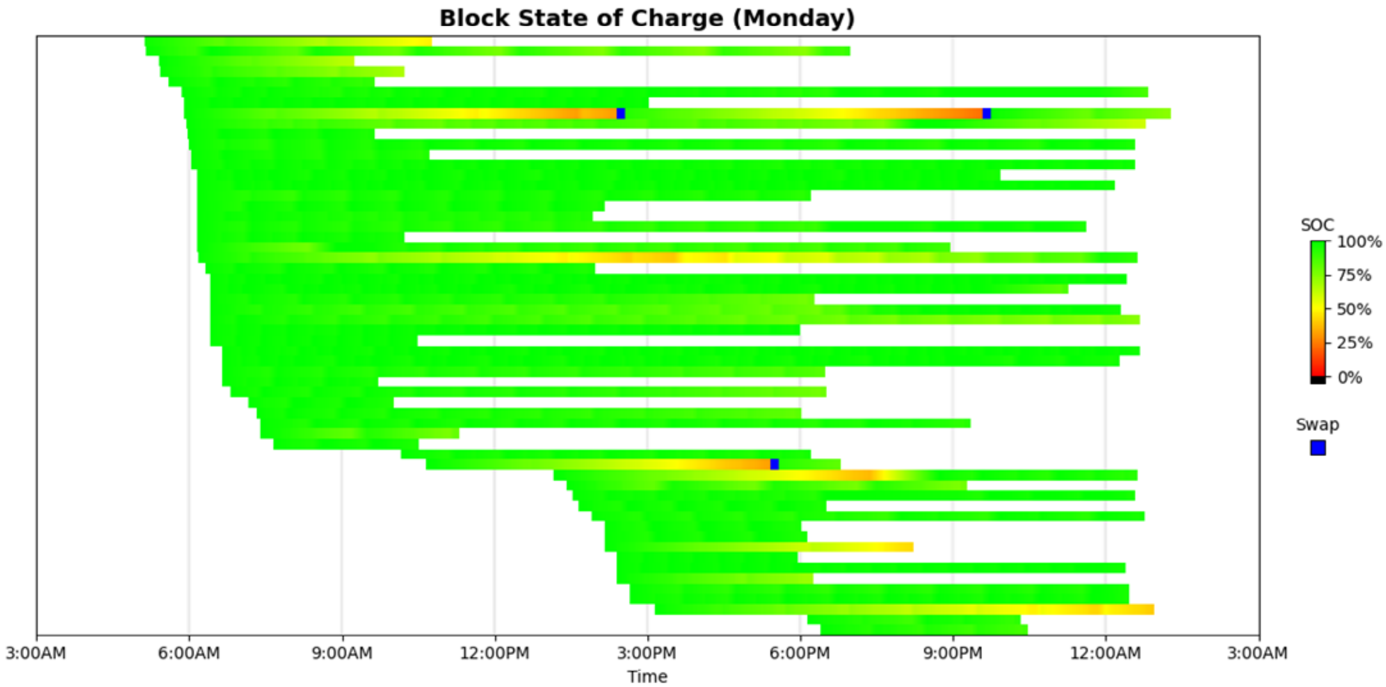


Figure 29. 675kWh BEB Depot and En-Route Charging (Three Locations)- Weekday Service Block SOC Heatmap

Power Requirements

Figure 30 shows the daily power demand profile at the depot facility, peaking at 450 kW, if GOVA elects to deploy en-route chargers at three locations with 675kWh BEBs in the future. The overnight peak demand is further reduced and the demand during the day is lower and more uniform in nature than in the depot charging only scenario.

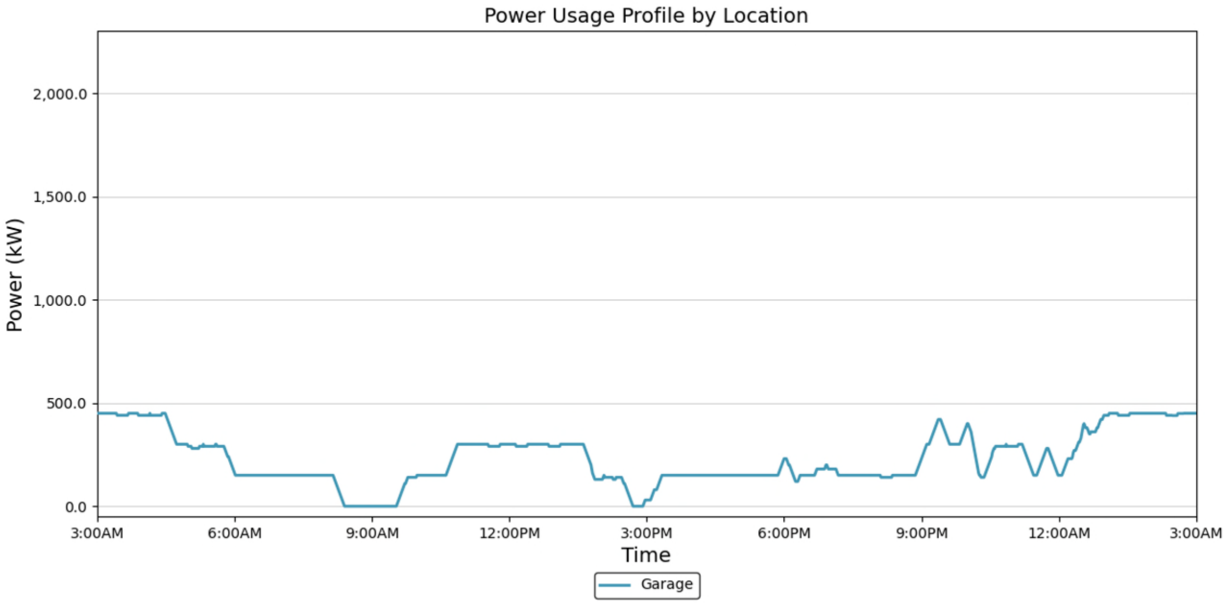


Figure 30. Depot and En-Route Charging (Three Locations) Maximum Daily Power Profile at Depot Facility with 675kWh BEB

APPENDIX B

FACILITY ASSESSMENT

APPENDIX B: FACILITY ASSESSMENT

DEPOT CHARGING

Depot charging refers to the siting and use of charging infrastructure at the facility where buses are typically stored overnight. At the depot, the main difference between plug-in and pantograph dispensers is the way the vehicle is connected to the charger. Charging speeds will be similar because both dispensers use the same charging modules to deliver the same amount of energy.

There are trade-offs with picking either plug-in or pantograph as the connection option. Pantographs take up less space if mounted to existing overhead structures and can offer an automatic way of connecting the vehicle that doesn't require an operator or service person to physically plug in a cable. Some of the drawbacks are that they're heavier, more expensive, require more maintenance, require precise vehicle alignment under the pantograph, and interference with wireless communication between the dispenser and the bus may lead to disruptions in the charging process.

Plug-in charging (**Figure 31**) has the benefits of typically being less expensive, with fewer physical alignment issues and typically fewer communication issues (since there is a hard-wired communication between the charger and dispenser and dispenser and the bus). The downsides are that someone must physically plug the bus in, it typically takes up more floor space (but can also be mounted to the ceiling), requires cable management, and plug-in connectors are more easily damaged.

For the depot facility, a dispenser for each bus is recommended to ensure that when the fleet is parked at night all vehicles can be charged without the need to circulate buses through a limited number of charging bays. It is likely that there will be times when a charger or dispenser will occasionally be out of service due to failure or routine maintenance. Since transit fleets typically maintain a fleet size that includes several spare buses beyond the number required to meet peak service each day, having at least one dispenser per bus will also provide for resiliency in that there will effectively be spare chargers.

Manufacturers offer products that enable several dispensers to be powered from a single charging module. This can be achieved either through "sequential charging," where buses are put in a queue and charged individually, or through "parallel charging," where power is shared among multiple connected vehicles. This infrastructure reduces the amount of charging modules required and provides multiple dispensers and charging options. Despite this advantage, the failure of a single charging module can impact the charging of multiple buses.

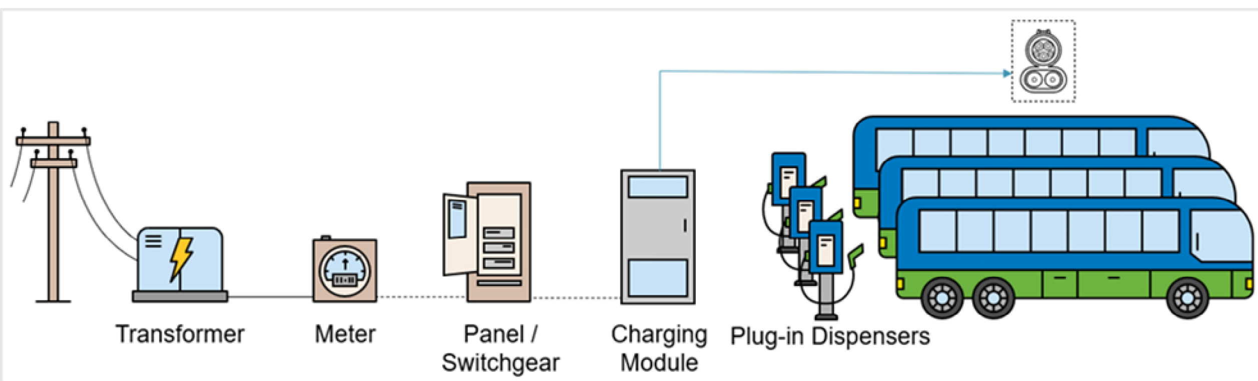


Figure 31. Equipment Required to Feed a Single Charging Module with 3 Plug-In Dispensers

Charging modules come in different sizes and power levels depending on the amount of charging required. Some modules can serve up to four dispensers, with the majority of chargers capable of serving up to three dispensers. Regardless of size, it's important to match the number of dispensers to the number of vehicles stored at the facility.

EN-ROUTE CHARGING

En-route or layover charging is a term used for high-speed charging infrastructure that is placed along a bus route (**Figure 32)**. This infrastructure allows BEBs to charge during layover time, which can be as little as 5 minutes, in order to regain some or all of their energy. The current en-route chargers have a rating of approximately 450 kW; however, buses can currently only accept up to 360 kW, so several charger manufacturers have begun to reduce their largest charger offering to between 300 and 360 kW. Should future bus models begin to accept higher power charging, the charger size may increase in the future.

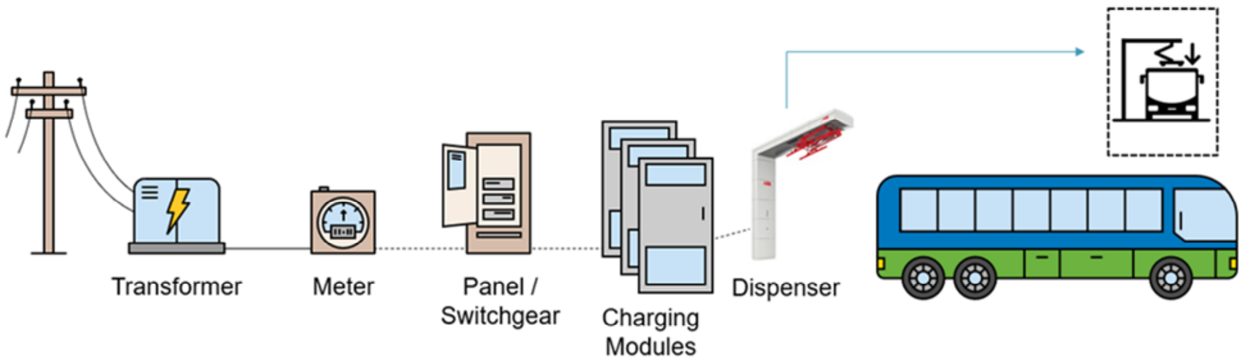


Figure 32. Equipment Required to Feed a Single High-Speed Pantograph Charger

Typically, all the charging equipment in **Figure 32** will be required on each en-route site, but sites with multiple en-route chargers are able to share larger transformers and switchgear. Charging modules can be separated from the dispensers by 100 meters with some manufactures extending to up to 150 meters. Charging modules and upstream electrical equipment should be in "back of house" areas away from passengers, if possible. Having electrical equipment located away from passenger areas makes it easier for repair and servicing without impacting the public. Charging modules also generate heat and minimal noise when in operation which is not ideal for customers. Locating charging modules in fenced compounds is further recommended to avoid risk of vandalism.

