ZERO EMISSION FLEET TRANSITION PLAN

10/27/2023

DISCLAIMER

In preparing this report, HDR relied, in whole or in part, on data and information provided by the Client and third parties that was current at the time of such usage, which information has not been independently verified by HDR and which HDR has assumed to be accurate, complete, reliable, and current. Therefore, while HDR has utilized its best efforts in preparing this report, HDR does not warrant or guarantee the conclusions set forth in this report which are dependent or based upon data, information or statements supplied by third parties or the client, or that the data and information have not changed since being provided in the report.

This report is intended for planning purposed for the Client, and for Client's sole and exclusive use and is not for the benefit of any third party and may not be distributed to, disclosed in any form to, used by, or relied upon by, any third party without prior written consent of HDR, which consent may be withheld in its sole discretion. Use of this preliminary feasibility report or any information contained herein, if by any party other than Client, shall be at the sole risk of such party and shall constitute a release and agreement by such party to defend and indemnify HDR and its affiliates, officers, employees and subcontractors from and against any liability for direct, indirect, incidental, consequential or special loss or damage or other liability of any nature arising from its use of the Report or reliance upon any of its content. To the maximum extent permitted by law, such release from and indemnification against liability shall apply in contract, tort (including negligence), strict liability, or any other theory of liability.

TABLE OF CONTENTS

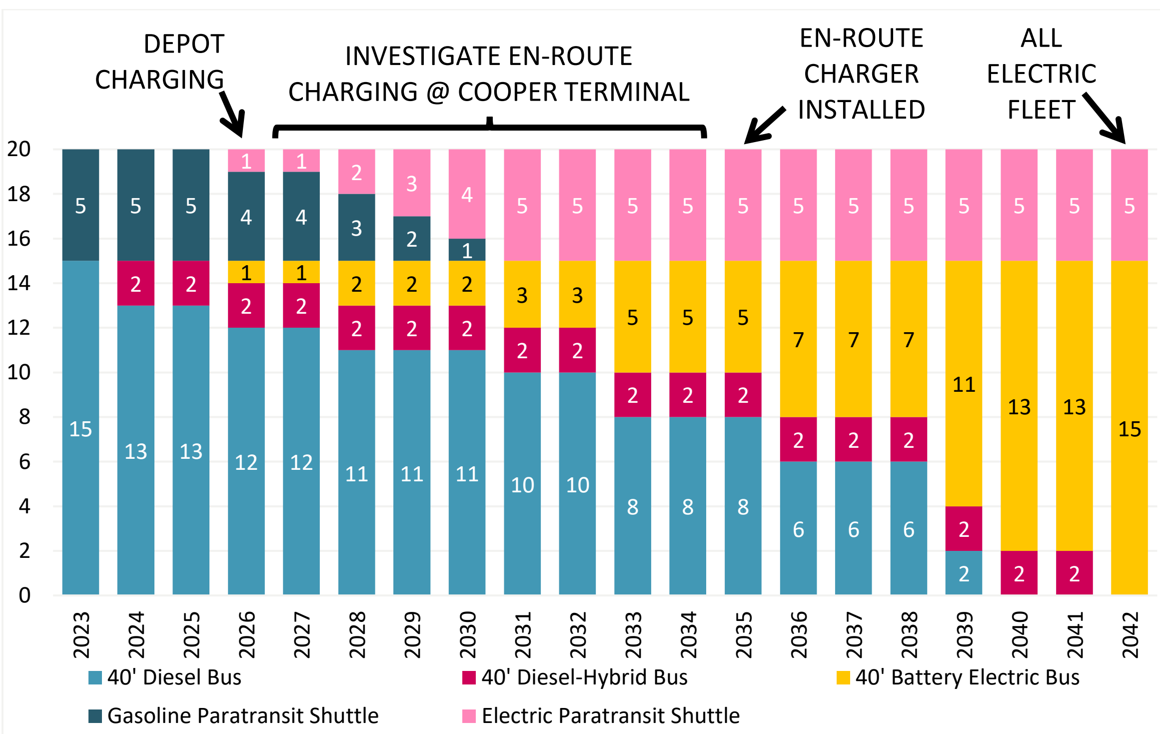
EXECUTIVE SUMMARY

The Zero Emission Fleet Transition Plan is a roadmap for Stratford Transit to convert its transit fleet to zero emission vehicles by 2042. This study included energy modelling of battery electric buses (BEBs) on their current routes to confirm feasibility and make recommendations on vehicle and charging infrastructure. The study also looked at other factors needed to support bus electrification such as utility coordination, changes in vehicle maintenance, facilities, staffing and operations.

Battery electric vehicle technology is improving rapidly, and capabilities may change vehicle and infrastructure requirements in the future. A phased approach that allows the agency to learn as it grows is recommended to account for changes as new information and technology becomes available. The transition plan recommends that over the next five years, Stratford Transit purchases a small number of BEBs to replace vehicles slated for retirement to become familiar with the technology rather than immediately implementing a full transition all at once.

The proposed transition plan indicates that if Stratford Transit were to cease purchasing diesel buses after 2023 and purchase 100% BEBs as replacements, the conversion to a 100% zero emissions fleet could be completed as early as 2042. **Figure 1** displays the long-term transition plan with the first BEBs arriving in 2026 based on an assumed lead time of two years after ordering. The plan is presented with the caveat that as technology advances and the agency learns more about the operation of BEBs, the plan should be revisited in approximately five years as there may be cost savings by leveraging technology improvements.

Figure 1 – Long-Term Fleet Replacement Plan – Fleet size and composition by year



Infrastructure upgrades are a major requirement for the fleet transition; further design refinement and procurement should begin as soon as possible based on the recommendations of this report. Timelines associated with electric grid connection and charging equipment delivery can take several years to be completed. High demand and supply chain issues for both vehicles and equipment mean that even though the first bus may not arrive until 2026, planning for the arrival of the first vehicles should start at least two years in advance. If the charging infrastructure is not in place when buses arrive, the buses will not be able to operate.

Staff skills upgrading is also key to a successful fleet transition. Operations staff will need to be trained on operating BEBs and supervisors will need to become familiar with the range limitations and charging procedures of vehicles. Maintenance staff will require training from manufacturers on the new electrical systems and additional safety procedures to work around high voltage systems.

An economic analysis was conducted to evaluate the Net-Present-Value cost of the fleet transition and compared a business-as-usual scenario where diesel buses are purchased between 2023-2050. BEBs generally offer lower operating costs at the expense of higher initial capital costs. While the overall cost of the full transition was found to be $9.8 Million more expensive than the baseline, government funding like the Zero Emission Transit Fund (ZETF) is available that may be able to off-set those costs.

The goal of the fleet transition is to assist the City of Stratford in its emissions reductions campaign. This transition will help Stratford continue their commitment to sustainability by reducing emissions of its transit fleet by 93% compared to existing conditions. This will assist in achieving its reduction goals, improving air quality and reducing noise impacts in the community, and increasing resilience to climate change.

1 INTRODUCTION

In response to the City of Stratford's climate emergency declaration in February 2020, the City is collaborating with local municipalities in the Perth County Greenhouse Gas (GHG) Reduction Plan to reduce GHG emissions and increase resiliency to climate change. The County's plan strives to achieve a 30% reduction of GHG emissions from the 2017 baseline year by 2030 and achieve net zero emissions by 2050.[1] A transition of the revenue transit fleet to zero emission vehicles will assist Stratford and the County in achieving net zero emissions by 2050.

As part of Metrolinx's Joint Transit Procurement Initiative, the City of Stratford engaged HDR Corporation to evaluate the feasibility of battery electric vehicles (BEVs) and to develop a transition plan for the revenue transit fleet to transition away from gas and diesel toward zero emission operations. The Fleet Transition Plan identifies feasible transition pathways, associated capital and operating costs, service impacts, and a preferred transition pathway.

[1] https://www.stratford.ca/en/live-here/resources/Climate-Change/Perth-County-and-Municipalities-Climate-Change-Plan-FINAL_cb.pdf

2 FLEET ELECTRIFICATION TRANSITION PLAN

The transition from conventional gasoline and diesel buses to BEBs is a significant undertaking requiring robust planning with many significant impacts to the organization. Infrastructure Canada has created the Zero Emission Transit Fund (ZETF) to support organizations in transitioning their fleets. In addition to funding planning projects, it has a capital stream that provides opportunities for transit agencies to receive funding for qualifying projects. To apply for capital funding there are six specific planning elements that applicants must satisfy and this Fleet Transition Plan has been developed to address those six 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. **Deployment Strategy:** Includes the fleet and infrastructure implementation plan.
3. **Operational and Maintenance Planning:** Identifies operational considerations to support innovative and effective BEB deployment and future operations. Operational considerations include aspects such as scheduling, dispatching, in-service monitoring, charging and storage strategies.
4. **Capacity to Implement the Technology:** Provides details on the organization's resources, skills and training required for the deployment and operation of a new ZEB fleet. It also provides an assessment of risks and mitigations that will need to be monitored during implementation.
5. **Financial Planning:** Provides preliminary cost estimates of different scenarios and their estimated lifecycle cost savings relative to the baseline scenario.
6. **Environmental Benefits:** Examines the GHG reduction impacts of the BEB transition.

The Fleet Transition Plan addresses these elements in the subsequent sections and in greater detail in the accompanying appendices.

2.1 SYSTEM LEVEL PLANNING

Transitioning to a zero emission fleet involves more than simply buying a vehicle and fueling system. The transition introduces new technology and processes into day-to-day operations of transit agencies. Successful fleet transition plans take a holistic approach considering operational requirements, market conditions, available power, infrastructure demands, and costs. While this Plan focuses on transitioning to BEBs, the below section provides a high-level overview of the zero emission technology options currently available.

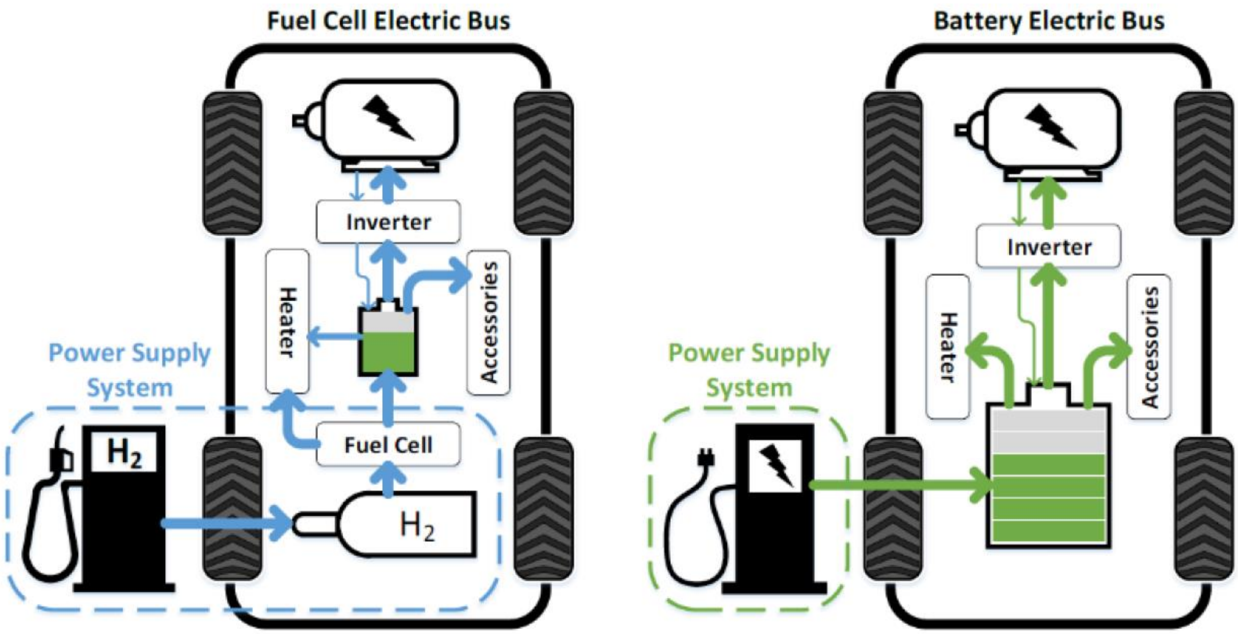
2.1.1 ZERO EMISSION BUS VEHICLES & FUELING OPTIONS

As transit agencies look for a zero emission technology to replace diesel buses, there are two primary options, BEBs and hydrogen fuel cell electric buses (FCEB). Currently, BEBs are the most popular replacement choice because they use the electrical grid as their fuel source, which is universally available and relatively "easy" to connect into and obtain the required power. However, both vehicle types have a limited range compared to diesel which means they are often not capable of directly replacing buses with long duty cycles or blocks. In some cases, it is not possible to adjust the routes and service to allow for the capability of a BEB, so an alternative zero emission vehicle type or enhancement is needed.

En-route charging is an enhancement that can greatly improve the feasibility of BEBs in many situations. En-route charging refers to the siting of charging infrastructure along the transit route where a BEB can charge during a layover or as needed. 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 should be located at places such as transit centers where buses operating on multiple routes have scheduled layover time. En-Route charging can extend the range of a BEB and facilitate one-to-one replacement of diesel vehicles when the routes are conducive to this charging strategy.

Hydrogen FCEBs are the other primary option as a propulsion type available for a zero emission transition. FCEBs use a drivetrain similar to that of a BEB as shown in **Figure 2**. However, they have a small battery on-board instead of a large battery. The small battery is recharged by an on-board fuel cell that generates electricity from hydrogen as the vehicle travels. The energy density of hydrogen is much higher than a battery, which allows for the range of these vehicles to closely match a conventional diesel bus.

Figure 2 – BEB and FCEB Vehicle Technology Comparison



The greatest benefit of FCEBs is that their range is comparable to diesel buses. However, the challenge with deploying FCEBs is locating a source of hydrogen, which is less readily available than electricity.

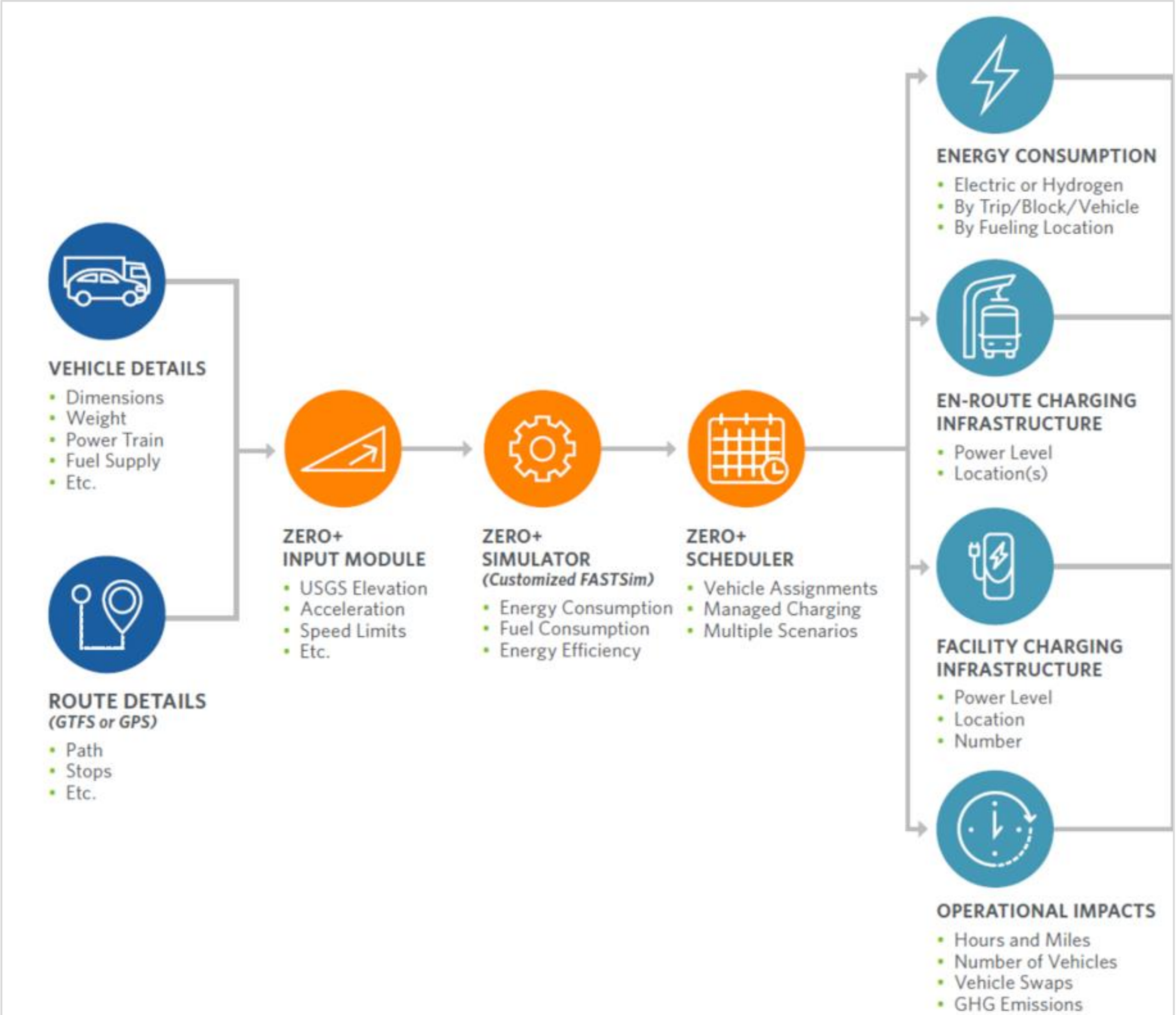
2.1.2 ENERGY CONSUMPTION ANALYSIS

To determine feasible transition pathways, system level planning was undertaken to understand how different BEVs could be deployed in Stratford Transit's fleet. Understanding energy consumption is a key component of system level planning for a fleet transition, as it informs the choice of vehicle technology, infrastructure requirements, finances, and fleet replacement strategies. The consultant's energy consumption model, Zero+ Model, provides a comprehensive understanding of the potential impacts zero emission technology may have on Stratford Transit's existing transit service. **Figure 3** shows the Zero+ Model inputs, outputs, and process.

Energy consumption is impacted by several factors including the slope and grade of the bus routes, number of vehicle stops, anticipated roadway traffic, and ambient temperature. The Zero+ Model analyzes variables known to impact lifetime vehicle performance, like energy density; battery degradation; operating environment; heating, air conditioning, and auxiliary power loads; as well as the lifecycle of bus batteries and hydrogen fuel cells. The model uses General Transit Feed Specification (GTFS) data, Geographic Information Systems (GIS) data, and vehicle specifications to create an accurate energy consumption profile unique to Stratford Transit's existing service, yielding the most accurate results possible to influence strong, effective decision making.

Six scenarios were modelled using the Zero+ Model to determine viable transition pathways and recommend a preferred transition scenario. The detailed results of the route modelling analysis can be found in **Appendix A: Energy Modelling Report**.

Figure 3 - Zero+ Model Inputs, Outputs, and Process



2.1.2.1 Key Findings

The Zero+ Model found that BEBs with 525 kWh of on-board energy and diesel auxiliary heaters can complete at least a half day of service and are the recommended option. Relying solely on depot charging is possible but the analysis indicates that the fleet size would need to increase. Additional buses would be required to be purchased to allow for a bus to be available at the garage to be able to replace the one that is coming out of service mid-day. The model found that en-route charging would be beneficial in reducing the need to swap vehicles at the garage mid-day if it were implemented. It would also avoid the need to purchase additional vehicles to accommodate vehicle swapping.

Stratford Transit also operates a school bus service Monday to Friday as well as an on-demand transit service on the weekends. Both of these services were determined to be feasible with the vehicle configuration mentioned above.

The paratransit fleet was also analyzed with the current BEV types that are available. The analysis indicates that the vehicles currently on the market are suitable and would be able to replace the current paratransit fleet 1:1 for that service by charging overnight at the garage without any additional fleet requirements.

The remaining sections use the 525 kWh with diesel auxiliary heating as the recommended vehicle technology.

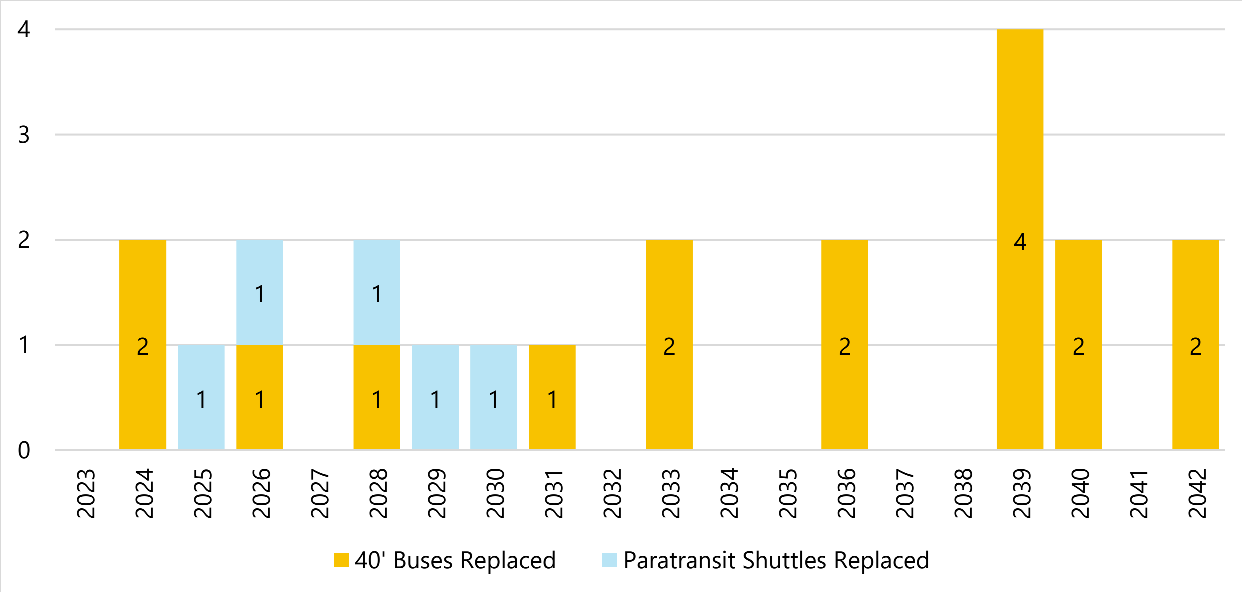
2.1.3 ZERO EMISSION BUS TRANSITION STRATEGY

Several transition scenarios were developed based on vehicle technology options, fleet replacement schedules, and block feasibilities. This strategy outlines how many vehicles should be purchased each year and identifies the infrastructure required to accommodate the new vehicles and when infrastructure would be needed. Stratford Transit's transition strategy has been divided into two phases:

- **The Near-Term Transition Plan** describes BEB purchases and infrastructure deployments for the next five years (2023-2027). This phase of the plan will be used to guide project development and grant applications for the next several years. During this five-year period, the market will mature, technology will advance, and Stratford will gain valuable real-world experience with BEB vehicles. By 2027, Stratford will have experience working with BEBs and will be able to determine the appropriate strategy for converting the rest of its fleet to 100% BEBs.
- **The Long-Term Transition Plan** describes BEB purchases and infrastructure deployments for full fleet transition and beyond (2027-2050). It provides a roadmap of what a transition would look like with today's technology, but it should be recognized that the plan will change as Stratford gains experience with the vehicle capabilities and as advancements in BEB technology change (such as battery improvements, extended ranges, grid reliability, etc.) key assumptions.

Stratford currently has 20 vehicles in its fleet, including 15 40-foot diesel buses and five accessible paratransit shuttles. There are no immediate plans to expand the fleet but there are plans to replace some of the 40-foot diesel buses that are end of life and need to be retired with diesel-hybrid buses. The current fleet replacement plan is shown in **Figure 4**. Diesel-hybrid buses will be a good steppingstone for maintenance staff to become familiar working with vehicles that have high-voltage electrical systems while also mitigating some GHG emissions prior to BEB infrastructure being ready.

Figure 4 - Existing Fleet Replacement Schedule



The useful life for a Stratford paratransit shuttle is eight years whereas the useful life of a 40-foot bus is 18 years which is why the replacement schedule is more spread out.

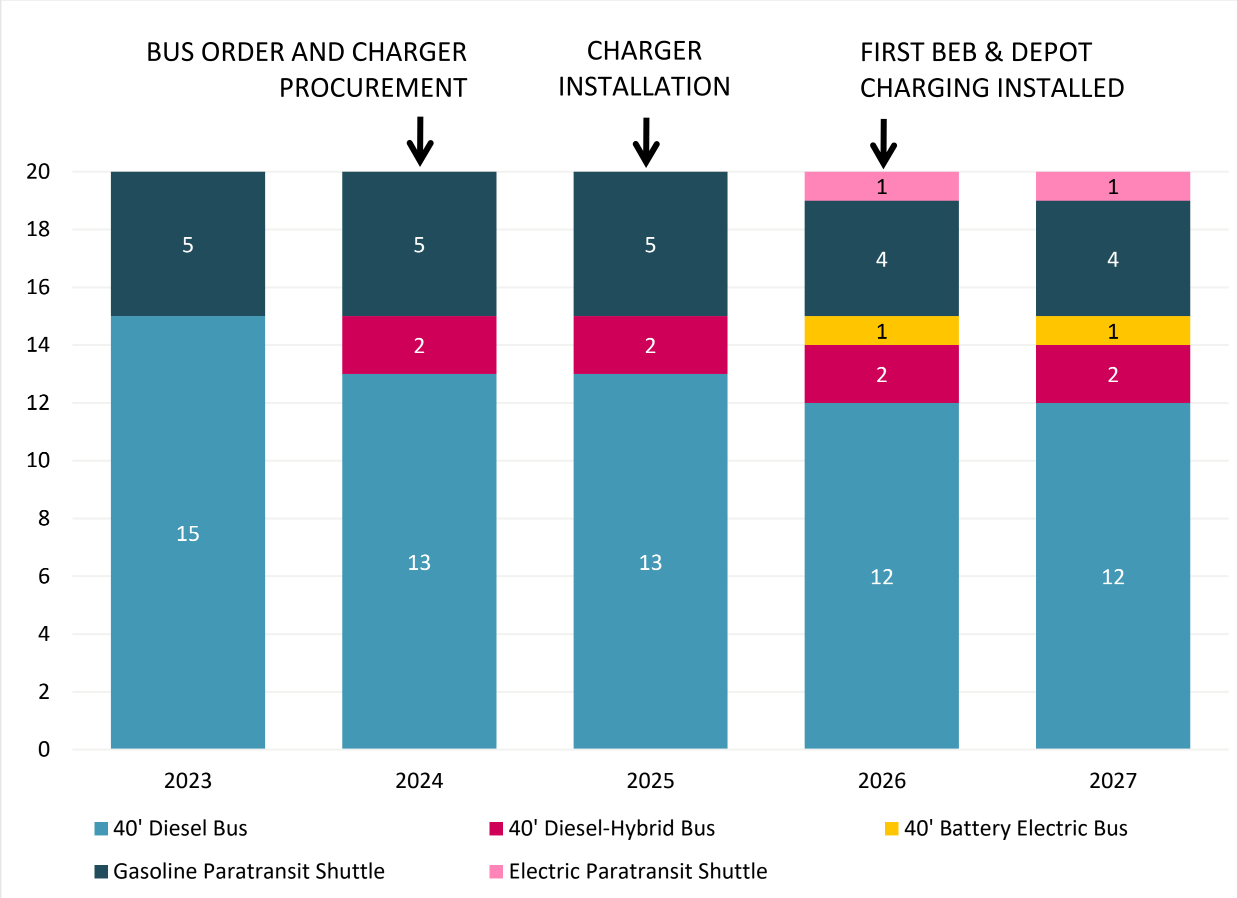
2.2 DEPLOYMENT PLAN

2.2.1 NEAR-TERM TRANSITION PLAN

Stratford Transit will begin by purchasing two hybrid-diesel buses in 2024 to address immediate replacement needs and then start purchasing battery electric buses to replace its retiring diesel fleet starting in 2026 after which 100% of all future bus procurement will be BEBs. Stratford will operate the BEBs using depot charging, swapping out buses as needed at the garage.

To facilitate the operation of BEBs, charging infrastructure will be required. To meet the bus purchase schedule, the infrastructure deployment will need to be completed by the time the first buses arrive in 2026. Planning, design, and construction will need to occur prior to the deployment. The infrastructure plan assumes that each charger will have three dispensers (plug-in cables) that will be located inside the garage and charge vehicles sequentially as they arrive. The Near-Term Transition Plan bus deployments and supporting infrastructure are described in **Figure 5**.

Figure 5 – Near-term transition plan - Fleet size and composition by year



The coming years will involve planning and procurement of initial vehicles and charging infrastructure. Due to demand and supply chain constraints, procurement of BEVs can take up to two years to arrive from time of order so it's important to place orders well in advance of when vehicles are needed.

Charging infrastructure also have similar arrival timelines. The initial installation of charging infrastructure will require coordination with Festival Hydro to have the electrical service upgraded to accommodate the future BEB fleet. After the initial service upgrade, future phases of charging infrastructure can be installed in the garage without changes to the electrical service. Additional information on facility infrastructure requirements can be found in **Appendix B: Facility Assessment Report**.

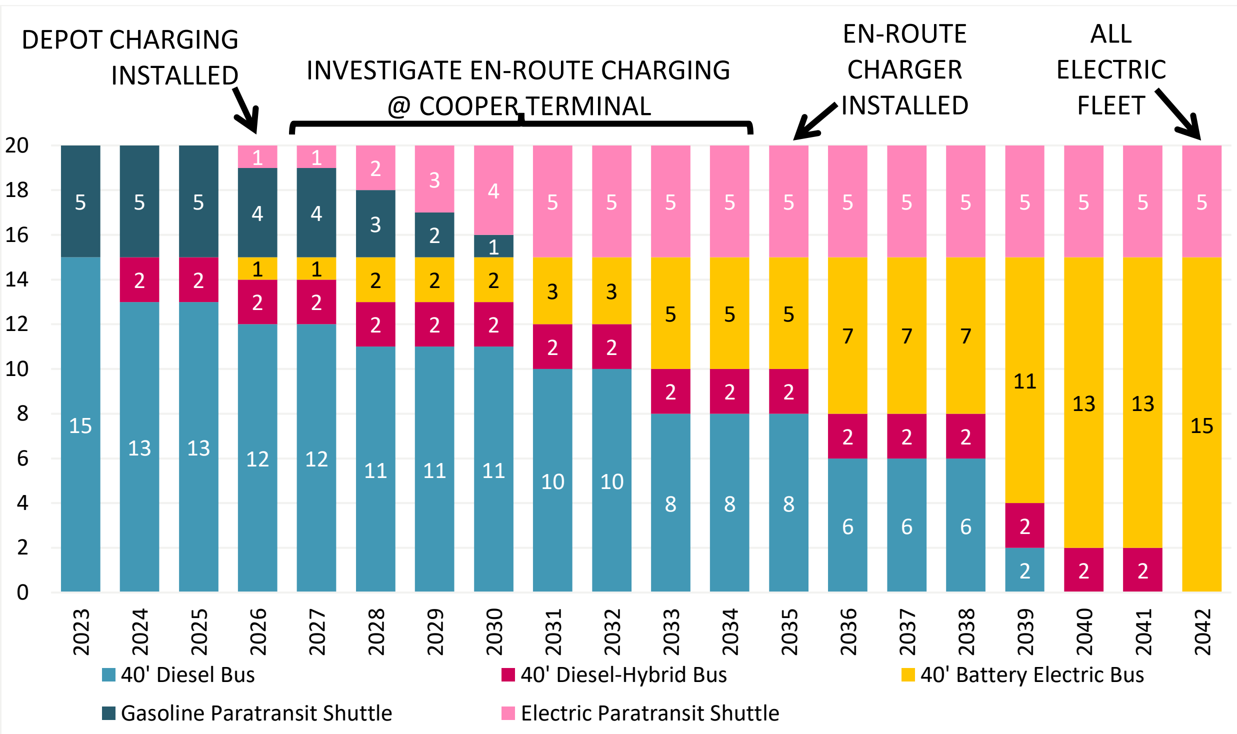
2.2.2 LONG-TERM TRANSITION PLAN

The Long-Term Transition Plan illustrates how Stratford Transit would fully transition the fleet to 100% battery electric based on the current retirement schedule (**Figure 6**). By 2042, Stratford Transit's fleet would be 100% zero emission with 15 x 40' BEBs and 5 paratransit battery-electric shuttles. The plan has not factored in any service expansion as the fleet size is assumed to remain the same for the foreseeable future. Because of the proximity of the service to the garage and the current number of spare buses, there are operational mitigations that can be implemented to avoid increasing the fleet size. Additional information on the assumed operating plan can be found in **Appendix A: Energy Modelling Report**.

Supportive infrastructure will include deployment of four depot chargers (four @ 150 kW) with 12 dispensers (three per charger) and one en-route fast charger (450 kW) at Cooper Terminal for the 40' bus fleet. The paratransit vehicles can use the same plug-in chargers as the 40' bus fleet initially with five plug-in depot chargers (22.5 kW each) planned longer term as the fleet gets closer to 100% battery electric. If paratransit vehicles can utilize AC charging, level 2 AC chargers could be installed in place of the lower powered DC chargers which may reduce infrastructure costs. Initially, one depot charger will be installed between 2023 and 2026 with additional depot chargers deployed starting in 2028.

In this scenario, the en-route fast charger at Cooper Terminal would be investigated over the next 10 years to determine if it can be integrated into plans at Cooper Terminal and installed closer to 2035. Stratford Transit will need to evaluate vehicle technology improvements over the coming years as it may eliminate the need for en-route charging. Note that the inclusion of an en-route charger was modelled for feasibility of the full transition but it is anticipated that Stratford Transit will operate using depot-charging in the near term. The Long-Term Plan includes the en-route charger to demonstrate a scenario where fleet is converted and illustrate a decision Stratford will have to evaluate over the next 10 years.

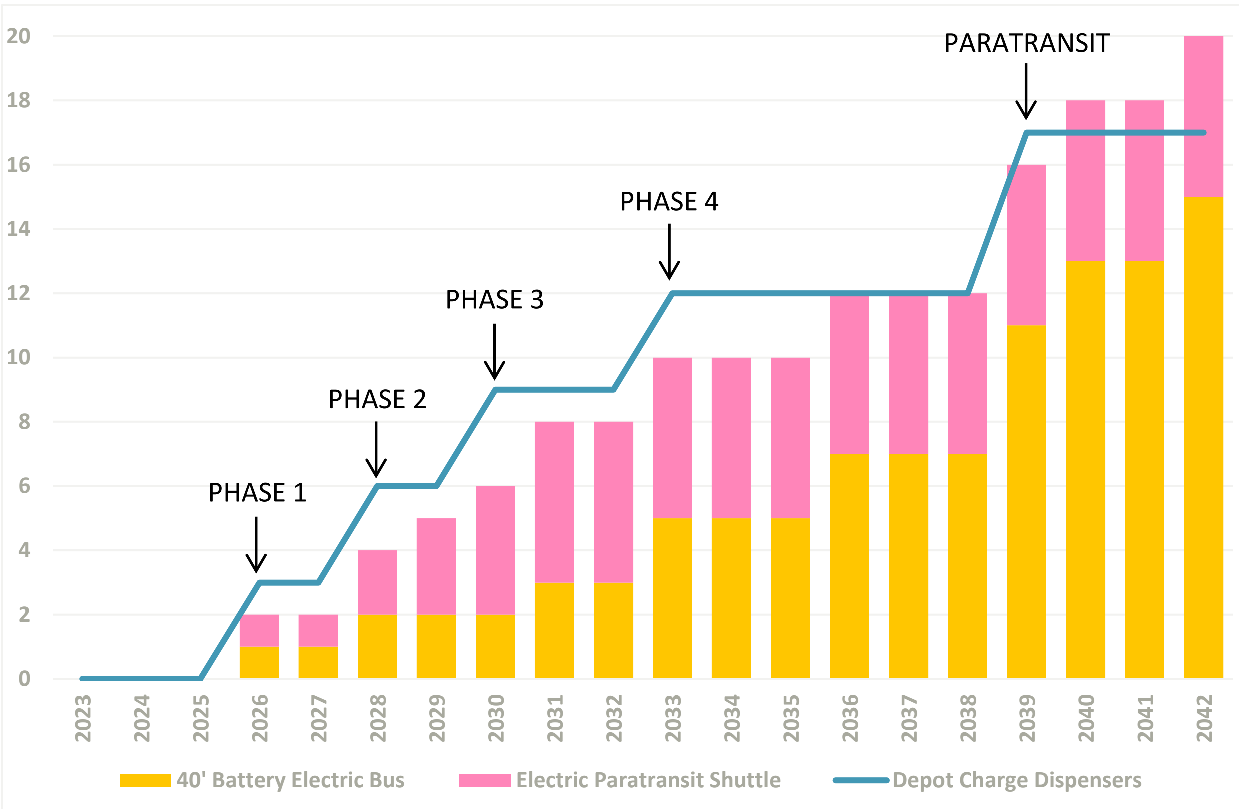
Figure 6 - Long-term transition plan – Fleet size and composition by year



Beyond the installation of the initial depot charging infrastructure, additional chargers and dispensers will need to be purchased to keep up with the number of BEBs in the fleet (**Figure 7**). The plan is phased so that the number of dispensers is equal to or greater than the number of BEBs in the fleet. The facility and infrastructure section below provides more details on the specifics of the charging infrastructure and phasing.

In the latter half of the transition plan, there will be more vehicles than dispensers since with the current operation, some of the vehicles park in locations that are not suitable for charging such as fueling/washing lanes and maintenance bays. This should not be an operational issue as a maximum of ten buses are typically in service matching the available chargers. Stratford Transit staff can arrange to move buses into available charging positions as vehicles leave for the day to charge buses that are not in service.

Figure 7 – Long-Term Garage Infrastructure Plan – Vehicles and Dispensers



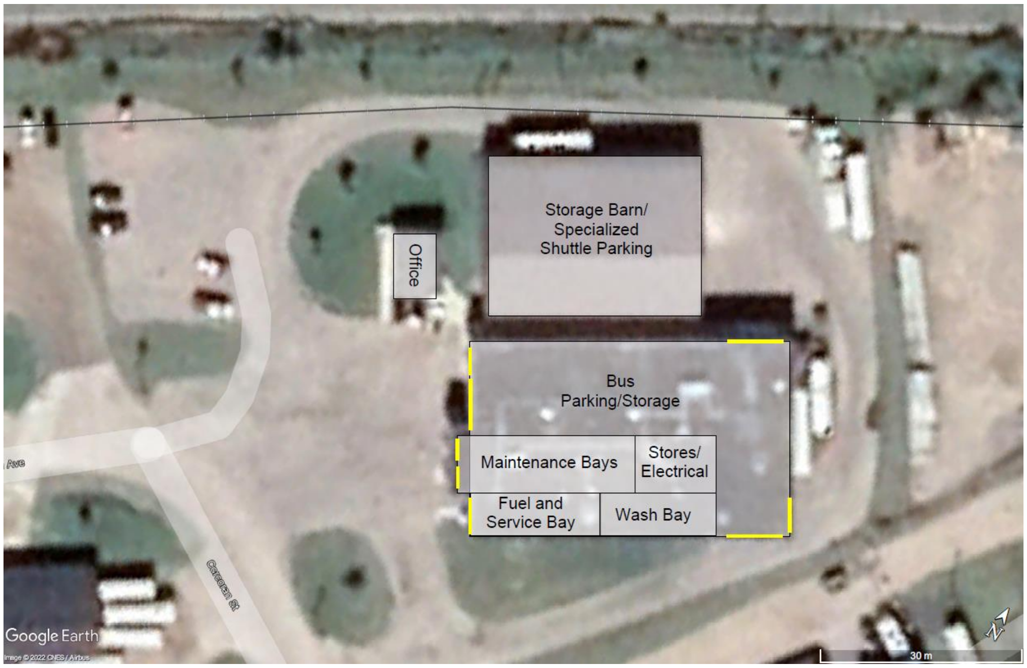
2.2.3 FACILITY & INFRASTRUCTURE PLAN

2.2.3.1 Existing Conditions

Stratford Transit's operations and maintenance facility for the revenue transit fleet and non-revenue vehicles is located at 60 Corcoran St, Stratford, Ontario. **Figure 8** shows an aerial photo of the site and highlights the functional areas of the garage. The facility has two maintenance bays, a wash bay, fuel/lube pit, and electrical room in the maintenance bay area located on the southwestern side of the facility. Beside the main maintenance area is the bus parking and storage area, office space, and a storage barn. Employee parking is on the eastern side of the facility. The property is owned by the City and there are currently plans to develop land to the south of the Transit Garage.

The site hosts 15 x 40' transit buses and five specialized paratransit shuttles. There are no current plans for expansion.

Figure 8 – Stratford Transit Garage



All of Stratford Transit's routes depart and terminate at the Cooper Transit Terminal. The terminal is located on Downie Street adjacent to Milton Street and Shakespeare Street and has eight sawtooth bus bays. The terminal is centrally located and provides parking for transit customers. The facility was recently renovated and has updated lighting, passenger shelters and an operator relief facility. Should Stratford Transit deem en-route charging necessary, Cooper Transit Terminal is a candidate location (**Figure 9**).