En-route quick charging requires a large amount of power for each charging station. Facilities that have separate drop-off, layover and pick-up areas are ideal for en-route charging since a fast charger in the layover location can potentially serve multiple routes. Terminus locations without separate drop-off/layover/pickup locations can also use en-route charging but may require additional pantograph dispensers that will allow for charging at the gate where vehicles normally park for the duration of the layover.

CHARGING INFRASTRUCTURE CONSIDERATIONS

The following sections list factors that were considered when developing the concept plans. They were developed using industry best practices.

DEPOT CHARGER SELECTION

There are currently several charging solutions, including plug-in, pantograph, and wireless inductive charging available for use in transit applications. For GOVA Transit, constraints from facility space may restrict the type of charger dispensers that are operationally feasible. For charging in the indoor parking structure, wall mounted chargers would be a good option for the parking lanes next to walls; while the inner parking spaces would employ overhead retractable plug-in cable reels or overhead pantograph chargers. These options minimize space requirements within the building by eliminating the need for bay restriping to include space for ground-mounted dispensers and protective bollards.

Ceiling- or wall-mounted cable retractors (**Figure 33**) that have enough cable range to reach the vehicles are the recommended option. However, a detailed design is necessary to identify specific locations and determine whether any conflicts with other infrastructure exist where the equipment would be mounted. Motorized cable reels that raise and lower the connectors when not in use are also available. When using motorized retractors, there should also be consideration given to how the reels will be activated, such as by pull cord, remote switch, or other automated custom solutions, or other available options.

Figure 33. Example of Wall Mounted Cable Reel

ROOF STRUCTURAL LOADING

During the facility design for BEB infrastructure improvements, the structural capacity will need to be designed to accommodate the additional weight of the pantograph or charger reel. The weights of equipment can vary significantly by manufacturer, and this may limit which types of dispensers could be used if mounting to the ceiling structure. In some cases, powered cable reels can be mounted on the wall to avoid putting additional weight on the roof structure of a building.

Table 17 provides information gathered from manufacturer specification sheets. It should be noted that the cable reel dispensers have a significant advantage in terms of the usable range between the dispenser and the bus which can make them a good option for areas with high ceilings.

Table 17. Dispenser Weight and Dimension Specifications of Select Manufacturers

Type	Manufacturer	Model	Weight	Useable Range	Dimensions
Pantograph	Wabtec	ChargePANTO	387 kg	1.50 – 1.7 m	2247 x 1250 x 574 mm
Pantograph	Wabtec	DepotPANTO	90 kg	1.0 m max	1524 x 825 x 475 mm

Pantograph	Schunk	SLS 301	90 kg	0.36 m max	1580 x 1020 x 1000 mm
Cable Reel	Wabtec	ChargeREEL	125 kg	6.7 m max	900 mm reel diameter

EN-ROUTE PANTOGRAPH CHARGERS

It is important to monitor the utilization of pantograph chargers if they are deployed for en-route charging. To secure a charge, drivers must align the vehicle correctly with the charger. One way to help drivers align the vehicles is by implementing a system, such as an indicator, that they can use for positioning. Some agencies have used markers both inside and outside the bus and/or speed bumps to help with positioning as shown in **Figure 34**. Given that potential charging stations at transfer points would be situated outdoors and exposed to snow, relying on on-ground markers may not be the best approach for GOVA Transit. It may be more practical to adopt another method, such as aligning the front bumper with a landmark that won't be obstructed by snow in the winter, like a bus stop sign.

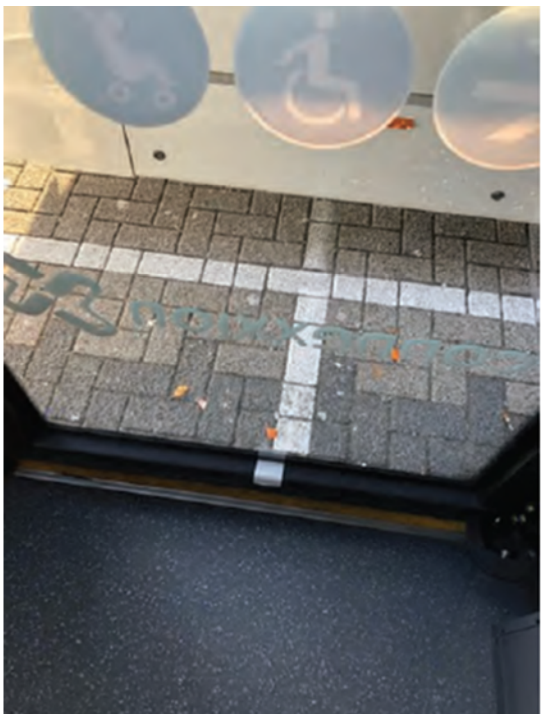


Figure 34. Example of Alignment Markers for Proper Bus Positioning[12]

UTILITY COORDINATION

Unanticipated utility infrastructure costs and long lead times for critical equipment such as transformers are causing delays for implementing fleet electrification. Furthermore, it will be important for GOVA Transit to understand how Greater Sudbury Utilities' (GSU) approved rate tariff will impact its fleet's charging costs.

GOVA Transit is in the conceptual stages of facility planning and design. Coordination with GSU determined the high-level service drop to feed the existing depot with additional electrical capacity. It is anticipated that a new

[12] **Source:** [Guidebook for Deploying Zero-Emission Transit Buses | Blurbs New | Blurbs | Publications (trb.org)]

utility riser pole would be inserted at the north corner of the property to tap from GSU's existing 44 kV overhead system. Any ancillary pad mounted switchgear, junctions and metering equipment would be located near the base of the pole. An underground power line would run to the southeast corner of the property and eventually feed two unit substations at the facility. One 44 kV to 480V transformer would be installed during phase one and two, responsible to feed 12 chargers within the Transit Depot. Both unit substations are needed to accommodate the phase one and two charging needs. Phases three and four would install an additional 8 chargers.

FACILITY UTILITY CONSIDERATIONS

Currently, most EV charging infrastructure is designed to operate at 480V which is commonly used in the US. If GSU is unable to provide a 480V connection and instead can only provide a 600V connection, a step-down transformer will need to be purchased to serve the charging equipment. By the time the City of Greater Sudbury is ready to construct its facility, more EV vendors may offer 600V equipment rated for Canada.

A secondary option, and the one currently depicted in the conceptual design, is to install a primary metered system. This would provide a utility meter near the source and then the City of Greater Sudbury would own and operate a small portion of medium voltage electrical line that feeds unit substations. The unit substations would operate at the specified voltages (44 kV supply and 480V load). Each unit substation would also consist of the 480V breakers required to supply the chargers.

SITE CONSTRAINTS

Site constraints of the existing facility are only known at a high-level at this time. The concept plans at the facility should have access to electrical utility infrastructure that can provide the anticipated energy needed for the electric bus conversion and will need to be further confirmed with GSU regarding the service drop cost and interconnection details (i.e. final design).

PRIMARY AND SECONDARY METERING

For a primary metered service connection, the utility brings power to the client at distribution and transmission voltage. The client, in this case the City of Greater Sudbury, is responsible for designing, constructing, owning, operating, and maintaining a substation or other medium voltage electrical equipment to step this voltage down and distribute it throughout the facility. Metering equipment for the client is done at the distribution/transmission voltage which is more costly than the equipment required for secondary metering but results in a lower cost per kwh. The client may also choose a primary service even if their power requirement can be provided as a secondary service if the client needs a different voltage than what the utility can supply as a secondary service voltage.

Secondary metering service connections have a transformer owned and maintained by the utility that reduces the voltage from the primary distribution voltage to a standardized lower voltage, either 600V three phase, 208V three phase, or 120-240V single phase. With a secondary metering service, a utility meter is then installed downstream of the transformer. Secondary services are generally preferred because they are less expensive and maintained by the utility. However, secondary services can be limited to a maximum service size that is determined by each utility.

REDUNDANT FEEDS

For critical infrastructure such as that which would power GOVA Transit services, redundant power feeds to a site are used to increase the reliability of the utility service. This is commonly achieved by bringing a separate circuit to the site that is fed from a different utility feeder and power line, preferably from a separate substation.

If the redundant feed comes from a separate feeder within the same substation, this only protects the site from an outage on one of the power lines, such as a tree falling on the power line or a pole breaking. In the event of an outage at the substation, both feeds may experience an outage depending on how the utility designed or operates the system. For this application, a redundant feed from the same substation is only practical if an alternate circuit is already nearby the site, otherwise a new power line would need to be brought to the site from the nearest location, which can be cost prohibitive. Redundant feeds from a separate substation provides the most robust utility feed for a site and are recommended whenever possible as they can be less costly and more reliable than other redundant sources. Energy resiliency is discussed elsewhere within this appendix.

A separate circuit could also be added from the existing circuit feeding the site; however, this is not very practical as it would only provide redundancy for the taps feeding the site and does not provide much benefit since outages may occur prior to the tap locations, causing both taps to trip.

For a specific site, the nearby circuits and substation feeding them is usually only known by the utility and typically not shared with clients as it is rarely of concern.

ELECTRICAL INFRASTRUCTURE OWNERSHIP

Some municipalities in other regions have looked to partner with their local utilities to install and maintain electrical infrastructure and charging equipment. Business models such as charging as a service (CaaS) and energy as a service (EaaS) are two examples where a third-party service provider offers energy-related assets and services to customers.

CaaS focuses specifically on providing EV charging infrastructure, whereas EaaS encompasses a wider range of energy-related assets and services, including energy storage, renewable energy sources, and energy management systems. Working with local utilities or third parties, there may be an opportunity to leverage their expertise to allow the transit agency to focus on its core business, which is operating transit service. Utilities have expertise in electrical infrastructure maintenance, energy management, energy market trends, renewable energy and regulatory compliance that can ensure that charging infrastructure is installed and scaled to meet the demands of the transit agency, and that energy usage is optimized to minimize costs.

Reliability and backup power are also critical components that can be included in EaaS agreements and are often factored into the service level agreements (SLAs) between the EaaS provider and the customer.

In future utility discussions with GSU, the City of Greater Sudbury can bring up these alternative options for consideration. In doing so, the City may be able to build a mutually beneficial relationship with GSU that leads to longer term cost savings in the future.

UTILITY RATE CONSIDERATIONS

Electrical costs are determined based on the utility's approved rate tariff which in Ontario is regulated and approved by the Ontario Energy Board (OEB). In Ontario's energy system, customers are classified into two categories: Class A and Class B.

A Class A customer in Ontario's energy system refers to a larger business or industrial customer that has an average peak demand of more than 5 megawatts (MW) in any of the previous twelve months. These customers have the option to participate in the Industrial Conservation Initiative (ICI) program, which allows them to reduce their Global Adjustment (GA) charges by reducing their electricity consumption during periods of peak demand.

A Class B customer refers to a residential or smaller business customer that has an average peak demand of less than 5 MW in any of the previous twelve months. These customers are charged a regulated price for the electricity they consume, which is set by the OEB and is based on the Hourly Ontario Energy Price (HOEP). Class B customers also pay a GA charge calculated on an hourly basis and is included in the overall electricity price that Class B customers pay.

Customers in Ontario also have the option of purchasing electricity from third party energy retailers approved by the OEB. When purchasing electricity through energy retailers, customers are still responsible for other aspects of electricity like delivery, regulatory and global adjustment charges.

APPLICABLE UTILITY CHARGES

The Greater Sudbury Utilities (GSU) has two General Service utility rates[13], which were updated on May 1, 2023. Time-of-use (TOU) rates are available to residential and small businesses, but not available for loads larger than 50 kW peak demand. Based on the predicted energy consumption to electrify the existing bus fleet, four chargers would peak at approximately 600 kW, which would qualify for the greater General Service 50 kW to 4,999 kW rate schedule. Increased fleet size may require additional charging load and may push GOVA Transit to a different rate category or possibly a negotiated rate.

- **Monthly Service Charges:** These base charges are assessed monthly included for every meter location. This likely will not change with adding BEB's to the fleet. The GSU Monthly Service Charges include a $185.60 Service Charge, a $11.12 Rate Rider for Recovery of Advanced Capital Module charge, and a $0.25 Standard Supply Service – Administrative Charge.

- **Demand Charges**: Demand is measured in kilowatts (kW) and the demand charge is a $/KW fee assessed based on the highest kW level drawn in the monthly billing period. This charge is of particular importance to fleet managers of BEBs. For example, if GOVA Transit charged BEBs in the middle of the afternoon at the exact time it is drawing its peak power for its other electric services, this may significantly increase its monthly demand charge. The use of charge management systems can help mitigate the effect of demand charges with BEBs and other EVs. There are numerous demand charges that apply to GSU rates including Distribution Volumetric, Low Voltage Service, Transmission Network and Line Connection, and rate riders. Including the riders, the Demand Charge is $14.533/kW.

- **Energy Consumption Charges**: Energy consumption charges quantify the amount of electrical energy consumed over a monthly period. Charge is based on kilowatt-hours (kWh) that are used, and the price GOVA Transit will pay depends on the time of day and time of year the BEBs are charging vehicles from the grid. Energy consumption charges can be difficult to predict with some rate schedules, but the GSU rates appear to be fairly straightforward. GSU currently charges $0.0052/kWh for energy consumption per their rate sheet.

CHANGING UTILITY RATE STRUCTURES

It's important to note that the demand for electricity is increasing, partly due to the shift towards clean electricity in fleets and building systems. This increase in demand is causing some utilities in North America to modify how they structure their rates. The following are examples of different rate structures that utilities have implemented to accommodate the rising demand. These examples are intended to provide insight into how rates may evolve in the future.

[13] March-23-2023-Tarrif-of-Rates-and-Charges.pdf (gsuinc.ca)

Seasonal Considerations

Many utilities utilize seasonal rates during different times of year. These rates generally reflect the rate changes from the bulk power provider and generally charge less when less is consumed (i.e. summer when daylight hours are longer and temperatures are more moderate).

Time of Use (TOU)

Some utilities also utilize TOU rates to incentivize customers to consume power during off-peak times, when possible, thus creating a peak-shaving effect. This approach allows utilities to defer large infrastructure projects that would otherwise be needed for high peak consumption but then not utilized during the majority of time. TOU rates also help to better regulate generation needs and mitigate costs.

GSU does not currently utilize TOU rates on their General Service rate schedules but may consider doing so in the future. If TOU rates become available to GOVA Transit, a follow up cost benefit analysis would help inform what the cost savings, if any, would be to change rate structures.

Electric Vehicle Charging Rates

Some utilities, including the Ontario Energy Board (OEB), are beginning to incentivize electric vehicle adoption with specific EV tariff structures. These tariff structures are designed to accommodate the unique electricity needs of EV's and EV fleets, and to incentivize EV charging at times that are optimal for the grid. For example, the OEB is introducing an "ultra-low" overnight rate for residential customers. While the initial focus of utilities is on residential applications, in future years EV rate structures applicable to Transit applications are expected; as of 2023, OEB's "ultra-low" rate structure is not applicable to GOVA Transit's fleet.

SEPARATE METERS/FEEDS FOR EV CHARGING

Many utilities have been employing a separate service and meter for electric vehicle charging. This meter is separate from the rest of the facilities at the site and means that it only measures the demand and consumption of EV charging.

Separate meters allow for the utility to isolate the demand and consumption of vehicle charging compared to other loads at the site which can allow them to apply discounted EV electricity rates. Separate meters or sub-meters are typically recommended for EV charging infrastructure even if the utility does not currently offer an EV rate. Utility tariffs are constantly changing and if an EV charging rate becomes available in the future, additional metering modifications will not be required.

Another reason this is preferable is that it allows for more precise data related to cost of services, where costs for conventional bus operation charging administration is segregated from costs such as building electrical and outside lighting. Separate meters, or sub-meters, will allow the City to understand cost for service to move/operate the transit fleet, as compared to normal building loads.

SOLAR GENERATION RATES

There are a few ways the photovoltaic (PV), also known as solar, system can benefit on-site loads. First, PV provides local power generation to offset the loads and reduce, or negate, the overall load during PV generation hours. In instances where the PV system is generating more energy than the load requires, the system can generate revenue through a net metering program. In the case of net metering, the excess solar energy is sold back to the grid/utility at a wholesale rate, which is typically less than the purchase price of energy, and the amount is credited to the owner's utility bill.

Due to most net metering policies, energy generated on-site from PV is most valuable when utilized to feed on-site loads. Further coordination with the utilities is recommended to ensure that future utility rates will allow for net metering and to understand any potential caveats or limits associated with it.

MAINTENANCE AREA CONSIDERATIONS

MAINTENANCE BAY CHARGING

It is not expected vehicles will be routinely charged in maintenance bays, however, there may be instances when having some charging capability in the maintenance bays can be useful. For example, in case of a charging issue with a vehicle, it can be placed in a maintenance bay to diagnose the problem.

Portable chargers are available that could be shared between maintenance bays and deployed as needed. They would require appropriate power for the equipment to be available to the maintenance bays which could be relocated between maintenance bays as needed.

VEHICLE ROOFTOP ACCESS

BEBs have a significant amount of equipment mounted on the roof of the vehicles including electrical converters, battery packs, and charging rails that will require service and/or troubleshooting. Fall protection systems will need to be in place to enable staff to safely work on those components of the vehicle. While personal fall protection equipment, such as harnesses and retractors, can allow this type of work to be done, the preferable way is to have permanent, or portable, scaffolding that allows staff to work on equipment, with personal fall protection equipment providing secondary securement.

LIFTING DEVICES FOR ROOFTOP EQUIPMENT

Along with access to the roof of the vehicle, it may also be necessary to be able to lift items like battery packs on or off the roof for service and replacement. The capacity of cranes that may assist in lifting battery packs should be verified against the heaviest equipment the manufacturer expects will need to be moved on or off the roof of the vehicle.

The weight of the batteries depends on several factors including the bus manufacturer, battery manufacturer, bus length, and battery size. Being a new technology that many agencies have not yet implemented, specificity regarding the recommended crane capacity or rating cannot be provided at this time. As agencies begin to implement BEBs and gain experience with the maintenance of rooftop battery packs, the development of an industry standard for equipment can be expected, but the timing of when a best practice may be developed is not yet know.

SPARE PARTS STORAGE

Having an adequate supply of spare parts that will be unique to the BEBs and charging infrastructure is something that is recommended. With fewer vehicles on the road compared to internal combustion engine (ICE) vehicles, parts can have longer than normal lead times and having critical spares for both BEB and ICE vehicles will be necessary as the fleet transitions. The space requirement for those additional spare parts should be evaluated once information from the supplier has been provided in terms of the recommended quantity and type of critical spares.

To ensure the timely repair of charging infrastructure, certain spare parts should be kept on hand. Below are some parts to consider keeping inventoried for plug in chargers.

- Cables (OEM cable could be purchased with the connector)
- Plug connectors
- Spare cable retractors

- Spare screen interfaces
- 10% spare ratio of cabinet dispensers

On-route chargers will also experience a high workload, due to the number of cycles required each day. Below are some of the parts to consider keeping inventoried on-site for on-route chargers.

- Manufacturers illustrated parts list and manufacturer's recommended parts inventory
- A complete pantograph unit including all attachments – this would be advantageous in the event of catastrophic failure or vehicle accident
- Replacement conductive blades
- Replacement springs
- Replacement electric motor
- Complete set of pins, bolts, electrical bulkhead connectors meeting OEM specifications – the number of parts needed should be determined based on total system size and expected delivery windows from the manufacturer
- Complete set of high voltage cables

FLOOR AND HOIST CAPACITY

The empty vehicle weight of a BEB is typically heavier than that of diesel bus, due to the significant weight of battery packs in the vehicle; this varies by manufacturer and battery pack configuration. Publicly available curb weights of several diesel, hybrid and BEBs are listed in **Table 18** to illustrate the magnitude of the weight difference between the different vehicle types:

Table 18. Curb Weight of BEBs from Select Manufacturers

Propulsion	Manufacturer	Model	Curb Weight
Diesel	Nova	LFS	12,981 kg
Battery Electric	Nova	LFSe+	16,002 kg
Diesel	New Flyer	Xcelsior	12,587 kg
Diesel-Hybrid	New Flyer	Xcelsior Hybrid	13,200 kg
Battery Electric	New Flyer	Xcelsior Charge NG	15,440 kg (480 kWh)*
Battery Electric	Proterra	ZX5 Max	15,131 kg (440 kWh)*
Battery Electric	BYD	K9MD	16,089 kg (496 kWh)*

**Note: Curb weights are from Altoona testing reports. Configuration options such as higher capacity battery packs can significantly impact vehicle weights.*

The structural capacity of the concrete floor inside the garage should be assessed to understand the impacts of operating heavier vehicles. If sufficient as-built information is available for the facility this may be able to be done through a desktop engineering analysis. If capacity of the flooring is unable to support heavier vehicle types, it may be possible to purchase lighter vehicles or consider if modifications could be made to the existing foundation.

The actual weight of vehicles purchased should be compared to the existing hoist capacity at the transit garage to ensure that the current equipment is capable of safely lifting the vehicles. Presently, the ECO 60 hoists are rated to approximately 27,000 kg, which is far greater than the current total weight rating of BEBs on the market today. However, the weight distribution of BEBs can be more disproportionate than diesel buses, so it's important that manufacturers are able to provide not only total curb weight but also the specific weight on a per axle basis.

SOLAR AND BATTERY ENERGY STORAGE

Some transit agencies deploying BEBs add distributed energy resources like solar panels and battery energy storage systems (BESS) for added benefit. Understanding how these resources could be deployed and operated at existing and proposed facilities will assist in determining potential benefits for GOVA Transit.

SOLAR PHOTOVOLTAICS (PV)

Solar PV is an increasingly popular choice for on-site supplemental energy generation as solar costs have decreased significantly over the last decade. Solar PV is typically not capable of offsetting the entire bus charging energy demand. However, PV can offset a meaningful portion of overall demand resulting in a "net load" that is lower than scenarios without PV. The overall impact of solar PV is dependent on a fleet's charging schedule. A solar installation will have a greater impact on demand charges, and thus, a utility bill, if fleet charging is aligned with solar PV production. Even if day-time fleet charging is limited, the integration of on-site solar may help offset the City of Greater Sudbury's increased load.

The PVWatts® Calculator was used to estimate the solar energy that could be generated at the conceptual site. PVWatts® is a tool created by the National Renewable Energy Laboratory (NREL) and uses the location and weather data for each site to estimate a monthly generated power output of the solar PV system, including overall system efficiency losses.