Figure 9 – Cooper Transit Terminal

2.2.3.2 Stratford Transit Garage Charging Infrastructure

A concept plan was developed for the Stratford's Transit Garage based on the recommended charging infrastructure required to operate the transitioned fleet. It is recommended that Stratford Transit attempt to have as close to a 1:1 dispenser to bus ratio to allow buses that return to the garage to be plugged in and left to charge when the equipment is available and avoid cycling of the fleet through a limited number of charging positions. In addition to avoiding cycling of buses through charging positions, this also provides resiliency in the event of a charger failure, as there would be a fallback option of cycling buses through the working charging positions until the equipment could be repaired. The long-term transition plan identifies an almost 1:1 dispenser to bus ratio and should be appropriate given discussions with Stratford Transit about their operations and their peak service requirement of ten buses.

With the available space in the garage, the concept plan includes four x 150 kW chargers with three dispensers each as well as five lower power level chargers to charge the paratransit fleet. For the 150 kW chargers, there is a 3:1 ratio of dispensers to chargers, meaning each charger will be connected to three plug-in dispensers and vehicles will be sequentially charged based on the order the buses are connected.

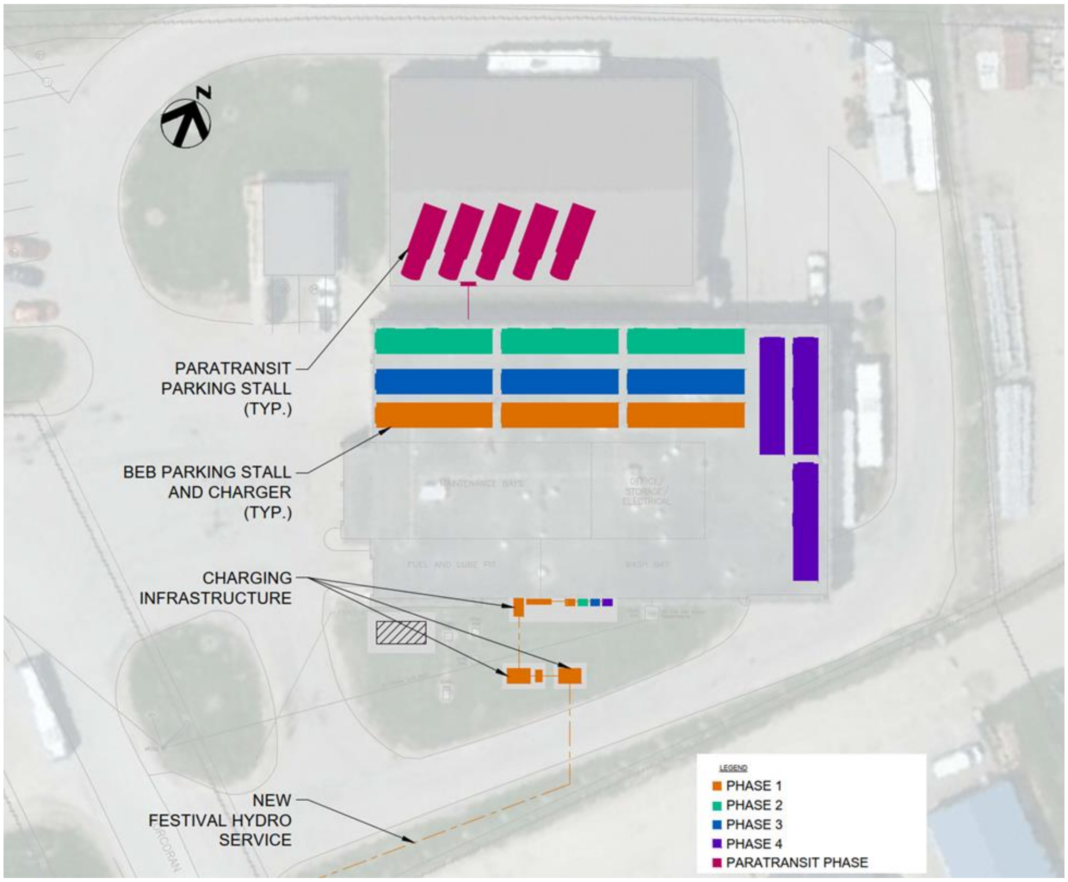
A phased implementation of infrastructure is recommended where charging infrastructure is incrementally purchased and installed as more BEBs are added to the fleet. **Table 1** lists the charging infrastructure for each phase of the transition plan.

Table 1 – Phased Charging Infrastructure Requirements for Stratford Transit Garage

Phase	Transit – 150 kW BEB Dispensers installed
1	Electrical Service Upgrade + 1 x 150 kW Charging Module w/ 3 Dispensers
2	1 x 150 kW Charging Module w/ 3 Dispensers
3	1 x 150 kW Charging Module w/ 3 Dispensers
4	1 x 150 kW Charging Module w/ 3 Dispensers
Paratransit	5 x 22.5 kW DC Wallbox Dispenser (Could also be AC if buses can accept it)
Total	**17 Dispensers**

The concept plan (**Figure 10**) shows the electrical infrastructure installed with one 150 kW charger installed per phase (and a single paratransit phase), however the phases could be combined to get more charging installed sooner depending on Stratford's fleet replacement plan.

Figure 10 - Conceptual Site Plan with Phased BEB Charging



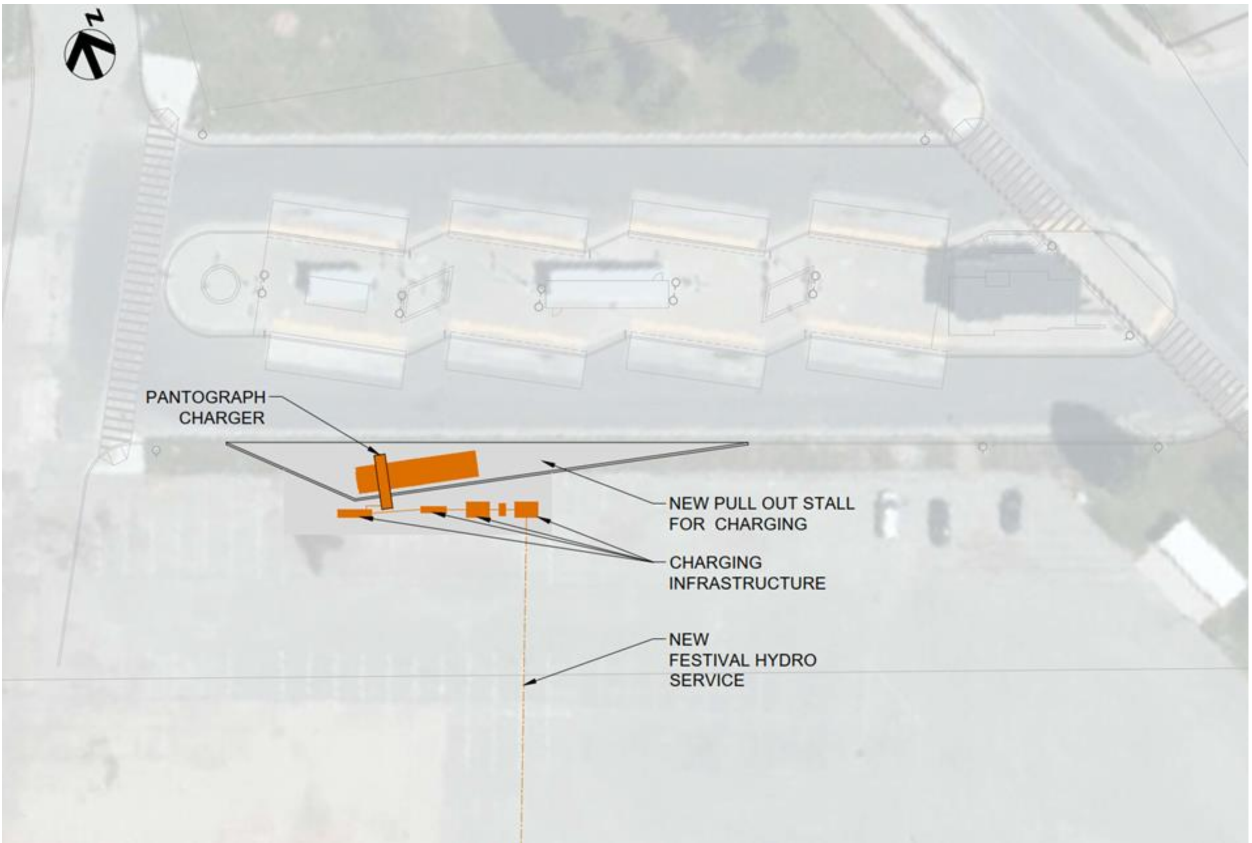
An in-person site visit was conducted of the Stratford Transit Garage to identify site specific and general constraints and opportunities that arise with the introduction of fleet electrification. While there are some aspects of the facility that will require further investigation during detailed design (such as roof and floor structural capacity) there were no significant constraints that would prohibit Stratford from starting to adopt BEBs.

The detailed results of the facility analysis can be found in **Appendix B: Facility Assessment Report**.

2.2.3.3 En-route Charging Infrastructure at Cooper Transit Terminal

Cooper Transit Terminal was selected as the most ideal location for en-route charging based on modelling results. Supplementing the longer range BEBs with en-route charging at Cooper Terminal would eliminate the need to swap buses from the Transit Garage with those at Cooper Terminal. Investigating en-route charging at Cooper Transit Terminal is recommended for Stratford Transit over the next 10 years. A single charging station would be required at the site as shown in the charging infrastructure concept plan in **Figure 11**. It is noted that this investigation was conducted for feasibility and is not a required element for the fleet's transition but can provide redundancy and eliminate the need for bus swapping.

Figure 11 – Conceptual Site Plan for Cooper Transit Terminal Charging Infrastructure



A single 450 kW pantograph charger could be installed in a new pullout that will allow for parking of the BEB on the exterior of the terminal without impeding traffic flow. The charging station would be shared by all buses that use the terminal. Since many of the routes arrive and depart the terminal around the same time, Stratford Transit would have to develop a system to let operators know when they should use the en-route charger. This could be either a fixed schedule or possibly based on when an operator's BEB goes below a certain state of charge.

Additional details on the en-route charging infrastructure at Cooper Terminal can be found in **Appendix B: Facility Assessment Report**.

2.3 OPERATIONAL PLANNING

With the introduction of BEBs, operations and maintenance procedures will need to be adapted to accommodate new requirements associated with electrification.

2.3.1 CHANGE MANAGEMENT

Stratford Transit's transition from diesel to battery electric buses is a major transformational change for the organization impacting all areas of operation. Transformational changes shift an organization's mission, strategy, structure, performance and processes.[2] The Perth County Greenhouse Gas (GHG) Reduction Plan identified the need for change and this Transition Plan initiates the process by assessing

[2] 5 Steps in the Change Management Process | HBS Online

feasibility and outlining a path forward. This Transition Plan can be used to help communicate the need for change and path forward to stakeholders who will be impacted by and ultimately enact the change.

The following elements are important considerations in Stratford Transit's change management plan:

- A clearly defined vision and goal (as outlined in the Perth County Greenhouse Gas (GHG) Reduction Plan) that is easily communicated;
- Identification of stakeholders:
    - Community (communicate goals of the change, communicate changes in service)
    - First Responders (communicate changes to infrastructure and vehicles, safety planning)
    - Employees (changes in operation, understand skills and knowledge gaps, training and education planning)
    - City Council (communicate plans for transition, secure approval and funding)
    - Transit Unions (communicate changes to responsibilities, updates to safety protocols/procedures, gather feedback)
    - Original Equipment Manufacturers (OEMs) (communicate needs, understand options
    - Contractors (communicate changes to infrastructure, operations, and requirements)
- Performance Indicators such as greenhouse gas emission reductions (see **Section 2.6**)
- An understanding of changes in knowledge and skills required to make a successful transition (see **Section 2.3.2** or **Appendix C: Training & Staffing Plan**)
- Documentation of changing procedures and operations
- A change management champion (such as the transition project manager, transit supervisor, or a similar position)
- Identification of risk and risk management plan (see **Section 2.4.1**)
- Identification of capital (such as ZETF) and on-going funding sources (see **Section 2.5.3**)

It is recommended that Stratford Transit develop a comprehensive change management plan that builds on the findings of this Transition Plan to successfully electrify their revenue transit fleet.

Learning is an important piece of change management and aspects of the plan can and will change as Stratford Transit becomes familiar with the technology, understands its impacts, and as technology advances. Early engagement with those stakeholders to communicate the expected benefits and challenges of the fleet transition can allow stakeholders understand why it is happening, what to expect and allow them to provide feedback that could be incorporated into the plan.

Some staff will also have more specific questions about how this may impact them directly. The following section on staffing and training highlights how different user groups are expected to be impacted by the transition and the types training and changes which may be required.

2.3.2 TRAINING AND STAFFING PLAN

To assist in the implementation of new zero emission bus technology, a Training and Staffing Plan is an important document which identifies the skills, training and engagement required. It identifies gaps in current skill sets, recommends ways to adapt and train the current workforce to work with the new equipment types confidently and safely.

The Training and Staffing Plan recommends the following actions for Stratford to adapt its current workforce to meet skill gaps:

- Require vehicle OEMs to provide maintenance and operations training to staff.
- Develop a high-voltage electrical safety program for employees working on and around battery electric vehicles.
- Develop a coordinated safety training plan with first responders.
- Explore opportunities to visit/learn from transit agencies with existing BEBs.
- Develop a qualification recordkeeping system.
- Identify a party who will be responsible to for maintenance and repair charging infrastructure.

The number of staff required to operate and maintain the vehicles is not expected to change based on the proposed transition plan. The Staffing and Training Plan identifies potential training curriculums for maintenance staff that would provide a solid foundation for the implementation of BEBs and associated infrastructure. **Appendix C: Training & Staffing Plan** provides the detailed plan.

2.3.3 INFRASTRUCTURE OPERATIONS / MAINTENANCE

A new aspect that Stratford Transit will need to consider will be maintaining the charging equipment and associated electrical infrastructure required to support the fleet. Proper maintenance helps reduce downtime and associated revenue loss from non-functional equipment. Typical preventive infrastructure maintenance includes cleaning cables, inspecting wires, charging cables and cabinets and checking operations and connectivity. Software should be used for dashboard monitoring for BEBs and charging infrastructure to monitor performance, identify issues, and schedule maintenance (as described in **Section 2.3.4**).

Stratford Transit will need to consider the following types of maintenance for its BEBs and charging infrastructure:

- Preventive (actions taken to prevent unexpected issues)
- Corrective (actions taken to correct issues)
- Warranty (action taken by OEM to correct issues for specified time period)

It is recommended that Stratford Transit develop a maintenance strategy for each of the maintenance types and processes for scheduling, performing, and contracting maintenance to ensure timely repair and service provision. For preventive maintenance, Stratford Transit should work with the OEM to receive information and training (via a Train the Trainer approach). Software systems should also be configured to assist in scheduling. A preventive maintenance standard operating procedure should be developed and documented. A corrective maintenance standard operating procedure should be developed and documented based on the considerations below and relevant maintenance approach. Stratford Transit should work with the OEM to understand the types of typical corrective maintenance required on BEBs and infrastructure to help inform the procedure. A standard operating procedure for warranty maintenance should be developed and documented in coordination with the OEM to ensure timely maintenance performance. This procedure should include a strong recordkeeping components of warranty claims to reduce risk for Stratford Transit.

There are several approaches to infrastructure maintenance that Stratford Transit can consider:

- Purchasing OEM warranties/service plans
- Hiring of trades certified in-house staff to manage equipment
- Engaging a local contractor
- Contracted design/build/maintain models like Charging as a Service (CaaS) and Energy as a Service (EaaS)

These approaches may work best for the different types of maintenance. Preventive maintenance can be undertaken by in-house staff through OEM-led training programs (as described in Section 2.4.1 and in **Appendix C: Training & Staffing Plan**), while corrective maintenance may be best managed through warranty agreements with the OEM. Contractors that specialize in BEBs and charging infrastructure could also be a viable option depending on experience, cost, and risk tolerance.

Based on a review of the consultant's experience with other transit agencies in the United States, it is noted that most agencies begin with OEM service agreements and re-evaluate after a few years to determine if they should continue with the OEM or adopt another approach (such as contracting or in-house servicing). The review of other agencies experience found there were some challenges with timeliness in OEM agreements and many have opted to include clauses to incentivize faster maintenance servicing turnarounds.

In Canada, the Toronto Transit Commission (TTC) has adopted CaaS/EaaS models to allocate risk to parties that are best able to manage it. Transit agencies are not naturally equipped to manage electrical infrastructure and optimize energy costs as it has not been part of their core business. EaaS/CaaS allows for more consistent fuel/energy pricing for the transit agency, while shifting riskier aspects of infrastructure that the agency may not necessarily understand very well (like operations and maintenance) to the contractor.

It is recommended that Stratford Transit consider various approaches to infrastructure maintenance including CaaS/EaaS and OEM warranties/service plans. Shifting risk and responsibility to OEMS or third parties will allow Stratford Transit to focus on vehicle operations and service provision which is its core function. Each of these strategies have advantages and disadvantages in terms of cost, level of risk and responsibility. Costs are typically higher for options like CaaS/EaaS but also allow the transit agency to focus on its core business of operating/maintaining transit fleet while allowing others with expertise in high voltage electrical infrastructure to manage those types of assets. With the limited number of staff available to manage this type of complex infrastructure, it's recommended that Stratford consider options that put more onus on a third party to manage the high voltage electrical infrastructure and charging equipment.

In addition to selecting a maintenance approach, it is wise for transit agencies to keep a reserve of spare parts for BEBs and charging infrastructure that can be easily utilized in preventive or corrective maintenance situations.

2.3.4 SOFTWARE SYSTEMS

Software systems are tools that operations and maintenance staff will need to effectively monitor and operate a fleet of BEBs. Stratford Transit should work with the software providers to determine if the existing systems can successfully integrate with new vehicle technology and charging infrastructure. In addition, new functions (such as charge and energy management) will be required to effectively schedule charging sessions between vehicles as they cycle through service.

OEMs typically offer proprietary software for their vehicles and infrastructure. Any software that is purchased or used should be compatible across vehicles and charging infrastructure – especially if procured from different OEMs. If proprietary software is not compatible across vehicles and infrastructure, Stratford Transit should turn to the market and opt for a third party solution that integrates the technology for ease of operation. If it is possible for existing software to be upgraded to include BEB technology, this would provide staff with a comfortable transition and potentially reduce training requirements.

- **Vehicle monitoring system –** To monitor the status and health of vehicles and equipment. With electric vehicles, constant monitoring and logging of system information is needed to know if there are errors and to aid staff with troubleshooting those errors. OEMs often offer software for this but there are also third-party options available. It is recommended that a third party vendor agnostic option be used as they can report on vehicles from different vendors on a single dashboard. Vehicle monitoring software should include telematic information that will also provide data on things like energy consumption and allow the agency to monitor vehicle performance and utilize data to plan for future BEB deployments.
- **Charging and energy management system –** To schedule and manage the charging sessions between the different vehicles and control the power delivery of the charging equipment. Depending on the manufacturer, this software can also provide additional value in controlling demand to optimize 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. More information on the software for infrastructure is provided in **Appendix B: Facility Assessment Report.**
- **Scheduling software –** Stratford Transit does not currently utilize software for scheduling of its transit service, and this is not expected to change for the transition to BEBs. Staff will need to become familiar with the range capabilities of vehicles and plan bus blocks that are appropriate for the type of vehicle.

Stratford Transit should also make sure any software can adhere to relevant industry standards and protocols (e.g., OCPP, ISO 15118, etc.).

It is also noted that no single software system currently packages all the above items into one cohesive system that connects chargers, vehicle state of charge, and operational software in a single dashboard. For now, agencies are using multiple dashboards to monitor the various systems, but it is recommended that Stratford Transit monitor the market for solutions that will improve and integrate these systems.

2.4 CAPACITY TO IMPLEMENT THE TECHNOLOGY

With the above considerations in mind, there is capacity to implement BEBs into Stratford Transit 's fleet provided that the above considerations are actioned prior to the fleet arriving and being put into service. **Appendix C: Training & Staffing Plan** highlights some of the key internal considerations Stratford Transit should evaluate and action as it transitions to a zero emission fleet. The Training and Staffing Plan provides a pathway to empower the existing workforce with the necessary skills to support the successful deployment and maintenance of BEBs. It balances the goals of ensuring consistent passenger service, recognizing the value, experience, and knowledge the of the existing workforce while considering where to leverage third party expertise.

2.4.1 PROJECT RISKS AND MITIGATION

There are risks associated with transitioning Stratford's transit fleet to a new technology and energy source. **Table 2** highlights potential areas of risk associated with implementation and operation of battery electric buses into Stratford Transit's fleet and the recommended responses. It is noted that risk exposure is subjective by nature and the Plan's risk exposure will continuously evolve as the Plan advances. Further information about personnel responsible for managing identified risks is in **Appendix C: Training & Staffing Plan.**

Table 2 - Risks and Responses

Risk Title	Risk Description	Response
Infrastructure Transition	As BEBs are added to the fleet, infrastructure will need to be in place for when vehicles arrive to be able to put them into service. Due to coordination with third parties such as local utilities and infrastructure manufacturers, timeframes for infrastructure can be very long and disruptive to current operations.	Begin planning for infrastructure changes as soon as practical and consider how construction can occur while maintaining current operations. Ensure that infrastructure upgrades can be completed at least six months in advance of vehicles arriving. Thorough testing and commissioning should be carried out after installation of new infrastructure servicing BEBs before vehicles and infrastructure are needed for service.
Internal Resource Availability to Support Implementation	The transition to BEBs will require program management and support from operations during implementation and there may be insufficient resources (including both people and equipment) which may result in additional costs for project support and delays.	Identify a resource who will be responsible for management of procuring the vehicles and infrastructure upgrades as a coordinated program. Supplementing of existing resources by identifying and hiring for new roles to address gaps and/or outsourcing of work where appropriate to contractors and consultants. Engage consultants as necessary to offer support during project delivery to support procurement, construction, delivery and commissioning.
Service Planning and Scheduling	The new electric fleet will introduce new variables and processes into service planning and scheduling which may require additional time for adoption and inclusion. These new variables and processes may also raise the cost of service delivery and potentially delay implementation if service planning and scheduling are unable to adapt to the new requirements.	Start adapting service planning practices early to understand the characteristics and operating constraints of BEBs based on information from the Transition Plan study. Allow staff to identify information and tools that will be required and support staff in obtaining additional capabilities that will allow them to optimize schedules with battery electric buses to maximize fleet utilization and minimize operating costs.
Collective Bargaining Agreement Impacts	Operational impacts following the transition to BEB may result in impacts to the Collective Bargaining Agreement which may increase operational costs. Operators may be asked to take on additional duties such as plugging-in and un-plugging buses from chargers. Driving behaviour heavily impacts vehicle range and it may be beneficial to monitor driver performance to correct inefficient driving practices.	Begin early and constructive engagement with unions on the coming changes to staff requirement to support BEB operations including staffing numbers, skillsets, and operational practices.
Revenue Operations Assumptions	The modelling forecasts the fleet size required to maintain current operations considering operator hours and associated operating cost. However, the underlying assumptions may not consider the full range of operations which may underestimate operational costs.	Start early in adapting service planning practices to the characteristics and operating constraints of BEBs based on information produced from this study to reduce probability of negative impact. Begin early and constructive engagement with unions to reduce the impact of deviation from model expectations.
Supply Chain Disruptions	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.	Applicable to both buses and fixed electrical infrastructure. Plan for adequate lead time to account for potential manufacturing and delivery delays. Ensure that a sufficient quantity of 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.
Resiliency	Utility blackouts, failure of primary and secondary utility infrastructure, natural disasters, or extreme weather events will more significantly impact operations.	Assess the impact and frequency of power outages to evaluate mitigation options that will meet the organizations 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 early and constructive engagement with local utilities to ensure necessary infrastructure upgrades are in place in time to support the charging equipment. Engagement was done as part of the facilities assessment and currently there are not expected to be capacity constraints at the sites identified.
Technology Interoperability	Potential incompatibility between buses and chargers from different manufactures may be discovered during testing and commissioning which would result in additional costs and delays.	Inquire and assess in detail the compatibility of the equipment to be procured during the procurement phase. Ensure contracts include testing and commissioning of vehicle with any equipment that is expected to be used.
Technological Obsolescence	Technology for electric vehicles is quickly changing and current generation vehicles/chargers may not be compatible with newer chargers/vehicles. Changes may be driven by changes to charging standards, battery technology, or design philosophy which may result in additional costs and delays for retrofits to incorporate the latest available technology.	Regular and periodic market scans of the current state of the industry especially prior to procurement of additional vehicles and infrastructure. Vehicle and charging manufacturers should be expected to maintain spare components for the expected lifespan of vehicles and/or a sufficient supply of spare components should be purchased to ensure equipment is able to be kept serviceable.
Software Issues	The smart charging software available in modern chargers is subject to bugs and disruptions which would negatively impact operations.	Ensure thorough testing and commissioning is carried out after installation of new infrastructure servicing BEBs and that timely support is available for software that is essential to operations.
Software Adoption	Delays or a lack of adopting the required software tools to support electrification (i.e. smart charging, dispatch/control, planning/scheduling, depot management, fleet telematics) may result in associated implementation delays for electrification.	Ensure all wholistic assessment of software and data needs is done prior to the procurement stage and ensure thorough testing and commissioning is carried out after installation of new infrastructure servicing BEBs.

2.5 FINANCIAL PLANNING

When undertaking any major transit technology and infrastructure project, the cost of implementation is a major consideration. Although capital costs are often estimated during the planning stage, the costs of operating and maintaining infrastructure over time, as well as the costs associated with periodic rehabilitations or replacements, are frequently left out of the decision-making process. These costs can become significant in the long-term and may influence the decision of which technology alternative provides the greatest long-term value to the agency.

This financial analysis compared Stratford Transit's existing diesel bus fleet to proposed BEB alternatives to identify the best value alternative for Stratford to reach 100 percent conversion to zero emissions technologies before 2050. A high-level summary is provided below. More detailed information on assumptions and results of the financial analysis can be found in **Appendix D: Budget & Financial Report**.

2.5.1 FLEET TRANSITION SCENARIOS

The costs evaluated included capital, operating and maintenance (O&M), and fuel/electricity over the 2023 to 2050 period. The two BEB scenarios are compared to a Baseline Scenario that reflects a situation in which transit service would be provided through 2050 based on Stratford Transit's current fleet mix (the status quo) to compare annual and total costs and calculate the net present value of each BEB scenario. The three scenarios are described below:

Baseline Scenario: This is the business as usual scenario where Stratford Transit continues to operate diesel buses and there is no transition to electric vehicles over the study period between 2023 and 2050.

BEB - 525 kWh: A deployment of battery electric buses with 525 kWh of on-board energy capacity with diesel heating that is charged both at the depot and en-route (one en-route charger). This scenario requires some swapping of vehicles mid-day.

BEB – 675 kWh: A deployment of battery electric buses with 675 kWh on-board energy capacity (longest range available) with diesel heating that is charged both at the depot and en-route. This scenario avoids any vehicle swapping but requires adding a second en-route charger.

2.5.2 LIFECYCLE COST COMPARISON

This section provides a Net Present Value (NPV) comparison of the capital, O&M, and fuel/electricity cost estimates among the three scenarios for the 2023 to 2050 period.

2.5.2.1 Capital Costs

Table 3 provides a comparison of total capital costs among the three scenarios. The capital cost of implementing BEB technology is significantly higher than continuing with diesel buses due primarily to the difference in vehicle costs as well as the additional infrastructure investments that would be required for BEB implementation.

Table 3 - Capital Cost Comparison, millions of 2022$ discounted at 8%

	Baseline	BEB - 525 kWh	BEB - 675 kWh
Diesel Buses	$6.4	-	-
BEBs	-	$15.7	$15.5
Total Fleet Purchases	**$6.4**	**$15.7**	**$15.5**
Additional Infrastructure	-	$5.2	$6.4
Total	**$6.4**	**$20.9**	**$21.9**

2.5.2.2 Operations and Maintenance.

Table 4 provides a comparison of total operating and maintenance cost (excluding fuel) estimated over the 2023 to 2050 period based on the assumptions described in the prior sections. The primary unknown for O&M costs is vehicle maintenance costs for BEBs. There is an expectation that with vehicles with fewer moving parts that maintenance costs will be lower but the technology is still relatively young and long-term detailed analysis of vehicle maintenance costs is not yet available.

Table 4 - O&M Cost Comparison, millions of 2022$ discounted at 8%

	Baseline	BEB - 525 kWh	BEB - 675 kWh
Diesel O&M Costs	$39.9	$22.2	$22.1
BEB	-	$17.6	$17.6
BEB Charger Maintenance Costs	-	$0.5	$0.7
Total	**$39.9**	**$40.3**	**$40.4**

2.5.2.3 Fuel and Electricity

Table 5 provides a comparison of total costs for diesel fuel and electricity over the 2023 to 2050 period. Cost-wise this is where BEBs offer a significant benefit over diesel buses. The analysis factors in forecasted fuel pricing and carbon tax over the study period. The results of the analysis show that BEBs would have lower fuel and electricity costs on a discounted basis.

Table 5 - Fuel and Electricity Cost Comparison, millions of 2022$ discounted at 8%

	Baseline	BEB - 525 kWh	BEB - 675 kWh
Diesel Costs	$9.7	$6.3	$6.2
Electricity Costs	-	$0.8	$0.9
Total Costs	**$9.7**	**$7.1**	**$7.1**

2.5.2.4 Overall Scenario Costs

Table 6 provides a comparison of three options considered from the energy modelling analysis. While BEBs offer significant operational cost savings compared to the baseline scenario, the recommended option of the BEB - 525 kWh scenario is still $9.5 million more expensive over the 2023-2050 period. Increasing the battery size to 675 kWh and adding a second en-route charger was evaluated to see if the operational cost savings (by not swapping vehicles) would offset the increased capital costs. As shown in the table below, the operational savings were not found to be significant enough to off-set the increased purchase costs of the higher capacity vehicles and extra charger which is why the BEB - 525 kWh scenario was recommended.

Table 6 - Overall Scenario Cost Comparison, millions of 2022$ discounted at 8%

Net Present Value, 2022$	Baseline	BEB - 525 kWh	BEB - 675 kWh
Life Cycle Capital Costs	**$6.4**	**$20.9**	**$21.9**
Buses	$6.4	$15.7	$15.5
Non-Revenue	-	-	-
Related Infrastructure	-	$5.2	$6.4
Life Cycle O&M	**$52.4**	**$47.4**	**$47.4**
Operations & Maintenance	$39.9	$39.8	$39.7
Propulsion	$12.5	$7.1	$7.1
Related Infrastructure O&M	-	$0.5	$0.7
Total	**$58.8**	**$68.3**	**$69.3**

It should be noted that the Net-Present Value calculations in this analysis do not factor in any funding programs that may be available to Stratford Transit to support a transition to a zero emission fleet. Available funding programs are discussed in the next section.

2.5.3 FUNDING PLAN

There are several financing opportunities available to Stratford to secure funding for its zero emission fleet transition. The two primary funding sources are the Investing in Canada Infrastructure Program (ICIP), and the Zero Emission Transit Fund (ZETF), and Canada Infrastructure Bank's Zero-Emission Bus Initiative.

The ICIP is administered by Infrastructure Canada and has invested $131 billion in over 85,000 projects. This program has already funded several other municipalities' transit fleet buses, including conventional transit and other mobility services. The federal government will invest up to 40% for most municipal public transit costs, though this may increase to 50% for rehabilitation projects. Funding provided by Infrastructure Canada is divided among the provinces who distribute funding by municipality.

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 this funding has not been secured by Stratford Transit, it is not included in this analysis.

With a clear understanding of capital, O&M, and fuel/electricity costs associated with a zero emission bus transition, Stratford can begin to incorporate these costs into future operating and capital budgets. Federal and provincial funding will be essential in helping Stratford meet the ambitious goal of reaching zero emission by 2050. Stratford should utilize this information to apply for funding from relevant programs at the local, regional, provincial, and federal level such as the ZETF and ICIP.

2.6 ENVIRONMENTAL BENEFITS

The lifecycle cost comparison below considers the financial costs associated with transitioning the Stratford Transit fleet from diesel buses to BEBs. An additional consideration is the potential greenhouse gas (GHG) emission reductions that may be realized from the transition to BEBs. HDR performed calculations to quantify the impacts of BEB operations on GHG emissions relative to the business as usual scenario. The analysis does not consider the GHG emissions associated with fabrication and constructing new BEB infrastructure or emissions associated with the resource extraction and fabrication of the vehicles.

2.6.1.1 GHG Emission Reduction Impacts

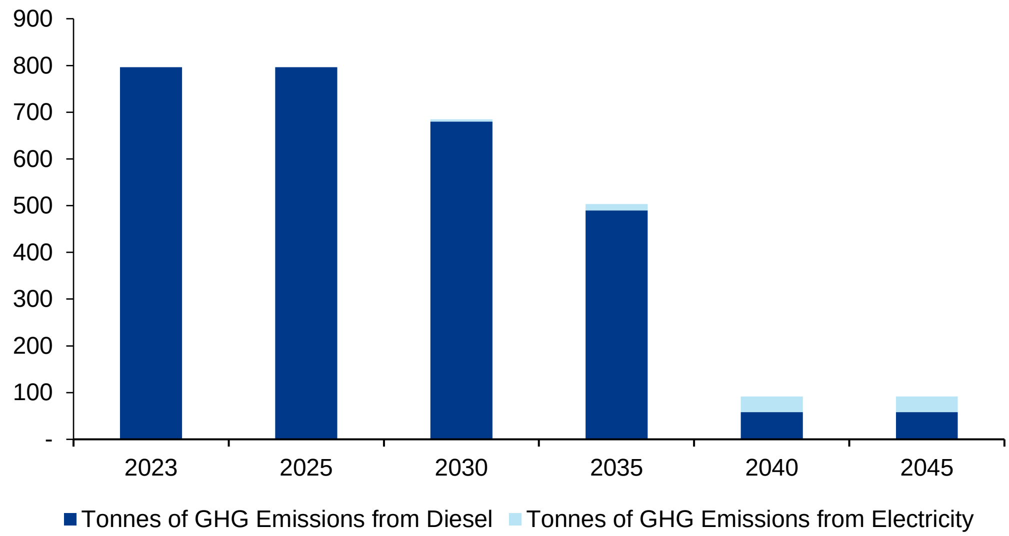
Based on the assumptions above, the GHG emissions from BEB operations are summarized in **Table** 7 below. Over the study period, BEBs will reduce emissions by approximately 12,000 tonnes.

Table 7 - GHG Emissions, Baseline and 525 kWh BEB Scenarios, Selected Years and Total, tonnes

	2025	2030	2040	Total (2023 to 2050)
Baseline	**796**	**796**	**796**	**22,296**
Diesel	796	796	796	22,296
BEB	-	-	-	-
BEB Scenario	**796**	**685**	**91**	**10,338**
Diesel	796	680	58	9,906
BEB	-	5	33	432

At the end of the transition, Stratford will have reduced its annual GHG emissions by approximately 93% compared to current operations (**Figure 12**). The remaining GHG emissions are associated with electricity production and the small amount of fuel consumed by the diesel heaters in cold weather which could be offset in the future when heater technology using zero emission fuel sources is viable.

Figure 12 - GHG Emissions by Year



Refer to **Appendix D: Budget & Financial Report** for more detailed information on the GHG Emissions Analysis.

3 CONCLUSION

The Fleet Transition Plan is a roadmap for Stratford Transit to transition from a diesel fleet to a zero emissions fleet by 2042. The Plan is structured based on the ZETF's six planning elements and provides Stratford Transit with the appropriate information to make informed decisions about their zero emissions transition and use the information provided in this Plan and the supporting Appendices to apply for funding through ZETF, or other funding sources as appropriate.

This Plan confirms that a transition to BEBs is feasible for Stratford Transit and would greatly reduce the agency's emissions compared to a baseline scenario in which they do not transition to any zero emissions technology.

4 APPENDICES

APPENDIX A: ENERGY MODELLING REPORT

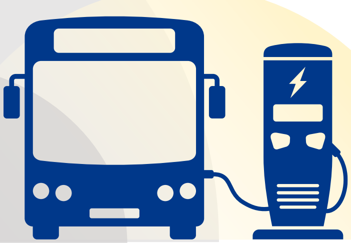
APPENDIX B: FACILITY ASSESSMENT REPORT

APPENDIX C: TRAINING & STAFFING PLAN

APPENDIX D: BUDGET & FINANCIAL REPORT

APPENDIX A ENERGY MODELLING REPORT

10/27/2023



DISCLAIMER

In preparing this report, HDR relied, in whole or in part, on data and information provided by the Client and third parties that was current at the time of such usage, which information has not been independently verified by HDR and which HDR has assumed to be accurate, complete, reliable, and current. Therefore, while HDR has utilized its best efforts in preparing this report, HDR does not warrant or guarantee the conclusions set forth in this report which are dependent or based upon data, information or statements supplied by third parties or the client, or that the data and information have not changed since being provided in the report.

This report is intended for planning purposed for the Client, and for Client's sole and exclusive use and is not for the benefit of any third party and may not be distributed to, disclosed in any form to, used by, or relied upon by, any third party without prior written consent of HDR, which consent may be withheld in its sole discretion. Use of this preliminary feasibility report or any information contained herein, if by any party other than Client, shall be at the sole risk of such party and shall constitute a release and agreement by such party to defend and indemnify HDR and its affiliates, officers, employees and subcontractors from and against any liability for direct, indirect, incidental, consequential or special loss or damage or other liability of any nature arising from its use of the Report or reliance upon any of its content. To the maximum extent permitted by law, such release from and indemnification against liability shall apply in contract, tort (including negligence), strict liability, or any other theory of liability.

TABLE OF CONTENTS

1 INTRODUCTION

The City of Stratford is addressing climate change by collaborating with other local area municipalities in the Perth County Greenhouse Gas (GHG) Reduction Plan. The document states that a minimum reduction target 10% below the 2017 baseline year should be achieved by 2030. It also notes that the community is supportive of a 30% reduction target for 2030 and net zero by 2050.[1] There is no target for transit emissions but there is discussion of prioritizing an increase of use of the transit system by residents in the future to reduce local transportation GHG emissions. In October 2021, Stratford's council recommended that the Plan be adopted, and that the City set 2030 and 2050 targets that align with the Plan.

One way the City of Stratford is taking action is by transitioning its transit fleet to battery electric vehicles. Stratford has begun planning the transition to a zero emissions fleet by developing a Fleet Transition Plan that will act as a roadmap to guide the process. The Fleet Transition Plan will identify the feasible transition pathway(s), associated capital and operating costs, service impacts, and, ultimately, the preferred transition pathway. This Energy Modelling Results Memo will feed the larger fleet transition plan to provide a strategy for electrification of the transit fleet.

When planning for a transition to battery electric buses (BEBs), it is important for agencies to not only look at the vehicle requirements, but also the infrastructure changes and other operational changes required to operate and maintain those vehicles. For many Canadian transit agencies, current BEB technology cannot replace diesel buses at a one-to-one replacement ratio while maintaining the same service level primarily due to vehicle range limitations. To mitigate BEB range limitations, agencies may require additional vehicles, en-route charging infrastructure, or a combination of both. It may therefore also likely impact schedules for operations, peak vehicle requirements, infrastructure, capital and operating costs, training requirements for maintenance staff and vehicle operators, as well as customers. Understanding how the system will need to operate with BEBs and how those decisions will impact these variables are important in determining an optimum fleet transition pathway.

This memo documents the process and analysis involved in the development, assessment, and recommendations for a transition pathway for Stratford's fleet from diesel internal combustion engine buses to BEBs. The processes and analyses include:

- Review of current fleet composition, the existing capital replacement plan, and service operations for transit and paratransit services
- Estimation of energy consumption of the transit fleet using the Zero+ tool and the consolidation of the model results to identify feasible transition pathway(s)
- Recommendation of the optimal vehicle battery size required for the BEB deployments based on the energy consumption modelling results
- Recommendation of a preferred transition pathway that will guide future analysis of Stratford's transition from diesel buses to BEBs
- Determination of charging infrastructure required to operate the vehicles based on the fleet's daily energy consumption profile

[1] https://www.stratford.ca/en/live-here/resources/Climate-Change/Perth-County-and-Municipalities-Climate-Change-Plan-FINAL_cb.pdf

2 EXISTING CONDITIONS

The first step in exploring battery electric vehicles is to document existing conditions and evaluate the current routes and fleet vehicles used to provide service. Key data includes:

- Operator blocks for weekdays and weekends
- Block and bus-type assignments
- General Transit Feed Specifications (GTFS) data from pre-COVID service for transit blocks on weekdays and weekends
- Fleet Replacement Plan

Adding this data to the Zero+ model creates an accurate energy consumption profile unique to Stratford's existing service. Below is a summary of the fleet composition, fleet replacement plan, and fixed route and paratransit service operations information that feeds into the modelling effort and analysis that follows.

2.1 FLEET COMPOSITION AND REPLACEMENT PLAN

2.1.1 CURRENT TRANSIT FLEET COMPOSITION

Based on the existing fleet replacement plan, the current transit fleet includes a mix of full-size, 40' fixed route diesel buses and paratransit gasoline transit shuttles as shown in **Table 1.** Currently, there are a total of 15 fixed route transit buses in service. Two hybrid buses will likely be purchased within the next two years and will arrive in 2024 to replace the oldest two hybrid buses in the fleet. There are 5 paratransit buses.