The existing depot roof has a total area of 12,068 square meters. It is assumed that 80% of the rooftop area can be used for PV. This can accommodate approximately 1,040 kW DC of solar, which would yield 1,290,000 kWh in Year 1.

Aligning a roof-mounted solar installation with an existing roof has some challenges as the roof must be structurally adequate to support the additional load, and in many cases, the roof may already have obstacles in the way of the ideal PV layout. For flat roofs, a ballasted racking system can secure panels and limit any penetrations to a single direction service connection from the roof to the electric service panel. Pitched roofs with a standing seam metal roof can utilize racking systems that clamp to the seam, similarly, reducing roof penetration needs to a single direction service connection.

A new solar installation would likely be connected to the grid through net-metering where any excess generated energy not used by charging infrastructure or building loads would be sold back to the utility and credited to GOVA Transit for future use.

BATTERY ENERGY STORAGE SYSTEM (BESS)

Energy storage devices can play a critical role within a microgrid or distributed energy resource (DER) system. Although energy storage systems (ESS) are not a generation method, they can provide greater reliability and resiliency for a microgrid, along with potential energy bill reduction applications. They are especially useful when utilizing renewable generation methods, as it can help reduce some of the intermittency issues and extract more value out of those types of assets. Battery energy storage systems (BESS) are the most prominent and mature technology for distributed scale systems and microgrids.

For transit facilities, BESS systems are typically utilized for shifting loads in a strategic way that may help reduce demand charges and total energy costs associated with large charging loads that occur during peak rate hours. The size (kW) and duration (kWh) of a potential BESS is heavily dependent on the available space for installation as size of the system will increase as the nameplate capacity and operational duration increases. BESS size will vary from vendor to vendor, but most solutions are typically of a containerized configuration. Systems of this nature are generally modular and flexible in terms of size with footprints ranging from 2.4 m x 3.7 m upwards to 12 m x 2.4 m (12 m ISO containers).

Agencies that are not subject to a tariff that has time of use charges and those that have access to net-metering may not require BESS since the grid can effectively act as that storage mechanism. Beyond the initial capital cost of purchasing the BESS, they have a usable life and will need to be replaced after operating a certain number of cycles. There are also operating maintenance costs to consider as well as some efficiency losses as energy is put into and taken out of the BESS.

For GOVA Transit, the electric vehicle charging system is already designed to manage the demand and keep it at a consistent level throughout the day. This means there are no significant peaks that would benefit from the addition of a BESS. Since the demand profile is relatively flat, there is no need to shift the load, and it is not recommended to use a BESS with the current tariff structure.

RESILIENCY CONSIDERATIONS

There are a number of technologies and strategies that can be considered at the City of Greater Sudbury Transit and Fleet facility to increase resiliency. Some involve installation of additional infrastructure while others are potential operational strategies that could reduce or mitigate risks which may impact service. These technologies may decline in price, and increase in efficiency, by the time construction commences in 2025-2026. This may include localized generation and battery energy storages systems as described above, along with items such as hydrogen fuel cells, spare buses, or service reductions. Each method provides different levels of support for the fleet and its infrastructure, and their costs to implement should be weighed against the need for increased reliability.

While the electric utility will never be able to maintain a system that provides power 100% of the time to every customer, some improvements can increase reliability to an area or a single customer. GOVA Transit must balance the operational risk and costs with the resiliency and reliability needs.

REDUNDANT GRID SOURCES

Depending on the base location another method to increase resiliency is to employ a redundant feeder from the utility grid. Ideally, this secondary redundant source is served by a separate circuit than the primary feeder and could provide power to the transit base in the event the primary source experiences an outage or fault. There are several main grid components that affect the grid source reliability.

Substations

The electric utility typically takes service from the generation and transmission grid at the utility's substation. The substation converts electricity from a high transmission voltage to the local medium voltage system. Due to land constraints and large load requirements, the local utilities generally operate multiple transformers within each substation and each transformer is connected to multiple medium voltage, distribution feeders. Most outages at the substation level are localized to a single substation transformer. The presence of multiple substation transformers provides redundancy during most normal operations. The utility usually plans maintenance outages to avoid impacting the entire substation; however, when planning for redundant power to the transit base chargers, GOVA Transit should request redundant distribution feeders be fed from separate substations if feasible or at the least from separate substation transformers.

Distribution Feeders

Medium voltage distribution feeders are installed and operated by the utility to supply electricity to their customers. Utility planners work to ensure that the grid will operate as reliably and efficiently as possible. Utility planners consider how to add new loads to the grid and how to best operate the local grid when maintenance or other outages impact an area or customer. In most cases, impacts to the distribution feeders are seldom known or experienced by the utility customer.

Unexpected outages at the distribution level are often localized and able to be fed from a separate distribution feed. Underground distribution feeder outages are most commonly caused by digging into the line. Underground feeder outages do not happen frequently but occur for a longer duration. To avoid long-duration underground outages, utilities typically operate a loop system that can be switched from one source to another to avoid lengthy delays.

Overhead distribution feeders are installed nearer to the ground than transmission lines, so they are more likely to be impacted by tree branches and animals contacting the bare conductors and shorting the system. Overhead distribution feeders are also not built to the same strength as the transmission lines, so wind and downed trees can also impact these overhead feeders. Overhead feeder outages occur more frequently than underground outages but are repaired much quicker because they are more accessible. Overhead feeders are often configured to allow multiple sources to back feed the line in the event of outage or maintenance.

Some factors for consideration of the distribution feeders may include:

- Whether the charging infrastructure will require a 100% redundant backup source; If 100% redundancy is required, this will increase cost and on-site space required for the utility to provide this level of redundancy.
- Providing separate distribution sources from two separate substations is most desirable but also most costly. If redundant distribution feeds are installed, the Town should consider utilizing sources from separate transformers within that substation.

INTERNAL COMBUSTION ENGINE (ICE) GENERATION

There are two traditional methods for generating power: combustion turbines and internal combustion engine driven generators. These technologies are both effective for generating power on a large or small scale, whether for primary power generation or backup power. Combustion turbines usually have a higher power output, ranging from 500 kW to 25 MW, but they can also be used to meet larger distributed loads. These machines require hydrocarbon fuel, such as natural gas, oil, or fuel mix, to operate. ICE generators come in a variety of sizes making them highly scalable. These machines have a high degree of reliability and can operate on demand but also require fuel input and maintenance. This provides high degrees of reliability and some resilience, but they may fall short in terms of environmental concerns due to the utilization of fossil fuels.

Using ICE generation to offset BEB charging load is generally not an optimal solution due to high maintenance costs, fuel input, and emissions that make it unsuitable for consistent use. However, these generation methods can still serve as backup power to enable reduced transit operations during electric service outages.

When selecting an ICE generator, footprint is an important consideration. A typical stationary diesel ICE backup generator will require a footprint of approximately 7 m^2/MW. Therefore, a 1.5 MW stationary backup generator would require approximately 10.5 m^2, not including ancillary equipment such as transfer switches or noise reduction enclosures.

In addition to stationary ICE generators, there are also portable ICE generators available in a variety of sizes up to about 2 MW. Charging infrastructure at facilities can be designed with capacity to connect portable generators. The benefits of having a portable generator at the depot facility should be considered. This option provides flexibility to relocate the generator as needed, in case of power outages, and eliminates the requirement for separate generators at each site where chargers are installed, including en-route charging locations. This also allows the option to scale up backup generation in the future by purchasing additional generators if reliability continues to be a challenge.

HYDROGEN FUEL CELL GENERATIONS

Hydrogen fuel cells can provide a large amount of power in a smaller footprint than other renewable sources and do not suffer from intermittency. Fuel cells also have low to no emissions depending on the fuel utilized but do require fuel input, additional infrastructure, and safety equipment to maintain high temperatures within the device and to safely store potentially volatile fuels.

Historically, fuel cells have relied on hydrogen as their primary fuel source. To use hydrogen fuel cells, a hydrogen fuel source must be available at the intended site. Hydrogen delivery can be accomplished either through on-site or off-site generation. On-site generation requires raw components that are readily available at the site, such as water or natural gas and electricity. The cleanliness of the hydrogen produced is largely determined by the source of the electricity used in the generation process. Renewable sources, such as hydropower, are considered more desirable than coal or hydrocarbon generation. Generating hydrogen on-site requires significantly more infrastructure than the existing facilities can accommodate. On the other hand, if hydrogen is generated off-site, storage tanks and pumps will be required to store and deliver the fuel to the fuel cells. Truck-and-tank delivery systems are typically used for off-site generation since hydrogen pipelines capable of supporting a 1 MW or larger generator are not currently available.

The size, form factor and fuel cell stack deployment are vendor dependent. A 440 kW containerized fuel cell will have a space requirement of 8.5 m x 3.4 m x 2.7 m or an approximate footprint of 0.07 m^2/kW. The estimated footprint includes only the space required for the fuel cell stacks and does not include the required space for ancillary equipment such as fuel storage or electrolyzers. A 1.5 MW containerized fuel cell installation would utilize 16 units and requires an approximately 100 m^2 footprint.

Similarly, a modular installation would have an approximate space requirement of 4.6 m x 2.7 m x 2.1 m for a 250 kW unit. A 1.5 MW modular installation would require 6 x 250 kW units with an estimated footprint of 100 m^2. These estimates do not include the necessary space for fuel storage and maintenance access.

In general, fuel cells are not ideal for emergency generator applications where the equipment is stored and operated only for a limited number of hours each year. The reason for this is that fuel cells need to maintain high operating temperatures to function effectively and efficiently. If a fuel cell is cold, it can take up to 10 hours to heat up to the optimal temperature. This long startup time is usually not acceptable for emergency generation applications. One potential solution to this problem is to equip the fuel cell to provide a small portion or the entirety of the full load during normal operation. This way, the fuel cell is always operating and maintains its ability to run during an outage. By operating in this way, the primary and backup power sources can effectively swap roles, so that the electrical grid serves as a backup to the fuel cell, providing the desired level of resiliency. Fuel cells have a very fast ramp rate, which means that they can quickly increase their power output to meet sudden demand. If a fuel cell is kept in hot standby mode and ramped up to full load during an outage, it can provide similar starting characteristics as internal combustion engine (ICE) generators. However, it's important to note that keeping the fuel cell in hot standby mode will require the consumption of natural gas or hydrogen during normal operation.

REDUCED BUS SERVICE

In the event of an outage, it's important to have a resiliency plan in place that involves reducing the number of bus services that are offered. This can help ensure that the buses are able to maintain a sustainable level of operation, depending on the severity, type, and duration of the outage (whether it's a utility, local, or software issue). Once the outage is resolved and the buses are fully charged, services can be returned to normal levels of operation. Different plans can be developed to optimize services for different outage categories to streamline service reductions. It should be noted that in the event of a large-scale outage, such as those caused by a large natural disaster, the overall demand for transit service will likely decrease as the disaster has larger regional impacts beyond local services. This should be considered if reduced operations plans are developed in the future. Overall, service reduction plans are dependent on the type and scale of an outage and are a viable option as a primary or secondary method of operation resiliency.

SPARE BUS CAPACITY

Maintaining a fleet of spare buses is also a viable option to sustain a higher percentage of operational transit routes in the event of an outage. Depending on the type and length of a potential outage, buses can be swapped with fully charged spares from a reserve fleet once they reach a low state of charge. Maintaining a reserve fleet of BEBs would allow GOVA Transit to maintain their emissions goals while enabling a greater sense of resiliency for transit operations. However, a reserve fleet of this style is still limited by the charging infrastructure which may be impacted by the potential outage.