Table 1 - Current Fixed Route and Paratransit Fleet Composition

Fleet Count	Vehicle Type	Vehicle Make	Model Year(s)	Fuel Type	Facility Assignment
Fixed Route Transit Fleet					
15	LFS	40' Nova	1997-2022	Diesel	Stratford Transit Garage
Paratransit Fleet					
1	ETV	Chevrolet	2013	Gasoline	Stratford Transit Garage
1	G4500	Chevrolet	2015	Gasoline	Stratford Transit Garage
1	3500 CTV	Ford	2019	Gasoline	Stratford Transit Garage
1	G4500	GMC	2021	Gasoline	Stratford Transit Garage
1	G4500	GMC	2022	Gasoline	Stratford Transit Garage

2.1.1.1 Existing Fleet Replacement Plan: 2022 - 2040

Stratford's current fleet replacement plan outlines in which year(s) the current fleet will be replaced. The replacement of BEBs will follow this schedule. For fixed route transit buses, Stratford plans for 15 replacements between 2026 and 2042. The two 2024 buses are the replacements for the hybrid buses that Stratford plans to be in service in 2024. There is no service expansion planned in the near future. **Figure 1** shows the transit fleet replacement schedule. **Figure 2** shows the replacement schedule for Stratford's five paratransit buses.

For Stratford's fixed route transit fleet to transition to 100% zero emissions within an eight-to-ten-year timeframe, the agency will need to consider an accelerated replacement.

Figure 1 - Fixed Route Transit Fleet Replacement Schedule

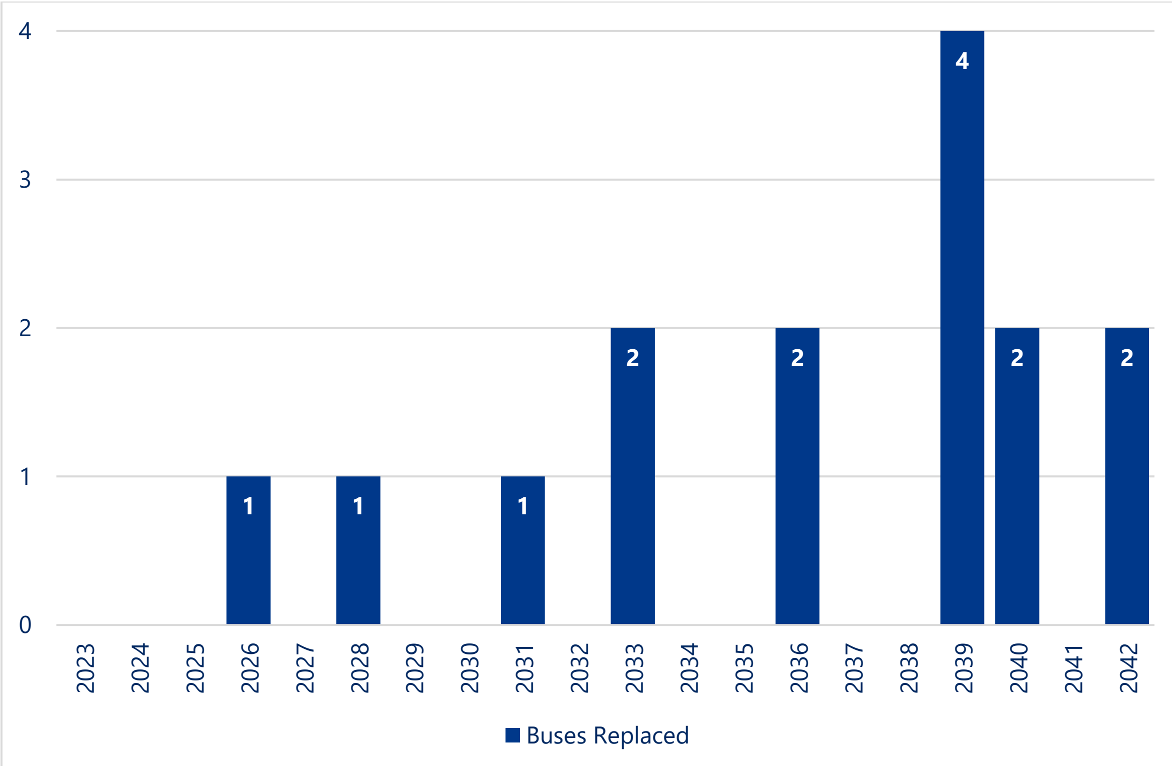
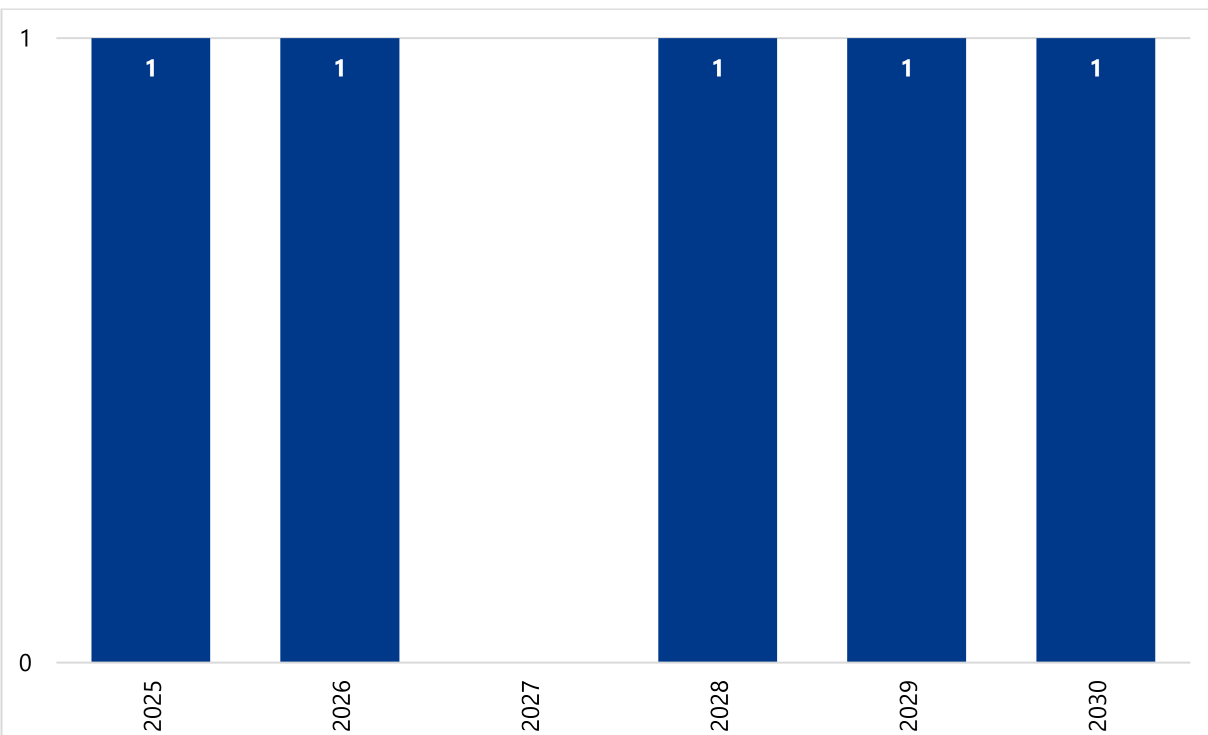


Figure 2 - Paratransit Fleet Replacement Schedule



2.2 FIXED ROUTE & PARATRANSIT SERVICE OPERATIONS

2.2.1 OPERATING SCHEDULES

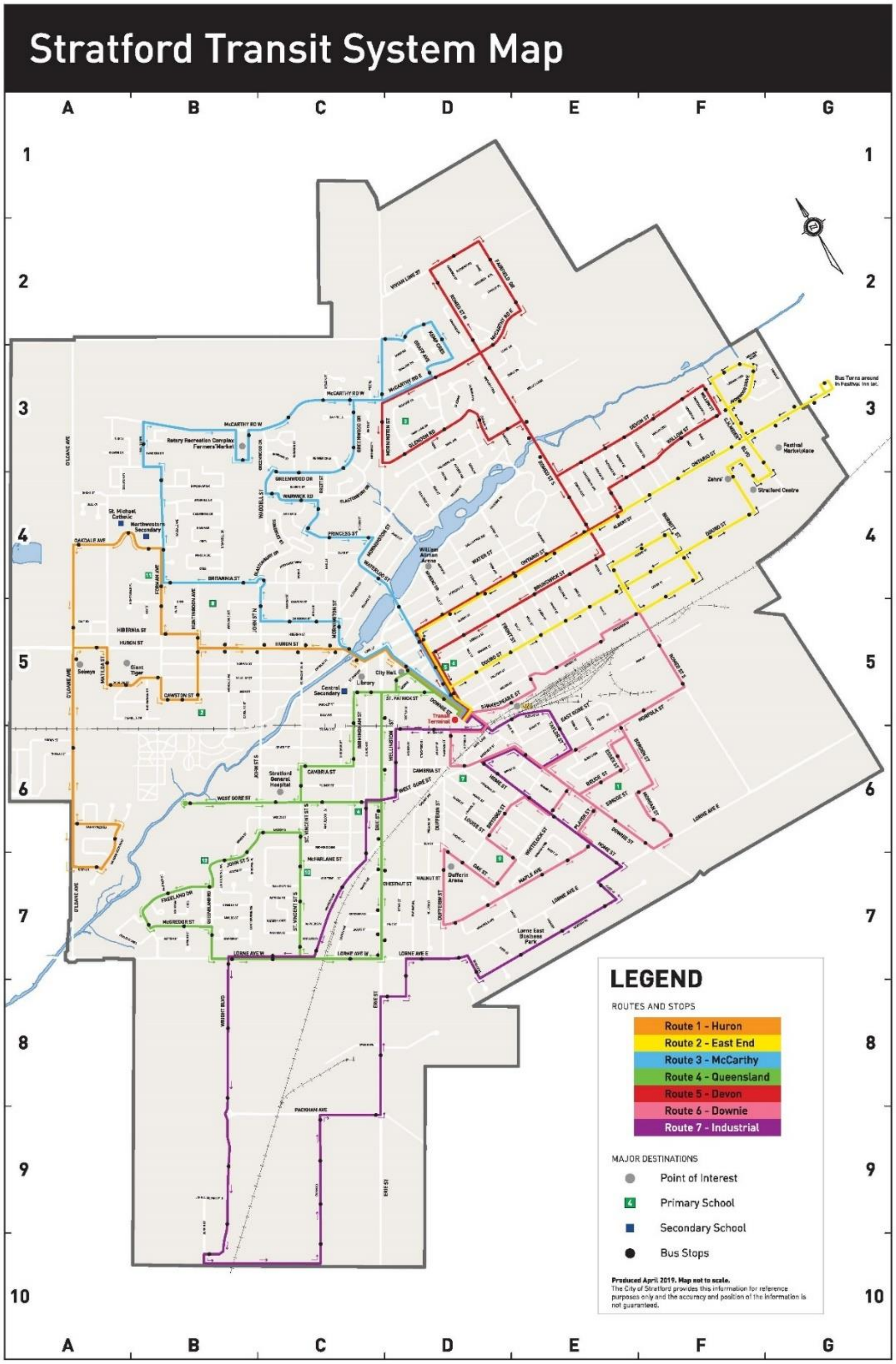
2.2.1.1 Stratford Fixed Route Transit (Weekday Only)

Stratford Transit has 7 bus routes that operate and start and end at the Transit Terminal at the centre of the City, as shown in **Figure 3.** Most routes are about half an hour end-to-end and average approximately 14km in length. There are 32 trips a day. One bus has the same route for the whole day and buses are out from 6am to 10pm.[2]

A piece of work for a transit bus is typically called a block which has information on the start/end time, routes on which it will operate and timetable of when it will be at various stops on the route. All of Stratford's blocks operate at approximately a distance of 300-400km.

[2] https://www.stratford.ca/en/live-here/transit.aspx#August-10-2022-Stratford-Transit-School-Specials-for-20222023

Figure 3 - Stratford Transit System



The operation of longer blocks (over 200kms) makes it challenging to accommodate battery electric vehicles because their operation is contingent on their battery capacities. Based on GTFS data from Fall 2022, the current diesel and hybrid fleet's blocks typically last 15 hours and run for 300-400 kms for a typical weekday

By comparison, BEBs can only continuously run for about 200 km, with less running time capacity in cold winter weather. This limits block times to approximately 10 hours, which in turn requires significant adjustments to route planning and scheduling.

2.2.1.2 Weekend On-Demand Service

Stratford Transit runs on-demand services on Saturday and Sunday. Six buses run on Saturday and three are out on Sunday. All buses run for eight and a half hours and customers request the stops they want to go to at the time they need to be there. Hours of operation are 6am to 8pm on Saturdays and 10am to 5:30pm on Sundays.[3]

2.2.1.3 School Bus Service

Stratford Transit provides School Special buses on mornings and afternoons during the weekdays for Stratford Intermediate School, Stratford District Secondary School, and Street Michael Catholic Secondary School. The buses leave the Terminal and travel to the schools at 7:25am until 8:45am. The times the buses arrive at the schools in the afternoon vary between 2:40pm and 3:05pm.[4]

2.2.1.4 Parallel Transit

Parallel Transit is Stratford's paratransit service. It is a door-to-door paratransit service for people with disabilities and/or who are unable to use the fixed route transit service. Parallel Transit service is available on a first come, first served basis between 6:20am and 9:40pm Monday through Friday, from 6:20am to 7:40pm on Saturday, and between 9:00am and 4:00pm on Sunday.

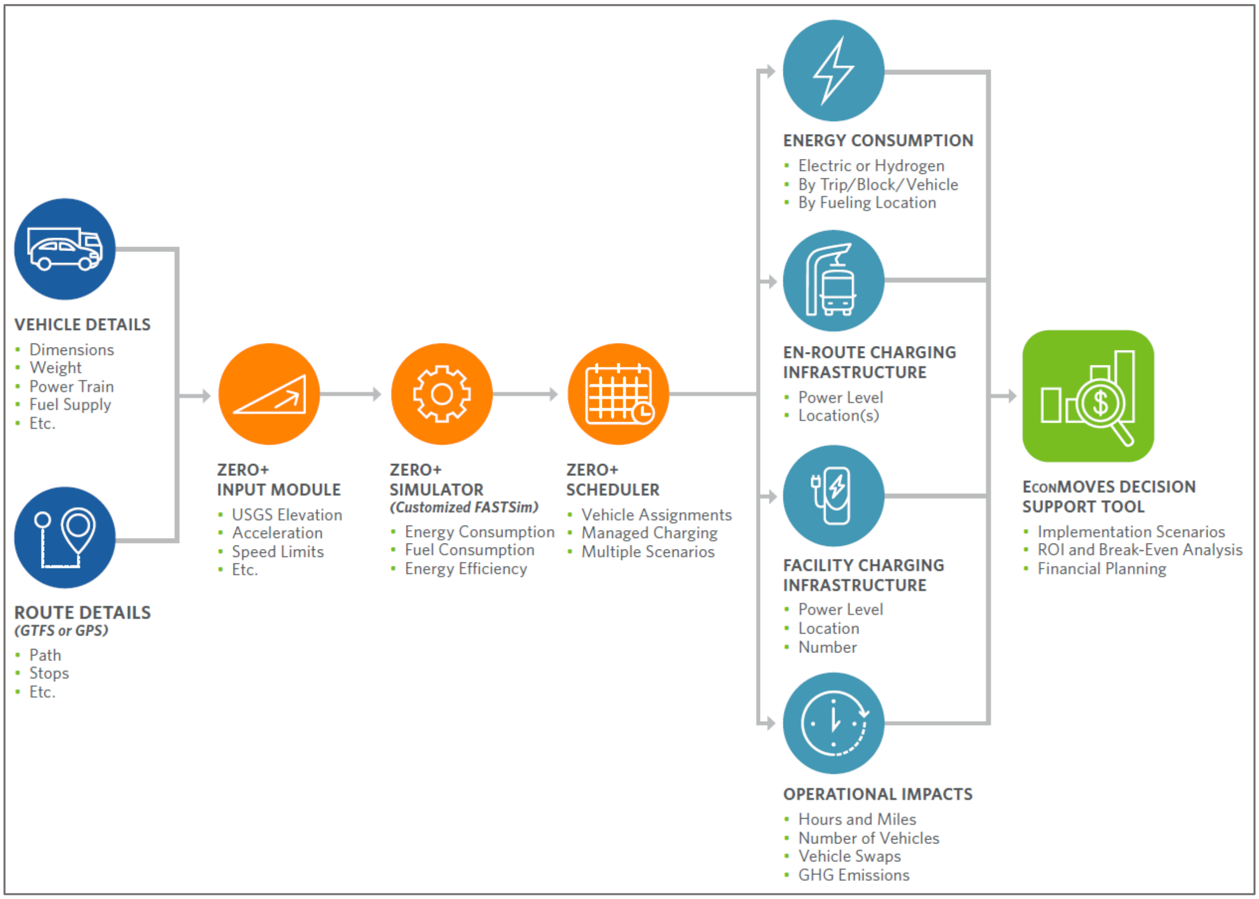
3 ENERGY CONSUMPTION ANALYSIS

The energy consumption analysis for Stratford's fixed route fleet was done using Zero+, HDR's proprietary energy consumption modelling tool to provide a comprehensive understanding of the potential impacts BEB technology may have on Stratford's existing service. Energy consumption is impacted by several factors; including slope and grade of the bus routes, number of vehicle stops, anticipated roadway traffic, terrain, and ambient temperature. Zero+ also analyzes variables known to affect lifetime vehicle performance like energy density, battery degradation, operating environment, auxiliary loads like heating and air conditioning, and lifecycle of bus batteries.

[3] https://www.stratford.ca/en/live-here/transit.aspx#August-10-2022-Stratford-Transit-School-Specials-for-20222023

[4] https://www.stratford.ca/en/live-here/transit.aspx#August-10-2022-Stratford-Transit-School-Specials-for-20222023

Figure 4 - Zero+ Fleet Optimization Tool



The service data used was based on the service schedule on Stratford Transit's website as of October 2022[5], which notes reduced service due to COVID. Energy modelling for paratransit vehicles was conducted using a high-level mathematical modelling analysis due to less available data and the less structured nature of the services. Three BEB scenarios were modelled:

- **Baseline:** Bus reuse only with depot charging allowed all day (no modifications to the existing schedule)
- **Block Split:** Bus reuse and mid-block swaps allowed with depot charging allowed all day
- **Enroute Charging:** Bus reuse and mid-block swaps allowed with depot AND enroute charging allowed all day

During the schedule optimization process, larger battery (675 kWh) scenarios for the en-route charging option were added for sensitivity. The scenario outcomes are detailed below following discussion of key assumptions.

3.1 KEY ASSUMPTIONS

To develop a model relevant for Stratford's fleet and operations, a set of assumptions and variables was identified (**Table 2**). It is noted that the assumptions regarding vehicle Original Equipment Manufacturer

[5] https://www.stratford.ca/en/live-here/transit.aspx, October 2022

(OEM) attributes represent a typical, commercially-available BEB model. Subsequent procurement of BEBs 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 2 - BEB Simulation Assumptions

Variable	Input
Service Data	October 2022
Battery Capacity	525 kWh (Larger assumed to be 675 kWh)
End-of-Life Battery State of Health	80% (max battery degradation)
Energy Reserve	20% state of charge (SOC)
Heating	Electric Heat, Diesel Heat
Ambient Temperature	-18C (Cold weather, 10^{th} percentile)
Passenger Capacity	100%
Depot Charger Power	150 kW @ 95% Efficiency
En-route Charger Power	450 kW (Vehicle Limited) @ 95% Efficiency

As shown in the table above, this model assumes a bus with a 525 kWh nameplate battery capacity, which is typical for longer-range BEBs available on the market today. While some bus manufacturers offer BEBs with greater battery capacities, modelling service with a standard vehicle provides flexibility when selecting a vehicle manufacturer.

The depot charging scenario is modelled with 150 kW chargers with a 95% efficiency and the en-route charging scenario is modelled with 450 kW chargers with a 95% efficiency. The main vehicle modelled in the Zero+ modelling tool are the 40' New Flyer Xcelsior Charge with a 525-kWh battery. For comparison purposes in some of the scenarios, the Proterra ZX5MAX is modelled as it currently has the largest battery capacity among manufacturers in North America with a nameplate capacity of 675 kWh.

A 20% reduction of battery capacity was applied to reflect end-of-life conditions. This is consistent with bus original equipment manufacturer (OEM) warranties which typically guarantee 80% of battery capacity for 12 years.

In addition to battery degradation, the model swaps out any vehicle that goes below the 20% state of charge (SOC) energy reserve. This is to account for both the fact that vehicles typically cannot use the last 10% SOC of a battery pack without performance reductions as well simulating the factor of safety most agencies use to reduce range anxiety for operators.

Energy consumption was modelled for the 10^{th} percentile lowest temperature in Stratford in February (-18 °C)[6]. The initial modelling scenario assumed the use of an electric heater (which requires a loading of about 24 kW). This is a relatively conservative assumption as a heater would likely not need to be run the full day. A modelling scenario was also created that assumed a diesel auxiliary heater would be used to reduce the power requirement and increase the range of vehicles during cold weather.

[6] https://weatherspark.com/s/19225/3/Average-Winter-Weather-in-Stratford-Canada#Figures-Temperature

It should be noted that while en-route chargers are capable of outputting 450 kW of power, the vehicle must be able to accept that level of power. In other words, as -is the case with the majority of transit buses today that can accept fast charging, the actual charge rate of a bus using a 450 kW charger is typically lower. The rate of output of the charger is determined by the vehicle and is based on a variety of factors that change based on the state of charge (SOC). The modelling factors in the charge curves (rate of charge vs SOC) are provided by manufacturers for each vehicle type. The achieved charging power in the Zero+ model is limited by both the charging curve for the vehicle and the maximum power of the charger.

3.2 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 to start another block that it can complete. This gives an indication of how feasible the blocks will be based on how Stratford currently operates. The main takeaway of the baseline scenario was that the vehicles were not able to complete the majority of the blocks so this option was discounted as there would be a significant increase in non-revenue hours, kilometres, and fleet.

3.3 DEPOT CHARGING ONLY SCENARIO

To develop a feasible alternative for Stratford, this scenario assumes that buses will be swapped out partway through the block with a fully-charged vehicle when the first vehicle reaches 20% SOC. From a scheduling perspective, this was done by swapping buses so they could run in shorter blocks that could be accommodated by BEB running time capacity.

The model assumes that when swaps occur, a bus that would normally stay in service would return to the depot, and another bus and bus 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 (non-revenue hours and kilometres between the depot and the first/last stop).

The scheduled blocks have had swaps inserted once a vehicle falls below the parameters set in the model assumptions. This gives an idea of what a schedule would look like that is able to be completed by a full fleet of BEBs and how it impacts fleet size and operational costs.

In reality, schedulers will use their judgment when cutting blocks where it makes the most sense to do so. The 20% reserve is meant only as a guideline, but gives schedulers operational flexibility (unforeseen events, traffic, detours), improves battery life, and reduces driver range anxiety.

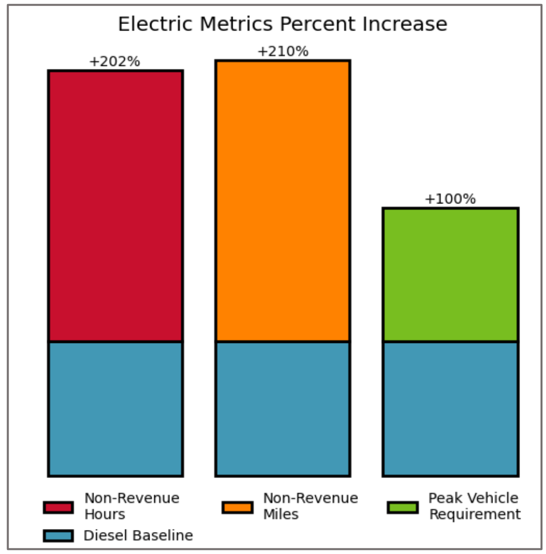
3.3.1 DEPOT CHARGING ONLY WITH ELECTRIC HEATERS

3.3.1.1 Model Results

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 BEB fleet. **Figure 5** 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.

Figure 5 - Depot-Only Charging, Bus Swap - Electrical Heating Outputs

- Revenue Hours & Kilometres remain the same
- Non-Revenue Hours: 202% increase
- Non-Revenue Kilometres: 210% increase
- Peak Vehicle Requirement: 100% increase
  Increase Fleet from 7 to 14 buses (does not include school service)
- At least 3 Depot Chargers will be required

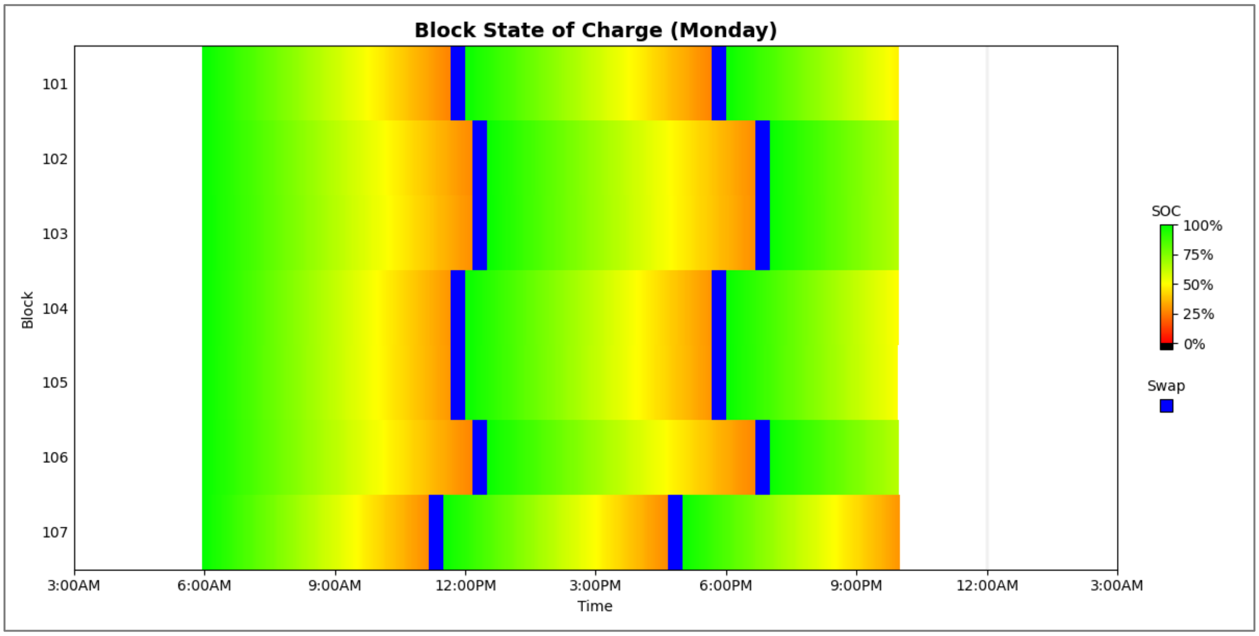


The vehicle battery state of charge on each block of typical weekday service are shown in **Figure 6.** Fleet and charging requirements are driven by weekday service.

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. 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.

All blocks require two swaps when we assume the buses are using electric heaters, which will be operationally challenging. Operating this service as defined would require a sizable increase in non-revenue hours, kilometres, and peak vehicles.

Figure 6 - State of Charge with Electric Heating, Bus Swaps



3.3.1.2 Power Requirements

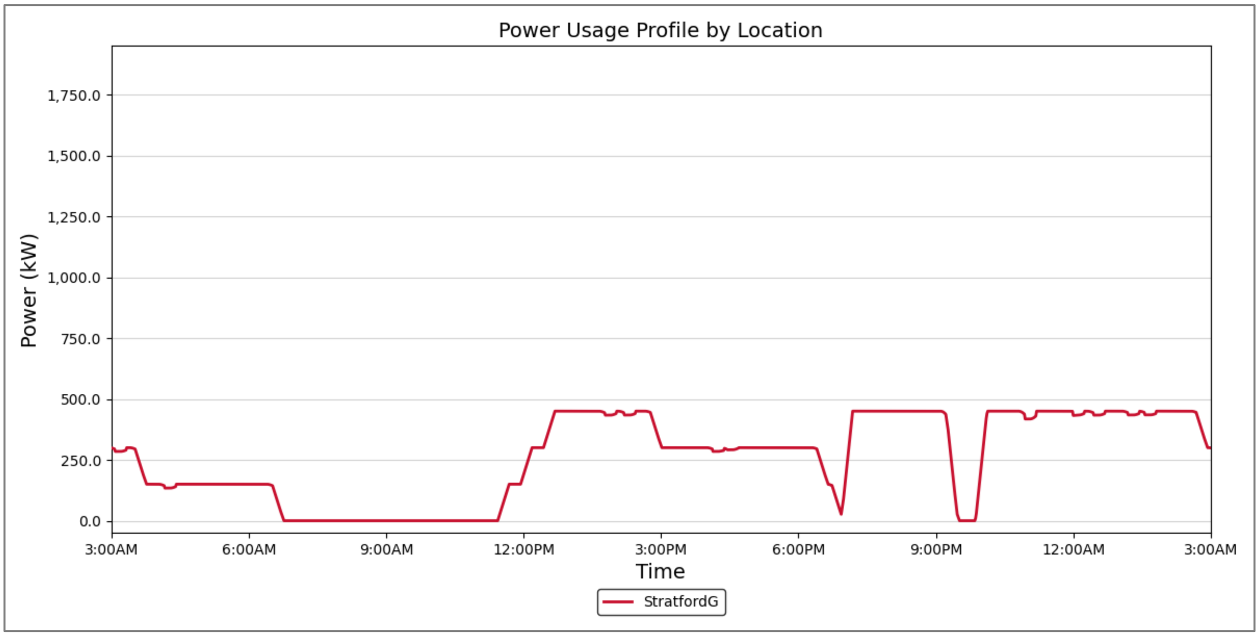
The modelling results provide estimates for both power demand and energy consumption at the Stratford Transit depot. Using these results, a preliminary assessment of the required infrastructure can be made. The baseline scenario is not shown here as it was not determined to be viable.

Below is the worst-case daily power demand, meaning the maximum load that would be required during weekday service with cold weather (10th percentile temperatures). Depending on the utility provider, the cost of energy depends not only on the peak power demand but also on the time of day when that peak demand occurs.

Electricity cost is typically billed based on two factors: peak power demand (kW) and amount of energy consumed (kWh). While consumption is the actual amount of energy consumed over the billing period, peak power demand is typically the maximum level seen over the billing period. Both of these factors can be impacted by the Time-of-Use (TOU) rates where costs fluctuate throughout the day.

The simulation results provide a power profile that can be used to understand when in the day the peak load occurs and how it is affected by any TOU charges. **Figure 7** shows the managed load profile, meaning the model attempts to use the fewest chargers to have vehicles ready for service the next day. The peak power demand for the Stratford Transit garage for a BEB fleet with electric heating and block swapping is around 0.45 MW assuming. three (3) 150 kW chargers would be required.

Figure 7 - Charging Profile for Electric Heating, Block Swaps

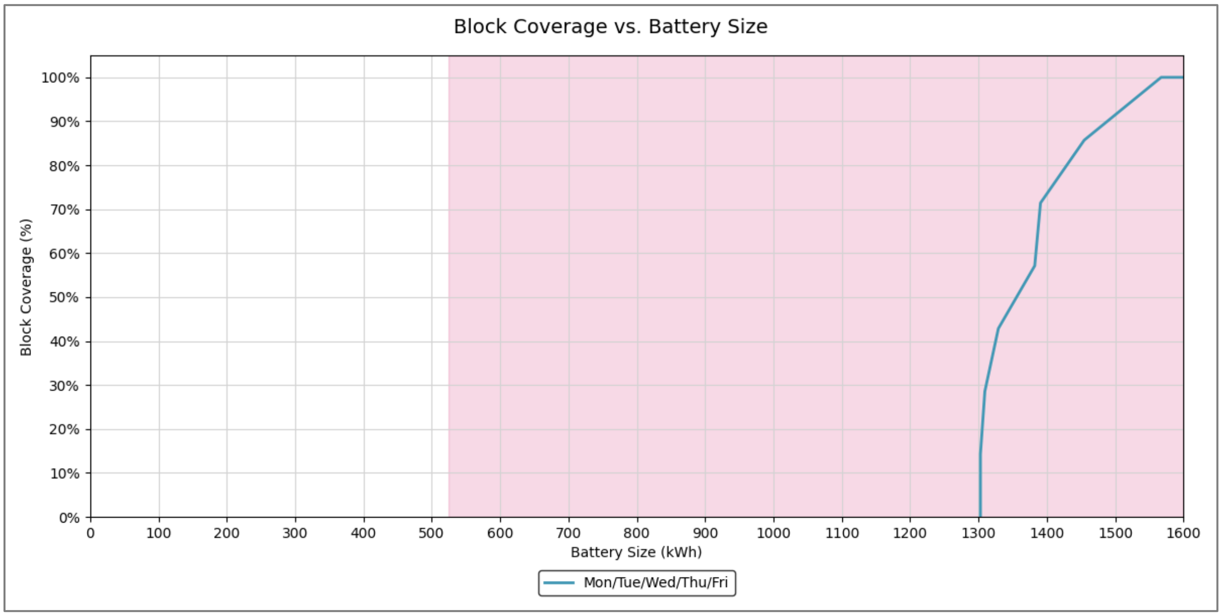


3.3.1.3 Vehicle Battery Sizes

With technological advances expected in the coming years, it may be possible to improve the performance of some scenarios by purchasing buses with larger battery sizes. There are vehicles with a battery size of (~600 kWh+) that offer more range than the 525 kWh battery that was modelled.

For the electric heating with bus swaps and depot charging only scenario, **Figure 8** illustrates that there is relatively little gain in performance when comparing a 525 kWh battery with a slightly larger batter (~600 kWh). A minimum 1,300 kWh battery would be needed to complete an entire block under present operating conditions and power usage rates. Batteries of this capacity do not yet exist.

Figure 8 – Battery Size Requirement, Electric Heating, Bus Swaps



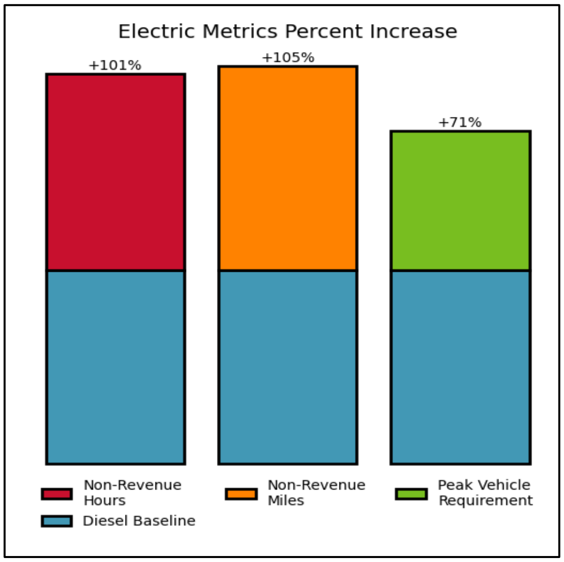
3.3.2 DEPOT CHARGING ONLY WITH DIESEL HEATERS

3.3.2.1 Model Results

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 BEB fleet, particularly if onboard heaters are diesel powered. **Figure 9** 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.

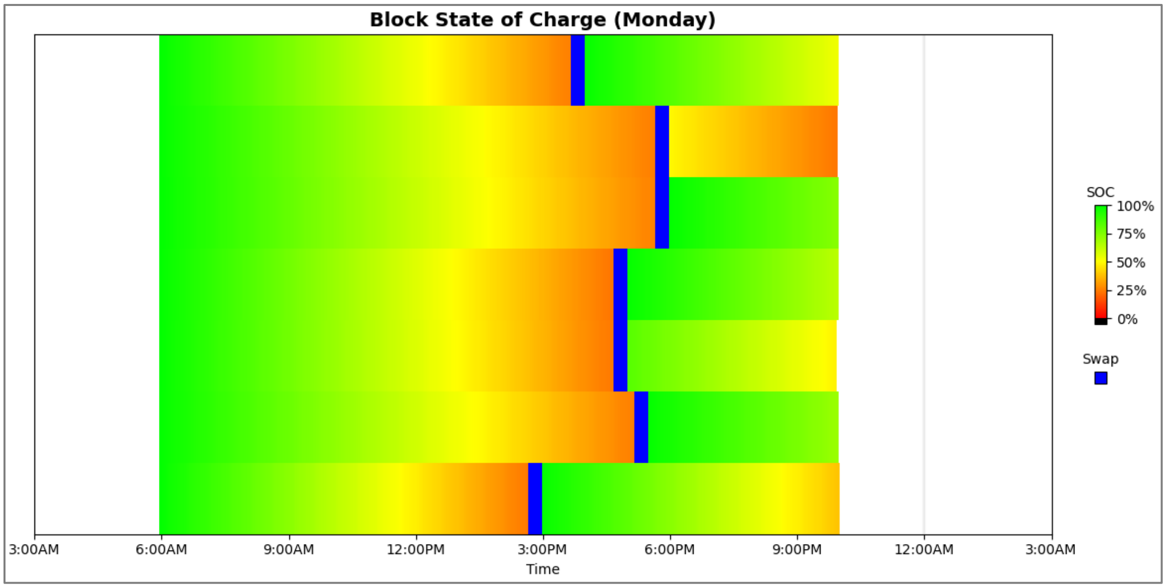
Figure 9 - Depot-Only, Charging, Bus Swap - Diesel Heating Outputs

- Revenue Hours & Kilometres remain the same
- Non-Revenue Hours: 101% increase
- Non-Revenue Kilometres: 105% increase
- Peak Vehicle Requirement: 71% increase
  Increase Fleet from 7 to 12 buses (does not include school service, which would be an additional 3 buses [15 total])
- At least 2 Depot Chargers will be required



Including diesel heaters on the BEBs does offer significant operational improvements for Stratford service as all blocks are feasible with only one swap. SOC is shown in **Figure 10.** The increase in non-revenue hours, kilometres, and peak vehicle requirement is still high, although this option has lower non-revenue costs compared to electric hearing on board.

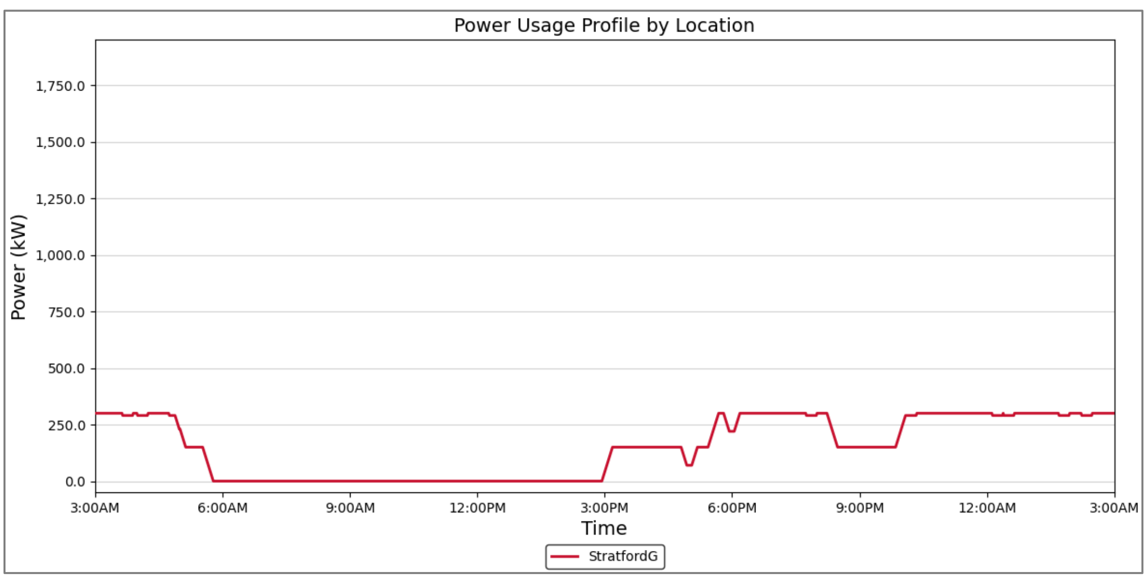
Figure 10 - State of Charge with Diesel Heating, Bus Swaps



3.3.2.2 Power Requirements

The power profile for the Stratford Transit garage is shown in **Figure 11** for buses with diesel heaters. Diesel heaters bring the power requirement down to about 0.3 MW at the depot. In this scenario, only two, 150 kW chargers would be required.

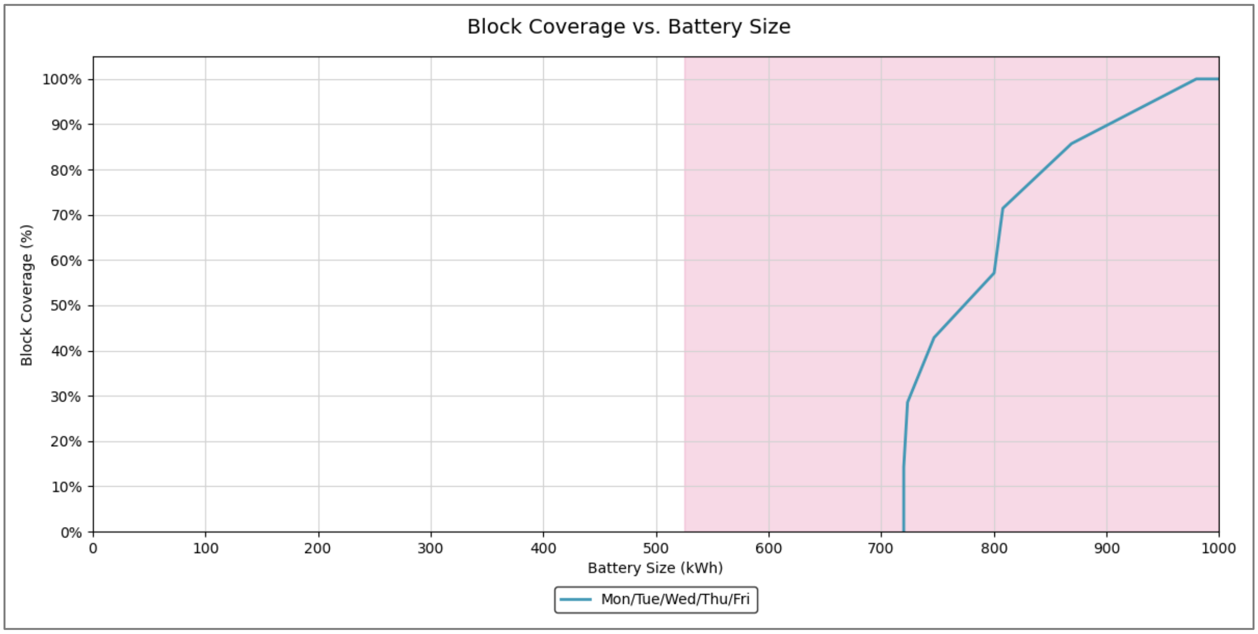
Figure 11 - Charging Profile for Diesel Heating, Bus Swaps



3.3.2.3 Vehicle Battery Sizes

There is slightly more block feasibility (around 30%) for the diesel heating depot charging scenario when purchasing buses with larger battery sizes. **Figure 12** shows that no blocks can be fully covered with a 525 kWh battery.

Figure 12 - Battery Size Requirement, Diesel Heating, Bus Swaps



3.4 DEPOT AND EN-ROUTE CHARGING SCENARIO

En-route (opportunity) charging is an enhancement that can greatly improve the feasibility of BEBs in many situations. This is particularly helpful with circulatory routes where the same en-route charger can be used by a vehicle multiple times throughout the day. En-route charging involves allowing a bus to charge for a short period of time using a high-powered charger (450 kW or greater) while stopped along its route while laying over. The mixture of en-route charging and charging in the bus depot greatly extends the range of a BEB and facilitates one-to-one replacement of a larger number of diesel vehicles when the routes are conducive to this charging strategy.

3.4.1 EN-ROUTE CHARGER LOCATION – COOPER TRANSIT TERMINAL

En-route charging infrastructure is ideally located at places such as transit centers where buses operating on multiple routes have scheduled layover time. When identifying potential en-route charging locations, property ownership and available grid capacity determine feasibility while average layover times and number of buses and riders passing through each site influence preference over other potential locations. Based on discussions with City staff on site feasibility and reviews of the current schedule for sites that have existing layover time, the Cooper Transit Terminal was identified as the primary location for en-route chargers as all routes start and end at the location and it is the only place on the transit network with scheduled layovers. The Terminal is off Downie Street as is shown in **Figure 13.**

Figure 13 - Cooper Transit Terminal Location

The modelling is meant to evaluate if opportunity charging would have significant operational and range benefits for BEBs. No modifications were made in the model to existing vehicle schedules to utilize these chargers. A more detailed evaluation of site suitability for the location would need to be conducted before implementing any infrastructure.

Chargers capable of outputting up to 450 kW using an overhead pantograph were assumed at the en-route charging location. The scenario is reviewed with electric and diesel heaters below. There are two options explored for diesel heaters with a 525 kWh battery size and a larger 675 kWh battery size. The 675 kWh battery option is used to examine the extent to which a larger battery can impact the number of blocks completed with no swaps, the number of vehicles, and non-revenue hours and kilometres.

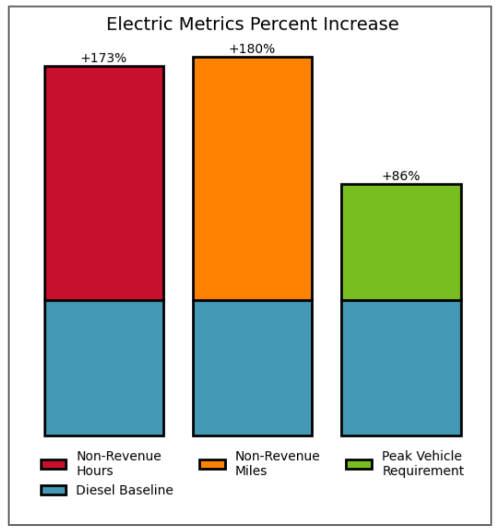
3.4.2 DEPOT CHARGING AND ONE EN-ROUTE CHARGER WITH ELECTRIC HEATERS

3.4.2.1 Model Results

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 BEB fleet. **Figure 14** 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.

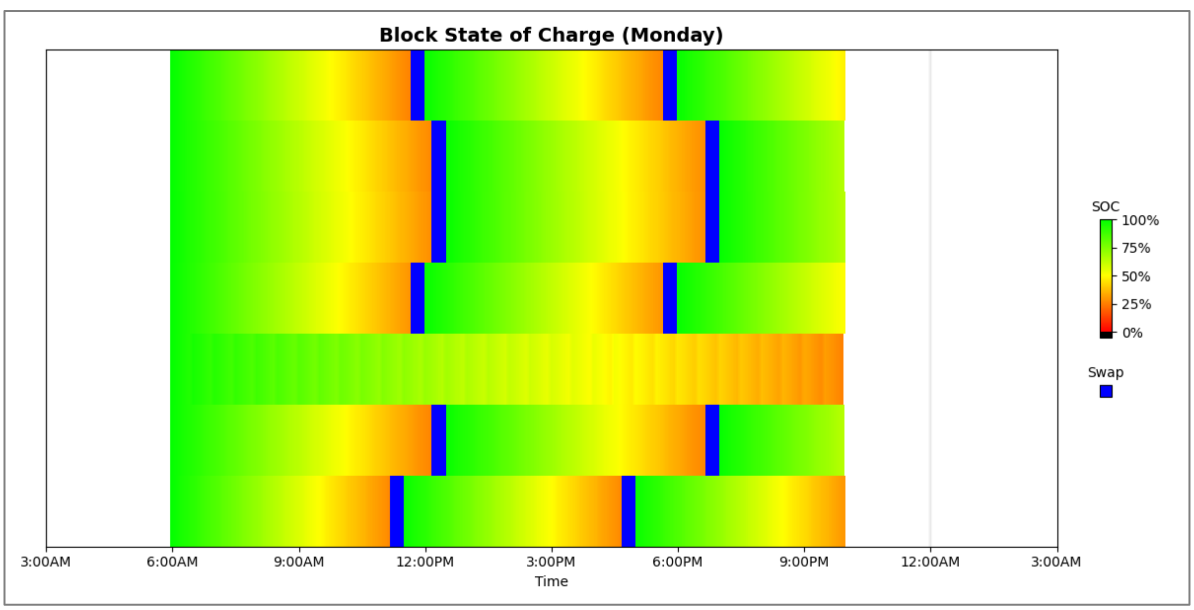
Figure 14 - Electric Heating, En-Route and Depot Charging Outputs

- Revenue Hours & Kilometres remain the same
- Non-Revenue Hours: 173% increase
- Non-Revenue Kilometres: 180% increase
- Peak Vehicle Requirement: 86% increase
  Increase Fleet from 7 to 13 buses
- At least 2 Depot Chargers will be required
- 1 En-route Charger required



With an electric heater on-board, opportunity charging would not make a significant difference as all except one block still require two bus swaps, as shown in **Figure 15**.

Figure 15 - State of Charge, Electric Heating, Bus Swaps, En-Route Charging

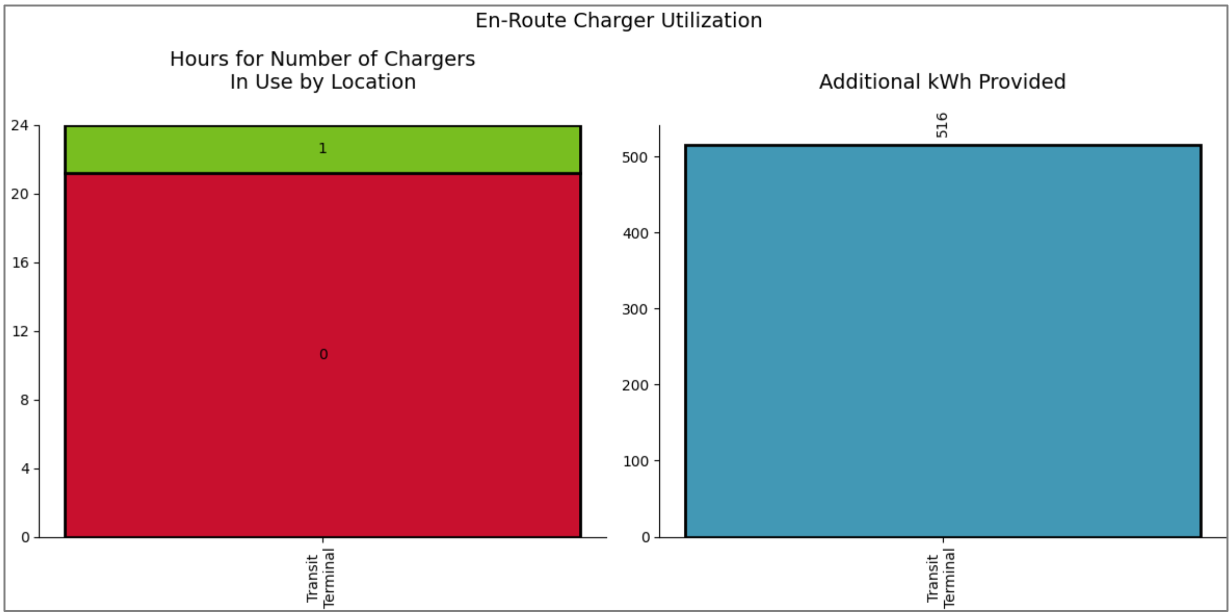


3.4.2.1.1 En-Route Charger Utilization

The en-route charger utilization is shown in **Figure 16.** Nine percent (9%) of total energy could be provided by en-route chargers, with the rest being supplied in depot.

In general, this gives a good indication of the quantity of equipment required at the Cooper Transit Terminal. There are operational benefits to having more than one charger at any location as it provides additional redundancy in case one charger goes out of service (or is down for maintenance), then there is at least one functioning charger at that location.

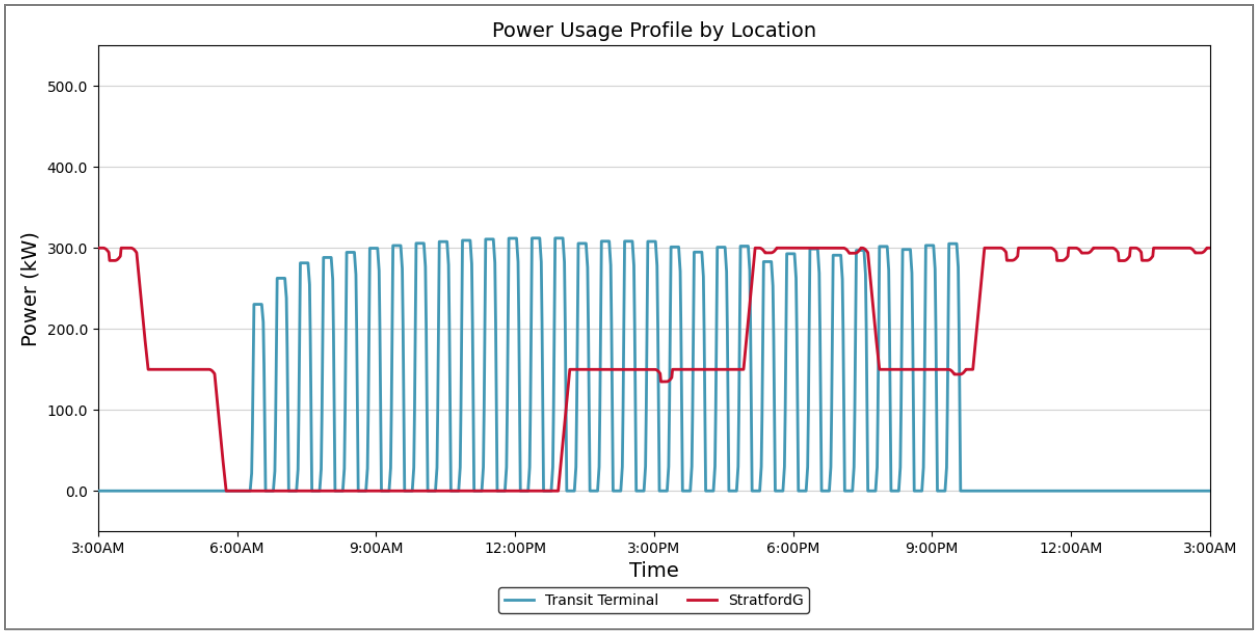
Figure 16 - En-Route Charger Utilization, Electric Heating, Bus Swaps, En-Route Charging



3.4.2.2 Power Requirements

Adding en-route charging to the electric heating option reduced the peak power requirement by 0.2MW at the depot. The peak power demand would be around 0.3 MW and two, 150 kW chargers would be required at the depot. There would be a similar peak power demand of 0.3 MW for the one en-route charger. The power usage profile for the en-route charger scenario is shown in **Figure 17.**

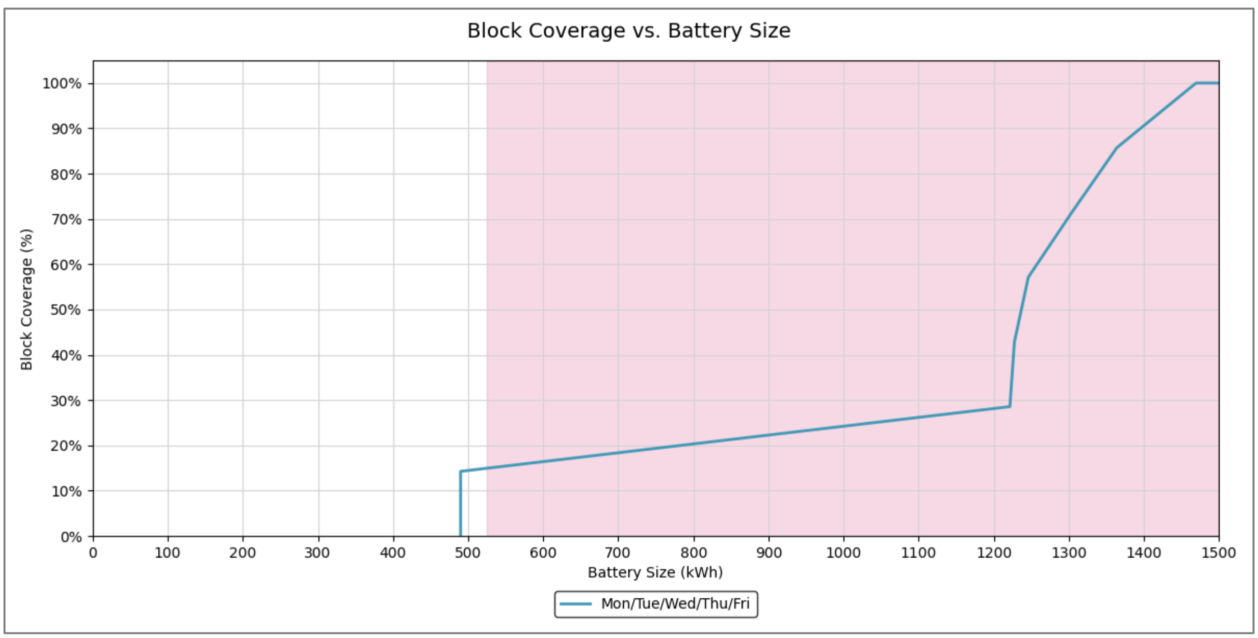
Figure 17 - Charging Profile for Depot and En-Route Chargers, Electric Heating, Bus Swaps



3.4.2.3 Vehicle Battery Size

There is slight improvement in block feasibility for the electric heating, en-route charging scenario when purchasing buses with larger battery sizes. **Figure 18** shows block coverage with a 525 kWh battery is around 16% and a larger battery (~600 kWh+) kWh battery can only cover slightly more (~18%+).

Figure 18 - Battery Size Requirement, Electric Heating, Bus Swaps, En-Route Charging



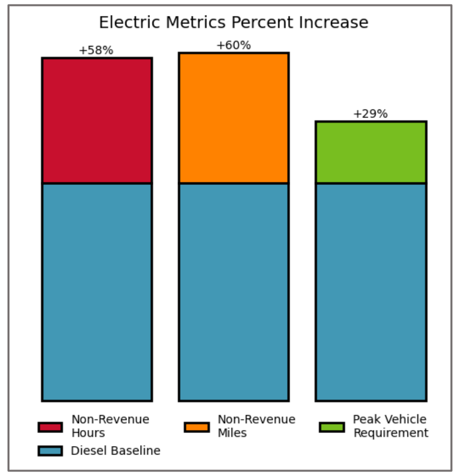
3.4.3 DEPOT CHARGING AND ONE EN-ROUTE CHARGER WITH DIESEL HEATERS (525 KWH BATTERY)

3.4.3.1 Model Results

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 BEB fleet. **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.

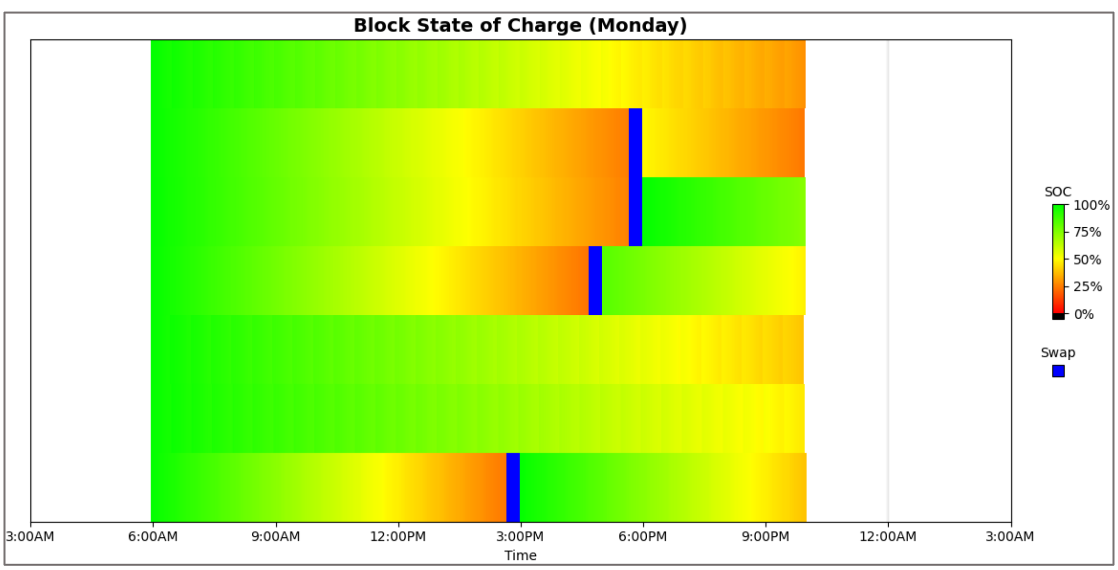
Figure 19 - Diesel Heating, 525 kWh Battery, En-Route and Depot Charging Outputs

- Revenue Hours & Kilometres remain the same
- Non-Revenue Hours: 58% increase
- Non-Revenue Kilometres: 60% increase
- Peak Vehicle Requirement: 29% increase
  Increase Fleet from 7 to 9 buses
- At least 1 Depot Charger will be required
- 1 En-route Charger required



With a diesel heater onboard instead of electric heating, the number of feasible blocks without any bus swaps increases from 14% to 43%, as shown in **Figure 20**. The reduced energy requirement from the buses allows en-route charging to keep some of the buses at a relatively high level of charge for most of the day.

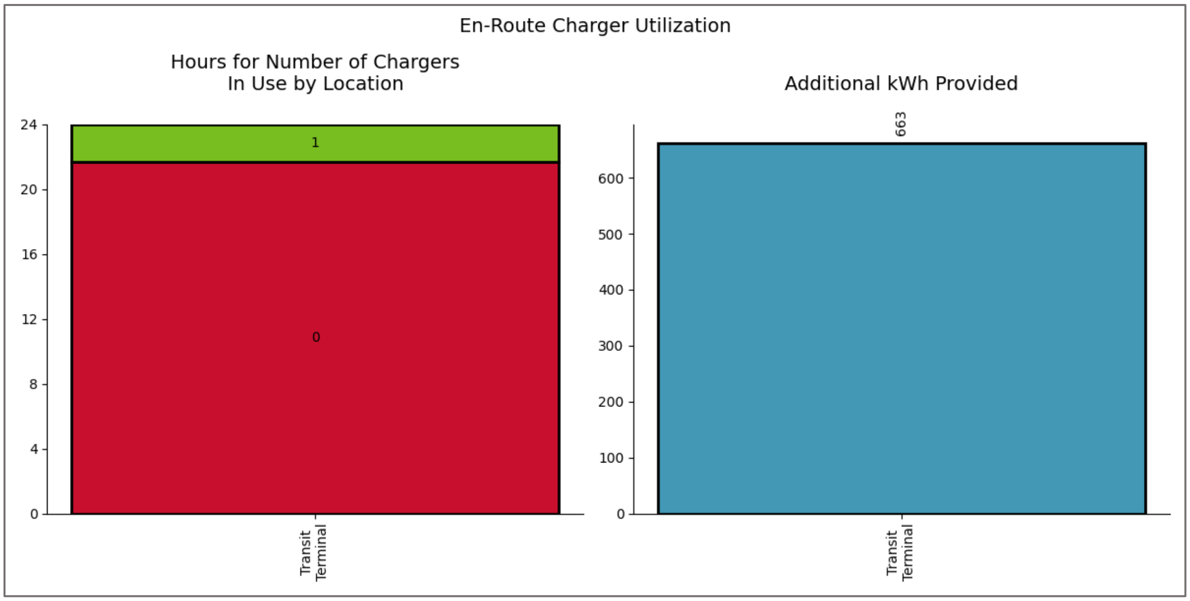
Figure 20 - State of Charge with Diesel Heating, 525 kWh Battery, Bus Swaps, En-Route Charging



3.4.3.2 En-Route Charger Utilization

The en-route charger utilization is shown in **Figure 21**. 19% of total energy could be provided by the en-route charger, with the rest being supplied in depot.

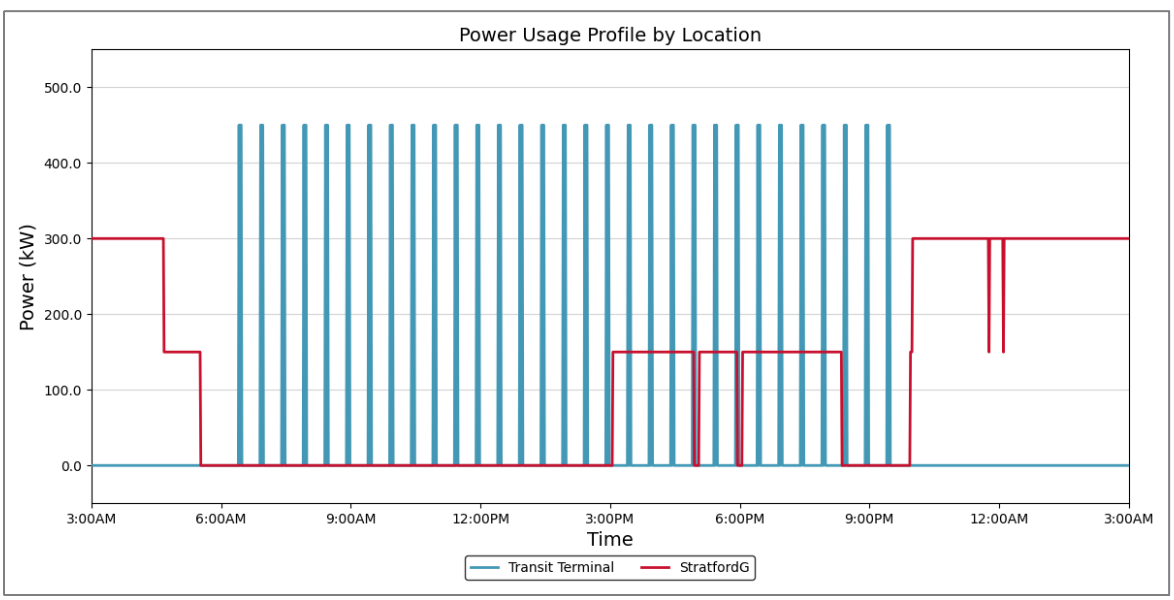
Figure 21 - En-Route Charger Utilization, Diesel Heating, 525 kWh Battery



3.4.3.3 Power Requirements

With en-route charging and a diesel heater on-board, the peak power requirement in-depot is similar to the electric heating and en-route charging option, as shown in **Figure 22.** The peak power requirement would be just over 0.3 MW at the Stratford Transit garage. The charging profile for en-route chargers increases from a peak power requirement of 0.3 MW in the electric heating and en-route charging option to 0.45 MW.

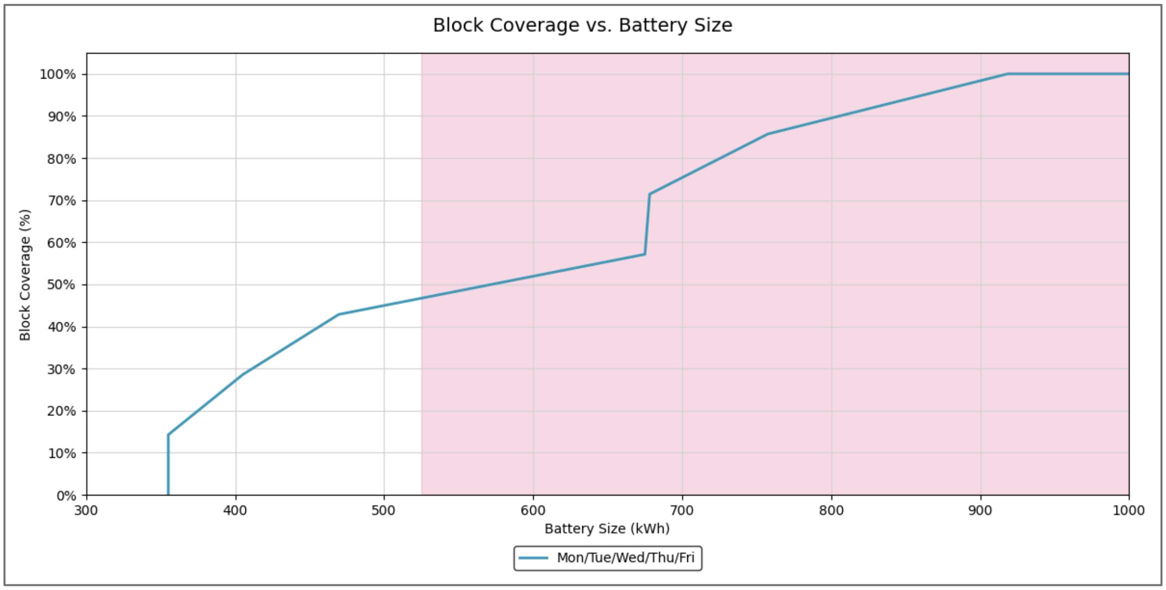
Figure 22 - Charging Profile for En-Route Chargers and Depot, Diesel Heating, 525 kWh Battery



3.4.3.4 Vehicle Battery Size

The scenario with en-route charging and diesel heating has 48% block coverage at 525 kWh, as shown in **Figure 23**, and a larger battery size (~600 kWh+) would have slightly more coverage with at least 51% block coverage.

Figure 23 - Battery Size Requirement, Diesel Heating, 525 kWh Battery, Bus Swaps, En-Route Charging



3.4.4 DEPOT CHARGING AND TWO EN-ROUTE CHARGERS WITH DIESEL HEATERS (675 KWH BATTERY)

3.4.4.1 Model Results

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 BEB fleet.

Figure 24: Diesel Heating, 675 kWh Battery, En-Route and Depot Charging Outputs

- Revenue Hours & Kilometres remain the same
- Non-Revenue Hours: 0% increase
- Non-Revenue Kilometres: 0% increase
- Peak Vehicle Requirement: 0% increase
- At least 3 Depot Charger will be required
- 2 En-route Charger required

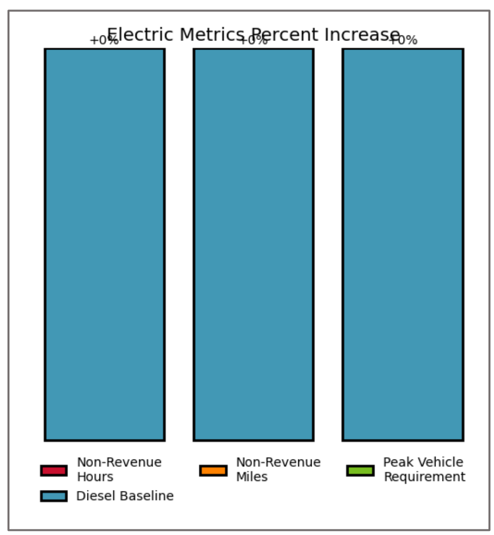


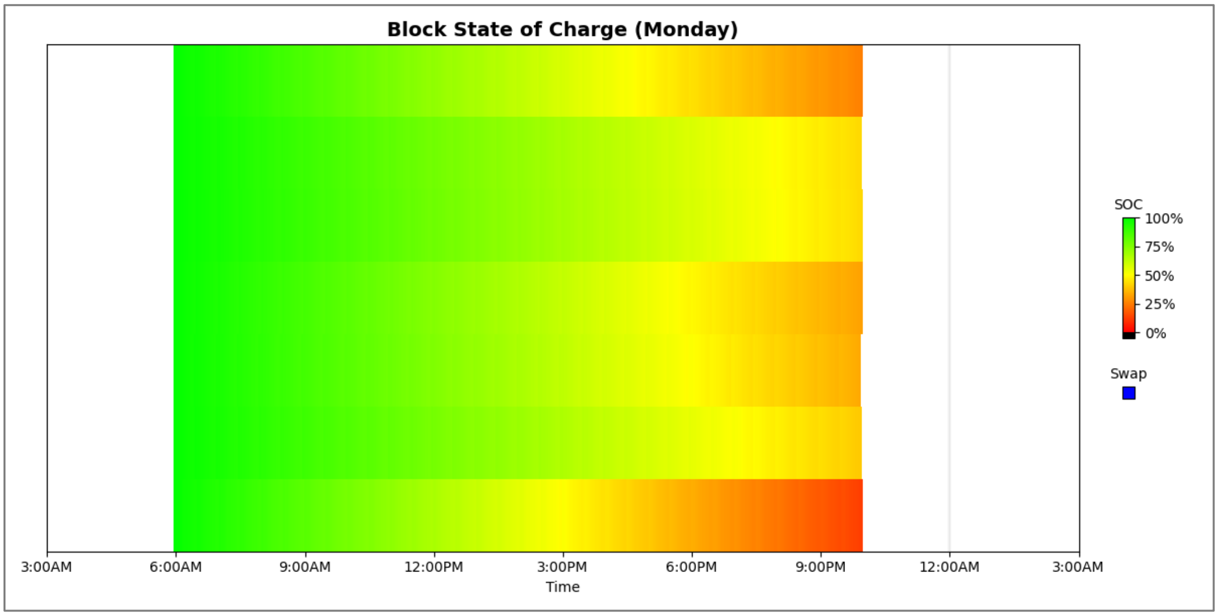
Figure 24 shows an estimate of the increase in non-revenue hours and kilometres as well as the estimated number of vehicles required to continue the current transit service.

The results are not shown but increasing the battery size with one en-route charger was modeled but did not have a significant advantage. Increasing the number of en-route chargers without increasing battery size also modeled but again did not have a significant advantage in terms of operating hours or fleet size. When both battery size and number of en-route chargers we increased, there was a noticeable change which is presented here.

The diesel scenario with depot charging, two en-route chargers, and a 675 kWh battery was modelled to show the extent to which a larger battery size can decrease mid-block swaps and vehicle requirements. Although the 675 kWh battery was used in the Zero+ model, there are other battery sizes on the market so Stratford is not limited to one battery size and manufacturer. Using a larger battery size on top of including diesel heaters on the BEBs offers significant operational improvements for Stratford service. With larger batteries, 100% of blocks are feasible without swapping buses, as shown in **Figure 25**. There is no increase to fleet or non-revenue costs.

With this option, operators would get a charge every other time they arrive at the terminal; For example, buses 1-4 would be able to charge at the top of every hour and buses 5-7 would get to charge at the top of every half hour.

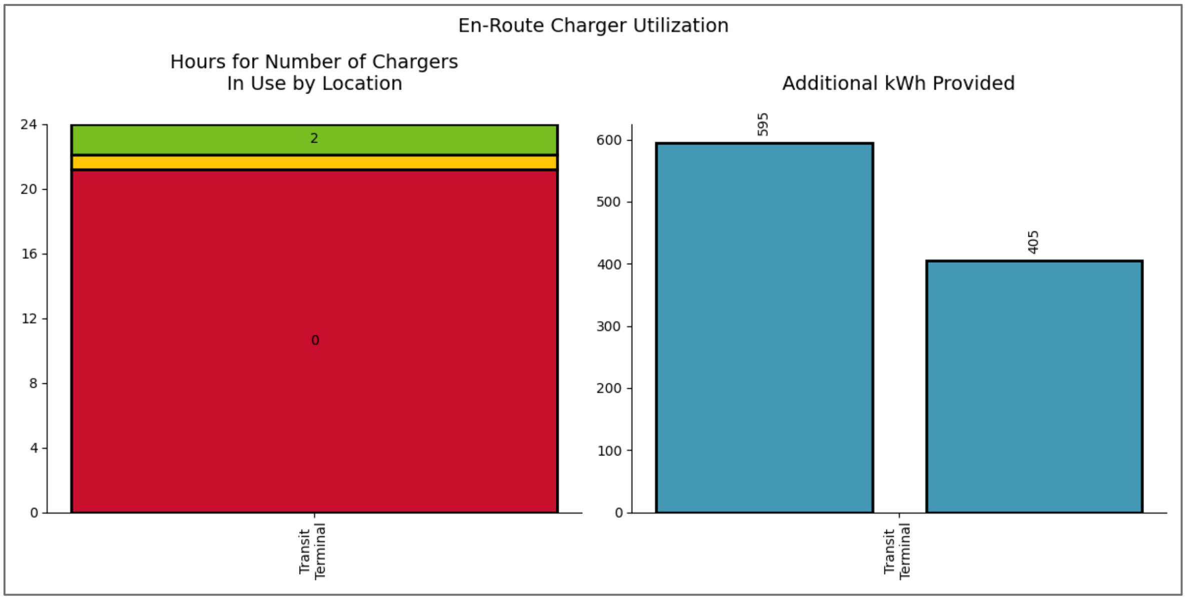
Figure 25 - State of Charge with Diesel Heating, 675 kWh Battery, Bus Swaps, En-Route Charging



3.4.4.2 En-Route Charger Utilization

The en-route charger utilization is shown in **Figure 26**. 28% of total energy could be provided by the en-route charger, with the rest being supplied in depot.

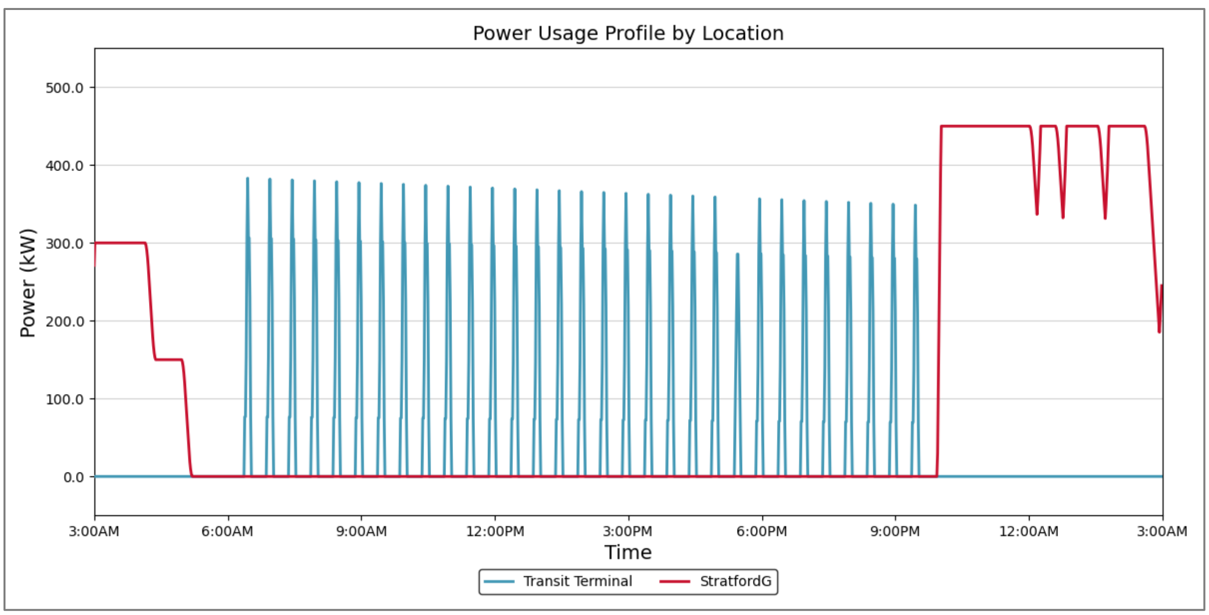
Figure 26: En-Route Charger Utilization, Diesel Heating, 675 kWh Battery, Bus Swaps, En-Route Charging



3.4.4.3 Power Requirements

With a larger battery and two chargers, the peak power requirement in-depot is higher than the other en-route charging options, as shown in **Figure 27.** The peak power requirement would be around 0.45 MW at the Stratford Transit garage. The charging profile for the two en-route chargers decreases slightly from the one en-route charger with diesel heaters (525 kWH Battery) option from 0.45 MW to just under 0.4 MW. For this option, there are no swaps which means that vehicles all go back to the garage at the end of service at similar times and complete a full charge for service back at the garage.

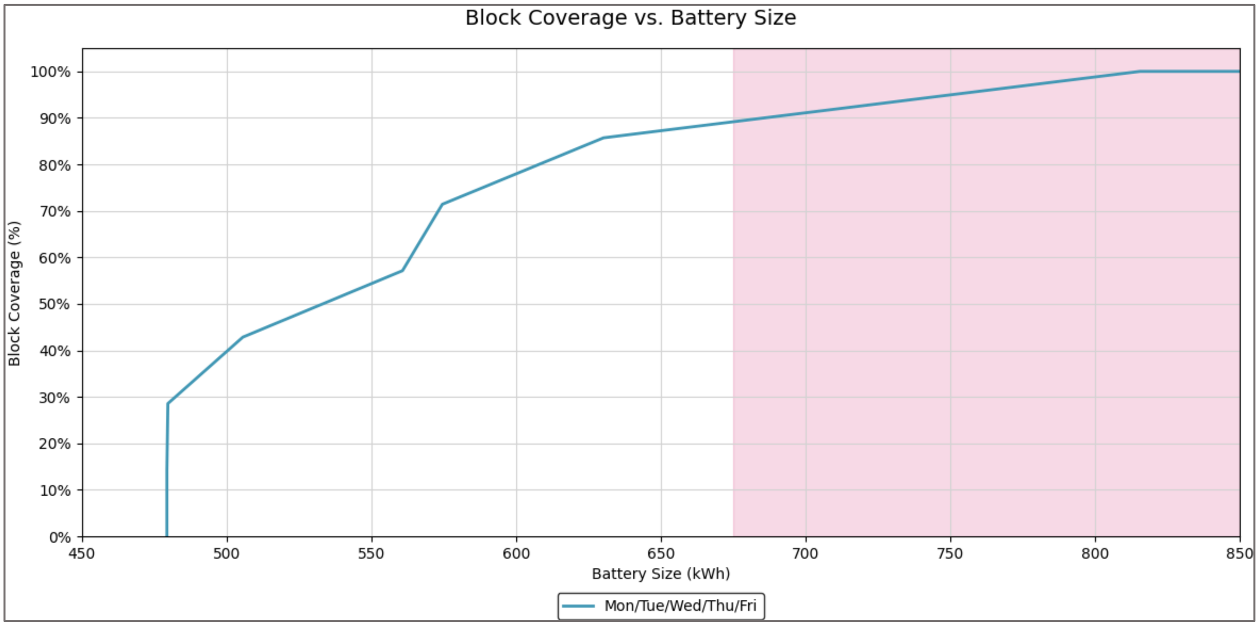
Figure 27 - Charging Profile for En-Route Chargers and Depot, Diesel Heating, 675 kWh Battery



3.4.4.4 Vehicle Battery Size

En-route charging and diesel heating with a larger battery has approximately 90% block coverage at 675 kWh, as shown in **Figure 28.** With the two chargers at the Cooper Transit Terminal there is full block coverage.

Figure 28 - Battery Size Requirement, Diesel Heating, 675 kWh Battery, Bus Swaps, En-Route Charging



4 FIXED ROUTE TRANSIT MODELLING SUMMARY

The modelled fleet requirement column in **Table 3** is a summary of the modelling results discussed above. The table shows the peak number of buses without spares and the chargers columns show the minimum number of charges required. The block feasibility column notes the percentage of how feasible the blocks will be based on how Stratford currently operates.

The modelled fleet requirement considers feasibility for On Demand transit as the On Demand service information was an input within each of the energy modelling scenarios but does not factor in spares or AM/PM school service, which would add approximately three buses for each scenario.