A reserve fleet containing diesel buses can provide a greater amount of bus swaps as they are not limited by potential charging outages. While this method may be viable during a phased fleet conversion, this would no longer be viable and considered once the entire fleet becomes battery electric.

While a reserve bus fleet can provide a greater sense of resiliency and allow for increased transit operations during an outage, there are significant costs and space requirements associated with purchasing and maintaining a reserve fleet that should be weighed against the benefits of developing and storing additional vehicles.

EN-ROUTE/LAYOVER CHARGING

In the event of an outage localized to a transit base, en-route chargers could be utilized to keep transit routes in service. An outage localized at a transit base could affect the charging infrastructure and the charging schedule at the base. As an alternative to significantly reducing transit services, specific routes could be rerouted to utilize en-route charging until the outage at the base is resolved. The duration in which this solution can be utilized for resiliency is dependent on the severity of the outage. Likely, this could be utilized for a short period of time to keep a single day's routes in service without major revision of the transit routes. This would be dependent on the final charging infrastructure design and the location of en-route chargers.

RESILIENCY RECOMMENDATIONS

Historically, power outages experienced by GOVA Transit have been short and infrequent. However, more frequent outages may occur due to extreme temperatures or severe weather events because of global climate change. There are several redundancies that GOVA Transit could implement, but in the short-term these will be limited to a reduction of transit bus services and the potential implementation of a diesel backup generator. If the agency experiences a short, isolated outage, GOVA Transit may be able to operate the existing service routes with decreased frequency, minimizing the impact reduced service has on riders. In the event of a widespread, prolonged outage, GOVA Transit may reduce service to strictly critical operations; this may include the transport of first responders or hospital transport. To support critical operations, GOVA Transit will likely need to operate at least 20% of the fleet although this may change depending on service coverage and requirements within the City's business continuity plans and any commitments to providing transportation during emergencies.

Reduction of services at the beginning of the transition to BEBs would not necessarily require backup power as this service could be supported by the diesel fleet, but alternative redundancies will need to be considered when BEBs make up a larger portion of the fleet.

While a generator may not be required immediately, it is suggested that the infrastructure be included in the initial phases of the transition to allow for the future installation of backup generation. This is a cost-effective option that GOVA Transit can utilize if the grid reliability changes or operational workarounds are insufficient, and a greater number of vehicles must be utilized to maintain critical operations.

Solar PV is being considered as an added improvement to the existing GOVA Transit Facility. BESS is also considered as part of this study and will be further evaluated during design development via cost-benefit and high-level pros and cons assessment. In the future, GOVA Transit may reconsider alternative backup power sources to reach a net-zero carbon footprint with 100% renewable energy.

GOVA Transit will continue to evaluate new ways to mitigate the risk of reduced operations through redundancy in power delivery by fueling a portion of the BEB fleet using backup power or by partnering with the utility power provider for a redundant feed. As other municipalities begin planning for transitions to zero emissions and implementing alternative backup or redundant power methods, GOVA Transit may opt for the same methods depending on performance and realized risk of outages now and in the future.

BUILDING CODE AND FIRE SAFETY

Indoor storage of vehicles is not a new concept, but the introduction of BEBs is an aspect that introduces new risks to facilities. Regulatory authorities are still working to determine if additional requirements will be needed. The biggest change with the introduction of BEBs and charging infrastructure is the increase in high voltage electrical equipment that is now being installed as well as the possibility of lithium-ion battery fires from vehicles stored inside facilities.

Each province and territory in Canada has its own building code, which may adopt the National Building Code of Canada (NBCC) or modify it to suit local requirements. These codes may include specific provisions related to fire safety in buildings that house BEBs or other hazardous materials. While the NBCC it does not specifically address battery electric vehicles currently, it sets standards for fire safety, electrical systems, ventilation, and other aspects that would apply to any building.

The Canadian Electric Code (CEC) is a national standard for electrical installations in Canada. It provides requirements for the safe installation and use of electrical equipment, including charging stations for BEBs. Electrical codes are already in place that dictate measures that would be required for installation of high voltage electrical equipment and their required safety devices. Electrical designs will need to be done by qualified professionals and will be reviewed through the building permit process to ensure the designs meet relevant electrical code requirements.

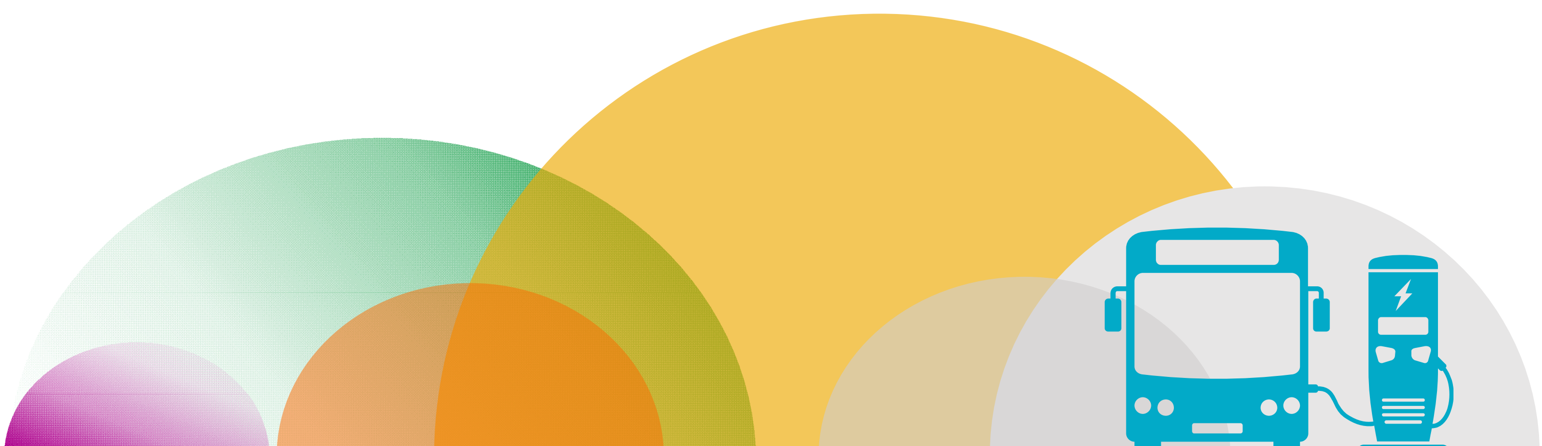
Fire safety standards for BEBs are an emerging area and some codes have not yet caught up to determine what the requirements should be for facilities that house BEVs. Vehicle fires are not a new concept for buildings and while, to date, battery electric vehicle fires are statistically less common than internal combustion vehicles, they do happen and behave differently. For example, if thermal runaway occurs in a battery pack, the fire can be difficult to extinguish and may take hours to put out.

Fleet operators have been proactive in thinking about how to mitigate these risks and while the current building codes may not explicitly dictate requirements, there are suggestions that can be provided based on experience as to what transit agencies should consider in terms of additional fire safety measures:

- Develop a fire safety plan with the local fire department that addresses how to deal with a fire.
- Performing a facility fire safety risk assessment to evaluate aspects such as:
  - Rating of the building fire suppression system in vehicle storage areas.
  - Availability of water for the fire department to be able to extinguish fires.
  - Emergency power shut offs for charging equipment.
  - Manual HVAC controls to exhaust smoke and fumes from a vehicle fire.
- Having an ongoing dialogue with first responders after implementation so that first responders are familiar with the facility, vehicles, and tools available to deal with fires at the facility.

APPENDIX C

BUDGET & FINANCIAL PLAN



APPENDIX C: BUDGET & FINANCIAL PLAN

This appendix breaks down all details of the financial analysis, including assumptions, model results, and supplementary tables for cost breakdowns over the whole analysis period.

FLEET TRANSITION SCENARIOS

The financial analysis considers two scenarios for GOVA Transit's fleet transition. Each scenario evaluates the capital, maintenance, and fuel/electricity costs required between 2023 and 2050.

- **Baseline (Business as Usual):** This reflects the scenario where no transition to BEVs occurs. All existing diesel buses are replaced with new diesel buses.
- **BEB Transition:** This reflects a full transition of the fleet's diesel buses to BEBs in alignment with the existing replacement schedule, beginning in 2025. In this analysis, depot charging is used until enroute chargers are introduced in 2030.

LIFECYCLE COST ANALYSIS

The analysis presents all dollar values in net present value (NPV) terms, unless otherwise noted. NPV analysis accounts for the "time value of money": the principle that a dollar today is worth more than a dollar tomorrow. NPV is used to present costs incurred over the 2023-2050 study period on a consistent basis. Year of expenditure (YOE) costs (costs escalated to reflect anticipated actual costs in a future year) are discounted to 2023-dollar terms by applying a discount factor of 8%. A nominal discount rate of 8% was selected based on a high-level estimate of municipal borrowing costs of 5% and a 3% general inflation rate. This value was used based on HDR experience with similar transit agencies.

KEY COST ASSUMPTIONS

The analysis relies on several assumptions like bus operating statistics and purchasing schedules for the Baseline and BEB Scenario. Capital costs include vehicle purchase costs, BEB charging infrastructure costs, and any required electric utility service upgrades.

VEHICLE CAPITAL COSTS

Table 19 presents the unit cost assumptions for buses. The modelling results indicate the fleet can be replaced at a one-to-one ratio; the transit fleet size is expected to remain the same after transitioning from diesel to BEBs.

Table 19. Vehicle Unit Capital Cost Assumptions, 2023$

Vehicle	Unit Cost
Diesel Bus	$780,000
Battery Electric Bus (675 kWh)	$1,874,287

INFRASTRUCTURE CAPITAL COSTS

Table 20 identifies the capital costs associated with charging infrastructure required for BEVs listed in the replacement schedule. As noted in the fleet modelling analysis, the City of Greater Sudbury Transit & Fleet Centre has been designed to phase in additional infrastructure primarily including substations, 150 kW charging equipment, circuit breakers, and other infrastructure needed to facilitate charging for the BEB fleet. Costs are escalated and discounted similarly to other capital costs modelled.

Table 20. Infrastructure Unit Cost Assumptions, 2023$

Infrastructure	Unit Cost
Plug-In Depot Charger (150 kW)	$133,900
Plug-In Depot Charger Cable Dispenser	$44,596
Pantograph Charger (450 kW)	$312,455

OPERATING AND MAINTENANCE COST ASSUMPTIONS

Ongoing operating and maintenance (O&M) costs for GOVA Transit's conventional diesel fleet and their modelled BEB replacements are part of this analysis.

- **Bus Operations and Maintenance**: The operating and maintenance cost per hour was based on GOVA Transit's submission to CUTA 2023 Conventional Transit Statistics. The cost per revenue hour provided by GOVA was adjusted to a cost per total hours, since Zero+ outputs total hours, the sum of revenue and non-revenue hours. The hourly cost of operations and maintenance was provided in 2023 dollars, then divided by total vehicle hours. To avoid Fuel costs were excluded by converting 2023 annual fuel costs to a dollar-per-hour unit, which was then subtracted from the total hourly operating & maintenance cost. This cost is applied to total estimated operating hours for diesels and BEBs throughout the transition plan. This cost includes labor costs and maintenance costs for buses in the fleet.
- **Fuel Efficiency:** Litres per 100 kilometres (L/100km) was calculated as an average of the diesel consumption divided by total vehicle kilometres travelled recorded by GOVA Transit reported in CUTA 2022 Conventional Transit Statistics. This was confirmed through correspondence with GOVA Transit staff.