Table 3 - Fixed Route Modelling Summary

Scenario		Block Feasibility	Modelled Fleet Requirement	Depot Charger Quantity	En-Route Charger Quantity
Electric Heating	Depot Only	100%	14	3	0
	Depot and En-Route	100%	13	2	1
	Depot Only	100%	12	2	0

Diesel Heating	Depot and En-Route	100%	9	2	1
	En-Route (Larger Battery, 2 En-Route Chargers)	100%	7	3	2
Diesel		100%	7	-	-

4.1 PARATRANSIT MODELLING SUMMARY

An energy consumption analysis was also conducted for paratransit fleet, as shown in **Table 4** and **Table 5** based on the range capabilities of the most similar EV equivalent vehicle. The range capabilities are shown as the average and maximum daily mileage based on an 8-hour shift assumption and 5% maximum mileage occurrence. The paratransit fleet can undergo a 1:1 replacement.

Table 4 - Proposed Energy Consumption Plan for Paratransit

Service	Vehicle Type	Proposed EV Replacement Model	Average km	Maximum km
Non-Revenue Fleet	28' Mobility Bus	Lightning Electric E-450 129	105	115

Table 5 - Chargers and Energy Demand Required for Paratransit Proposed Energy Consumption Plan

Total Charger Quantity	Total Power (kW)	Daily Energy Demand (kWh)	Required EV Fleet Size	Current Fleet Size
5	50	542	5	5

5 PATHWAY OPTIONS

To arrive at a final transition pathway, Stratford will select one or two scenarios that were discussed in the previous section. The number of BEBs required, costs, and GHG savings are detailed in this section based on the model outputs.

5.1 FIXED ROUTE TRANSIT

High level projections of fleet size requirements, charging equipment requirements, cost estimates, and emission reductions were produced for each option and compared to the baseline diesel "business as usual" (BAU) scenario.

The capital cost estimates include the purchase and installation cost for buses and fueling/charging infrastructure. The capital cost estimates are based on averages of best available quotes from the manufacturers or best available information from industry studies. It should be noted that the number of depot chargers is assumed to be the same for all scenarios to assure a 1:1 bus to dispenser ratio.

Operating costs includes energy and fuel cost, operating costs, and maintenance costs. These cost estimates are based on information provided by Stratford and best available information from industry studies.

Emissions reductions were estimated based on emission intensity data produced by Environmental and Climate Change Canada. **Table 6** summarizes these high-level projections.

In addition to the high-level quantitative estimates, each technology option was evaluated across a number of qualitative criteria:

- Route Flexibility – The routing and operational flexibility given the proposed fleet composition of each pathway
- Facility Constraints – The physical space requirements of supporting infrastructure and vehicle parking/storage
- Maintenance Complexity – The maintenance complexity of both the buses and the supporting equipment including chargers or hydrogen storage equipment
- Future Maintainability Risk – The expected availability of parts for maintenance in the future
- Technology Maturity – The maturity of both the technology and the supporting fuel and parts supply chain

Each pathway was graded on a scale of with the lowest number (1) being the best and highest number (3-5, depending on the category) being the worst. Some option rankings are combined, which means that they are tied. The grading of each pathway is presented in the **Table 6** below along with the quantitative estimate.

Table 6 - Pathway Options High Level Summaries

Measure		Business as Usual (BAU)	Depot Only + Electric Heat (DE)	Depot Only + Diesel Heat (DH)	En-route + Electric Heat (EE)	En-route + Diesel Heat (EH)	
		Diesel	BEB Elec. Heat	BEB Hyb. Diesel Heat	BEB Elec. Heat	BEB (525 kWh) Hyb. Diesel Heat	BEB (675 kWh) Hyb. Diesel Heat
		N/A	Depot Only	Depot Only	En-Route + Depot	En-Route + Depot	En-Route + Depot
Peak Vehicle Requirement	BEB		14	12	13	9	7
	Alternative	7					
Garage Chargers			5	5	5	5	5
En-Route Chargers					1	1	2
Transformers			1	1	1	1	1
Capital Cost (Cumulative)[1]		$4,200,000	$19,400,000	$17,000,000	$19,400,000	$14,600,000	$13,400,000
Annual Operating Cost[2]		$1,545,177	$1,127,855	$1,023,016	$1,120,102	$1,018,738	$1,023,438
Annual GHGs Emissions (tCO2eq)		1,343	50	97	50	29	98
Annual GHGs Savings (%)[3]		0%	96%	93%	96%	98%	93%
Route Flexibility		1	3	2	5	4	
Facility Constraint		1	5	4	3	2	
Maintenance Complexity		1	3	2	5	4	
Future Maintainability Risk		1	2		3		
Technology Maturity		1	2		3		

[1]Total raw conversion costs. Capital Costs: Fleet, Depot Charger, En-route Charger, Transformer

[2]Operating Cost (based on current costs): Electricity Demand & Regulatory Cost, Electricity Consumption Cost, Fuel Cost, Maintenance Cost

[3]Relative to service level under diesel baseline. Includes upstream emissions and emissions from auxiliary heater.

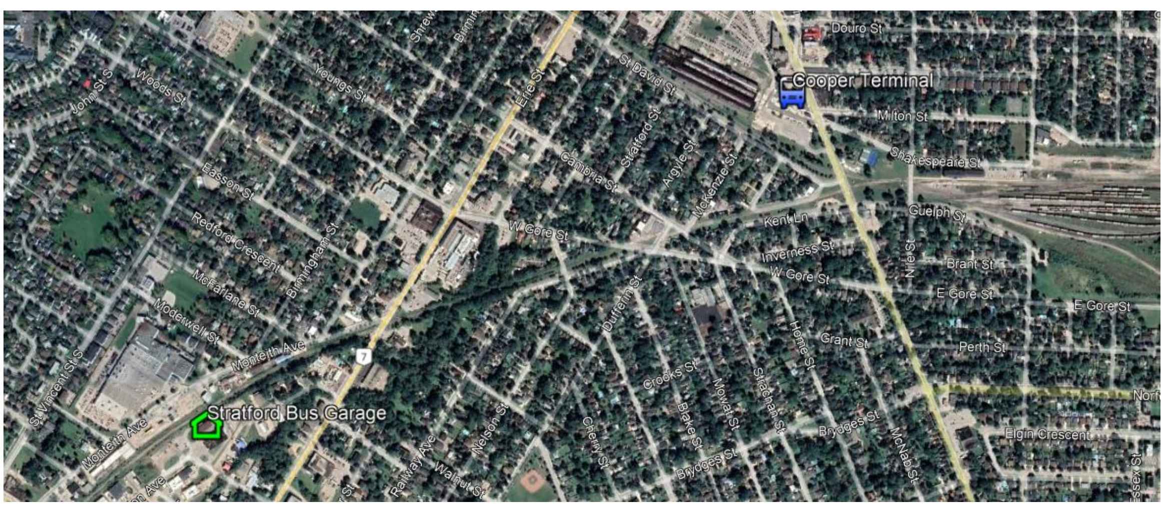
When considering options, it is important to consider both the initial capital costs of purchasing the vehicles as well as the operating costs. Typically, when transit fleets transition to BEBs, there is a significant shift from operating costs to capital costs. While the vehicles are more expensive to purchase, they are typically more cost effective to operate and maintain. One reason for this efficiency is due to electricity being typically a cheaper way to power vehicles than diesel, with more stable prices.

As can be seen in **Table 6**, all options require significant capital investment compared to the BAU scenario. However, there are savings in annual operating costs for the BEB scenarios compared to the BAU scenario. Capital and operating costs are comparable across each of the BEB options with the en-route and diesel heating scenario holding a slight advantage in both capital investment and operational cost. Although there are advantages for the en-route and diesel heating scenario, the en-route charging technology is not as mature as depot charging so there is a larger maintainability risk in the future.

It should be noted that the costs shown in **Table 6** assume that the entire fleet and facilities were converted in 2022 dollars with 2022 costs for vehicles and infrastructure. Recognizing the actual transition will occur over 10+ years, actual costs will be impacted by inflation and other factors. This will be evaluated in more detail in later phases of this study. It is also not necessary to commit to a single strategy now and a flexible plan that can adapt to technology improvements is recommended.

Cooper Terminal is where all of Stratford's transit service currently terminates and only 2.2 kms from Stratford's bus garage (see **Figure 29**). With the proximity of the garage being so close, the cost to swap buses is minimized. Furthermore, there is precedent with maintenance and operations for this, as Stratford already does this type of swap when there are issues with vehicles that are in service.

Figure 29 - Aerial photo of Cooper Terminal and Stratford Bus Garage which are 2.2km apart



5.2 PARATRANSIT FLEET

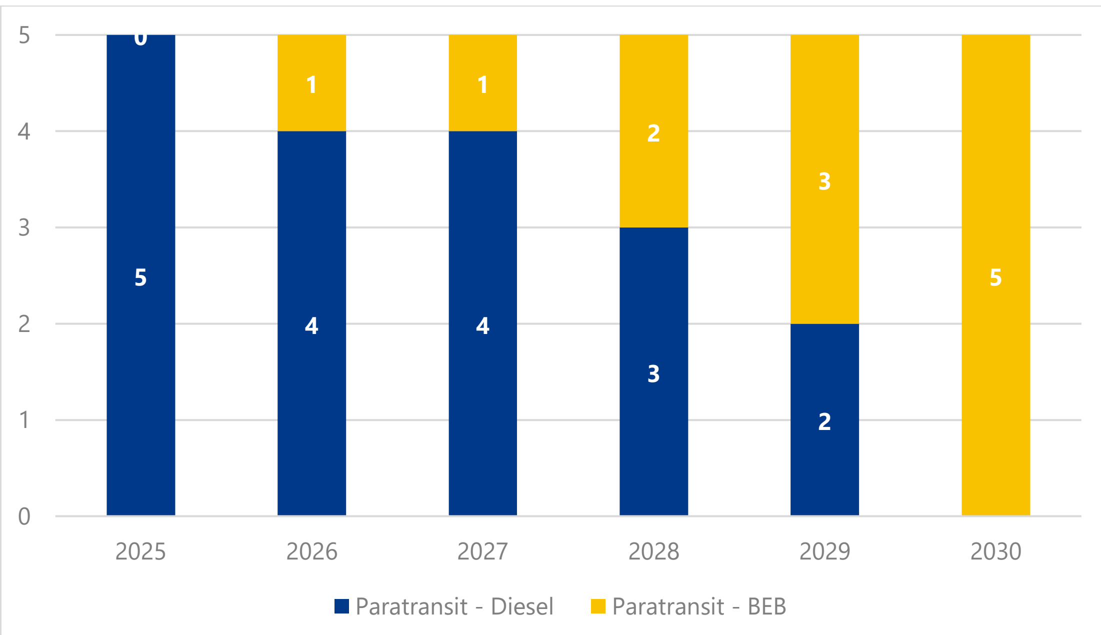
The transition of the paratransit vehicle fleet is based on the analysis of the range capabilities of a similar EV equivalent. The project procurement timelines are established based on the retirement schedule provided by Stratford where vehicles are typically replaced eight years from their production.

The composition forecast also considers Stratford's plans for purchase of hybrid models between 2025 and 2028 and plans to start transitioning to battery electric paratransit buses in 2028. The recommended yearly fleet composition of the paratransit fleet is shown in **Figure 30**.

The Lightning Electric E-450 129 is currently the only similar style mini-bus that has been Altoona tested and is avialable on the market. This model is recommended because it is the most similar in passenger capacity, physical dimensions, and range capability to the 4500 GMC, 3500 Ford CTV, and the Chevrolet 4500 and ETV. Although this model is currently the best option, other models might become available in the coming years.

Currently a one-to-one replacement is possible for current distances but fleet size increases may be required if service changes to support longer distances. Purchase of the first vehicle would occur in 2026 and their arrival would be in 2028.

Figure 30 - Paratransit Fleet Composition Forecast



APPENDIX B FACILITY ASSESSMENT REPORT

10/27/2023

DISCLAIMER

In preparing this report, HDR relied, in whole or in part, on data and information provided by the Client and third parties that was current at the time of such usage, which information has not been independently verified by HDR and which HDR has assumed to be accurate, complete, reliable, and current. Therefore, while HDR has utilized its best efforts in preparing this report, HDR does not warrant or guarantee the conclusions set forth in this report which are dependent or based upon data, information or statements supplied by third parties or the client, or that the data and information have not changed since being provided in the report.

This report is intended for planning purposed for the Client, and for Client's sole and exclusive use and is not for the benefit of any third party and may not be distributed to, disclosed in any form to, used by, or relied upon by, any third party without prior written consent of HDR, which consent may be withheld in its sole discretion. Use of this preliminary feasibility report or any information contained herein, if by any party other than Client, shall be at the sole risk of such party and shall constitute a release and agreement by such party to defend and indemnify HDR and its affiliates, officers, employees and subcontractors from and against any liability for direct, indirect, incidental, consequential or special loss or damage or other liability of any nature arising from its use of the Report or reliance upon any of its content. To the maximum extent permitted by law, such release from and indemnification against liability shall apply in contract, tort (including negligence), strict liability, or any other theory of liability.

TABLE OF CONTENTS

1 INTRODUCTION

This report identifies planned infrastructure upgrades that will be required to operate battery electric buses (BEBs) in Stratford's transit fleet. The report takes the infrastructure requirements identified in the **Appendix A: Energy Modelling Report** and determines how they would be deployed to accommodate a fleet transition. The locations of infrastructure upgrades include both upgrades to the main transit garage where vehicles are stored overnight and Cooper Transit Terminal which was identified as a prospective location for en-route charging.

The memo includes:

- A review of the current state of Stratford Transit's existing facilities (review of facility records, drawings, and site servicing plans) and fleet composition;
- A summary of the findings of an on-site visit to the Transit Garage and Cooper Transit Terminal;
- Maintenance facility considerations, constraints and opportunities for the operation and maintenance of BEBs;
- Assessment of the transit facilities in terms of power capacity and expected future load modelling with the addition of battery electric bus charging; and
- Conceptual site plans for parking and charging system layouts.

2 ENERGY MODELLING RESULTS

Task 1 of HDR's scope was to perform energy modelling of transit service to identify feasible transition pathways for Stratford to convert its transit fleet to battery electric vehicles. The results of the energy modelling for the conventional fleet of 40' buses indicated that while several options were viable, the most promising options were:

- Using a depot-charging only operational strategy that would deploy longer range battery electric buses with 525 kWh+ of on-board energy depot charging only with that can complete more than a half day of service before needing to return to the garage.
- Using a combination of depot-charging overnight with the addition of en-route charging at Cooper terminal to top-up buses throughout the day. Adding en-route charging to Cooper Terminal would be beneficial in the long term as it would avoid the need to expand the fleet to accommodate the bus swapping of buses mid-day.

A minimum of 3 x 150 kw charging stations are required to accommodate the charging needs for a transitioned conventional 40' fleet. This requirement eliminates the need for buses to cycle through charging positions throughout the night to accomplish regular weekday service with 10 buses.

For the specialized paratransit fleet, it was determined that a 1:1 conversion using charging at the depot is feasible. Each vehicle would require a 25 kW charger which means that 5 x 25 kW chargers would be required at the garage to have vehicles charged overnight.

3 FACILITIES EXISTING CONDITIONS

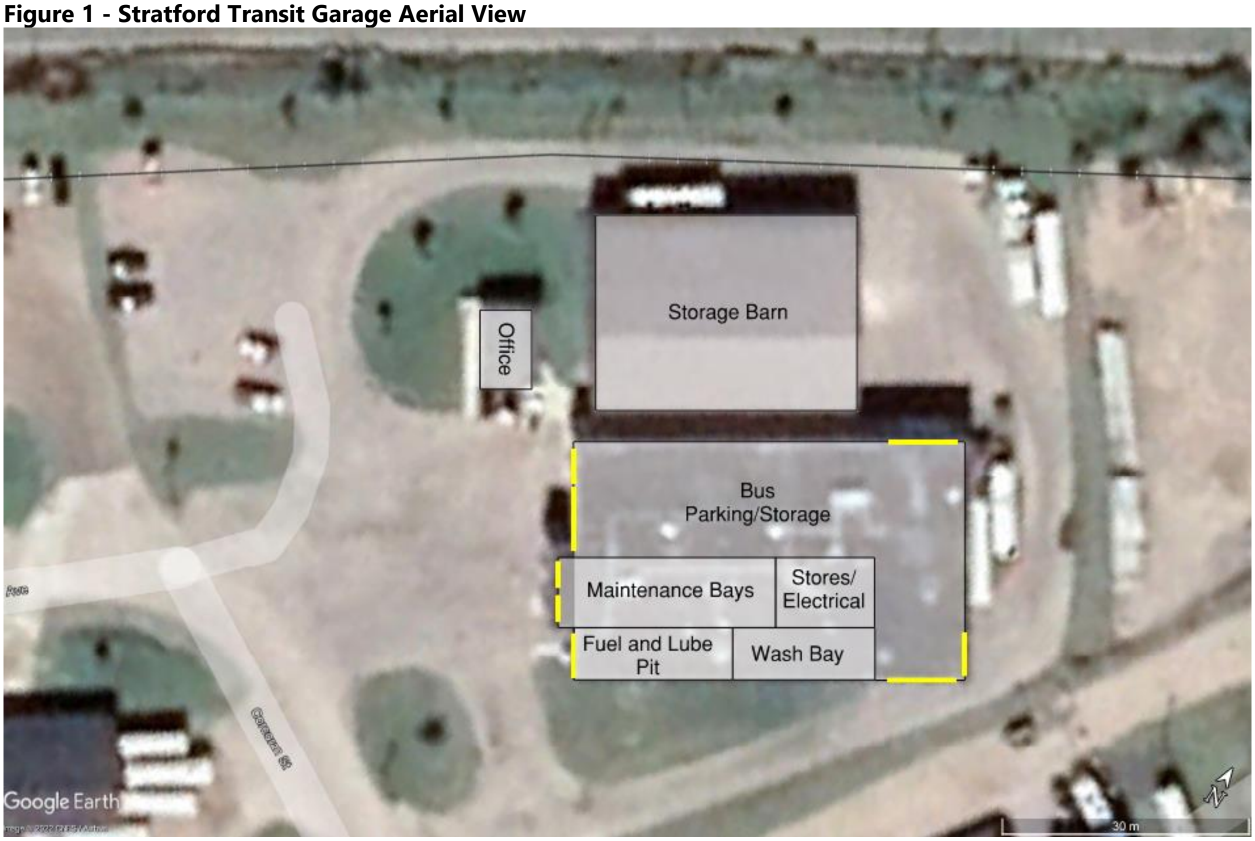
Stratford Transit's only depot facility is located at 60 Corcoran Street in Stratford, Ontario. An assessment of this facility was conducted based on a detailed review of technical drawings and plans provided by the City of Stratford, including utility, servicing, structural, architectural, and electrical single line diagrams. This assessment also included a review of Cooper Transit Terminal located at the northwest corner of Downie Street and St David Street in Stratford, Ontario; the proposed location of Stratford Transit's en-route charging infrastructure. A site visit of both locations was performed on October 24th, 2022.

3.1 STRATFORD TRANSIT GARAGE

A satellite image of the Stratford Transit Garage is shown in **Figure 1** with operations and maintenance functions labeled. This facility includes an administrative office building, (2) maintenance bays, a wash bay, a fueling and lube pit, a bus wash, a bus parking area adjacent to the maintenance area, and a storage barn in an adjacent building. Employee parking is located on the east side of the property with additional property to the north and south of the current facility with plans to develop this land.

This facility houses (15) 40' buses which are stored in the bus parking area and (5) minibus paratransit vehicles which are stored in the storage barn; there are currently no plans to expand the fleet. An overhead 27.6 kV distribution powerline is located next to the garage on Corcoran Street, this powerline currently provides power to the building through a 150 kVA transformer.

Figure 1 - Stratford Transit Garage Aerial View



The facility is at capacity and there are no immediate expansion plans for the transit garage.

3.2 COOPER TRANSIT TERMINAL

Cooper Terminal was identified as the preferred en-route charger location because it is the central hub for Stratford's transit service where all of its routes start and terminate. The location is owned by the City of Stratford. Buses currently enter and exit the terminal from Downie Street and park in a sawtooth pattern at one of eight assigned gates based on route. The Terminal is a being consideration as a potential future operational consideration and included for feasibility purposes only.

An overhead 27.6 kV distribution powerline is located South of the site on St David Street that could provide power to the site.

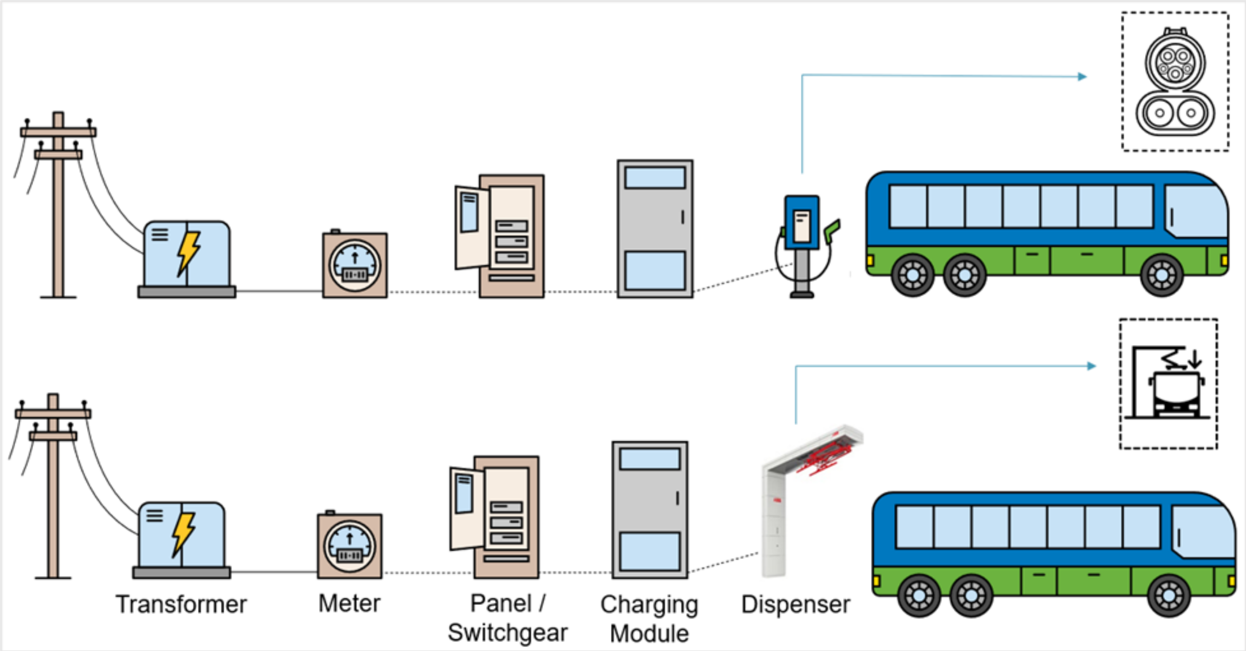
Figure 2 - Cooper Transit Terminal Aerial View

While the current terminal is very open with significant amounts of space for potential charging infrastructure, the area around Cooper Transit Terminal is a location that the City of Stratford is being considered for future development.

4 CHARGING INFRASTRUCTURE OVERVIEW

The main components for charging BEBs are the electrical equipment that feeds the chargers (service feeds, transformers, switchgear, etc.), and the electric vehicle charging module containing one or more power modules that can charge buses and dispensers that provide the means to connect the charger to the bus.

Figure 3 - Example of Equipment Required For Plug-In Or Pantograph Chargers



BEB chargers are largely connected to vehicles in one of two ways:

- A cable with a CCS1 connector (SAE J1772) for plug in charging (**Figure 4**); or
- Inverted pantograph that touches down on the charging rails mounted on the roof of the bus (SAE J3105-1) (**Figure 5**).

Figure 4 - Plug-In Charging Connector

Figure 5 - Components Of Overhead Pantograph Charging Equipment

While there are other options available such as roof-mounted pantograph-up, wireless inductive charging and others, they are either not currently available in North America or have limited adoption. The concepts presented below assume facilities are designed with CCS1 and pantograph down being the charging interface options.

4.1 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 have to plug in a cable. Some of the drawbacks are that they're heavier, the purchase cost is higher, the mechanical portion can require maintenance, vehicle alignment under the pantograph can be a challenge and interference with wireless communication between the dispenser and the bus can lead to challenges in successfully charging vehicles.

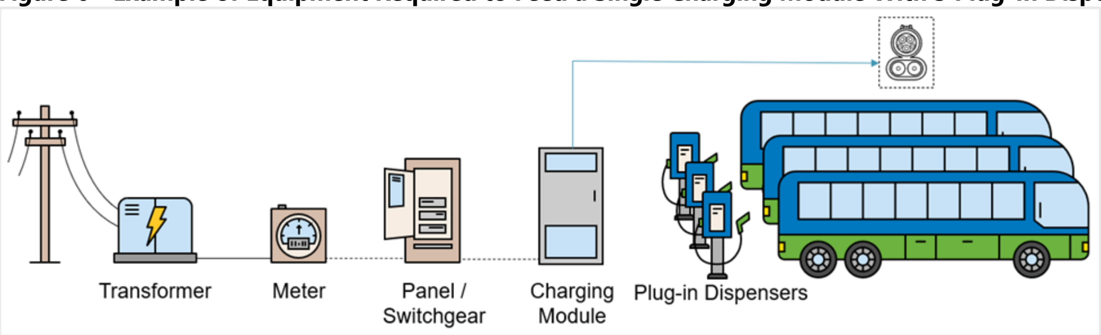
Plug-in charging has the benefits of typically being lower cost, fewer physical alignment issues, and fewer communication issues (since there is hard wired communication). The downsides are that someone must physically plug the bus in, it typically takes up more floor space (but can also be mounted to the ceiling), cable management needs to be considered, and plug-in connectors are more easily damaged.

The CCS plug-in charging standard (SAE J1772) has been around since 2011 and is a more mature standard. The first version of charging standard J3105-1 (pantograph down) was published in 2020 and some aspects of the standard are currently being refined to address some of the issues mentioned above. Several of the of the changes are to address the depot setting where pantographs are in proximity to each other and have had challenges with communication due to cross talk between wireless communication the dispenser use.

At the Transit Garage, it is recommended that there is a dispenser (plug-in or pantograph) for each bus to ensure that when the fleet is parked at night, that all vehicles can be charged without the need to circulate buses through a limited number of charging bays. It is anticipated that there will be times when a charger or dispenser be out of service due to failure or 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.

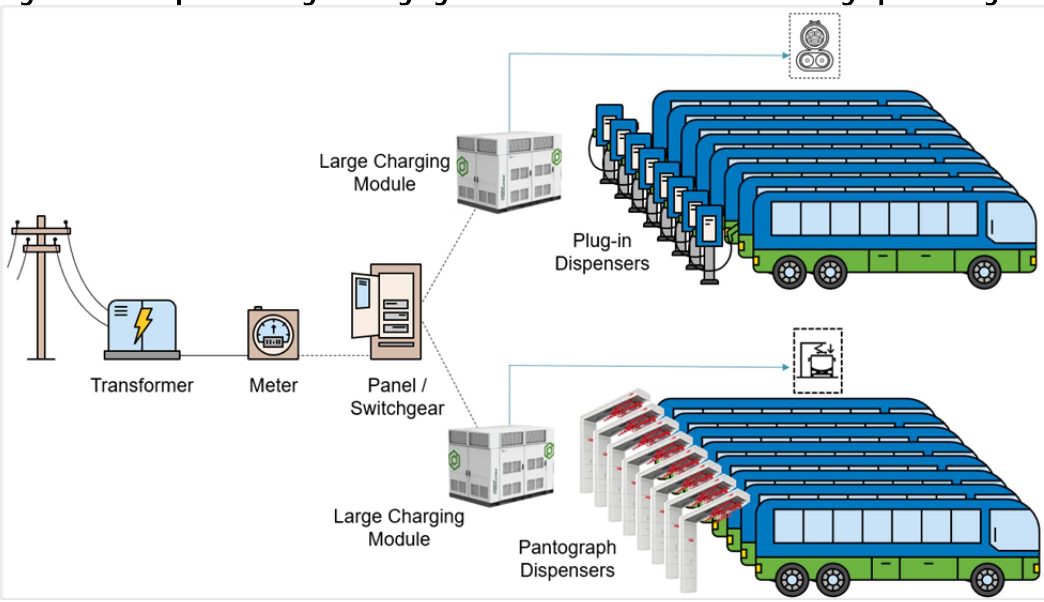
Manufacturers have products that allow multiple dispensers to be fed from a single charging cabinet. Some manufacturers achieve this through “sequential charging” where buses are put in a queue and charged individually. Other manufacturers employ “parallel charging” where power is shared between multiple connected vehicles. This infrastructure reduces the amount of charging modules required and providing multiple dispensers and charging options. Despite this advantage, the failure of a single charging cabinet can impact the charging of multiple buses.

Figure 6 - Example of Equipment Required to Feed a Single Charging Module With 3 Plug-In Dispensers



Depending on the amount of charging required, charging modules can come in different sizes with a variety of power levels. Some can serve 1-4 dispensers while some newer options offer larger charging modules that can provide charging to up to 40+ dispensers. Regardless of if it is a large charging module or multiple smaller charging modules, the same principle applies that we recommend that the number of dispensers should match the number of vehicles stored at that facility.

Figure 7 - Example of a Larger Charging Module Able To Feed Either Pantograph Or Plug-In Dispensers



4.2 PARATRANSIT VEHICLE CHARGING

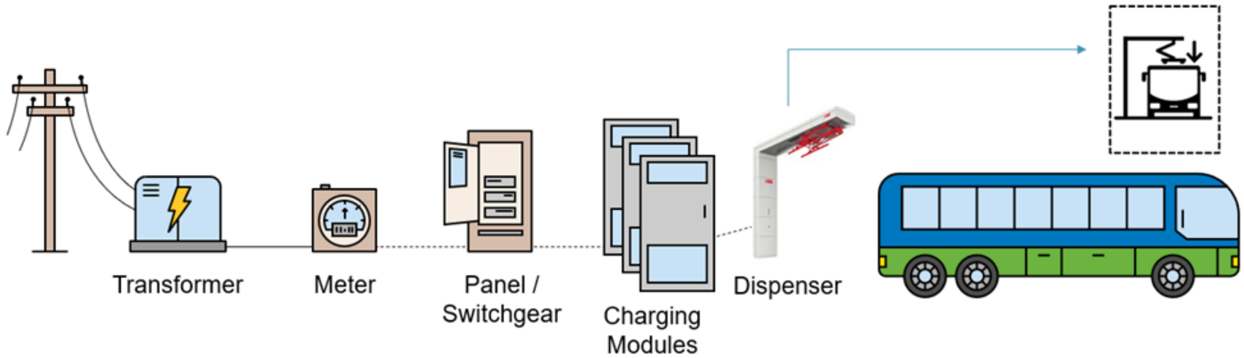
While Paratransit vehicles connect using the same CCS1 connector, they are generally smaller and have smaller batteries that cannot fully utilize the same high-powered charging that the heavy duty transit fleet can. Either lower powered charging modules or smaller wall-box style chargers can be utilized to charge these vehicles. The concept plans in this study allocate these smaller 25 kW DC wall boxes due to their more limited power demand and lower cost.

Figure 8 - Illustration of A 25 kW ABB Terra DC Wallbox

4.3 EN-ROUTE CHARGING

En-route or layover charging refers to high-speed charging infrastructure sited along a bus route where BEBs can charge during layover time (as little as 5 minutes) to regain all or a portion of their energy. Current en-route chargers are typically rated around 450 kW and may increase in the future. The current bottleneck for charging speed are the vehicles which control the charging process and limit chargers (regardless of the rating) to what the vehicle can accept.

Figure 9 - Example Of Equipment Required To Feed A Single High-Speed Pantograph Charger



Typically, all the charging equipment above 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 up to 150 metres and it is recommended that the charging modules and upstream electrical equipment be in "back of house" areas away from passengers if possible. Having them located away from passenger areas make it easier for repair and servicing without impacting service. Charging modules generate heat and noise when in operation which may not be ideal for customers. Locating charging modules in fenced compounds is recommended to avoid risk of vandalism.

The concept of en-route charging is to charge the vehicle as quickly as possible, as a result a large amount of power is required for each en-route 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 in the bay where vehicles that require charging normally stop.

4.4 CHARGING INFRASTRUCTURE CONSTRAINTS & OPPORTUNITIES

The following sections list factors that were considered when developing the concept plans. They were developed using a combination of information obtained during the site visit, information determined from site plans provided by Stratford as well as industry best practices.

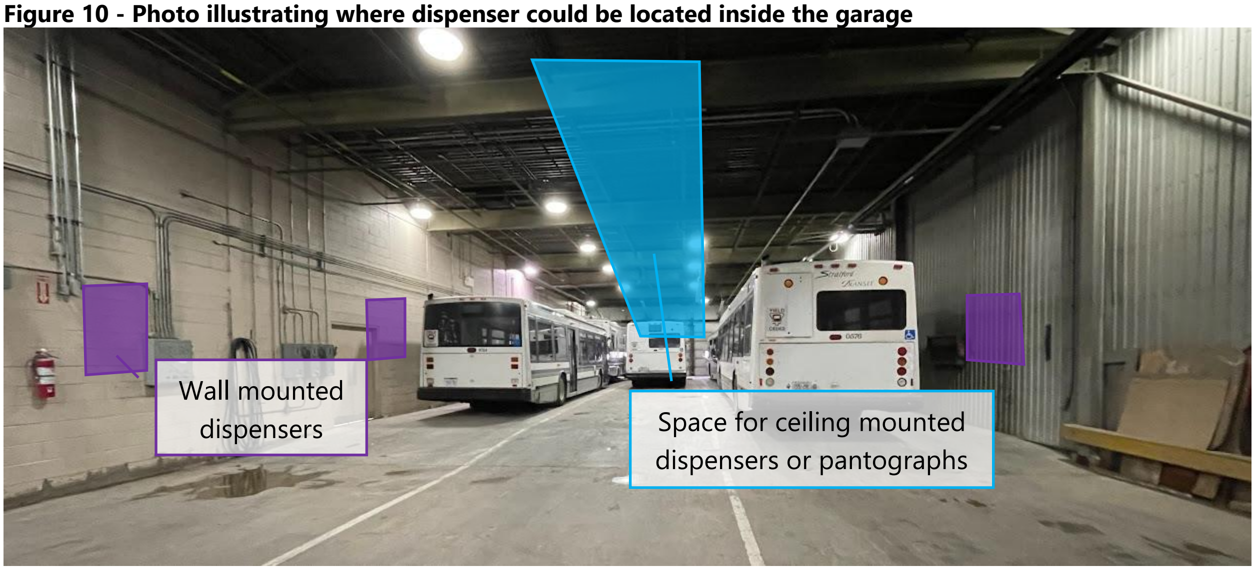
4.4.1 DEPOT CHARGER SELECTION

As mentioned above, there are currently a number of charging solutions available for use in transit applications. With limited parking in the main transit garage, selecting space efficient charging options is recommended for Stratford. Charging infrastructure that takes up space and eliminates parking spaces should be avoided. There are also opportunities to mount charging equipment (like retractable plug-in cable chargers) to the ceiling of the facility, if the ceiling is able to support the additional weight. The roof also allows for routing of conduit to feed dispensers which can avoid installation of underground conduits.

For charging in the bus parking area, wall mounted chargers are a good option for the two outer most parking bays that are adjacent to the walls; and overhead retractable plug-in cable reels could be installed for the inner parking bays. This option minimizes space requirements within the building by eliminating the need for ground-mounted dispensers and protective bollards.

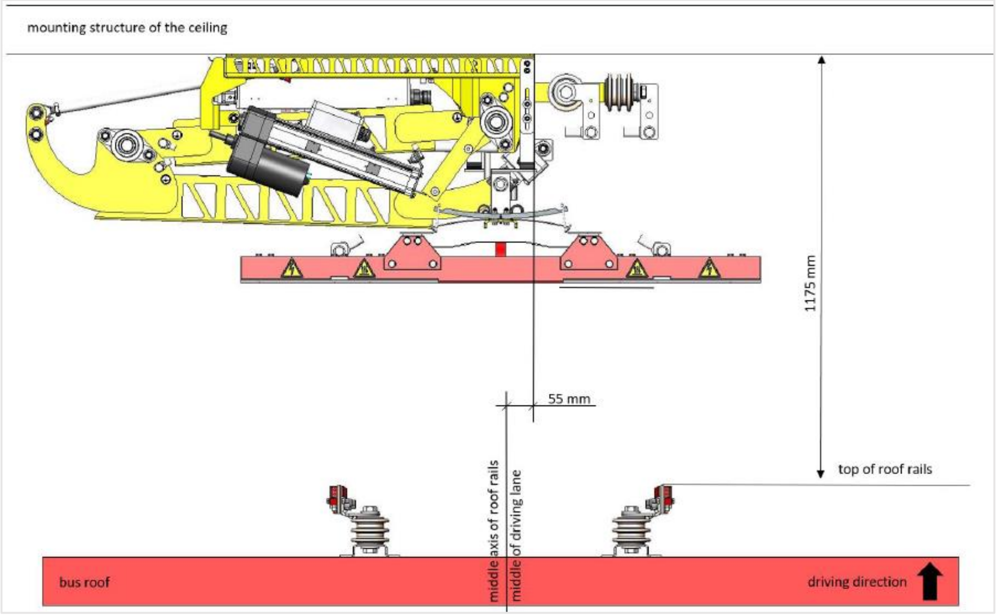
Without retractor systems, ground and wall mounted charging dispensers can create challenges if cables are left on the ground. These cables create tripping hazards and are easily damaged. Wall mounted chargers at the Transit Garage should include a retractor system that keeps cable off the ground when not in use and allow for staff to use the walkway while the vehicle is charging.

Figure 10 - Photo illustrating where dispenser could be located inside the garage



Pantographs are another option for space-saving charging infrastructure but may not be feasible at the Stratford garage due to the facility's high ceiling height. Pantographs are more particular in terms of the mounting height above the vehicle. As shown in **Figure 11**, the typical depot pantographs need to be mounted around 1.175m above the bus and because of the high ceiling in Stratford's garage, they may require a gantry or ceiling mounted structure to separate the pantograph from the ceiling to the appropriate height.

Figure 11 - Wabtec - Optimal installation position of the DepotPanto



The paratransit fleet is stored in a separate building that does not have the same space constraints as the main transit garage building. There is a significant amount of space for wall mounting of all chargers as shown in **Figure 12**.

Figure 12 - Photo of storage barn and proposed location for charging equipment

4.4.1.1 Roof Structural Loading

While there appears to be adequate physical space for either hanging of plug-in dispensers or pantograph chargers based on photos of the inside of the garage, the structural capacity requires further investigation. A detailed design should be conducted to determine the feasibility (if there is structural capacity to support the weight) of ceiling mounted charging dispensers or pantographs (with gantry or ceiling mounted structure) and where the appropriate locations are. The weights of dispensers can vary significantly by manufacturer and may limit which types of dispensers could be used.

Figure 13 - Example of wall mounted cable reel

The powered cable reels can also be wall mounted to avoid putting loads on the building ceiling which may be another option that could be considered during detailed design if the roof capacity doesn't allow for additional weight. A similar analysis of the walls would need to be done to confirm it could handle the additional load.

The table below provides information gathered from manufacturer specification sheets. Note that the cable reel dispensers have a significant advantage in terms of useable range between the dispenser and the bus:

Table 1 – Example dispenser weights and dimensions

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

4.4.2 EN-ROUTE PANTOGRAPH CHARGERS

If pantograph chargers are employed for en-route charging, it is important to have drivers correctly align the vehicle to the charger to secure a charge. A system to help drivers align the vehicles under the pantograph chargers should be employed like an indicator that drivers use for positioning. Some agencies have used markers both inside and outside the bus and/or speed bumps to help with positioning (see **Figure 14**). Considering the potential en-route charging location at Cooper Transit Terminal is located outdoors and will encounter snow, on-ground markers may not be the preferred method of positioning for Stratford. It may be preferable to use another method, like aligning the front bumper to another landmark (bus stop sign) that won't be covered by snow in the winter.

Figure 14 - Example of Alignment Markers Inside/Outside The Bus To Help Operators With Positioning

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

5 RECOMMENDED IMPLEMENTATION PLAN

5.1 STRATFORD TRANSIT GARAGE

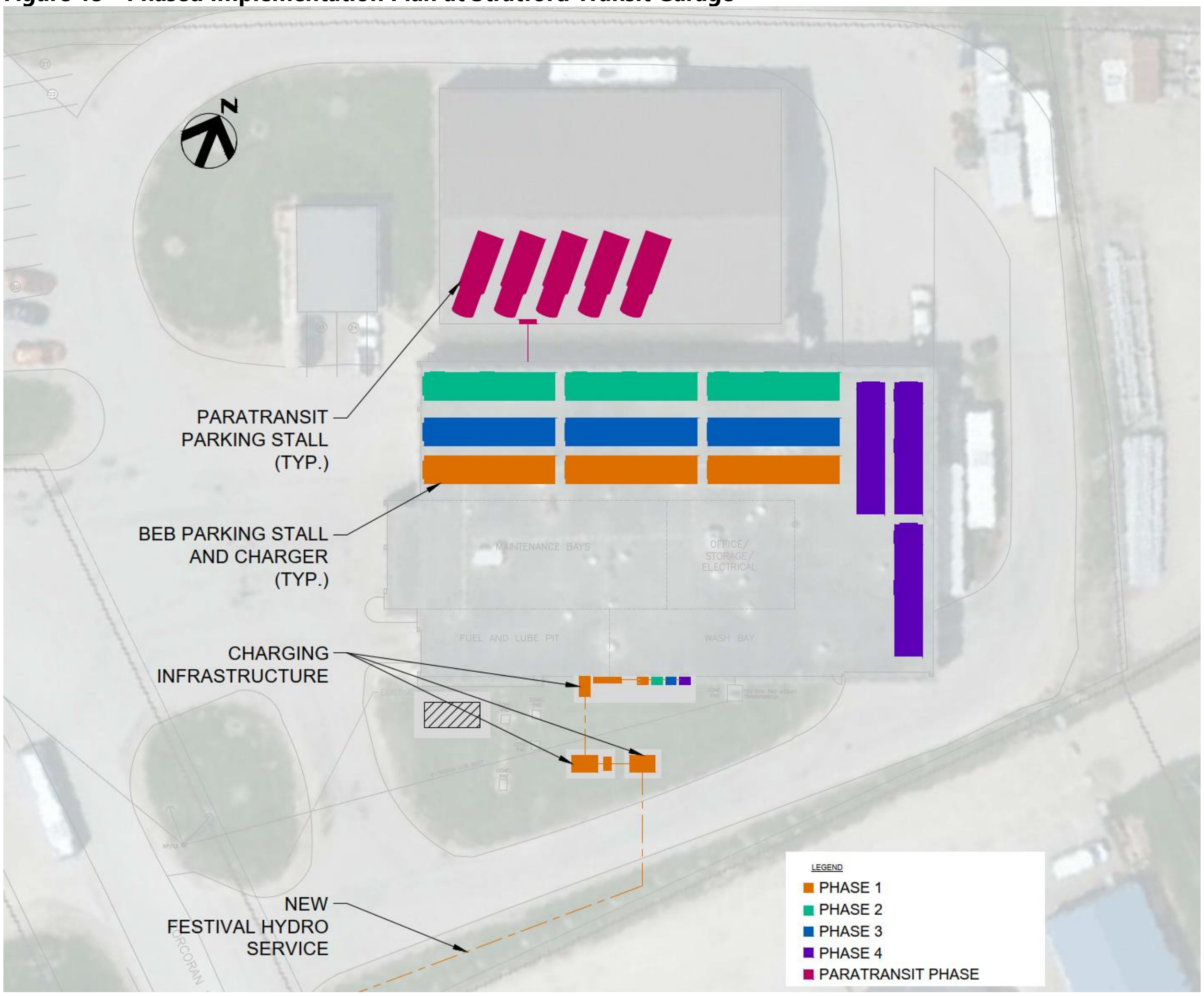
The phased implementation plan for the Stratford Transit Garage (including the storage barn) was developed based on site visits, discussions with City of Stratford staff, and the infrastructure requirements identified in the **Appendix A: Energy Modelling Report**. The Implementation Plan recommends the Stratford Transit Garage and storage barn are outfitted with charging infrastructure for the fixed route and paratransit fleets over the course of five phases (as shown in **Figure 15**). Detailed concept plans can be found in **Appendix B1**.

The fixed route fleet will be supported by (4) 150kW plug-in chargers with 3 dispensers each and the paratransit fleet will be supported by (5) 25kW plug-in chargers with 1 dispenser each. Chargers installed in Phases 1 and 2 will be wall mounted while chargers installed in Phases 3 and 4 may need to have overhead retractable cable reel dispensers or pantographs. Phase 5 will include the installation of all (5) 25kW wall mounted chargers in the storage barn.

In Phases 1 through 4 a single 150kW charger will be installed in each phase; Phase 5, the paratransit phase, will include the installation of all (5) 25kW chargers at once. Depending on Stratford Transit's capital planning, Phases 1 through 4 may be condensed or combined if additional funding becomes available. The transformers and distribution switchboard required for full buildout will be installed during Phase 1 to ensure faster implementation of chargers in later phases and avoid construction rework in additional phases. More information on utilities can be found in Facility Utility Considerations.

Note that this implementation plan is based on existing conditions, is conceptual in nature, and may change as part of a future detailed design project. A structural analysis of the roof of the building would also need to be completed during detailed design to determine if the building structure can handle the additional load of the charging equipment such as dispenser reels, and cable tray for the new wiring.

Figure 15 - Phased Implementation Plan at Stratford Transit Garage



Preliminary Cost Considerations

Table 2 shows a breakdown of costs per phase for the charging infrastructure required at the Stratford Transit Garage and storage barn. More detailed information on equipment can be found in **Appendix B1**. The estimate does not include a specific scope for facility modifications such as changes to fire suppression systems or structural upgrades as that scope is not yet defined and will need to be determined, if required, during detailed design. The 20% contingency is included to allow for the risk of some of those costs materializing during detailed design. The costs in the following table are rounded up to the nearest $10,000.

Festival Hydro provided the rough cost for the utility connection, which would be separate of the existing building feed. Their pricing includes 2 pole changes to get 3-phase service to site, the utility 27.6 kV – 600 V transformer, associated cabling from the powerline to the transformer, the meter and metering wiring equipment.

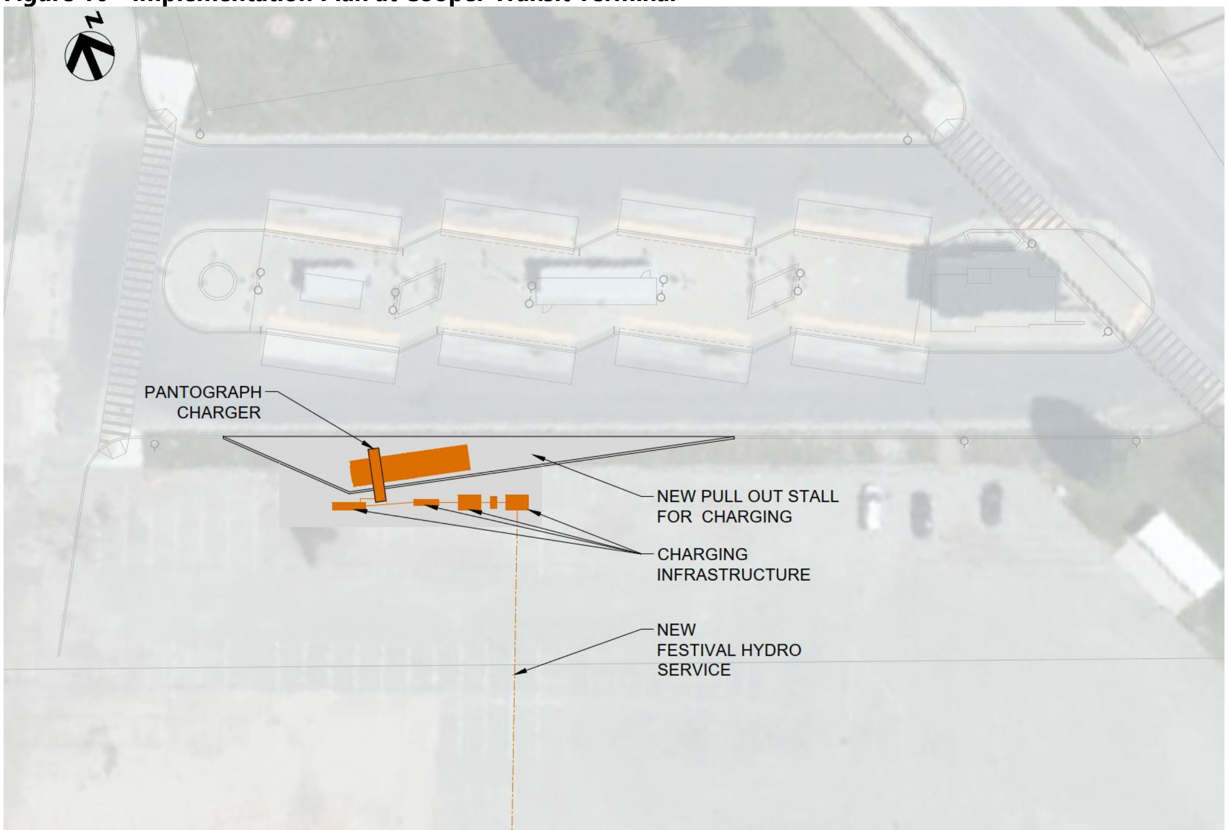
Table 2 - Stratford Transit Garage Charging Infrastructure Cost Breakdown

Description		Lump Sum Cost ($)
Utility Connection	• Powerline upgrade to bring 3-phase power to site • New power feed to site for charging infrastructure including 27.6 kV – 600 V Transformer • Cabling to transformer • Meter and Associated Wiring Equipment	$80,000
Phase 1	• Distribution Switchboard • 600 V – 480 V Transformer and cabling • Metering Cabinet and Main Circuit Breaker • 1x150 kW Chargers w/ Cabling • 3x150 kW Wall Mounted Dispensers • Underground ducting for Transit Phases 1-4 • Concrete pad for charging infrastructure	$1,360,000
Phase 2	• 1x150 kW Chargers w/ Cabling • 3x150 kW Wall Mounted Dispensers	$250,000
Phase 3	• 1x150 kW Chargers w/ Cabling • 3x150 kW Pull Down Reel Dispensers	$310,000
Phase 4	• 1x150 kW Chargers w/ Cabling • 2x150 kW Wall Mounted Dispensers • 1x150 kW Pull Down Reel Dispenser	$270,000
Paratransit Phase	• 5x25 kW Wall Mounted Chargers/Dispensers • Distribution Panelboard • Underground Ducting and Cabling	$190,000
Total Infrastructure Cost		**$2,400,000**
Engineering Costs (4%)		$100,000
Contingency (20%)		$490,000
Grand Total		**$3,030,000**

5.2 COOPER TRANSIT TERMINAL

If Stratford Transit installs an en-route charger at Cooper Transit Terminal to support the fleet and provide supplemental opportunities to charge during layovers and extend the operational range of BEBs. A single 450kW pantograph charger should be installed attached to a mast arm in a new stall on the outer edge of the island as shown in **Figure 16**. The inclusion of a new pullout will allow for bus parking that does not impede normal traffic flow at the facility; a detailed concept plan can be found in **Appendix B1**.

Figure 16 - Implementation Plan at Cooper Transit Terminal



As Stratford noted that the area around the Cooper Transit Terminal is being considered for future development, any plans for space adjacent to the site should include space provisions for power feeds and charging equipment that may be required in the future. As previously noted, this location for en-route charging is a future operational consideration only and is being assessed for feasibility.

5.2.1 PRELIMINARY COST CONSIDERATIONS

Table 3 shows a breakdown of estimated costs per phase for the charging infrastructure required for full build out at Cooper Terminal and includes all material and commissioning costs for the transit infrastructure. More detailed information on equipment can be found in **Appendix B1**. The 20% contingency is included to allow for the risk of some of those costs materializing during detailed design. The costs in the following table are rounded up to the nearest $10,000.

Festival Hydro provided the rough cost for the utility connection. Their pricing includes the utility 27.6 kV – 600 V transformer, associated cabling from the powerline to the transformer, the meter and metering wiring equipment. If the power is fed from St. David Street as shown in the drawings, CN railroad tracks will need to be crossed, Festival Hydro was not able to provide a specific cost estimate for this type of work from past projects. Festival Hydro recommended that an additional $20,000-$30,000 should be budgeted to cover permitting and flagging based on recent overhead work completed. CN was not contacted to provide an estimate at this time.

Table 3 - Cooper Transit Terminal Charging Infrastructure Cost Breakdown

Phase		Lump Sum Cost ($)
Utility Connection	- New power feed to site for charging infrastructure including 27.6 kV – 600 V Transformer - Cabling to transformer - Meter and Associated Wiring Equipment	$65,000
CN Railroad Crossing	- Additional costs associated with crossing the railroad tracks	$30,000
Charging Infrastructure	- Distribution Switchboard - 600 V – 480 V Transformer and cabling - Metering Cabinet and Main Circuit Breaker - 1x450kW Chargers w/ Pantograph and cabling - Underground ducting - Concrete pad and new bus pullout	$1,790,000
Total Infrastructure Cost		**$1,880,000**
Engineering Costs (4%)		$80,000
Contingency (20%)		$380,000
Grand Total		**$2,340,000**

6 UTILITY COORDINATION

It is crucial to begin conversations early with the utility serving the electric chargers. The utility infrastructure costs, and construction lead times can sometimes be neglected until late in the project and cause issues for transit agency budgets and schedules. Understanding electrical tariffs is also an essential part of planning for a transition to BEBs.

6.1 FACILITY UTILITY CONSIDERATIONS

Both the Transit Garage and Cooper Terminal can be provided as secondary services from the utility. During the utility discussion, Festival Hydro informed the consultant that they can provide a 600 Volt (V) secondary connection but cannot provide a 480 V secondary connection. Currently most EV charging infrastructure is designed to operate at only 480 V which is commonly used in the US. This means that a separate 600 V to 480 V transformer will need to be purchased by the transit agency to step down the voltage to 480 V for the chargers.

Currently few EV vendors offer 600 V equipment rated for Canada, but this may become more standard for companies in the coming years. Buying 600 V equipment would lower the overall charging infrastructure footprint and cost as this removes the need for a step-down transformer to be installed on each site. Currently the design package shows a step-down transformer at each site to illustrate a worst-case scenario for each site.

Based on the discussions with the utility and the results from the Energy Modelling Memo recommending a phased transition, a facility utility analysis is presented below.

6.2 PRIMARY AND SECONDARY METERING

Typically, utilities provide service connections to clients either as primary or secondary metered services. Festival Hydro provides a maximum service size of 1,500 kVA for secondary metered connections, larger services require primary metered connections.

For a primary metered service connection, the utility brings power to the client at distribution and transmission voltage. The client is responsible for designing, constructing, owning, operating, and maintaining a substation 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 typically comes with a per kwh discount. 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 stepdown transformer owned and maintained by the utility that reduces the voltage from the primary distribution voltage to a standardized lower voltage, either 600 V three phase, 208 V three phase, or 120-240 V single phase. With a secondary metering service, a utility meter is then installed downstream of the transformer. Secondary services are preferred because they are less expensive and maintained by the utility but are limited to a maximum service size that is determined by each utility.

Utilities have different billing rates and structures for primary and secondary services with primary service being less expensive since the customer is responsible for owning and operating the infrastructure.

6.2.1 TRANSIT GARAGE

An overhead 27.6 kV distribution powerline is located next to the garage on Corcoran Street, this powerline currently provides power to the building through a 150 kVA transformer. Preferably, the power for the charging infrastructure would come from an independent underground service from the same distribution power line on Corcoran Street as a secondary metered connection. Power delivered to the charging fleet would be fed from a 1000 kVA 27.6 kV to 600 V pad mounted transformer supplied by the utility, a second 1000 kVA 600 V to 480 V pad mounted transformer owned by the transit agency will need to be installed to step down the voltage for the EV charging equipment. All transformers and distribution equipment will be installed as part of Phase 1 with capacity allocated for Phases 2 through 4. Each phase will have a 150 kW DC fast charger installed with 3 dispensers each which will be used to sequentially charge 3 buses.

6.2.2 COOPER TRANSIT TERMINAL

An overhead 27.6 kV distribution powerline is located South of the site on St David Street that could provide power to the site. A 750 kVA 27.6 kV to 600 V pad mounted transformer supplied by the utility and a customer owned second 750 kVA 600 V to 480 V pad mounted transformer will need to be installed to step down the voltage for the BEB charging equipment. Since there is only one en-route charger recommended, the charging infrastructure would be installed at once with a single 450 kW pantograph charger fed from the transformer.

Stratford also noted that there are plans to further develop the area around the Cooper Terminal. As those plans move forward, Stratford should ensure that they coordinate with Festival Hydro and the developer to ensure that electrical capacity and physical space is planned for any future en-route charging equipment.

6.3 REDUNDANT FEEDS

For critical infrastructure, 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 by the same substation off a different circuit and power line, or by a separate substation and powerline.

If the redundant feed comes from the same substation and a different circuit this only protects the site from an outage on one of the powerlines, such as a tree falling on the powerline or a pole breaking. In the event of an outage at the substation, both feeds would also experience an outage. 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 powerline would need to be brought to the site from the nearest location which is expensive. A separate circuit could also be added from the existing powerline feeding the site. However, this is not very practical as it would only provide a redundancy for the run of cables leaving the powerline going to the site and does not provide much benefit. Since typically any outages along one of the powerlines would cause both circuits to trip.

A redundant feed from a separate substation provides the most robust utility feed for the site. However, this is also the most expensive option as substations are rarely geographically close to each other, requiring new powerlines to be installed which is extremely costly.

Except for very specific scenarios when there are already nearby substations or secondary circuits to the site, redundant feeds are not recommended as there are more cost-effective alternative power sources that can be utilized such as diesel generation or battery energy storage systems that also provide a better redundancy since they are entirely separate from the power grid.

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. In the utility discussion meeting, Festival Hydro said that a redundant feed could not practically be brought to the bus garage.

6.4 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 utility discussions with Festival Hydro, they indicated that their un-regulated branch currently has no similar offered services for charging equipment leasing but would be open to discussing arrangements where they could own/operate infrastructure. Further discussion between City of Stratford and Festival Hydro are recommended to understand how they could partner.

6.5 UTILITY RATE CONSIDERATIONS

Electrical costs are determined based on the utility's (Festival Hydro) 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.[1] 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 delivery like delivery, regulatory and global adjustment charges.

Given its current fleet size and expected electrical demand, Stratford is a Class B customer. There are three basic components that make up energy costs in a given monthly billing cycle:

[1] Hourly Ontario Energy Price, [Hourly Ontario Energy Price (HOEP) (ieso.ca)]

- Monthly Service Charges – These are base charges, assessed monthly that are included for every meter location.
- Energy Consumption Charges – These are charges that are based on the quantity of electrical energy consumed over a monthly period. These charges are based on the kWh that are used and the rate may include taxes, delivery, transmission and global adjustment fees.
- Demand Charges – These are charges that are based on the highest electrical demand observed over the billing period. Demand is measured in kilowatts (kW) and is based on the highest kW level drawn in each month. This can be thought of as high-water mark type charge where once peak demand is reached once in a month, there are no additional costs for having any demand levels that are at or below that level.

6.6 APPLICABLE UTILITY CHARGES

The projected fleet charging loads are expected to be in the General Service Business Class greater than 50 kW but under 4,999 kW.

Stratford currently purchases electricity through a third-party called Local Authority Services (LAS) at a fixed rate. LAS is a non-profit corporation that allows municipalities in Ontario to purchase power at a fixed rate that is hedged and does not include any time-of-use charges. They pay a fixed per kWh rate and which does not have charge associated with peak electrical demand based on the billing information provided. With increased electrical demand due to charging infrastructure Stratford will be above the 50 kW demand threshold which may move it into the tariff classification listed above. It is likely that Stratford Transit would begin to pay a tariff that would factor in demand, though it is anticipated they would remain a Class B customer. More information on Festival Hydro's commercial rates can be found one their website (Commercial Electricity Rates | Festival Hydro).

6.7 CHANGING UTILITY RATE STRUCTURES

Increasing electrical demand (in part due to the transition of fleets and building systems to clean electricity) is changing how some utilities structure their rates. Below are examples of ways utilities in North America have structured their rates to facilitate increasing demand. This is mainly to highlight how rates may change in the future.

6.7.1 SEASONAL CONSIDERATIONS

Some utilities, including Festival Hydro (for residential and small-business customers) charge different rates during the summer and the winter. Some utilities vary both the demand and energy charges. In Ontario, commercial customers pay the HOEP + GA and seasonal considerations are already included in the fluctuating rates that are paid.

6.7.2 TIME OF USE (TOU)

Some utilities vary rates during different times of the day, often in a three-tiered structure. Utilities can often charge a peak rate, during the middle of the day when energy consumption is highest to decrease this peak usage. Shoulder periods, often one to two hours before and/or after the peak periods are billed at a slightly lower rate, while off-peak consumption is rewarded with the lowest rate. Off-peak periods are generally overnight and coincide nicely with bus depot charging needs.

Festival Hydro doesn't currently offer time of use rates for the projected service size and instead requires that consumers pay the HOEP+GA as a Class B customer or purchase electricity through a third party. If it were offered to Stratford, a time of use rate structure would provide an opportunity for the transit agency to plan some of its electrical usage (like depot charging) to take advantage of overnight off-peak rates to handle a majority for the charging.

While the charging at the depot can be postponed and scheduled to take advantage of TOU rates, en-route charging requires that energy be used all-day during service. With TOU rates, en-route charging may become a more costly option as more of the energy consumption would likely land in the more expensive tiers.

6.7.3 ELECTRIC VEHICLE (EV) CHARGING RATES

Some utilities have elected to incentivize EV adoption by reducing demand charges to decrease the overall operational cost of ownership. Some of these EV rates are temporary, though the utility may elect to keep these indefinitely. Festival Hydro does not currently offer an EV rate applicable for the level of electrical service that's required.

In the upcoming months, the OEB will be unveiling an "ultra-low" overnight rate for residential and small business customers. However, it is not clear if this rate will be applicable for the transit fleet.

6.8 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. The current conceptual designs presented for Stratford employ separate meters and utility feeds for the EV charging equipment.

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 so that transit agencies can track vehicle energy costs like they do for fuel today. Utility tariffs are also constantly changing and if an EV charging tariff were to become available in the future, the separate metering would enable an easier transition into that rate.

Another reason this is preferable is that different departments within the transit agency are responsible for different expenses, such as bus operations for charging versus administration for building electrical and outside lighting. Separate meters or sub-meters will allow the agency to understand how much of their energy costs are going to move the fleet compared to normal building loads.

6.9 SOLAR ENERGY GENERATION RATES

Many utilities have elected to incentivize adoption of solar photovoltaic (PV) systems by adopting special rates for purchasing solar energy. This is only applicable for PV systems installed in a net metered arrangement, where the solar PV system directly offsets electricity usage from the utility, and the utility buys any excess energy generated by the PV system. This only occurs when the PV system generates more power than the site is demanding.

Currently, Festival Hydro does not purchase surplus energy generated in a net metering agreement. However, they do permit the accumulation of credits for up to 12 months if a site generates more electricity than it consumes in a month. Festival Hydro purchases these credits back using the same rate structure that the energy is bought during the billing cycle.

The amount of electricity consumed by the facility with a fleet of BEBs is typically much more than what is generated from a rooftop solar system in Canada. The challenge is that solar generation is highest during the day when most buses are on the road and in service. The benefit of net-metering is that when buses are out in service during the day the transit agency is able send that energy into the grid to get a credit for that generation then use the grid at night to charge the buses back up. This net-metering credit system allows transit agencies to deploy solar generation that doesn't align with consumption without needing to store it in something like a battery energy storage system.

7 OTHER CONSIDERATIONS

7.1 FLEET AND CHARGER MANAGEMENT SYSTEMS

7.1.1 CHARGE MANAGEMENT SYSTEM

It is recommended that any charging equipment procured come with a system that enables the operator to remotely know the status of a charging session, log error codes and reset equipment. Manufacturers typically offer a proprietary system with their equipment that requires an annual subscription and can require internet connection/cell connection as well as a computer with internet access to access any dashboards through a web browser.

Manufacturers also use these connections to their equipment to troubleshoot issues remotely and push software updates that may be required to resolve issues or upgrade functionality. The information available and capability of charge management systems varies by manufacturer, so it is important to understand the differences of what's being offered and if it meets the organization's needs.

Most charging station manufacturers design their equipment to be compatible with Open Charge Point Protocol (OCPP) which allows for third party software to be able to monitor and manage infrastructure as well. One of the advantages of third-party software providers is that they are typically able to manage multiple equipment vendors in a single platform which may be desirable in a situation where the en-route charger is not the same manufacturer as the depot chargers. Some also offer additional functionality beyond charge management and provide information on dispatching and on-board telematics systems.

7.1.2 ENERGY MANAGEMENT SYSTEM

With electricity becoming the new fuel for the fleet, energy consumption will significantly increase. Transit agencies will become much more sensitive to changes in electricity rates and tariff structures. Having the capability to manage when vehicles are charged that matches with a given electricity tariff can significantly reduce energy costs. Manufacturers are now offering energy management systems with the capability to manage electrical loads such as EV charging stations and/or incorporate other distributed energy resources at the appropriate times to help reduce those costs. Having an energy management system with the ability to control both charging stations and distributed energy systems in a coordinated way to reduce electricity costs will allow flexibility in the future.

7.2 GENERAL FACILITY CONSIDERATIONS

7.2.1 MAINTENANCE BAY CHARGING

While it's not envisioned that vehicles will necessarily be regularly charged in maintenance bays, there may be times when having some charging capability in the maintenance bays would be helpful. For instance, if there's a charging issue with a given vehicle it may be helpful to have it in a maintenance bay to diagnose that problem.

Portable chargers are available that could be shared between maintenance bays and deployed as needed. They would require appropriate power for the equipment be brought to the maintenance bays which could be connected by a Mennekes connection and moved between maintenance bays as needed.

7.2.2 VEHICLE ROOFTOP ACCESS PLATFORMS

BEBs have a significant amount of equipment mounted on the roof of the vehicles including electrical converters, battery packs, charging rails that will require service and/or troubleshooting. Fall protection systems will need to be in place that 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 without the need for personal fall protection equipment. Stratford does not currently have work platforms for accessing rooftop equipment. With a deployment of battery electric buses, capacity to work on the roof of buses will be important and will increase the volume of work requiring this type of equipment. Portable or permanent scaffolding should be considered as the agency becomes more familiar with maintaining BEBs.

7.2.3 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/replacement. The capacity of cranes attached to the roof should be checked against the heaviest equipment the manufacturer expects will need to be moved on or off the roof of the vehicle.

7.2.4 SPARE PARTS STORAGE

Having and adequate supply of spare parts that will be unique to the battery electric buses and charging infrastructure is something that is recommended. With fewer vehicles on the road compared to 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.

7.2.5 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 and vary by manufacturer and battery pack configuration.

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 require that lighter vehicles be purchased or consider if modifications could be made to the existing foundation.

To evaluate the vehicle hoist capacity, the actual weight of vehicles purchased should be compared to the hoist capacity at the transit garage to ensure that the current equipment is capable of safely lifting the vehicles. Weight distribution of battery electric vehicles 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.

7.2.6 OVERHEAD CLEARANCE

Areas like garage doors and wash racks can often be the lowest clearance points at transit facilities. The current garage doors are 12' (3.65 m) which is adequate for the models listed below. Photos from the site also confirm that the overhead clearance of the garage should not be an issue as there appears to be a significant amount of clearance for the existing Nova Buses.

Figure 17 - Photo illustrating existing garage door clearance

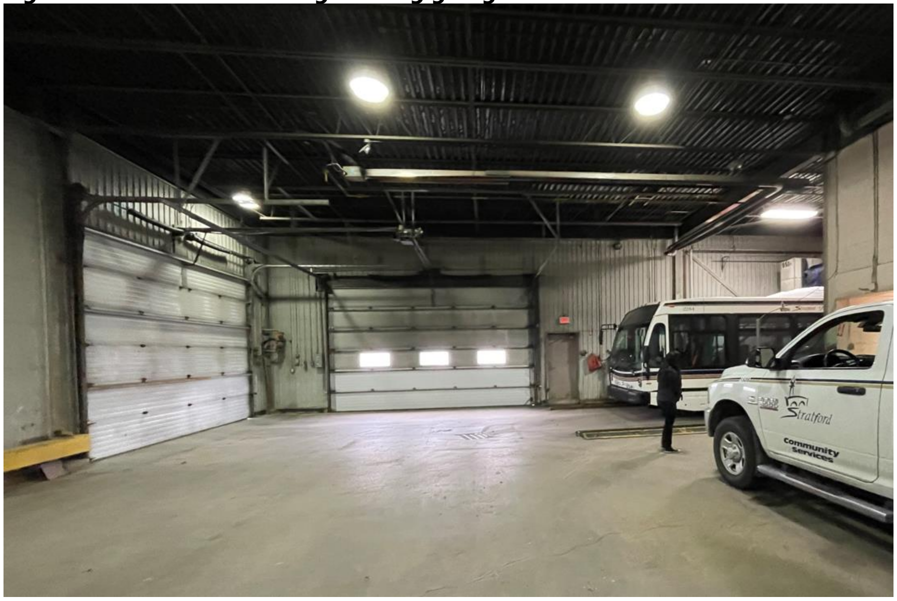


Table 4 shows the vehicle heights of current diesel and battery electric transit buses. While there is some variation between OEMs, the height of the vehicles are generally similar regardless of fuel type and does not exceed the current overhead clearance for garage doors.

Table 4 - Bus Height

Propulsion	Manufacturer	Model	Height
Diesel	Nova	LFS	3.20 m
Battery Electric	Nova	LFSe+	3.30 m

Diesel-Hybrid	New Flyer	Xcelsior Hybrid	3.30 m
Battery Electric	New Flyer	Xcelsior Charge NG	3.38 m
Battery Electric	Proterra	ZX5 Max	3.29 m
Battery Electric	BYD	K9MD	3.40 m

The maximum clearance of the bus wash should be checked against the intended vehicle being purchased to ensure that modifications or replacement of the bus wash are not required but seeing as there is not a significant difference in height, it's not expected to be an issue for any manufacturer. In addition to vehicle clearance, installation of pantograph chargers also requires a sufficient distance between the retracted pantograph and the roof of the vehicle. A detailed design would be required to determine if clearance would be adequate for overhead pantograph charging since the mounting location and pantograph model would need to be known.

7.3 SOLAR & 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 facilities will assist in determining potential benefit for Stratford Transit. This report will address the feasibility of implementing the below energy resources but will not address the economic viability; economic viability will be addressed in the final full report.

7.3.1 SOLAR PHOTOVOLTAICS (PV)

Solar PV provides a scalable choice for energy generation and produces no emissions or noise. Over the past decade solar PV has become more reliable and lifetime maintenance requirements have reduced. Solar PV requires a large area/footprint to achieve large power output and is subject to fluctuations in solar irradiance. Given the use case, solar PV could be expanded on the overhead canopy of the fleet maintenance building, provided there is structural capacity for charging infrastructure in addition to the weight of added PV panels. The overall solar PV system can be scaled depending on the available space or module size but may be subject to fluctuations depending on module tilt and azimuth angles.

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 also dependent on the bus charging schedule. A solar installation will have a greater impact if more of the charging occurs during peak solar generation hours. However, with the addition of net-metering or on-site energy storage, solar energy can be utilized even if the bus charging load is less than PV output during some daylight hours.

7.3.1.1 Solar Generation Analysis

As part of this study, a solar generation analysis was performed using PVWatts® Calculator, 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 results of the solar generation analysis represent a best case scenario and may differ from the installations currently installed at the depot facility by assuming the panels will be cleared of snow and have a denser installation of panels for the same given area than the current installations. The analysis for this project does not factor the structural limits of the roof and assumes the roof can handle the additional weight of the solar installation.

PVWatts® Calculator was used to estimate the solar energy that could be generated at each of the sites. 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 results generated by PVWatts® represents a best-case scenario and assumes the panels will be cleared of snow during winter months. The analysis for this project does not factor the structural limits of the roof and assumes the roof can handle the additional weight of the solar installation.

Neither of the sites covered in this report have existing PV installations, other municipalities have contracts with their local unregulated utilities to own and operate the PV system, with roofing space leased by the transit agency. This type of arrangement could be further discussed during later stages of the project if a PV installation is of interest to both parties. A PV installation would be connected to the grid as net-metering where any excess generated energy not used by charging infrastructure or building loads would be sold back to the utility.

7.3.1.2 Stratford Transit Garage

Two scenarios for the Stratford Transit Garage were analyzed to estimate the potential energy that could be generated at the facility.

7.3.1.2.1 Scenario 1: Bus Maintenance Building Rooftop Solar

The first scenario would be to cover the entire roof space of the garage with solar panels. This is shown in the image below with an estimated yearly generation of 250,017 kWh.

Figure 18 - Scenario 1 Rooftop Solar Layout at Stratford Transit Garage

7.3.1.2.2 Scenario 2: Bus Maintenance Building and Storage Barn Rooftop Solar

The second scenario covers the same area of the bus maintenance building with the addition of the adjacent Storage Barn. This could be implemented as an addition of panels over the garage. The proposed solar panels are shown as the enclosed space of the image below with an estimated yearly generation of 408,098 kWh.

Figure 19 - Scenario 2 Rooftop Solar Layout at Stratford Transit Garage

7.3.1.3 Cooper Transit Terminal

To add solar panels to the terminal, an overhead gantry would need to be constructed over the island of the bus pull-out for the panels to be placed on. The construction of the gantry adds significant complexity for adding a PV system to this site. The proposed solar panels are shown as the enclosed space of the image below with an estimated yearly generation of 203,674 kWh.

Figure 20 - Enclosed Area Shows the Additional Coverage Of Solar Panels For The Site

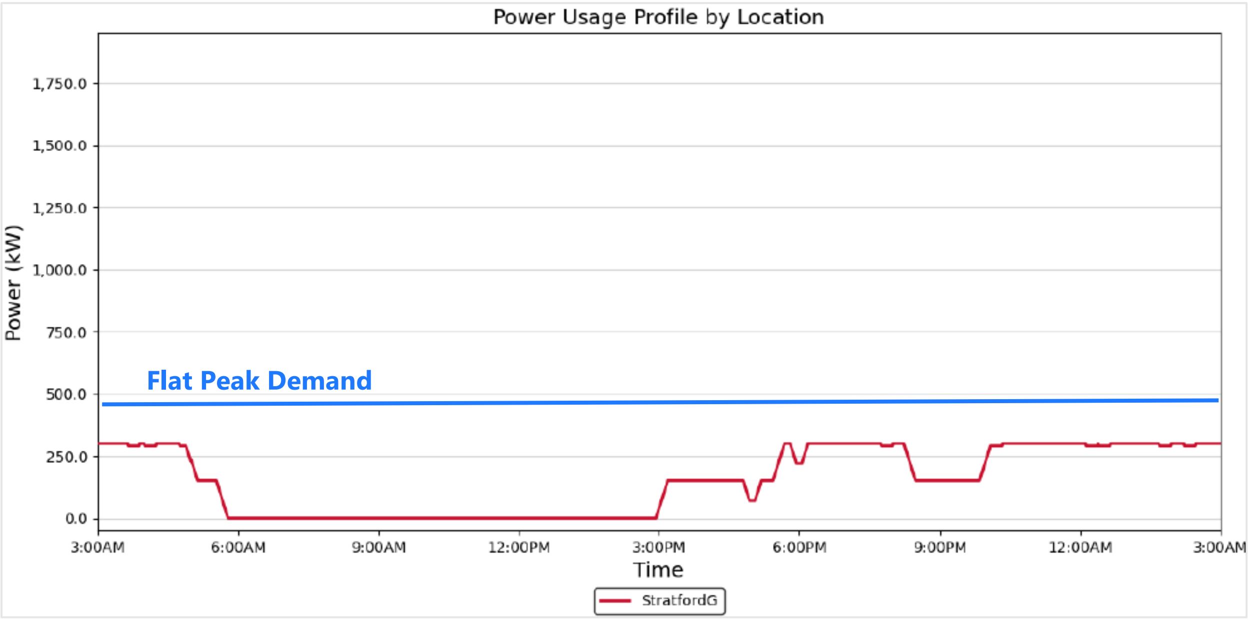
7.3.2 BATTERY ENERGY STORAGE SYSTEM (BESS)

Energy storage devices can play a critical role within a microgrid or distributed energy resource (DER) system. Although energy storage systems 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 typically the most prominent and mature technology for distributed scale systems and microgrids. BESS systems are scalable and can help provide a greater sense of resiliency for a more renewable focused system but typically come at a relatively high installation cost and may experience degradation in energy capacity over the system’s life.

For transit bases, BESS systems are typically utilized for shifting load and/or generation 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 and duration 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 style. Systems of this nature are generally modular and flexible in terms of system size with footprints ranging from 8′ x 12′ upwards to 40′ x 8′ (40′ ISO containers).

For Stratford, the modelled electrical demand profile of charging (with a charge management system) already flattens the demand to be at a consistent level throughout most of the day. There are not any peaks that would be avoided by incorporating a BESS. Because of this relatively flat demand profile and there not being a need to time shift the load, it's not recommended that a BESS be used with the current tariff structure.

Figure 21 - Stratford Garage Zero+ bus charging electrical demand profile



7.4 RESILIENCY

There are several different systems or strategies that could be utilized to create a more resilient and reliable system for Stratford's Transit service. Some involve installation of additional infrastructure while others are potential operational strategies that could reduce or mitigate risks which may impact service. Each method provides different levels of support for the fleet and its infrastructure thus increasing the overall system resiliency.

While the electric utility will never be able to maintain a system that provides power 100% of the time to every customer, customers of utilities that have reliable electrical feeds may not require the same types of infrastructure as places that experience frequent or long power interruptions. Some improvements on the utility side can also increase reliability to an area or a single customer. Stratford Transit must balance the operational risk and costs with the resiliency and reliability needs.

7.4.1 GRID RELIABILITY

Before considering adding additional infrastructure to mitigate power outages, it's important to understand the context as to how many outages typically occur and how long they last. Short duration outages (less than an hour) will have minimal impact on operations whereas sustained outages (over one hour) would be more likely to cause a disruption to the service provided by the transit agency. If sustained outages are more common for a facility, a backup power source should be considered for the facility to limit the impact of outages on the transit network.

Upon HDR's request, Festival Hydro was able to provide information on the outage frequency and duration of outages for the circuit that provides power to the Transit Garage for five years, between 2017-2021. Information was not provided for 2022, since planned outages to improve infrastructure were performed that year that would skew the outage time averages. Based on the information provided, it can be noted that the Transit Garage has a very reliable service history. The Transit Garage averages three extended outages per year with an average yearly outage time of 2.5 hours, excluding a few yearly momentary outages which would that have a negligible impact on charge time.

7.4.2 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.

7.4.2.1 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, Stratford Transit should request redundant distribution feeders be fed from separate substations or at the least from separate substation transformers.

7.4.2.2 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:

- Does the charging infrastructure 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, consider utilizing sources from a single substation but from separate transformers within that substation.

7.4.3 INTERNAL COMBUSTION ENGINE (ICE) GENERATION

More traditional generation methods usually include combustion turbines and internal combustion engine driven generators. Both technologies are proven to be effective at both a large and distributed scale for main power generation or backup power. Typically, combustion turbines have a larger power output (500 kW to 25 MW) but can still be utilized to meet larger distributed loads. These machines require hydrocarbon fuel input (i.e.: natural gas, oil, or fuel mix).

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.

ICE generation is typically not an ideal solution to offset battery electric bus (BEB) charging load as the fuel input, high maintenance costs, and emissions are not suitable for consistent use. These generation methods can serve as backup generation to allow reduced transit operations to continue in the event of an electric service outage.

The large ICE generator footprint is an important consideration. A typical stationary diesel ICE backup generator will require a footprint of approximately 75 ft^2/MW. Therefore, a 2 MW stationary backup generator would require approximately 150 ft^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. Having a portable generator on-site at the depot facility may be a good option as it could also be relocated to other facilities (such as en-route or municipal facilities) as needed in the event of power disruption without the need to have individual generators located at each site. This also allows the option to scale up backup generation in the future by purchasing additional generators if reliability continues be a challenge.

7.4.4 HYDROGEN FUEL CELL GENERATION

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 safely store potentially volatile fuels.

Fuel cells have historically operated using hydrogen as the fuel source. Hydrogen fuel cells can be procured if a hydrogen fuel source is available at the intended site. Hydrogen delivery can be completed either through on-site or off-site generation. On-site generation requires the raw components available at the site. These raw components typically include either water or natural gas and electricity. The electricity source determines hydrogen's cleanliness as most consider coal or hydrocarbon generation less desirable than hydropower or renewable sources.

On-site generation requires much more infrastructure that may not be able to fit on the existing facilities, whereas off-site generation would require storage tanks and pumps to store and deliver the fuel to the fuel cells. Off-site generation typically requires a truck-and-tank delivery system, as adequate hydrogen pipelines capable of supporting a 1 MW or larger generator is not likely available.

The fuel cell footprint is dependent on the vendor, system size, and form factor. Fuel cell stacks can be deployed as a containerized unit or as modular units mounted to a foundation. A 440 kW containerized fuel cell will have a space requirement of 28′ x 11′ x 9′ or an approximate footprint of 0.7 ft^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 2 MW containerized fuel cell installation would utilize 16 units and requires an approximately 1,400 ft^2 footprint.

Similarly, a modular installation would have an approximate space requirement of 15′ x 9′ x 7′ for a 250 kW unit. A 2 MW modular installation would require 8 x 250 kW units with an estimated footprint of 1,080 ft^2. These estimates do not include the necessary space for fuel storage and maintenance access.

Additionally, fuel cells are generally not well suited for typical emergency generator application where the asset is stored and only operated for a limited number of hours per year. Fuel cells require high operating temperatures to maintain effective and efficient operation. A cold fuel cell can take as long as 10 hours to be heated to optimal temperature, which is typically unacceptable for emergency generation applications. One solution fuel cell manufacturers have proposed to mitigate this startup time involves equipping the fuel cell to serve either a small portion or the entirety of the full load during normal operation. This means the fuel cell is always operating and maintains its ability to operate during an outage. Operating in this fashion could effectively swap the primary and backup power sources so that the electrical grid provides a backup to the fuel cell to reach the desired level of resiliency.

The ramp rate of an operating fuel cell is extremely fast, and a fuel cell operating in hot standby and ramped to full load during an outage would be able to meet similar starting characteristic as ICE generators. It should be noted that operating the fuel cell in hot standby will require the consumption of natural gas or hydrogen during normal operation.