OPERATING COST ASSUMPTIONS

The cost of labor in both scenarios is based on the anticipated operating hours in both scenarios. The cost per hour is assumed to be the same, but the total cost in the BEB Transition Scenario is greater due to an increase in non-revenue hours due to deadhead to and from the garage. Fuel costs were excluded from the hourly operating to prevent double counting fuel costs, calculated separately using expected kilometres travelled and fuel efficiency of the transit buses. Annual fuel costs for 2023 were divided by total vehicle hours to estimate a dollar-per-hour value. This was then subtracted from the hourly operations and maintenance cost described above.

Table 21. Unit Operating Cost Assumptions, 2023$

	2023	2025	2030	2035	2040	2045	2050
Operating Cost ($/hour)	$132.00	$140.04	$162.34	$188.20	$218.17	$252.92	$293.20

FUELING COST ASSUMPTIONS

Estimated annual diesel fuel and electricity reflect a combination of growth rate assumptions. Additionally, the following assumptions and sources were used to estimate projected change in cost of diesel and electricity.

Diesel Fuel Costs

The analysis assumed diesel fuel costs in 2023 are $1.48 per litre. This assumption was based on the average wholesale price for diesel fuel in the City of Greater Sudbury, with data available for 2023. The wholesale price had provincial and federal taxes layered on, including the unrecoverable net HST. Wholesale diesel fuel costs were assumed to escalate based on forecasted real changes in diesel estimated in the US Energy Information

Administration's Annual Energy Outlook 2023. The carbon tax was assumed to escalate in line with the latest federal carbon pricing plan, while other provincial and federal taxes were assumed to remain constant for the duration of the analysis. Prices were escalated by 3 percent annual growth rate to be converted to year of expenditure (YOE) dollars. All BEBs are assumed to have diesel heaters to ensure electric power can focus on maintaining maximum driving range. The average fuel efficiency of diesel heaters was obtained based on industry experience to estimate the diesel usage per kilometre travelled.

Table 22. Diesel Unit Cost Assumptions, YOE$

	2023	2025	2030	2035	2040	2045	2050
Diesel Fuel Price ($/L)	$1.48	$1.53	$1.89	$2.24	$2.64	$3.09	$3.64

Electricity Costs

There are two types of electricity costs that are included in the analysis: a per kilowatt-hour (kWh) usage fee, and demand charges per kilowatt (kW). The values used were obtained from GOVA Transit's Greater Sudbury Hydro invoice from January 1, 2023. The dollar per kWh ($/kWh) usage fee is based on the average Hourly Ontario Energy Price and the Global Adjustment Factor for 2023. Prices were escalated by 3 percent annually to be converted to YOE dollars. The analysis assumes a 5% efficiency loss between chargers and BEBs.

Table 23. Electricity Unit Cost Assumptions, YOE$

	2023	2025	2030	2035	2040	2045	2050
Electricity Price ($/kWh)	$0.11	$0.11	$0.13	$0.15	$0.18	$0.21	$0.24
Demand Charge ($/kW)	$13.38	$14.20	$16.46	$19.08	$22.12	$25.64	$29.72

MAINTENANCE COST ASSUMPTIONS

Maintenance costs for buses are included under the operating cost assumptions section above. Other maintenance costs in the model include maintenance costs for in-depot dispensers and enroute charger maintenance. Charger maintenance costs are based on recent industry experience with other transit agencies.

Table 24. Maintenance Unit Cost Assumptions, YOE$

	2023	2025	2030	2035	2040	2045	2050
Depot Charger Maintenance ($/Year)	$5,959	$6,322	$7,329	$8,496	$9,849	$11,418	$13,237
En-Route Charger Maintenance ($/Year)	$12,000	$12,731	$14,758	$17,109	$19,834	$22,993	$26,655

BASELINE SCENARIO

As described above, the Baseline Scenario refers to the current diesel fleet being replaced strictly by new diesel buses in alignment with the current fleet replacement schedule**. Table 25** below shows the annual total number of hours and kilometres operated by the diesel fleet; this service level is assumed to be the same in each year from 2023 through 2050 in the Baseline Scenario.

Table 25. Annual Service Levels, Baseline Scenario

Annual Service Level	Quantity - Modeled	Quantity - 2023 Actuals
Kilometres Travelled	4,330,240	4,246,823
Hours of Operation	181,443	179,118
Litres of Fuel Consumed	2,097,559	2,207,601

Zero+ modeling used in the analysis was representative of the Fall 2023 bus service schedule, which has higher total hours of operation than the Spring and Winter schedule. Unadjusted, this overstates annual operating statistics for the GOVA Transit fleet. To normalize operating data for different seasonal schedules, the proportion of Winter and Spring weekday hours of operation was compared to the value of Fall weekday hours of operation. The weighted average of these quantities was applied to the weekday assumption of kilometres traveled, hours of operations, and kWh consumed. A comparison of modeled results and 2023 actuals provided by GOVA Transit is shown in **Table 25** above.

BASELINE CAPITAL COST ESTIMATES

Under the Baseline Scenario, the fleet mix remains entirely ICE for the duration of the study period. A fleet replacement schedule was prepared based upon the known service life and purchase date for vehicles in the municipal fleet, which was used to determine the capital purchase assumptions by year. **Table 26** illustrates the near-, mid-, and long-term total number of replacement ICEVs purchased based on the fleet replacement schedule. These vehicle purchases also assume that some vehicles are replaced more than once between now and 2050, thus a total that is larger than the 59 vehicles.

Table 26. Baseline Scenario Periodic Diesel Bus Purchase Assumptions Based on the Fleet Replacement Schedule

	2023 - 2030	2031 - 2040	2041 - 2050
Diesel Bus	32	54	53
Peak Service	23	39	39
`Spares	9	15	14
BEBs	-	-	-

Table 27 presents the annual costs estimates based on the unit cost and growth rate assumptions and the annual fleet needs shown in **Table 26**.

Table 27. Baseline Scenario Periodic Total Capital Cost Estimates, YOE $, Millions

	2023 - 2030	2031 - 2040	2041 - 2050
Diesel Bus	$28.6	$61.3	$80.7
BEBs	-	-	-
Total	**$28.6**	**$61.3**	**$80.7**

BASELINE OPERATING & MAINTENANCE COST ESTIMATES

The annual operating and maintenance costs between 2023 and 2050 are calculated by multiplying the hours of operation by the estimated hourly operating cost. **Table 28** presents the near-, mid-, and long-term total periodic operating costs under the Baseline Scenario.

Table 28. Baseline Scenario Periodic Total Operating Cost Estimates, YOE$, Millions

	2023 – 2030	2031 – 2040	2041 - 2050
Operating Costs	$213.0	$347.8	$467.4

BASELINE FUELING COST ESTIMATES

Under the Baseline Scenario, the only fuel required to operate the fleet is diesel. The annual diesel fuel costs are calculated based on the annual kilometres travelled, the average fuel economy, and the cost of diesel. The estimated diesel fuel consumed by buses is calculated by multiplying the average fuel economy from GOVA Transit fleet data and the total kilometres travelled. The litres of fuel are then multiplied by the average price per litre of diesel detailed in the O&M Cost Assumptions section above. The diesel cost calculation is shown in **Table 29** below.

Table 29. Baseline Scenario Periodic Total Fuel Estimates, YOE$, Millions

	2023 – 2030	2031 – 2040	2041 - 2050
Diesel Costs	$27.3	$47.9	$66.4

BASELINE SUMMARY

Under the Baseline Scenario, the total cost of implementation is $489.2 million in discounted 2023 dollars. The total capital costs are $58.0 million. Total lifecycle O&M costs of $431.2 million include operations, maintenance, and fueling costs. Fueling costs are $51.1 million in discounted 2023 dollars.

Table 30. Baseline Scenario Summary, Discounted 2023$, Millions

	NPV
Bus Purchases	$58.0
Related Infrastructure	-
Lifecycle Capital Costs	**$58.0**
Operations & Maintenance	$380.1
Fueling	$51.1
Related Infrastructure O&M	-
Lifecycle O&M	**$431.2**
Total, 2023-2050	**$489.2**

BEB TRANSITION SCENARIO

As described above, the BEB Transition Scenario refers to the current diesel fleet being replaced with BEBs in alignment with the current fleet replacement schedule. In the model, blocks are converted from diesel to electric buses using a two-step prioritization method. Blocks are prioritized first if they can be converted on a one-to-one basis (diesel to BEB) without the need for en-route charging infrastructure. After the initial conversion, BEBs are reprioritized based on blocks that can be converted on a one-to-one basis with the greatest total kilometers travelled.

Table 31 below shows the incremental annual total number of hours, kilometres, litres of diesel, and kWh of electricity operated and consumed by the fleet. As diesel buses are phased out and BEBs are introduced into the fleet, the total operating hours and kilometres increases due to an increase in non-revenue hours and kilometres, impacting costs and fuel consumption. In later years of the transition, diesel consumption is attributed solely to diesel auxiliary heaters equipped on the BEBs.

Table 31. BEB Transition Annual Service Levels

	2023	2025	2030	2035	2040	2045	2050
Diesel							
Kilometres	4,330,240	4,330,240	579,638	-	-	-	-
Hours	181,443	181,443	20,829	-	-	-	-
Litres of Diesel	2,097,559	2,097,559	408,271	150,725	150,725	150,725	150,725
BEB							
Kilometres	-	-	3,721,827	4,399,936	4,399,936	4,399,936	4,399,936
Hours	-	-	161,092	182,691	182,691	182,691	182,691
kWh	-	-	5,814,093	6,771,952	6,771,952	6,771,952	6,771,952

BEB TRANSITION CAPITAL COST ESTIMATES

The focus for the BEB Transition Scenario is the financial impact of the changes in fleet mix and associated capital infrastructure and service plans over the 2023 to 2050 period for this scenario. **Table 32** illustrates the near-, mid-, and long-term total number of vehicles and chargers purchased based on the fleet replacement schedule. These vehicle purchases also assume that vehicles are replaced more than once between now and 2050, thus a total that is greater than 59 buses.

Table 32. BEB Transition Scenario Periodic Capital Purchase Assumptions Based on the Fleet Replacement Schedule

	2023 - 2030	2031 - 2040	2041 - 2050
Diesel Bus	-	-	-
Battery Electric Bus	32	54	53
Depot Dispensers	33	48	51
En-route Charger	8	-	8

Table 33 presents the annual cost estimates based on the unit cost and growth rate assumptions, as well as the annual fleet needs shown in **Table 32**.

Table 33. BEB Transition Scenario Periodic Total Capital Cost Estimates, YOE$, Millions

	2023 - 2030	2031 - 2040	2041 - 2050
Diesel Bus	-	-	-
Battery Electric Bus	$68.7	$147.2	$194.0
Infrastructure Costs	$14.3	$9.9	$16.5
Total	**$83.0**	**$157.1**	**$210.6**

Figure 35 below shows the implementation of BEBs in line with the number of dispensers in service based on the four-stage dispenser phasing plan. This phasing was determined based on additional infrastructure requirements for installing new dispenser equipment and the planned acquisition of BEBs.

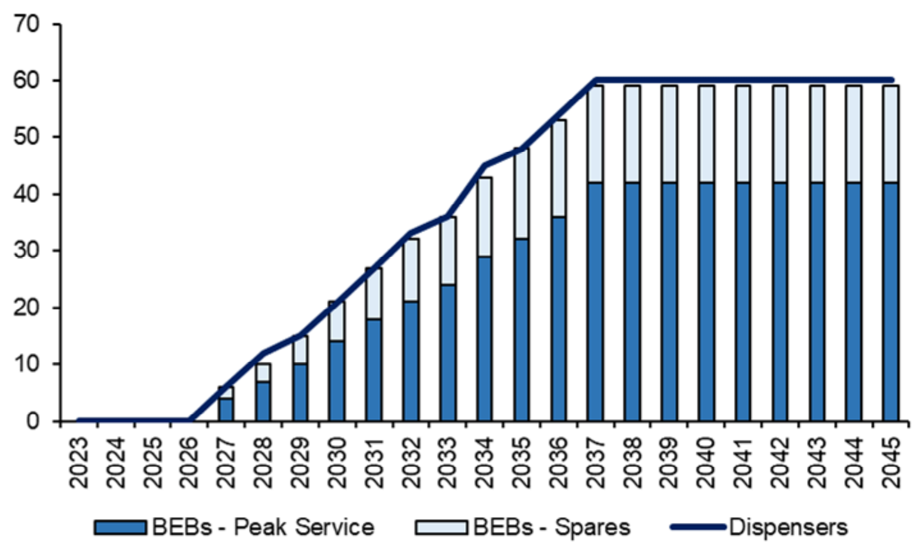


Figure 35. Peak Service BEBs & Dispensers in Service

Over the 2023 to 2050 period, total capital costs for the BEB Scenario are estimated to be $156.2 million in discounted 2023$. As shown on the previous figures and tables, the BEB fleet transition would occur between 2025 and 2035, with the remaining diesel buses in service replaced by BEBs by 2037. To accommodate the BEB fleet, a total of sixty (60) 150 kW in-depot dispensers and eight (8) 450 kW en-route chargers will be acquired between 2025 and 2035.

In addition to the cost of vehicles and chargers, lump sum phasing costs shown in include budgetary pricing provided by electrical infrastructure OEMs for unit substations, and typical unit costs for other civil and electrical work (conduits, grounding, patching), and other anticipated construction expenses. The per-phase costs also factor in a 4% engineering design and a 20% contingency based on concept plan details.

Table 34. Charging Infrastructure Lump Sum Cost by Phase, 2023$

	Years	Cost	Key Items
Phase 1	2025-2029	$5,217,464	One (1) 2,000 kVA unit substation; (9) 150kW chargers & (27) dispensers
Phase 2	2030-2031	$7,319,188	**Depot:** One (1) 2,000 kVA unit substation; (3) 150kW chargers & (9) dispensers **En-Route:** One (1) 4,000 kVA unit substation; (8) 450 kW pantograph chargers
Phase 3	2032	$1,682,444	(3) 150kW chargers & (9) dispensers
Phase 4	2033-2035	$2,623,969	(5) 150kW chargers & (15) dispensers

BEB TRANSITION OPERATING COST ESTIMATES

The annual operating costs between 2023 and 2050 are calculated by multiplying the hours of operation by the estimated hourly operating cost. **Table 28** presents the near-, mid-, and long-term total periodic operating costs under the Baseline Scenario. **Table 35** summarizes the annual incremental labour costs between 2023 and 2050. As noted above, by 2035 the entire fleet has been transitioned to BEBs.

Table 35. BEB Transition Scenario Periodic Total Operating Cost Estimates, YOE$, Millions

	2023-2030	2031-2040	2041-2050
Diesel Operating Costs	$193.5	$56.2	-
BEB Operating Costs	$25.9	$299.1	$470.6
Total	**$219.4**	**$355.3**	**$470.6**

BEB TRANSITION FUELING COST ESTIMATES

Based on the methodology described in **Table 36** summarizes the fuel and electricity cost estimates for the BEB scenario for selected years over the 2023 to 2050 period. Diesel costs remaining after the full transition to BEBs is due to auxiliary heating on board BEBs.

Table 36. BEB Transition Scenario Periodic Total Fuel Cost Estimates, YOE$, Millions

	2023 – 2030	2031 – 2040	2041 - 2050
Diesel Costs	$24.9	$10.9	$4.8
Electricity Costs	$1.3	$9.4	$14.5
Total	**$26.2**	**$20.3**	**$19.3**

BEB TRANSITION MAINTENANCE COST ESTIMATES

Table 37 summarizes the infrastructure maintenance cost estimates for near-, mid- and long-term periodic costs for in-depot dispensers and enroute chargers. Maintenance costs for the diesel buses and BEBs are included in operating costs presented above.

Table 37. BEB Transition Scenario Periodic Total Maintenance Cost Estimates, YOE$, Millions

	2023-2030	2031-2040	2041-2050
Infrastructure Maintenance Costs	$0.1	$2.7	$4.2

BEB TRANSITION SUMMARY

Under the BEB Scenario, the total cost of implementation is $578.3 million in discounted 2023 dollars. The total capital costs are $156.2 million. Total lifecycle O&M costs of $422.1 million include operations, maintenance, and fueling costs.

Table 38. BEB Scenario Summary, Discounted 2023$, Millions

	BEB
Bus Purchases	$139.3
Related Infrastructure	$16.8
Lifecycle Capital Costs	**$156.2**
Operations & Maintenance	$388.3
Fueling	$32.1
Related Infrastructure O&M	$1.8
Lifecycle O&M	**$422.1**
Total	**$578.3**

LIFECYCLE COST COMPARISON

This section provides a comparison of the capital, O&M, and fuel/electricity cost estimates between the two scenarios over the entire 2023-2050 study period. All values are presented in NPV terms, unless otherwise noted.

CAPITAL COST COMPARISON

Table 39 provides a comparison of total capital costs between the two scenarios. As shown in the table, the BEB Scenario is more than twice as expensive due primarily to the difference in vehicle costs as well as the additional equipment and infrastructure investments that would be required for BEB implementation.

Table 39. Capital Cost Comparison, Discounted 2023$ millions

	Baseline	BEB	Variance
Diesel Buses	$58.0	-	-$58.0
BEBs	-	$139.3	$139.3
Total Fleet Purchases	**$58.0**	**$139.3**	**$81.4**
Additional Infrastructure	-	$16.8	$16.8
Total	**$58.0**	**$156.2**	**$98.2**

OPERATING & MAINTENANCE COST COMPARISON

Table 40 provides a comparison of total operating cost estimates over the 2023 to 2050 period for the Baseline and BEB Scenarios, based on the assumptions described in the prior sections. As mentioned earlier the primary unknown for O&M costs is vehicle maintenance costs for BEBs. The technology is still relatively new and long-term detailed analysis of vehicle maintenance costs is not available. Diesel spending is significantly lower in the BEB Scenario due to the rapid transition to BEBs. Higher BEB operating costs (due to incrementally higher miles travelled from swaps) more than offset the decrease in operating costs attributable to diesel buses. Values in the variance column represent expenditures by bus type under each scenario, and do not represent savings.

Table 40. Operating and Maintenance Cost Comparison, Discounted 2023$ millions

	Baseline	BEB	Variance
Diesel Operating Costs	$380.1	$178.5	-$201.7
BEB Operating Costs	-	$209.8	$209.8
Related Infrastructure O&M Costs	-	$1.8	$1.8
Total	**$380.1**	**$390.1**	**$10.0**

Finally, **Table 41** provides a comparison of total costs for diesel fuel and electricity over the 2023 to 2050 period. Based on the assumptions in this analysis, BEB would have lower fuel and electricity costs on a discounted basis.

Table 41. Fuel and Electricity Cost Comparison, Discounted 2023$ millions

	Baseline	BEB	Variance
Diesel Costs	$51.1	$25.2	-$25.9
Electricity Costs	-	$6.9	$6.9
Total Costs	**$51.1**	**$32.1**	**-$19.0**

NET PRESENT VALUE (NPV) ANALYSIS

A net present value (NPV) was conducted to compare the BEB Scenario to the Baseline Scenario. Costs over the 2023 to 2050 period are presented in 2023 dollars, discounted at 8%. The analysis evaluates the direct cost impacts to GOVA to understand the additional costs of implementing a BEB transition plan relative to operating business-as-usual.

This analysis assumes no changes to ridership or service levels. The analysis only looks at direct cost impacts to the City of Greater Sudbury and does not attempt to monetize public benefits to society.

Additionally, the analysis assumes that capital costs will not be offset by grant or incentive funding. Including additional funding sources, such as ZETF, may affect the results of the analysis.

The transition to BEBs is anticipated to cost $89.1 million (discounted) more than maintaining a fully diesel fleet. The result shows that the higher capital costs of BEB buses is not offset by fueling cost savings relative to the Baseline Scenario.

Table 42. Overall Lifecycle Cost Comparison, Discounted 2023$, millions

	Baseline	BEB	Variance
Bus Purchases	$58.0	$139.3	$81.4
Related Infrastructure	-	$16.8	$16.8
Lifecycle Capital Costs	**$58.0**	**$156.2**	**$98.2**
Operations & Maintenance	$380.1	$388.3	$8.1
Fueling	$51.1	$32.1	-$19.0
Related Infrastructure O&M	-	$1.8	$1.8
Lifecycle O&M	**$431.2**	**$422.1**	**-$9.1**
Total	**$489.2**	**$578.3**	**$89.1**

INFRASTRUCTURE FINANCING OPTIONS

There are several financing opportunities available to the City of Greater Sudbury to secure funding for its zero emission vehicle (ZEV) fleet transition. The primary funding sources are the Canadian Permanent Transit Fund, the Infrastructure for Housing Initiative, and the Zero Emission Transit Fund (ZETF).

The ZETF is administered by the Canadian Infrastructure Bank, and targets projects that enable or implement transit fleet electrification. The ZETF offers flexible financing solutions, including grants and loans to applicants. ZETF funding decisions are determined by project viability, estimated operational savings, and estimated GHG emission reduction. Approximately $2.75 billion in funding is earmarked for the ZETF program to numerous municipal transit agencies.

In March 2024, Canada Infrastructure Bank (CIB) announced the Infrastructure for Housing Initiative, a $6 billion fund dedicated to "housing enabling infrastructure," which includes public transit.[14] CIB primarily invests in revenue-generating assets. Interested applicants work with CIB to secure a mix of public and private funding. Smaller municipalities are eligible for access to lower borrowing rates, without access to capital markets or federal borrowing programs.

Finally, the Canadian Permanent Transit Fund plans to begin disbursing funds in 2026.[15] This fund is allocated $3 billion annually over the next 10 years. It includes a funding stream specific to fleet electrification, along with funding that can flow from the federal government to provinces or municipalities. The program has begun accepting intake for Metro-Region and Baseline funding agreements. The majority of funding will be through the Metro-Region Agreements stream, which is accessed through collaboration with the provincial government.

Funding from either program may be used to offset planning, capital, and operating costs associated with transitioning diesel fleets to BEBs or alternative fuel technologies. As this funding has not been secured by the City of Greater Sudbury, it is not included in this analysis.

[14] Infrastructure for Housing Initiative | Canada Infrastructure Bank (CIB) (cib-bic.ca)

[15] The largest public transit investment in Canadian history | Prime Minister of Canada (pm.gc.ca)

APPENDIX D

GHG EMISSIONS ANALYSIS

APPENDIX D: GHG EMISSIONS ANALYSIS

Greenhouse gas (GHG) emission reductions is an additional benefit of transitioning from diesel buses to BEBs. HDR performed supplementary calculations to quantify the impacts of BEB operations on GHG emissions relative to the Baseline Scenario.

ASSUMPTIONS AND METHODOLOGY

The analysis quantifies GHG impacts based on estimates of diesel fuel and electricity usage by conventional transit buses over the 2023-2050 study period. The following assumptions were used to quantify emissions based on litres of fuel and kWh of electricity consumed.

The emission rate for diesel fuel is 2.681 kilograms (kgs) of carbon dioxide (CO2) per litre of fuel. This value was obtained from the Canadian National Inventory Report, 2023. The emission rate was multiplied by the annual litres of fuel consumed to calculate the annual kgs of CO2 emitted. To quantify the impact of electricity usage on GHG emissions, the total kWh of electricity used per year was multiplied by the corresponding Electricity Emission Intensity factor for Ontario from 2023 to 2050. This factor represents the kg of CO2 per kWh based on the average electricity grid mix for the province. The intensity factor declines over time due to anticipated introduction of new renewable power generation sources.