7.4.5 REDUCED BUS SERVICES

In the case of an outage, a viable resiliency practice includes reducing the amount of bus services offered for the duration of the outage or while the buses affected by the outage are completely charged. Services can be reduced to a maintainable level depending on the severity, type, and outage duration (utility, local, software, etc.) and then returned to baseline operation once an outage is restored and buses are fully charged for 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 different transit service will likely decrease as the disaster has larger regional impacts beyond transit 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.

7.4.6 SPARE BUS CAPACITY

Maintaining a fleet of spare buses (BEB or diesel) is a viable option to maintain 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 for a reserve fleet once they reach a low state of charge. Maintaining a reserve fleet of BEBs would allow for Stratford 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 once the entire fleet became 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 one.

7.4.7 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.

7.4.8 RESILIENCY RECOMMENDATIONS

Although past usage data cannot guarantee the same future reliability at the Transit Garage, it indicates that the types of outages experienced at the garage could be manageable with operational adjustments.

If operational plans can mitigate these disruptions, backup generation should not be required as the reliability of the electrical grid should be able to keep the city's transit system at an acceptable level of reliability. Provisioning for incorporating a back-up generation source is recommended at this stage as it is a low cost option that will allow Stratford to add back-up power down the road if grid reliability changes or operational workarounds are found to not be adequate.

7.5 BUILDING CODE & FIRE SAFETY

Indoor storage of vehicles is not a new concept, but the introduction of battery electric vehicles (BEVs) 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 battery electric vehicles and charging infrastructure is the increase in high voltage electrical equipment that is now being installed as well as the possibility of a lithium ion battery fires on vehicles stored inside of 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 BEVs 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 BEVs. 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 designs meet electrical code requirements.

Fire safety standards for BEVs is 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 transit agencies have provided based on experience as to what 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

Engaging with insurance underwriters is another recommended to make sure that buildings and/or fleet will be covered by existing insurance coverage. Insurance underwriters may also have recommendations or additional requirements as to how risks could be mitigated that are not captured by current building or electrical codes.

8 APPENDIX B1: FACILITY CONCEPT PLANS

BEB CHARGING INFRASTRUCTURE

STAGE	QUANTITY OF DCFC 150 kW DISPENSERS W/ CCS PLUGS	QUANTITY OF DCFC 22.5 kW DISPENSERS W/ CCS PLUGS
PHASE 1	3	0
PHASE 2	3	0
PHASE 3	3	0
PHASE 4	3	0
PARATRANSIT	0	5
TOTAL	**12**	**0**

HDR

ISSUE	DATE	DESCRIPTION	DRAWN BY	DESIGNED BY	CHECKED BY
P2	05/08/2023	DRAFT ISSUED TO UTILITY	MN	AB	DK
P1	03/07/2023	ISSUED FOR INFORMATION	AB	AB	DK

PROJECT NUMBER 10355463

PRELIMINARY FOR DISCUSSION PURPOSES ONLY

Stratford

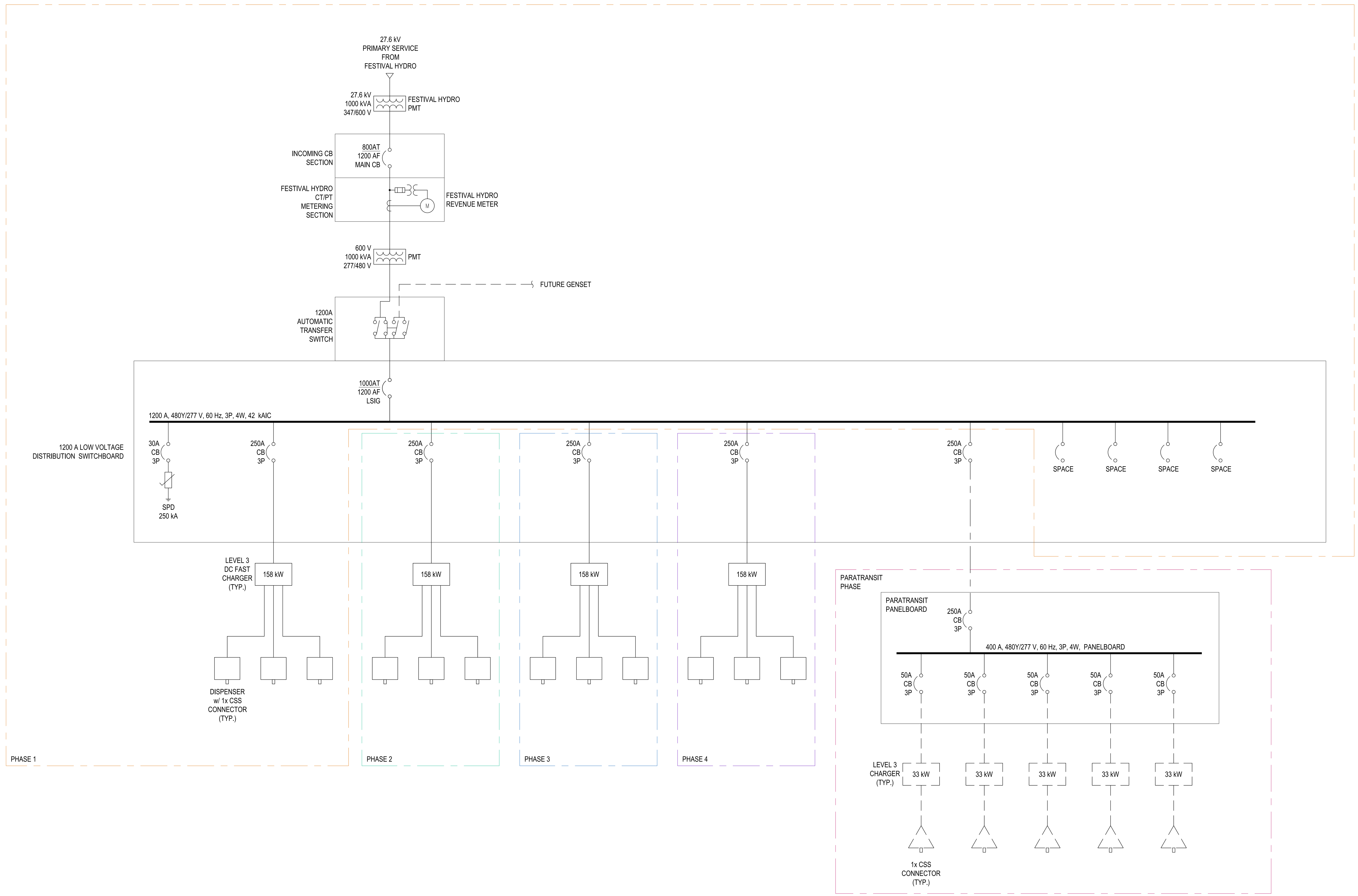
METROLINX - STRATFORD BUS GARAGE ELECTRICAL SITE PLAN INDICATIVE DESIGN

1:200 0 1 2 3 4 5 8m

FILENAME

SCALE 1:200

SHEET E001



ISSUE	DATE	DESCRIPTION	DRAWN BY	DESIGNED BY	CHECKED BY
P2	05/24/2023	DRAFT ISSUED TO UTILITY	MN	AB	DK
P1	03/07/2023	ISSUED FOR INFORMATION	AB	AB	DK

PROJECT NUMBER 10355463

PRELIMINARY FOR DISCUSSION PURPOSES ONLY

Stratford

METROLINX - STRATFORD BUS GARAGE SINGLE LINE DIAGRAM INDICATIVE DESIGN

FILENAME

SCALE 1:200

SHEET E002

ISSUE	DATE	DESCRIPTION	DRAWN BY	DESIGNED BY	CHECKED BY
P2	05/08/2023	DRAFT ISSUED TO UTILITY	MN	AB	DK
P1	03/07/2023	ISSUED FOR INFORMATION	AB	AB	DK

PROJECT NUMBER 10355463

PRELIMINARY FOR DISCUSSION PURPOSES ONLY

Stratford

METROLINX - STRATFORD COOPER TERMINAL ELECTRICAL SITE PLAN INDICATIVE DESIGN

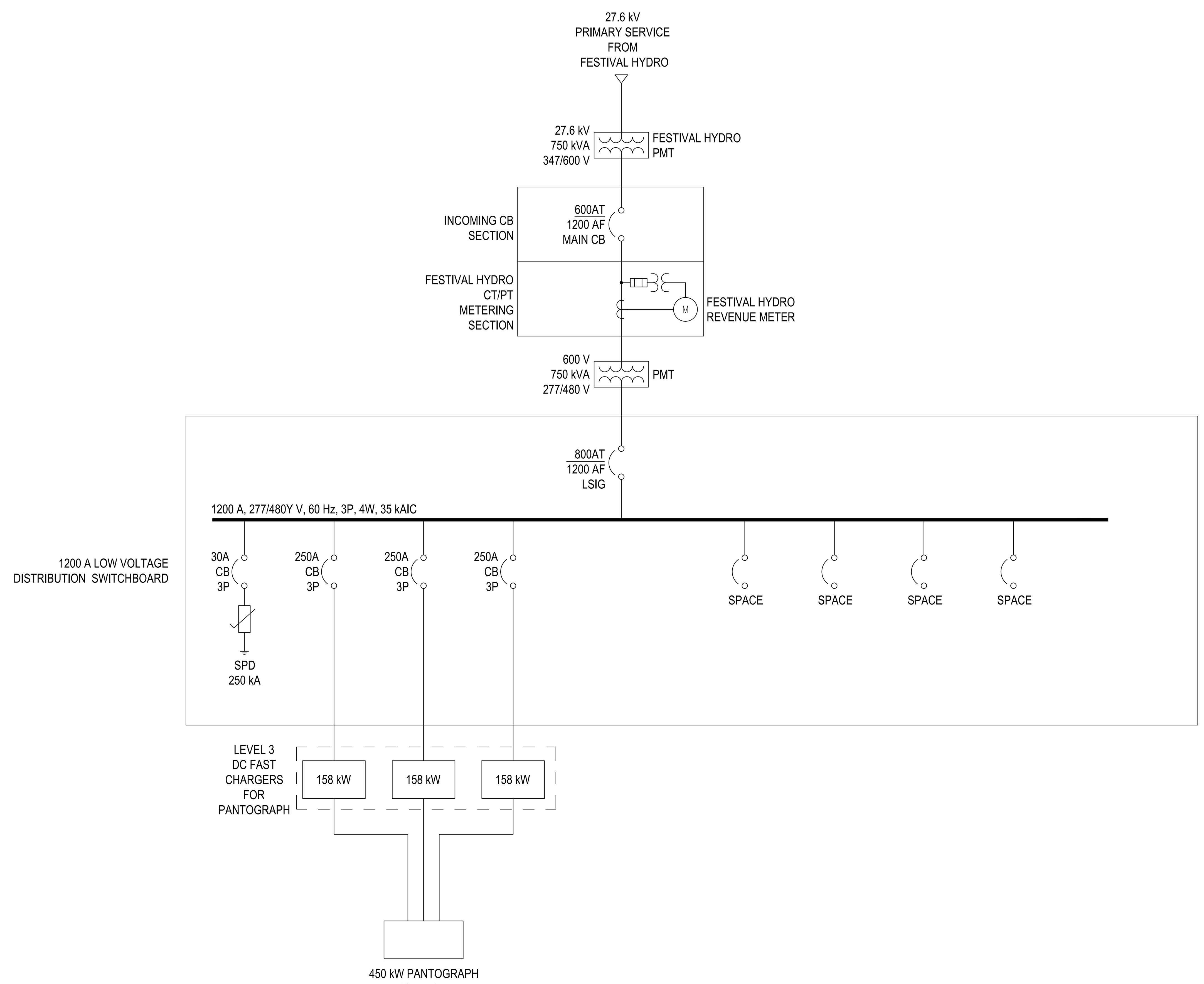
0 5 10 15 20m

1:500

FILENAME

SCALE 1:500

SHEET E001



ISSUE	DATE	DESCRIPTION	DRAWN BY	DESIGNED BY	CHECKED BY
P2	05/08/2023	DRAFT ISSUED TO UTILITY	MN	AB	DK
P1	03/07/2023	ISSUED FOR INFORMATION	AB	AB	DK

PROJECT NUMBER 10355463

PRELIMINARY FOR DISCUSSION PURPOSES ONLY

METROLINX - STRATFORD COOPER TERMINAL ELECTRICAL SITE PLAN INDICATIVE DESIGN

FILENAME

SCALE N.T.S.

SHEET E002

APPENDIX C TRAINING & STAFFING PLAN

10/27/2023

DISCLAIMER

In preparing this report, HDR relied, in whole or in part, on data and information provided by the Client and third parties that was current at the time of such usage, which information has not been independently verified by HDR and which HDR has assumed to be accurate, complete, reliable, and current. Therefore, while HDR has utilized its best efforts in preparing this report, HDR does not warrant or guarantee the conclusions set forth in this report which are dependent or based upon data, information or statements supplied by third parties or the client, or that the data and information have not changed since being provided in the report.

This report is intended for planning purposed for the Client, and for Client's sole and exclusive use and is not for the benefit of any third party and may not be distributed to, disclosed in any form to, used by, or relied upon by, any third party without prior written consent of HDR, which consent may be withheld in its sole discretion. Use of this preliminary feasibility report or any information contained herein, if by any party other than Client, shall be at the sole risk of such party and shall constitute a release and agreement by such party to defend and indemnify HDR and its affiliates, officers, employees and subcontractors from and against any liability for direct, indirect, incidental, consequential or special loss or damage or other liability of any nature arising from its use of the Report or reliance upon any of its content. To the maximum extent permitted by law, such release from and indemnification against liability shall apply in contract, tort (including negligence), strict liability, or any other theory of liability.

TABLE OF CONTENTS

1 INTRODUCTION

With the introduction of battery electric technology, it is critical to provide proper training on the unique systems and subcomponents for battery electric buses (BEBs) to ensure the safe, efficient operation and maintenance of the electric fleet. Stratford Transit should work with internal training departments and in close coordination with Original Equipment Manufacturers (OEMs) to acclimate the existing workforce to the new technology, empowering them to become champions of the BEB technology, and avoiding displacement of the existing workforce.

It is recommended that Stratford Transit take the following actions to ensure a safe workplace, capable workforce, and successful fleet transition:

- **Safe Battery Electric Workplace and Risk Assessment**: Develop and implement safe work procedures for working on battery electric vehicles. This includes procedures for de-energizing and re-energizing high voltage systems, lockout/tagout procedures, and personal protective equipment (PPE) requirements.
- **Training Program:** Provide workforce training regarding safe work procedures for operating and maintaining BEBs. This should include training on the risks associated with high voltage systems, safe work practices, and the use of PPE. Ensure that BEB equipment is properly inspected, maintained, and tested. This includes equipment such as battery packs, chargers, and cables.
- **Staffing:** Continuously evaluate staffing needs as they relate to the introduction of BEBs and monitor the market for specific training and qualifications that can be added to job postings, etc. Work with unions to ensure work requirements are consistent with the collective agreements.
- **Emergency Response:** Establish an emergency response plan for incidents involving BEBs, such as battery fires or explosions. The plan should outline the procedures for evacuating the area and responding to the emergency.

This Training & Staffing Plan (Plan) provides a starting point for Stratford Transit and their staff as they consider the transition to BEBs. This Plan will review the aforementioned actions and highlight considerations, provide insight, and make recommendations as it relates to training and staffing for a BEB workplace and service.

2 A SAFE BATTERY ELECTRIC WORKPLACE

2.1 SAFE WORKPLACE POLICY 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 the 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 (like charging infrastructure) and do not directly address "mobile" high-voltage systems like 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.

2.2 PROCUREMENT

It is recommended that Stratford Transit incorporate a "safety by design" principle into the procurement process. Instead of holding only the user accountable for safety, safety by design ensures that the vehicles and equipment are designed and built with safety in mind. Stratford Transit should assess and compare OEM products and encourage manufacturers to demonstrate how their products consider the needs of all users, including passengers, operators, and maintenance staff.

Manufacturers with well-developed training programs and products that engineer hazards away from employees, minimizing the amount of PPE required for maintenance activities, are indicators that safety is important to the manufacturer. Products that protect employees from hazards simplify maintenance and reduce the need for safety procedures (ex. Lock-out, tag-out) are preferable to ones that require PPE from hazards.

2.3 RISK ASSESSMENT

It is recommended that Stratford Transit work with Festival Hydro or internal workplace safety resources to assess the risks associated with working on BEBs and take steps to minimize or eliminate those risks. This includes identifying hazards related to high voltage systems, flammable electrolytes, and other potential dangers. Stratford Transit, during and after procurement, should engage with the OEMs for information related to risk, safe handling, operation, and maintenance of new equipment and infrastructure. Staff will become aware of the risks associated with BEBs through training. It is important to ensure staff are knowledgeable about the risks, understand best mitigation and protection procedures, and are constantly working to eliminate hazards and maintain a safe workplace.

2.4 PERSONAL PROTECTIVE EQUIPMENT (PPE)

Personal Protective Equipment (PPE) is designed to protect users from health and safety hazards. PPE must be implemented when elimination, substitution, engineering and administrative controls are insufficient at removing or reducing hazards.[1]

Under Canadian and Ontarian law, PPE is required to be provided by the employer and worn by the employees to maintain safe working conditions. The following policies and standards related to PPE are applicable to workplaces:

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

---

[1] https://www.ccohs.ca/oshanswers/hsprograms/hazard/hierarchy_controls.pdf

- 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 and 28 outlines the duties of supervisors and workers to work within the provisions of the Act and use or wear equipment, protective devices or clothing required by the employer.

As previously referenced, CSA Z462:21 is the electrical safety standard and identifies appropriate PPE for workplaces operating electrical equipment to protect workers from high voltage incidents and arc-flash.

Battery electric buses are considered high voltage systems and require additional tools and PPE that are not typically required when working the typical 12/24 V systems on diesel buses. Examples of the types of additional PPE that may be required to work on high voltage systems. The Transportation Learning Center[2] provides a list of typical tools and PPE that are expected to be needed to work on BEBs which are shown in **Table 1** and **Table 2**.

Table 1 - Recommended Insulated Tools

Tool	Recommended Quantity	Notes
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 BEB OEM)	1 set for each BEB technician that could be working on a BEB at any given time	

[2] ITLC_ZEB_Report_Final_2-11-2022.pdf (transportcenter.org)

Table 2 - Recommended Personal Protective Equipment (PPE)

Tool	Recommended Quantity	Notes
ASTM Class 0 insulated gloves with red label	1 pair, properly sized for each BEB 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 BEB technician	
Insulated EH Rated Safety Shoes	1 pair, properly sized for each BEB technician	
NRR 33 rated ear plugs	Ample supply for each BEB technician that could be working on a BEB at any given time	
NRR 331 rated (overhead) earmuffs	Ample supply for each BEB technician that could be working on a BEB at any given time	Note: 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 BEB technician that could be working on a BEB at any given time	
Combination arc flash shield and hardhat	Ample supply for each BEB 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)	

For more information about PPE, visit the Canadian Centre for Occupational Health and Safety website: CCOHS: Designing an Effective PPE Program.

3 TRAINING PROGRAM

3.1 LABOUR CATEGORIZATION, SKILLS ASSESSMENT AND GAP IDENTIFICATION

This section outlines the workplace responsibilities of staff based on qualifications and the skills they contribute to Stratford Transit's service. It is acknowledged that existing staff do not currently engage with battery electric vehicles and are unfamiliar with their operation in a revenue service setting. The current qualifications for labour do not include pre-existing training with BEBs and while newer staff may have some in-class or on-the-job battery electric vehicle training, the agency will need to provide a comprehensive training program to operate as a zero emissions operation successfully and safely. **Section 3.2** identifies a prospective training curriculum for Stratford Transit's staff.

Generally, staff can be grouped into four categories:

Operations Support: Staff in this category include those who are critical to bus operations but do not drive the buses. As it relates to BEBs, minimal training is required as staff only need to have a high-level understanding of the technology and its capabilities. Operations Support may require training related to BEB's operational range as it relates to dispatching, scheduling, and assigning vehicles to appropriate routes. Typically, scheduling and dispatching is conducted by Stratford Transit leadership.

Operators: Staff in this category include staff who drive the buses but do not perform any vehicle maintenance. Operators will require more training than Operations Support staff given their direct interaction with the vehicles. For example, Operators must be familiar with all dash indicator lights, operation of doors and wheelchair access, and safety procedures. Operators will not perform vehicle maintenance on the BEBs but may be required to plug-in or unplug buses for use. Operators are required to hold a valid Ontario Class C, D and Z Driver's License, and this requirement does not change with the introduction of BEB technology. At this time, there is no new license required for operating BEBs.

Maintenance Support: Staff in this category include technical specialists who directly interact with the buses, support or lead bus maintenance training, and/or are responsible for the assignment and oversight of maintenance functions. Maintenance Support will receive the same training as Maintenance personnel as their roles require full familiarity with all vehicle systems and mechanical components.

Maintenance: Staff in this category include technical specialists who directly interact with the buses and perform routine and unplanned maintenance functions. Maintenance personnel require the most comprehensive training. Within the Maintenance category, personnel should be individually assessed on current skills and assigned to training modules as necessary. Maintenance staff are required to complete 310T certification prior to hiring. 310T is a designation for Truck and Coach Technicians that trains students in issue diagnosis, repair and maintenance of commercial vehicles. In addition to this designation, duty-specific training is required for maintenance staff.

3.2 TRAINING CURRICULUM

Operations and Maintenance staff differ in their daily interaction and function with BEBs and, therefore, require different training. While all staff should be familiar with safety protocols for interacting with BEBs, duty-specific training will be required. The following sections identify and outline recommended training programs for the safe operation and maintenance of BEBs.

A comprehensive BEB training program should be integrated with existing training programs for operators and maintenance staff. The training curriculum should be jointly developed with and reviewed by Stratford Transit, and their unions: Amalgamated Transit Union (ATU), and International Brotherhood of Electrical Workers (IBEW).

The development of a high-quality training program will entail coordination with internal and external resources. The following list identifies potential resources that may assist Stratford Transit with program development:

- Vehicle and charger OEM training curriculum purchased as part of new rolling stock procurements;
- Vehicle sub-system/sub-component training from component OEMs;
- Collaboration with transit agencies with operational zero emission fleets and in-house training programs;
- Partnership with local first responding agencies; and
- Membership through training consortiums, transit associations or unions

3.2.1 OPERATIONS

Bus Operators will interact with BEBs on a daily basis as the main users of the BEBs. Though they will not perform maintenance functions on the BEBs, they require a solid understanding of the differences in the operation of BEBs compared to diesel buses. The training program for Operators is anticipated to be similar to existing conditions, with OEMs providing training to Operators when the vehicle is purchased and transitioned into the fleet. After OEM training is provided, orientation programs for new operators should be modified to include an orientation on BEBs that includes the additional aspects that are specific to BEBs.

The Stratford Transit leadership team carries out support functions like scheduling and dispatching. This team will require a strong understanding of the BEB's battery life and operational range to appropriately assign buses to routes and send replacement buses when battery levels are low. As Stratford Transit does not currently utilize software for scheduling and dispatching, it is recommended that the leadership work with OEMs and operators to understand operational range and determine a protocol for contacting the transit garage when batteries are running low and replacement buses need to be sent. Support staff should also have a general understanding of vehicle systems so that if an operator contacts dispatch with an issue, they are able to understand the issue and respond appropriately.

Table 3 provides an example of they types of training that could be required for the different operations staff:

Table 3 - Recommended Operations Staff Training

Training	Description	Delivery Method		Operators	Operations Support
Vehicle Orientation	As with any new fleet type, operators will need to understand basics like start-up/ shut-down procedures, operator gauges and indicators, and hot to operate vehicles systems (lights, heat, AC). Staff will also need to understand some new aspects like the state of charge of vehicle, regenerative braking and how to drive the vehicle efficiently.	6 hours	OEM OR in-house Certified Trainer	x	x
High voltage system safety	High-level overview of the safety system on the vehicle and procedures to follow in the event of an emergency. This should include the types of indicators that may signal that there is an issue with a battery electric vehicle and how to disconnect the traction power if an emergency occurs.	2 hours	OEM OR in-house Certified Trainer	x	x
Charging procedures	How to charge the bus by connecting using either plug-in or overhead chargers. Setting the bus up for charging, starting the charger, safety features of charging equipment.	2 hours	OEM OR in-house Certified Trainer	x	x
Operations and Scheduling Systems	Staff will need an understanding of vehicle range and strategies for scheduling vehicles. Training on systems that staff may use to monitor vehicles (ex: understanding remaining range to determine if a vehicle needs to be return to the garage or not).	8 hours	OEM OR in-house trainer		x

In addition, procedures for refueling and recharging, hand-off at the garage, and dispatching should be discussed with operators as part of Stratford Transit's standard operating procedures.

3.2.2 MAINTENANCE

BEBs contain high-voltage batteries, requiring all maintenance technicians to be certified to work on high voltage systems. Stratford Transit Bus Maintenance Departments, with the inclusion of ATU and IBEW, should work to supplement any existing electrical safety programs with guidance from the Canadian Standards Association (CSA), OEMs, and industry best practices. At a minimum, safety training programs should include:

- Proper use and inspection of personal protective equipment;
- CPR and first aid training;
- High voltage onboard systems familiarization and identification; and
- Lock-Out-Tag-Out training and compliance.

Table 4 presents the recommended high voltage safety training curriculum for Maintenance Staff. The proposed training curriculum accounts for specialized technicians (identified under "Maintenance" in **Section 3**), supervisors and maintenance leadership (identified under "Maintenance Support" in **Section 3**). A proposed maintenance training curriculum has been provided in **Table 5**.

Table 4 - High Voltage Safety Training

System	Description		Delivery Method	Maintenance – BEB Specialized Technicians	Maintenance Support - Shift Supervisors	Maintenance Support - Managers/Directors
Fall Prevention	General description of the type of system that is required, with do’s and don'ts that are specific to high voltage work	1 hour	OEM, Certified Inspector OR in-house Certified Trainer	X	X	X
Harness Use and Inspection	Designed to instruct the end user with the information they need to ensure the equipment is safe to use. For standard harness and arc-flash rated harness.	2 hours	OEM, Certified Inspector OR in-house Certified Trainer	X	X	
High Voltage PPE and inspection	This course will provide a description of the various forms of high-voltage PPE, its use, inspections, and certification	3 hours	OEM, Certified Inspector OR in-house Certified Trainer	X	X	
Arc-Flash PPE, inspection and Maintenance	Instruction on arc-flash range, protective barriers and PPE, and maintenance of required PPE.	3 hours	OEM, Certified Inspector OR in-house Certified Trainer	X	X	X
Who can work on what?	Qualified/Certified vs. Unqualified/Uncertified	1 Hour	OEM, Certified Inspector OR in-house Certified Trainer	X	X	X
Tool Inspection	Inspection process for various Hi-Voltage insulated tools	1 hour	OEM, Certified Inspector OR in-house Certified Trainer	X	X	X

Table 5 - Recommended Maintenance Staff Training

System	Description		Delivery Method	Maintenance – BEB Specialized Technicians	Maintenance Support - Shift Supervisors	Maintenance Support - Managers/ Directors
Preventative Maintenance & Inspections (PMI)	Designed to instruct technicians in the routine preventative maintenance procedures and repair of the electric bus	16 hours hands-on and classroom.	OEM or in-house Certified Trainer	X	X	X
Propulsion & Regenerative Braking System	Technicians gain familiarity with the Motor Drive system (Theory and Hands-On), and Regenerative Braking System	16 hours hands-on and classroom	OEM or in-house Certified Trainer	X	X	
Bus Plug-In Charging	Instructs staff on the proper and safe use of plug-in charge stations, and inspections of receptacles	4 hours classroom and hands-on	In-House Certified Training	X	X	X
High Voltage Charging System – Battery	Extensive training covers High Voltage disabling, Lithium-Ion Battery Pack, Inverters for AC/DC Conversion, 24V Charging System, Electrical Architecture, CAN bus, and Thermal Management System	48 hours hands-on and classroom	OEM or in-house Certified Trainer	X	X	
Battery Management System	Technicians learn about the difference in the operation of the battery management system and software	8 hours-classroom and hands-on	OEM or in-house Certified Trainer	X	X	
HVAC High Voltage System	Technicians learn the major operating principles of the HVAC "High Voltage System" - Diagnose and repair, including system maintenance	8 hours hands-on and classroom	OEM or in-house Certified Trainer	X	X	X
Special Equipment & Tools	Instruction on how to use specialized High Voltage insulated tools and computers to assist with vehicle repair and maintenance.	8 hour hands-on and classroom	In-House Certified Trainer	X	X	
High Voltage Accessory Motors	Technicians are trained in the operating principle, diagnosis, and repair of high voltage drive motors for air compressors, power steering pumps, etc.	8 hours hands-on and classroom	In-House Certified Trainer	X	X	

3.3 TRAINING PROGRAM IMPLEMENTATION

For larger fleets, a phased training program is typically recommended. Given the smaller size of the maintenance staff at Stratford Transit compared to larger agencies, it is recommended that the technicians are trained together.

It is recommended that training begins one or more months prior to the delivery of the first BEBs and includes hands-on experience with the vehicles. If possible, it is recommended that Stratford Transit send staff to manufacturer facilities or other transit agencies to learn and receive BEB training prior to delivery. This will ensure a level of familiarity when the BEBs are delivered.

When the BEBs arrive, it is recommended that Stratford Transit consider having OEMs provide on-site support for a period after the delivery of vehicles so knowledge can be transferred to Stratford Transit staff. There is value in having OEM staff on-site for diagnosing issues, troubleshooting and problem-solving. OEM staff can provide guidance and help Stratford staff learn to operate independently.

3.3.1 BUDGET AND FUNDING OPPORTUNITIES

At the onset of the transition, it is recommended that Stratford Transit engage with other transit agencies undergoing this transition to determine appropriate budgeting requirements.

The cost of workforce training will fluctuate in response to the widespread adoption of BEBs. Funding is anticipated to come from a number of sources including procurement (where the cost of training is included in the budgeted cost of the vehicle or infrastructure procurement), existing training budgets, and federal and local funding shares.

As highlighted by the International Transportation Learning Center, the following costs should 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 cost; and
- Training materials/mock-ups/software/simulation cost.

3.3.2 ADDITIONAL RESOURCES

In 2021, the OPTA (Ontario Public Transit Association) Board recommended the creation of a ZEB (Zero Emission Bus) Committee[3] in response to the needs expressed by members to learn and share from on-another as fleets are transitioned to zero emission technology.

The OPTA ZEB Committee has identified workstreams for the committee and Workstream 1B focuses specifically on ZEB Safety, Training and Maintenance. Participating in this committee may be a good opportunity for Stratford to engage with other Ontario transit agencies, learn the challenges they're facing and the solutions they've developed. It's also an opportunity for Stratford to share their experiences and solutions they have developed.

3.3.3 RECORDKEEPING

It is recommended that Stratford Transit understand the requirements for recordkeeping outlined in OHSA and develop practices to ensure staff records are updated as they progress through the training program. As the industry becomes more knowledgeable about BEBs, Stratford Transit may be able to include requirements for training prior to hiring for technicians. A strong recordkeeping program will assist Stratford Transit in communicating its expectations for future employees and budget appropriately for training hours when hiring new staff.

4 STAFFING

It is recommended that Stratford Transit identify a resource responsible for the management of procuring vehicles and infrastructure upgrades as a coordinated program. In addition, outsourcing to consultants, OEMs, and third parties to fill resource and knowledge gaps is recommended. It is recommended that Stratford Transit re-evaluate staffing needs on a rolling basis based on overall fleet growth and approve additional maintenance positions as necessary (as described further in the **Section 4.1** and **4.2**).

Table 6 displays the composition of Stratford 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 6 - Stratford Transit Staff Complement

Job Title	Role Type	# of Filled Positions	# of Authorized Positions	Union Affiliation
Leadership (Manager, Supervisor, Weekend Supervisor, Fleet Supervisor, Admin)	Operations (Support)	5	5	IBEW
Operators (Full and Part-time)	Operations	34	38	ATU and IBEW
Maintenance (Full-time)	Maintenance (Support)	2	2	ATU

[3] Zero Emission Bus (ZEB) Committee – OPTA | Ontario Public Transit Association

Mechanics/Technicians (Full-Time)	Maintenance	3	3	ATU

Changes in operations may result in impacts to the Collective Bargaining Agreement which may increase operational costs. Stratford Transit staff belong to two unions: Amalgamated Transit Union (ATU) and International Brotherhood of Electrical Workers (IBEW). It is important that unions are engaged early to support transitioning of the workforce. For example, Operators may be asked to take on additional duties such as plugging-in and un-plugging buses from chargers. Driving behaviour heavily impacts vehicle range and it may be beneficial to monitor driver performance to correct inefficient driving practices. It is recommended that Stratford Transit initiate constructive engagement with unions on the coming changes to staff requirement to support BEB operations including staffing numbers, skillsets, and operational practices.

4.1 OPERATIONS STAFF RIGHT-SIZING

In general, the modelling scenarios for bus electrification in the **Appendix A: Energy Modelling Report** resulted in more service hours than the existing conditions. It is recommended that Stratford Transit review the rules of the Operators' collective agreements and the number of service hours travelled to determine if any increase in the number of Operators would be required. It is not anticipated that there will be a need to increase the number of Operators in the short to medium term. Stratford Transit should continue to evaluate its Operator staffing needs on a rolling basis as BEBs are introduced to the fleet.

4.2 MAINTENANCE STAFF RIGHT-SIZING

The financial analysis assumed there would be approximately 10% savings in maintenance costs by transitioning to BEBs from diesel. It is noted as transit fleet transitions are in their infancy, there is a lack of data to support a conclusion regarding increases or decreases in vehicle maintenance staffing levels at this time. This lack of conclusive data to support increases coupled with the fact that there is no significant increase in Stratford Transit's fleet size, it is not anticipated that additional maintenance staff will be required.

It is recommended that Stratford Transit monitor this transition and make appropriate decisions based on observed conditions when the vehicles arrive.

4.3 INFRASTRUCTURE MAINTENANCE

A new aspect that Stratford Transit will need to consider will be maintenance of the charging equipment and associated electrical infrastructure required to service the BEBs. Some larger agencies have permanent electrical trades staff already part of their facilities maintenance team, though Stratford Transit does not. Stratford Transit will need to consider one of several models for preventative and corrective maintenance of charging infrastructure:

- Hiring of trades certified in-house staff to manage equipment;
- Engaging a local contractor;
- Purchasing OEM warranties/service plans; and

- Contracted design/build/maintain models like Charging as a Service (CaaS) and Energy as a Service (EaaS).

There is precedent that larger agencies such as the Toronto Transit Commission (TTC) are using CaaS/EaaS models as it better allocates the risk to the party that is best able to manage it. Transit agencies are not naturally equipped to manage electrical infrastructure and optimize energy costs, as it's not part of their core business. EaaS/CaaS can allow for more consistent fuel/energy pricing for the transit agency, while shifting riskier aspects of infrastructure that the agency may not necessarily understand very well (like operations and maintenance) to the contractor.

Ultimately the decision to determine which model to adopt will depend on the capacity of the agency to manage those assets, the value offered by the contractor, and the organization's risk tolerance.

5 EMERGENCY RESPONSE

One of the key groups that will require engagement, outside of Stratford Transit staff, are the City's first responders. It is recommended that Stratford Transit engage local first responders (like the fire department, emergency medical service, etc.) to offer to provide education and training on the BEB technology and safety features of buses used by Stratford Transit. This training will provide first responders with the knowledge necessary to safely act and address an emergency situation involving BEBs or BEB infrastructure.

A sample engagement plan to educate the Stratford Fire Department on BEBs is presented below:

1. **Contact the local fire department:** Stratford Transit should contact the Stratford Fire Department and set up an education and training session. Stratford Transit should work with the Stratford Fire Department to determine the appropriate attendees and number of sessions based on any potential pre-existing training the first responders have related to electric vehicles.
2. **Provide information on the BEB technology:** Stratford Transit (in consultation with the OEM) should prepare an information package on BEB technology including information on the battery systems and charging infrastructure. This information should be used by the fire department to identify risks associated with BEBs and develop appropriate response strategies.
3. **Identify key safety features:** Stratford Transit, in coordination with OEMs, should identify the key safety features of the BEBs (emergency shut-off switches, access points for battery disconnection). This information can help fire departments respond to incidents involving BEBs more effectively.
4. **Offer hands-on training:** Stratford Transit (in coordination with OEMs) should offer hands-on training opportunities for fire departments to familiarize them with BEBs and their safety features. This could involve simulations of emergency situations or demonstrations of how to disconnect a BEB's battery system.
5. **Encourage ongoing collaboration:** Transit agencies should encourage ongoing collaboration with fire departments to ensure that they are kept up to date on any changes to BEB technology or safety features.

Coordination and knowledge-sharing with first responders ensures that all parties are prepared to respond to incidents involving BEBs and protect passengers and employees.

APPENDIX D BUDGET & FINANCIAL REPORT

10/27/2023

DISCLAIMER

In preparing this report, HDR relied, in whole or in part, on data and information provided by the Client and third parties that was current at the time of such usage, which information has not been independently verified by HDR and which HDR has assumed to be accurate, complete, reliable, and current. Therefore, while HDR has utilized its best efforts in preparing this report, HDR does not warrant or guarantee the conclusions set forth in this report which are dependent or based upon data, information or statements supplied by third parties or the client, or that the data and information have not changed since being provided in the report.

This report is intended for planning purposed for the Client, and for Client's sole and exclusive use and is not for the benefit of any third party and may not be distributed to, disclosed in any form to, used by, or relied upon by, any third party without prior written consent of HDR, which consent may be withheld in its sole discretion. Use of this preliminary feasibility report or any information contained herein, if by any party other than Client, shall be at the sole risk of such party and shall constitute a release and agreement by such party to defend and indemnify HDR and its affiliates, officers, employees and subcontractors from and against any liability for direct, indirect, incidental, consequential or special loss or damage or other liability of any nature arising from its use of the Report or reliance upon any of its content. To the maximum extent permitted by law, such release from and indemnification against liability shall apply in contract, tort (including negligence), strict liability, or any other theory of liability.

TABLE OF CONTENTS

1 INTRODUCTION

This technical memorandum evaluates the lifecycle costs associated with the battery electric bus (BEB) Fleet Transition Plan currently being considered by the City of Stratford to achieve its goal of net zero emissions by 2050. The costs evaluated include capital, operating and maintenance (O&M), and fuel/electricity over the 2023 to 2050 period. The BEB scenarios are compared against a Baseline (Business as Usual) Scenario that reflects a situation where transit service would be provided by diesel buses through 2050. In addition to the electrification of buses, the BEB Scenarios also include en-route charging infrastructure. As described in more detail in the following sections, the three scenarios 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 Scenario (525 kWh): This scenario reflects the full transition of Stratford's fleet to BEBs with 525 kWh batteries, beginning in 2026.
- BEB Scenario (675 kWh): This scenario reflects the full transition of Stratford's fleet to BEBs with 675 kWh batteries, beginning in 2026.

Table 1 provides a comparison of projected fleet mix and operating statistics for selected years under each scenario based on the results of the Zero+ model outputs. The analysis assumes constant ridership and service levels over the study period.

Table 1 - Comparison of 2040 Fleet Mix and Service Levels by Vehicle Type

	2025	2030	2035	2040
	Fleet Mix			
Baseline	**15**	**15**	**15**	**15**
Diesel	15	15	15	15
BEB	-	-	-	-
Transition - 525 kWh	**15**	**15**	**16**	**20**
Diesel	15	13	10	2
BEB	-	2	6	18
Transition - 675 kWh	**15**	**15**	**16**	**16**
Diesel	15	13	10	2
BEB	-	2	6	14
	Kilometres Travelled			
Baseline	**727,169**	**727,169**	**727,169**	**727,169**
Diesel	727,169	727,169	727,169	727,169
BEB	-	-	-	-
Transition - 525 kWh	**749,009**	**749,009**	**749,009**	**754,175**
Diesel	749,009	631,235	437,900	-
BEB	-	117,775	311,109	754,175
Transition - 675 kWh	**749,009**	**749,009**	**749,009**	**749,009**
Diesel	749,009	631,235	399,739	-
BEB	-	117,775	349,271	749,009
	Hours of Operation			
Baseline	**36,514**	**36,514**	**36,514**	**36,514**
Diesel	36,514	36,514	36,514	36,514
BEB	-	-	-	-
Transition – 525 kWh	**36,514**	**36,514**	**36,514**	**36,634**
Diesel	36,514	31,522	21,571	-
BEB	-	4,992	14,944	36,634
Transition – 675 kWh	**36,514**	**36,514**	**36,514**	**36,514**
Diesel	36,514	31,522	20,733	-
BEB	-	4,992	15,782	36,514

The Key Cost Assumptions section provides an overview of the capital and O&M cost assumptions that will be used in the analysis of both scenarios. The Baseline Scenario, BEB Scenario – 525 kWh, and BEB Scenario – 675 kWh sections describe the key assumptions and costs drivers for each scenario. Lifecycle Cost Comparison compares the lifecycle cost results for the Baseline and BEB scenarios. Greenhouse Gas Emissions Analysis contains the estimated reduction in greenhouse gas emissions based on the transition to BEBs. The Solar Feasibility Analysis contains cost-benefit analyses for various potential solar array installations at Stratford transit facilities.

2 KEY COST ASSUMPTIONS

The analysis relies on several assumptions like bus operating statistics and purchasing schedules for the Baseline and BEB Scenarios.

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 2022-dollar terms by applying a discount factor of 8%.[1] This value was used based on HDR experience with similar transit agencies.

2.1 CAPITAL COST ASSUMPTIONS

Table 2 presents the unit cost assumptions for buses and BEB charging equipment that are common to both scenarios.