GHG EMISSION REDUCTION IMPACTS

Based on the assumptions above, the GHG emissions from BEB operations are summarized in **Table 43** below. Over the study period, BEBs will reduce emissions by approximately 94,300 tonnes relative to the Baseline Scenario. This translates to approximately 157 tonnes of CO_2 saved per year, per bus. Residual GHG emissions in the BEB scenario after the fleet is fully transitioned are attributed to the diesel auxiliary heaters installed on the BEBs.

Table 43. GHG Emissions, Baseline and BEB Scenarios, Selected Years and Total, tonnes

	2025 Snapshot	2035 Snapshot	2050 Snapshot	Study Period Cumulative Total
Baseline				
Diesel	5,624	5,624	5,624	157,460
BEB	-	-	-	-
Total, Baseline Scenario	**5,624**	**5,624**	**5,624**	**157,460**
BEB Scenario				
Diesel	5,624	1,095	404	59,215
BEB	-	174	203	3,918
Total, BEB Scenario	**5,624**	**1,269**	**607**	**63,133**

This reduction is due to the dramatically lower operating emissions of BEBs relative to diesel buses. **Figure 36** below shows the annual GHG emissions from operations as the fleet mix changes in the BEB Scenario. There is a substantial decline from about 5,600 tonnes of GHGs per year to approximately 610 tonnes per year in the full build BEB Scenario.

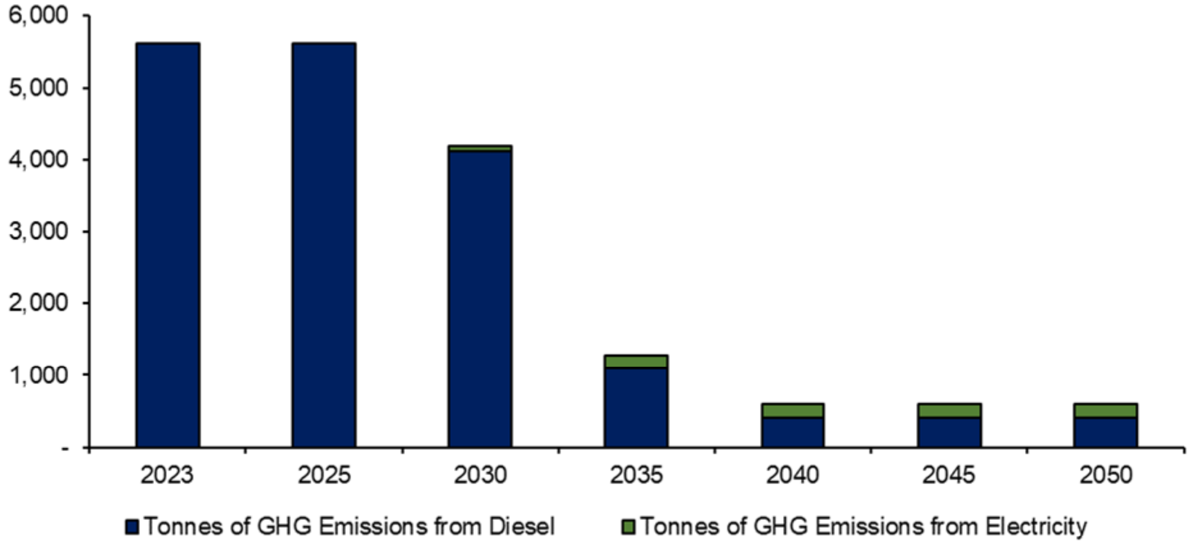


Figure 36. Annual GHG Emissions, BEB Scenario, tonnes

The cumulative reduction in GHG emissions is shown in **Figure 37** below. The annual reduced emissions grow substantially over time as the diesel fleet is converted to BEBs. By the end of the transition to BEBs, annual emissions are reduced by approximately 89%.

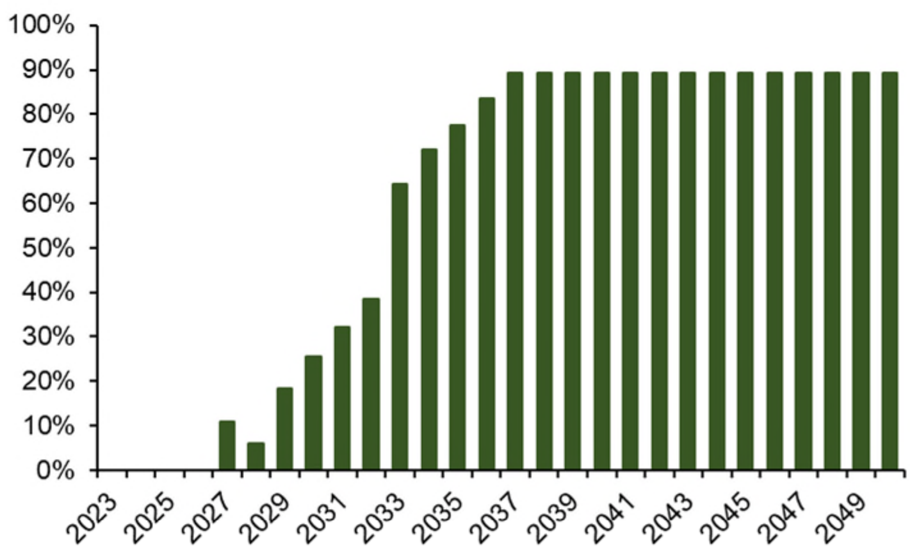
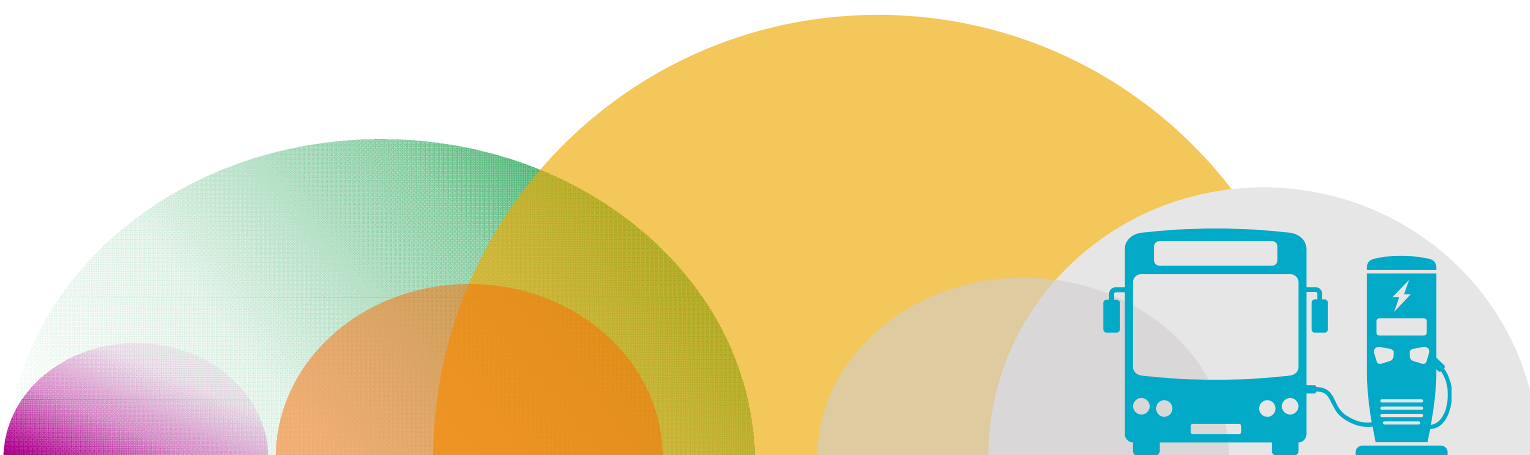


Figure 37. Cumulative Percent GHG Reductions in BEB Scenario, percent

APPENDIX E

SOLAR FEASIBILITY ANALYSIS



APPENDIX E: SOLAR FEASIBILITY ANALYSIS

HDR prepared a solar feasibility analysis to assess the cost effectiveness of installing solar photovoltaic (PV) units on various GOVA Transit properties. The analysis solely considers the overnight capital costs of adding solar PV and does not include an assessment of the existing roof conditions at the GOVA facility. **Table 44** below contains the general assumptions used in the solar feasibility analysis.

Table 44. Solar Analysis Assumptions

General Inputs	Value	Notes/Source
Base Year	2024	
Study Period	30	Assumed
End Year	2053	Calculated using base year and study period
Discount Rate	8%	Assumed
Price Escalation	3%	Assumed
Solar Degradation	-0.5%	Assumed
O&M Escalation	3%	Assumed
$/kW CapEx	$2,326	Natural Survey Report of PV Power Applications in Canada suggests value of $2.10 per Watt (W) in 2021$, escalated to 2023$ terms
$/kW OpEx	$27.90	Index | Electricity | 2022 | ATB | NREL suggests value of USD $18.80 per $kW, which is converted to Canadian dollars and escalated to 2023$.
2020 USD/CAD Conversion	1.3415	Annual exchange rates - Bank of Canada
Watt to Kilowatt Conversion	1,000	Known conversion
2023 Average Electricity Price	$0.11	Average HOEP, summed with Average Global Adjustment Factor, units $ per kilowatt-hour ($/kWh)
Solar Panel Density	150	Watt per square meter (W/m^2)

There is one option considered in the analysis at the 1160 Lorne Facility. Under this option, new solar panels are installed to cover available surface area of the facility roof, including the barn. Approximately 12,300 square meters would be available for solar panels, allowing for a nameplate capacity 1,840 kilowatts (kW). Annual generation would be approximately 2,300,000 kWh.

A summary of assumptions by project is shown below in Table 48. The capital and annual O&M costs are calculated using the $/kW values in **Table 44** above.

Table 45. Project-Specific Assumptions

Variable	1160 Lorne St
Capital Cost ($, millions)	$4.3
Annual O&M ($)	$51,339
BEB Demand (kWh, million)	1.9
Solar Generated (kWh, millions)	2.3
Grid Energy Required (kWh, millions)	0.4
Net Capacity Factor	14%
Construction Year	2024
Nameplate Capacity (kW)	1,840

METHODOLOGY

The analysis defines a No Build case and a Build case for each option defined above to estimate the benefits of installing solar PV arrays. The No Build is defined as where no solar PV is installed, and total electricity demand is supplied by the electricity grid, charged at the Hourly Ontario Energy Price plus any global adjustment charges. The Build case assumes that the solar PV is built, and the solar PV array supplies part of the total electricity demand, with the remainder of the electricity needed supplied by the grid. While there are O&M costs associated with maintaining the solar PV array, the electricity generated from it reduces the costs of electricity purchased from the grid. The analysis assumes a degradation factor on installed solar PV output of 0.5% per year, compounding. The total costs under the No Build case are compared against the total costs under the Build case to determine whether there are cost savings.

RESULTS

The estimated benefits are presented for each scenario below, using the calculated present value of costs to estimate the benefit cost ratio (BCR). All monetary values in the table are in discounted 2023-dollar terms.

Table 46. Solar Feasibility Analysis Results (Discounted 2023$, millions)

	1160 Lorne St
Energy Cost Savings, millions	$3.3
Capital Costs, millions	$4.0
O&M Costs, millions	$0.8
NPV, millions	-$1.4
BCR	0.65

Based on the modelling, the discounted electricity cost savings at the 1160 Lorne St facility are $3.3 million over the study period. The total capital costs are $4.0 million. The NPV of this option is -$1.4 million, and the project has an estimated cost-benefit ratio of 0.65. For every dollar spent on constructing the project, the project will only yield 65 cents of savings, discounted.