Table 2 - Bus and BEB Infrastructure Capital Cost Assumptions (2022$)

Conventional Fleet Capital Assumptions	
Diesel Bus Cost	$600,000
Battery Electric Bus Cost (525 kWh)	$1,200,000
Battery Electric Bus Cost (675 kWh)	$1,405,714
Enroute Charger ($/charger)	$1,200,000

Further details on these assumptions are detailed below.

Planned costs between 2023 to 2050: As described in more detail in the BEB Scenario sections, Stratford is planning to have BEBs enter operations starting in 2026. These costs are included in the BEB Scenario and reflect vehicle and BEB equipment cost estimates completed to date by Stratford staff and the consultant team. Cost estimates produced in support of the active procurement of the BEBs and associated equipment were aligned with Stratford's current grant application for ICIP funding.

- **Annual Cost Growth Assumptions:** Capital cost estimates are in 2022 dollars and were escalated by a base 3 percent annual inflation assumption. The annual inflation assumption is consistent among all three scenarios.
- **Bus Unit Costs:** Diesel bus costs reflect recent Stratford procurement of 40-foot buses. The BEB cost estimate was based on the current procurement process for Stratford's initial BEB purchases.
- **Mid-Life Bus Rehabilitation Costs:** Consistent with Stratford's existing operating data, this analysis assumed all bus types will have a 12-year useful life. Additionally, consistent with the current mid-life rehabilitation schedule for diesel buses, it was assumed that all vehicle types will go through one mid-life rehabilitation during the 12-year period. The mid-life rehabilitation for diesel buses reflects costs associated with diesel engine replacements.

[1] Present value - Wikipedia

- Given the recent and on-going implementation and evolution of BEB propulsion systems, there is limited information on mid-life rehabilitation requirements for these technologies. The analysis assumed there would need to be battery replacements for the BEBs. The cost associated with these changes is assumed to be equal to 10% of the capital cost of BEBs.

BEB Charging Equipment and Installation: Cost estimates for BEB charging equipment and the installation of the charging equipment reflect recent estimates for equipment and additional infrastructure required for the Transit Garage and Cooper Terminal facilities. New infrastructure includes, but is not limited to underground ducting, pantograph chargers, wall-mounted dispensers, and unit substations. Full details for the additional infrastructure are included in **Appendix B: Facility Assessment Report**. Additionally, since there is no long-term data and analysis on the lifecycle of BEB chargers, the analysis assumed the charging equipment is purchased once.

Infrastructure cost assumptions are shown in **Table 3** below. The costs shown include a 20% contingency and 4% percent engineering cost. The implementation year was assumed based on the deployment of BEBs in the conventional fleet. The detailed components and work required for each phase are detailed in the Facility Assessment Memo prepared by HDR.

Table 3 - Infrastructure Phasing Assumptions

Phase	Cost	Year	Key Equipment
Transit Facility Phase 1	$1,872,400	2026	Utility connection, switchboard, cabling, three 150 kW dispensers (wall mounted)
Transit Facility Phase 2	$310,000	2028	Three 150 kW dispensers (wall mounted)
Transit Facility Phase 3	$384,400	2030	Three 150 kW dispensers (pull down)
Transit Facility Phase 4	$334,800	2033	Three 150 kW dispensers (pull down & wall mounted)
Cooper Terminal Phase 1	$2,219,600	2030	Switchboard, transformer, metering cabinet, underground ducting, concrete pad
Paratransit Infrastructure	$235,600	2035	Five 25 kW dispensers (wall mounted)

Tables in the Baseline Scenario and BEB Scenario sections summarize the annual costs under each scenario.

2.2 O&M COST ASSUMPTIONS

Details on assumptions used to estimate O&M costs, fuel and electricity costs include the following:

- **Bus Operations and Maintenance:** The maintenance cost per kilometre for diesel buses was calculated by inflating Stratford Transit's 2021 vehicle maintenance costs to 2022 dollars and dividing it by the total kilometres travelled. A literature review of maintenance costs for BEBs identified a range of 10%-30% cost savings relative to diesel, primarily due to fewer part replacements and simpler drivetrain maintenance. For BEB annual maintenance costs, a 10% cost savings assumption was applied to remain conservative. The operating cost per hour was based on Stratford's submission to CUTA 2021 Conventional Transit Statistics. The total cost of operations was inflated to 2022 dollars, then divided by total vehicle hours. This cost was applied to total estimated operating hours for diesels and BEBs throughout the transition plan.
- **Maintenance of BEB Charging Equipment:** Costs shown in **Table 5** reflect values used in projects with other transit agencies to provide on-going maintenance of BEB charging equipment.

- **Annual Growth Rate for Bus O&M, and Maintenance of EV Charging Infrastructure:** Annual O&M costs in this analysis are escalated by 3 percent to present them in YOE dollars.
- **Propulsion 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 2022 are $1.72 per litre. This assumption was based on the average wholesale price for diesel fuel in Kitchener, a close major city with data available for 2022. The wholesale price had provincial and federal taxes layered on, including the unrecoverable net HST. Wholesale diesel fuel costs were assumed to escalate based on forecasted real changes in diesel estimated in the US Energy Information Administration's Annual Energy Outlook 2022. The carbon tax was assumed to escalate in line with the latest federal carbon pricing plan, while other provincial and federal taxes were assumed to remain constant for the duration of the analysis. Prices were escalated by 3 percent annual growth rate to be converted to YOE dollars. All BEBs are assumed to have diesel heaters to ensure electric power can focus on maintaining maximum driving range. The average fuel efficiency of diesel heaters was obtained based on industry experience to estimate the diesel usage per kilometre travelled.
- **Electricity Costs:** Electricity costs that was included in the analysis is a per kilowatt-hour (kWh) usage fee. The values shown in the table below were obtained from Stratford's electricity invoice from March 22, 2023 from Festival Hydro. The dollar per kWh ($/kWh) usage fee was based on the average Hourly Ontario Energy Price and the Global Adjustment Factor for 2022. Prices were escalated by 3 percent annually to be converted to YOE dollars. The analysis assumed a 5% efficiency loss between chargers and BEBs.
- **Fuel Efficiency:** Litres per 100 kilometres (L/100km) was calculated as an average of the high and low diesel bus fuel consumption recorded by Stratford Transit in 2022.
- **School Bus Service:** Stratford Transit currently employs spare or older model diesel buses to operate weekday post-secondary school routes. Based on current operations, three buses are required to service this non-revenue service for the fleet, and each bus travels approximately 28 kms, or approximately 3 hours each day. BEBs were anticipated to replace diesel spares servicing school routes as they enter service. Their operating statistics were assumed to be identical for both the Base and BEB scenarios. Stratford Transit provided the above operating assumptions for the school bus transit fleet.
- **On-Demand Transit:** Stratford Transit currently employs spare or older model diesel buses to operate on-demand weekend transit. Based on current operations, six buses are required to service this non-revenue service for the fleet, and each bus travels approximately 158.9 kms, or approximately 8 hours each day. BEBs were anticipated to replace diesel spares servicing on-demand routes as they enter service. Their operating statistics were assumed to be identical for both the Base and BEB scenarios. Stratford Transit provided the operating assumptions for the on-demand transit fleet.

The Assumptions for on-demand transit and school bus service are contained in **Table 4** below.

Table 4 - On-Demand Transit and School Bus Service Operating Assumptions

Non-Conventional Fleet Operating Assumptions	
School Buses in Use (maximum)	3
School Bus Ratio (as % of full build spares)	38%
School Bus Average Daily Kilometres Driven	28
School Bus Hours of Use	3
On-Demand Transit Buses in Use (maximum)	6
On-Demand Transit Ratio (as % of full build spares)	75%
On-Demand Transit Average Daily Kilometres Driven	158.9
On-Demand Transit Hours of Use (per Bus per Day)	8

Similar to capital costs, for both scenarios, annual O&M costs that will be incurred between 2023 and 2050 reflect the annual hours and kilometres of service by bus type shown in **Table 5** as well and the equipment and infrastructure needed for BEBs shown previously in **Table 3.**

Table 5 - Annual Operating and Maintenance Cost Assumptions (2022$)

Conventional Fleet Operating Assumptions	Diesel	BEB
Operating Costs ($/hr)	$50.47	$50.47
Maintenance Cost ($/km)	$0.85	$0.77
BEB Maintenance Cost Efficiency Factor	-	10%
Charger Maintenance Cost ($/year)	-	$12,000
Charger Efficiency	-	95%
Average Useful Life of New Bus	12	12
Bus Fuel Efficiency (L/100 km)	47.0	-
Diesel Heater Efficiency (L/km)	-	0.03
Bus Fuel Efficiency (kWh/100 km)	-	139.9
Spare Bus Ratio (Peak Fleet/Total Fleet)	53%	53%
Mid-Life Rehabilitation Cost ($)	$80,000	$120,000

3 BASELINE SCENARIO

The Baseline Scenario is defined as where there is no transition to electric vehicles over the study period. The current diesel fleet is replaced by new diesel buses on an as-needed basis.

3.1 CAPITAL COST ASSUMPTIONS AND ESTIMATES

Under the Baseline Scenario, the fleet mix remains entirely diesel for the duration of the study period. Stratford's fleet retirement schedule as of November 2022 was used to determine the capital purchases needed each year. **Table 6** illustrates the annual capital purchase assumptions for diesel buses based on the fleet retirement schedule. The table shows purchases for selected years within the study period. For instance, between 2023-2030, a total of three diesel buses are purchased.

Table 6 - Annual Capital Purchases / Infrastructure Implementation Assumptions, Selected years

	2023 – 2030	2031 – 2040	2041 – 2050
Diesel Bus	3	12	5
Peak Service	1	6	2
Spares	2	6	3
BEBs	-	-	-

Table 7 presents the annual costs estimates based on the unit cost and growth rate assumptions and the annual fleet needs shown in **Table 6**. The values are in year of expenditure (YOE) dollars. Over the 2023 to 2050 period, total capital costs for the Baseline Scenario are estimated to be $6.4 million in discounted 2022$ terms. An excerpt from 2023 to 2050 is shown below.

Table 7 - Annual Capital Cost Estimates, Selected years, (YOE $, millions)

	2023 – 2030	2031 – 2040	2041 – 2050
Diesel Bus	$2.0	$10.7	$6.0
BEBs	-	-	-
Total	**$2.0**	**$10.7**	**$6.0**

3.2 O&M COST ASSUMPTIONS AND ESTIMATES

Under the Baseline Scenario, as shown in **Table 8** the total of annual hours and miles operated by diesel buses was assumed to remain at the 2023 service levels through 2050.

Table 8 - Annual Service Levels

	2023-2050
Kilometres Travelled	897,741
Hours of Operation	36,514
Litres of Fuel Consumed	421,938

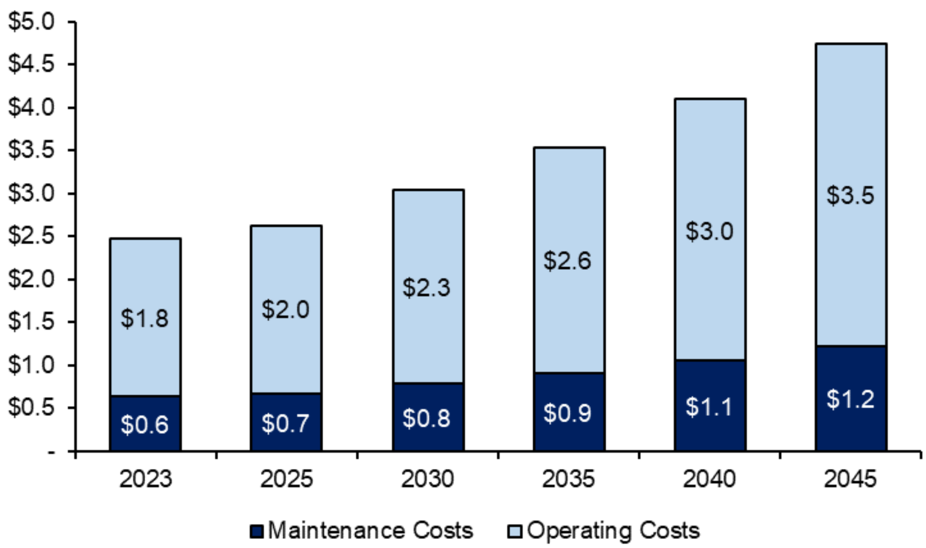
The annual operating and vehicle maintenance costs between 2023 and 2050 were calculated by multiplying the kilometres travelled by diesel buses by the estimated maintenance cost per kilometre, and multiplying the hours of operation by the estimated hourly operating cost. Under the Baseline Scenario, the estimated total operating and maintenance costs were projected to be $39.8 million in discounted 2022 dollars.

Table 9 - Annual O&M Costs, Selected years, (YOE$, millions)

	2023	2025	2030	2035	2040	2045
Cost per Kilometre	$0.85	$0.90	$1.05	$1.21	$1.40	$1.63
Cost per Hour	$50.47	$53.54	$62.07	$71.95	$83.41	$96.70
Annual Maintenance Cost	**$0.6**	**$0.7**	**$0.8**	**$0.9**	**$1.1**	**$1.2**
Annual Operating Cost	**$1.8**	**$2.0**	**$2.3**	**$2.6**	**$3.0**	**$3.5**
Total Cost	**$2.5**	**$2.6**	**$3.0**	**$3.5**	**$4.1**	**$4.8**

Figure 1 shows the annual O&M costs under the baseline in YOE dollars for selected years.

Figure 1 - Annual O&M Costs, Selected years, (YOE$ millions)



3.3 DIESEL FUEL COST ASSUMPTIONS AND ESTIMATES

Under the Baseline Scenario, the only fuel required to operate the fleet is diesel.

The annual diesel fuel costs were calculated based on the annual kilometres travelled included in **Table 8** above, the average fuel economy, and the cost of diesel. The estimated diesel fuel consumed by buses was calculated by multiplying the average fuel economy from Stratford fleet data and the total kilometres travelled. The litres of fuel were 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 10** below.

Table 10 - Annual Diesel Costs, (YOE$, millions)

	2023	2025	2030	2035	2040	2045
Average Cost per Litre	$2.31	$2.50	$3.23	$3.93	$4.73	$5.74
Annual Diesel Cost	$0.7	$0.7	$1.0	$1.2	$1.4	$1.7

4 BEB SCENARIO – 525 KWH

This section contains the assumptions and methodology for the two BEB scenarios considered. It presents the results for the 525-kWh scenario. The 675-kWh scenario is presented in the subsequent section.

4.1 CAPITAL COST DRIVERS AND ANNUAL COST ESTIMATES

The focus for the BEB Scenario is the financial impact of the changes in fleet mix and associated capital infrastructure and service plans over the 2023 to 2050 period. **Figure 2** and **Figure 3** provide a graphical representation of the incremental replacement of all diesel buses with BEBs over this period in terms of the fleet mix and annual levels of service.

Figure 2 - Annual Fleet Mix Assumptions, Selected Years

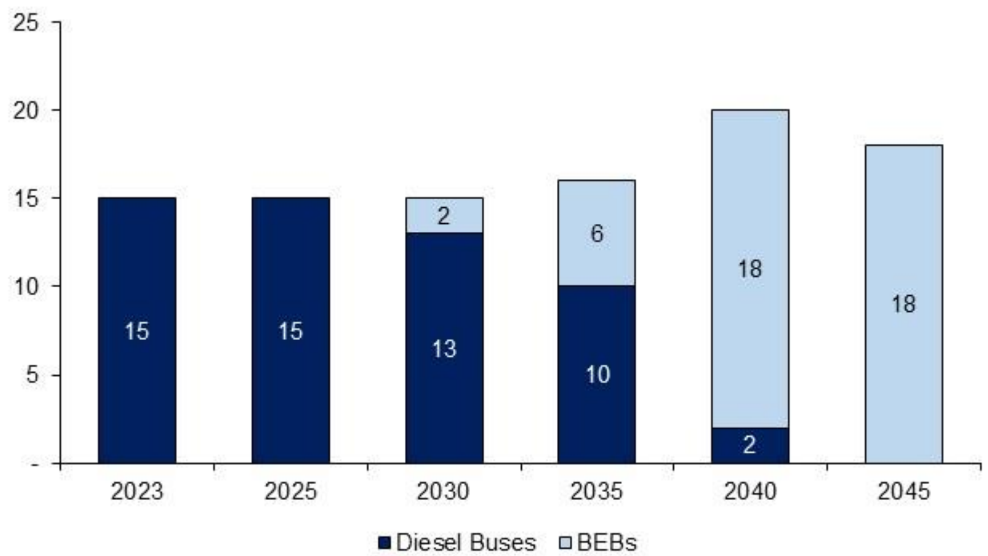


Figure 3 - Annual Kilometres of Service by Bus Type, Selected years (millions)

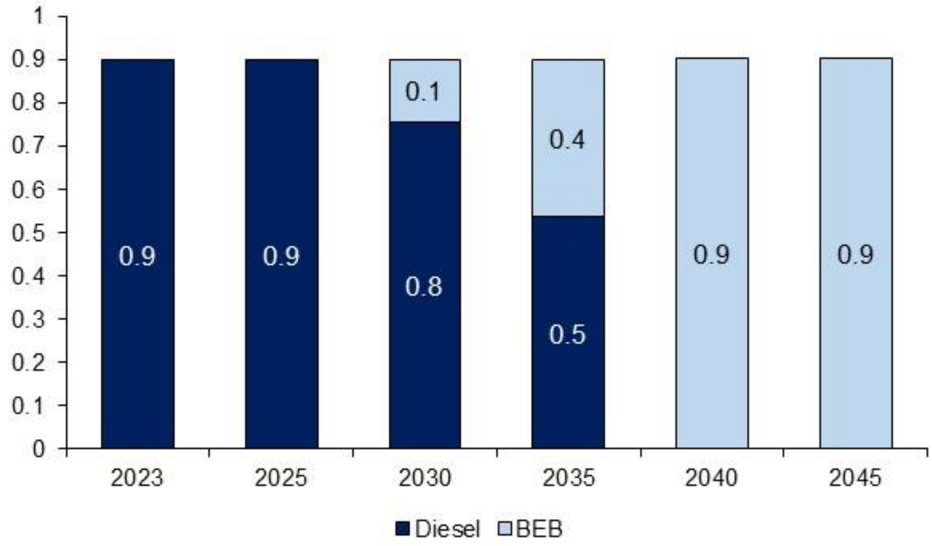


Table 11 summarizes the capital purchases that will occur between 2023 and 2050 and indicates most capital costs will be associated with on-going replacement of diesel buses, and the acquisition and implementation of EV charging equipment. Between 2031-2040, 14 BEBs and 3 in-depot dispensers are purchased, indicating the bulk of the fleet transition will occur between those years.

Table 11 - BEB Capital Purchase Assumptions

	2023 - 2030	2031 - 2040	2041 - 2050
Diesel Bus	-	-	-
Battery Electric Bus	4	14	6
In-Depot Dispensers	9	3	-
Enroute Charger	1	-	-

BEBs were assumed to be purchased two years prior to entering service. Once BEBs can no longer replace a diesel bus on a one-to-one basis without enroute chargers, we assumed enroute chargers are purchased and installed to achieve more one-to-one replacements.

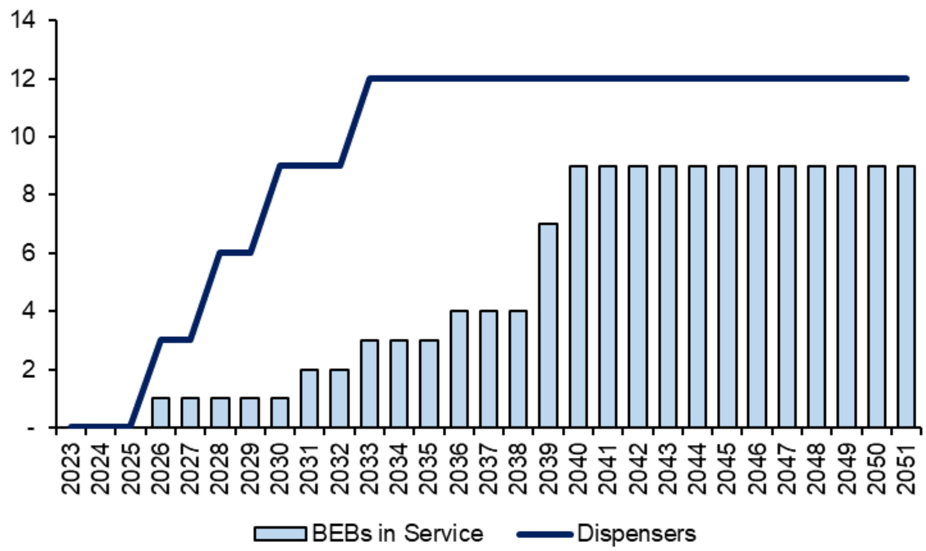
Table 12 presents the costs estimates based on the unit cost, growth rate assumptions and the capital needs for given periods.

Table 12 - Annual Capital Cost Estimates, Selected years, (YOE $, millions)

	2023 - 2030	2031 - 2040	2041 - 2050
Diesel Bus	-	-	-
Battery Electric Bus	$5.3	$24.7	$14.3
Enroute Charger	$1.2	-	-
Additional Infrastructure	$5.6	$0.8	-
Total	**$12.2**	**$25.5**	**$14.3**

Figure 4 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 4 - Peak Service BEBs & Dispensers in Service

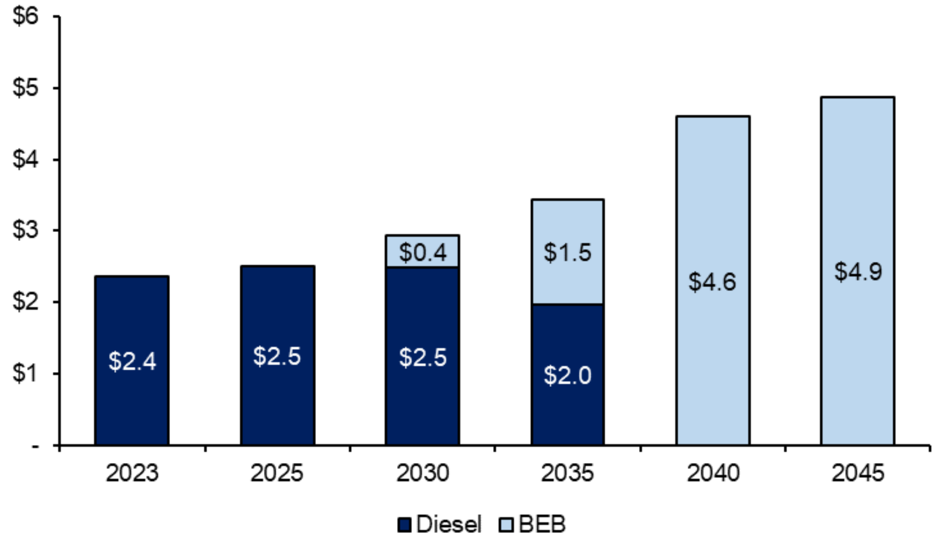


Over the 2023 to 2050 period, total capital costs for the BEB 525 kWh Scenario were estimated to be $17.8 million in discounted 2022$. As shown on the previous figures and tables, the bulk of the BEB fleet transition would occur between 2025 and 2040, with the remaining diesel buses in service replaced by BEBs by 2042. To accommodate the BEB fleet, a total of twelve (12) 150 kW in-depot dispensers and one 450 kW enroute charger would be acquired between 2025 and 2040.

4.2 O&M COST ASSUMPTIONS AND ESTIMATES

Figure 5 summarizes the change in annual O&M cost allocation among the fleet mix under the BEB 525 kWh Scenario.

Figure 5 - Annual O&M Costs by Bus Type, (YOE$, millions)



In the model, blocks were converted from diesel to electric buses using a two-step prioritization method. Blocks were prioritized first if they could be converted on a one-to-one basis (diesel to BEB) without the need for enroute charging infrastructure. After the initial conversion, BEBs were reprioritized based on blocks that could be converted on a one-for-one basis with the greatest total kilometers travelled. **Table 13** summarizes the incremental transition from diesel to BEBs and the associated change in the allocation of annual hours and kilometres of service among the vehicle types.

Table 13 - Operational Statistics Travelled by Bus Type

	2023	2025	2030	2035	2040	2045
Diesel						
Kilometres	749,009	749,009	631,235	437,900	-	-
Hours	36,514	36,514	31,522	21,571	-	-
Litres of Diesel	352,034	352,034	300,715	216,470	25,835	25,835
BEB						
Kilometres	-	-	117,775	311,109	754,175	754,175
Hours	-	-	4,992	14,944	36,634	36,634
kWh	-	-	154,534	453,183	1,101,679	1,101,679

Table 14 summarizes the annual vehicle maintenance costs, mid-life rehabilitation costs, and the annual EV chargers' maintenance costs between 2023 and 2050. As noted above, by 2040 the entire fleet has been transitioned to BEBs.

Table 14 - Annual Operating and Maintenance Cost Estimates, (YOE $, millions)

	2023	2025	2030	2035	2040	2045
Diesel	$2.5	$2.6	$2.6	$2.1	-	-
BEB	-	-	$0.4	$1.4	$4.4	$4.6
Infrastructure	-	-	$0.05	$0.1	$0.1	$0.1
Total	**$2.5**	**$2.6**	**$3.1**	**$3.6**	**$4.5**	**$4.7**

Under the 525 kWh BEB Scenario, it was estimated that operating and maintenance costs will total $40.3 million and reflect a combination of $10.5 million for vehicle maintenance, $29.3 million in operating costs, and $0.5 million in infrastructure maintenance in discounted 2022 dollars.

4.3 DIESEL FUEL AND ELECTRICITY USAGE COST ESTIMATES

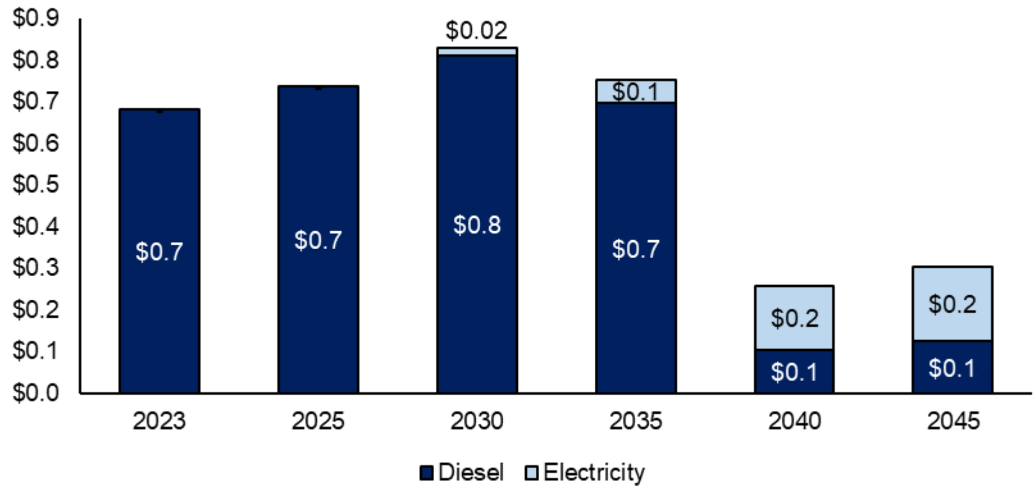
Based on the methodology described in O&M Cost Assumptions, **Table 15** summarizes the fuel and electricity cost estimates for the BEB scenario for selected years over the 2023 to 2050 period. These costs were estimated to be $6.3 million for diesel and $0.8 million in discounted 2022$ terms for electricity.

Table 15 - Fuel and Electricity Cost Drivers and Annual Cost Estimates (YOE $, millions)

	2023	2025	2030	2035	2040	2045
kWh Usage	-	-	154,534	453,183	1,101,679	1,101,679
Litres of Fuel Consumed	352,034	352,034	300,715	216,470	25,835	25,835
Annual Diesel Fuel Costs	**$0.8**	**$0.9**	**$0.9**	**$0.8**	**$0.1**	**$0.1**
Annual Electricity Costs	**-**	**-**	**$0.0**	**$0.1**	**$0.2**	**$0.2**
Total	**$0.8**	**$0.9**	**$1.0**	**$0.9**	**$0.3**	**$0.4**

Electricity and fuel costs change substantially over time under the BEB Scenario. This is illustrated in **Figure 6** below.

Figure 6 - Electricity and Diesel Costs, Selected Years, (YOE $, millions)



4.4 SUMMARY

Under the 525 kWh BEB Scenario, the total cost of implementation is $68.3 million in discounted 2022 dollars. The total capital costs are $20.9 million. Total lifecycle O&M costs of $47.4 million include operations, maintenance, and propulsion costs. Operations makes up the largest fraction of O&M costs with over $29 million in costs in discounted 2022 dollars. Overall, the transition would cost $10.5 million more discounted, relative to maintaining a diesel fleet.

Table 16 - 525 kWh BEB Scenario Summary, (discounted 2022$, millions)

Net Present Value, 2022$	Baseline	BEB - 525 kWh
Life Cycle Capital Costs	**$6.4**	**$20.9**
Buses	$6.4	$15.7
Non-Revenue	-	-
Related Infrastructure	-	$5.2
Life Cycle O&M	**$51.3**	**$47.4**
Operations & Maintenance	$39.8	$39.8
Propulsion	$11.5	$7.1
Related Infrastructure O&M	-	$0.5
Total	**$57.8**	**$68.3**

5 BEB SCENARIO – 675 KWH

This scenario examines the impact of transitioning to BEBs with a larger battery size. Most assumptions are identical to those presented in the Key Cost Assumptions and BEB Scenario – 525 kWh sections above, unless noted below. The capital costs assumed for 675 kWh BEBs is $1.4 million to reflect the cost of a larger battery relative to the 525 kWh model. In addition, updated Zero+ model outputs were used to estimate the kilometres travelled, hours of operation, and kWh used by 675 kWh BEBs. As a result of the larger battery, the Zero+ modelling indicated that there would be a slightly smaller peak fleet requirement of seven (7) 675-kWh buses, compared to the nine (9) 525 kWh buses required. Another key difference under the 675 scenario is that 2 enroute chargers are required, contributing to higher capital costs.

The results of these changes in assumptions are presented in the tables below. The purchase schedule for BEBs was assumed to remain in line with the provided diesel replacement schedule for Stratford and is not restated here.

Table 17 below applies the capital costs to the revised capital purchase schedule presented above.

Table 17 - Annual Capital Cost Assumptions, YOE$, millions

	2023 - 2030	2031 - 2040	2041 - 2050
Diesel Bus	-	-	-
Battery Electric Bus	$6.3	$20.3	$16.7
Enroute Chargers	$2.5	-	-
Additional Infrastructure	$5.6	$0.8	-
Total	**$14.3**	**$21.1**	**$16.7**

To accommodate the BEB fleet, a total of twelve (12) 150 kW in-depot dispensers and two 450 kW enroute chargers will be acquired between 2025 and 2040. **Table 18** below contains the operating statistics of the 675 kWh BEB fleet.

Table 18 - Operating Statistics by Bus Type, Selected Years

	2023	2025	2030	2035	2040	2045
Diesel						
Kilometres	749,009	749,009	631,235	399,739	-	-
Hours	36,514	36,514	31,522	20,733	-	-
Litres of Diesel	352,034	352,034	300,715	199,842	25,658	25,658
BEB						
Kilometres	-	-	117,775	349,271	749,009	749,009
Hours	-	-	4,992	15,782	36,514	36,514
kWh	-	-	163,734	535,607	1,162,214	1,162,214

Table 19 summarizes the annual vehicle maintenance costs, mid-life rehabilitation costs, and the annual EV chargers' maintenance costs between 2023 and 2050. As noted above, by 2040 the entire fleet has been transitioned to BEBs.

Table 19 - Annual Operating and Maintenance Cost Estimates, (YOE $, millions)

	2023	2025	2030	2035	2040	2045
Diesel	$2.5	$2.6	$2.6	$2.0	-	-
BEB	-	-	$0.4	$1.5	$4.0	$4.6
Infrastructure Maintenance	-	-	$0.04	$0.07	$0.10	$0.12
Total	**$2.5**	**$2.6**	**$3.1**	**$3.6**	**$4.1**	**$4.7**

Figure 7 below illustrates the ramp up of O&M costs due to the introduction of BEBs to the fleet mix.

Figure 7 - Annual O&M Costs, Selected Years, YOE$, millions

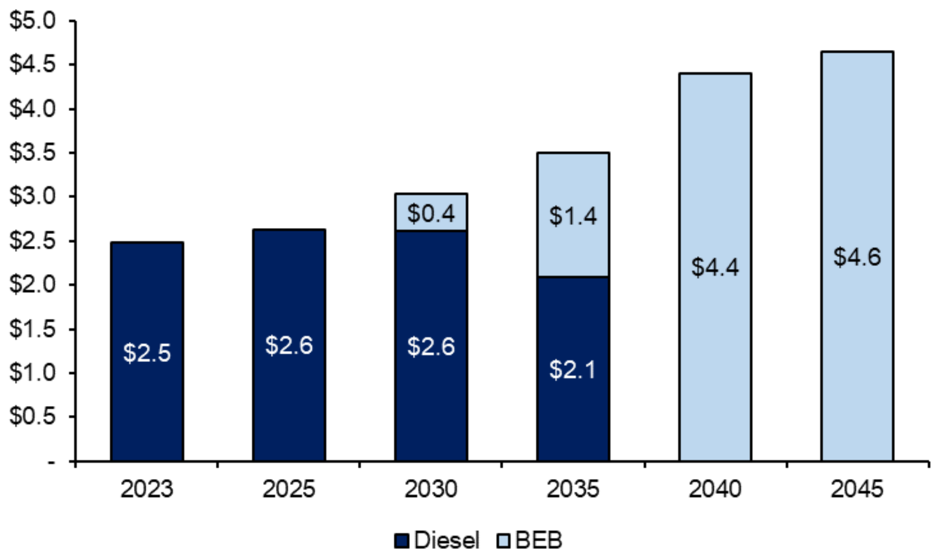


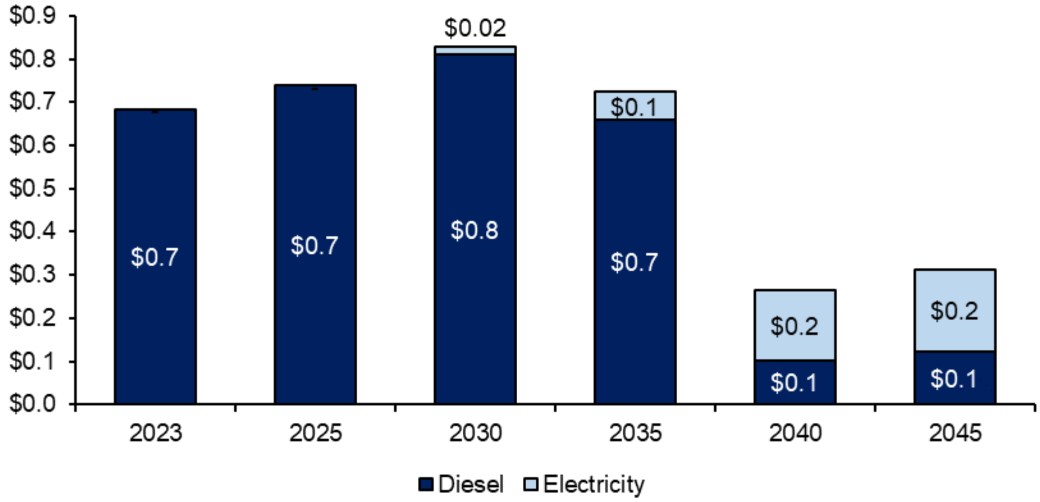
Table 20 summarizes the fuel and electricity cost estimates for the BEB scenario for selected years over the 2023 to 2050 period.

Table 20 - Fuel and Electricity Cost Drivers and Annual Cost Estimates (YOE $, millions)

	2023	2025	2030	2035	2040	2045
Annual Diesel Fuel Costs	$0.8	$0.9	$0.9	$0.7	$0.1	$0.1
Annual Electricity Costs	-	-	$0.0	$0.1	$0.2	$0.2
Total	**$0.8**	**$0.9**	**$1.0**	**$0.8**	**$0.3**	**$0.4**

Figure 8 below contains the annual electricity costs for selected years over the study period.

Figure 8 - Annual Electricity Cost Assumptions, Selected Years, YOE$, millions



5.1 SUMMARY

Under the 675 kWh BEB Scenario, the total cost of implementation is $69.3 in discounted 2022 dollars. The total capital costs are $21.9 million. Total lifecycle O&M costs of $47.4 million include operations, maintenance, and propulsion costs. Operations makes up the largest fraction of O&M costs with over $29 million in costs in discounted 2022 dollars. Overall, the transition would cost $11.6 million more discounted, relative to maintaining a diesel fleet.

Table 21 - 675 kWh BEB Scenario Summary, (discounted 2022$, millions)

Net Present Value, 2022$	Baseline	BEB - 675 kWh
Life Cycle Capital Costs	**$6.4**	**$21.9**
Buses	$6.4	$15.5
Non-Revenue	-	-
Related Infrastructure	-	$6.4
Life Cycle O&M	**$52.4**	**$47.4**
Operations & Maintenance	$39.9	$39.7
Propulsion	$12.5	$7.1
Related Infrastructure O&M	-	$0.7
Total	**$57.8**	**$69.3**

6 LIFECYCLE COST COMPARISON

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

6.1 CAPITAL COST COMPARISON

Table 22 provides a comparison of total capital costs among the three scenarios. As shown in the table, the BEB Scenario is more than twice as expensive due primarily to the difference in vehicle costs shown in **Table 2** as well as the additional equipment and infrastructure investments that would be required for BEB implementation.

Table 22 - Capital Cost Comparison, 2022$ millions

	Baseline	BEB - 525 kWh	BEB - 675 kWh
Diesel Buses	$6.4	-	-
BEBs	-	$15.7	$15.5
Total Fleet Purchases	**$6.4**	**$15.7**	**$15.5**
Additional Infrastructure	-	$5.2	$6.4
Total	**$6.4**	**$20.9**	**$21.9**

6.2 Operations And Maintenance Costs Comparison

Table 23 provides a comparison of total operating and maintenance cost estimates over the 2023 to 2050 period 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.

Table 23 - O&M Cost Comparison, 2022$ millions

	Baseline	BEB - 525 kWh	BEB - 675 kWh
Diesel O&M Costs	$39.9	$22.2	$22.1
BEB	-	$17.6	$17.6
BEB Charger Maintenance Costs	-	$0.5	$0.7
Total	**$39.9**	**$40.3**	**$40.4**

FUEL AND ELECTRICITY COSTS COMPARISON

Finally, **Table 24** 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 24 - Fuel and Electricity Cost Comparison, 2022$ millions

	Baseline	BEB - 525 kWh	BEB - 675 kWh
Diesel Costs	$9.7	$6.3	$6.2
Electricity Costs	-	$0.8	$0.9
Total Costs	**$9.7**	**$7.1**	**$7.1**

6.3 NET PRESENT VALUE 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 2022 dollars, discounted at 8%. The analysis evaluated the direct cost impacts to Stratford Transit to understand the additional costs of implementing a BEB transition plan relative to operating business-as-usual.

This analysis assumed no changes to ridership or service levels. The analysis only looked at direct cost impacts to Stratford and did not attempt to monetize public benefits to society.

Additionally, the analysis assumed that capital costs will not be offset by grant or incentive funding. Including additional funding sources, such as ICIP or ZETF, may affect the results of the analysis. However, since these funds have not been applied for or secured by Stratford, they were not included in this analysis.

The transition to BEBs is anticipated to cost $10.5 million and $11.6 million (discounted) more than maintaining a fully diesel fleet for the 525 and 675-kWh scenarios, respectively. The result shows that the higher capital costs of BEB buses is not offset by O&M and propulsion cost savings relative to the Baseline Scenario.

Table 25 - Overall Lifecycle Cost Comparison, 2022$

Net Present Value, 2022$	Baseline	BEB - 525 kWh	BEB - 675 kWh
Life Cycle Capital Costs	**$6.4**	**$20.9**	**$21.9**
Buses	$6.4	$15.7	$15.5
Non-Revenue	-	-	-
Related Infrastructure	-	$5.2	$6.4
Life Cycle O&M	**$52.4**	**$47.4**	**$47.4**
Operations & Maintenance	$39.9	$39.8	$39.7
Propulsion	$12.5	$7.1	$7.1
Related Infrastructure O&M	-	$0.5	$0.7
Total	**$58.8**	**$68.3**	**$69.3**

6.4 INFRASTRUCTURE FINANCING OPTIONS

There are several financing opportunities available to Stratford to secure funding for its zero emission vehicle (ZEV) fleet transition. The two primary funding sources are the Investing in Canada Infrastructure Program (ICIP), and the Zero Emission Transit Fund (ZETF). [2],[3]

The ICIP is administered by Infrastructure Canada, and has invested $131 billion in over 85,000 projects. This program has already funded several other municipalities' transit fleet buses, including conventional transit and other mobility services. The federal government will invest up to 40% for most municipal public transit costs, though this may increase to 50% for rehabilitation projects. Funding provided by Infrastructure Canada is divided among the provinces who distribute funding by municipality.

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.

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 Stratford, it is not included in this analysis.

[2] Infrastructure Canada - Investing in Canada Infrastructure Program

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

7 GREENHOUSE GAS 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.

7.1 ASSUMPTIONS AND METHODOLOGY

The analysis quantified GHG impacts based on estimates of diesel fuel and electricity usage by conventional transit buses over the 2023-2050 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 2.262 kilograms (kgs) of carbon dioxide (CO_2) 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 CO_2 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 CO_2 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.

7.2 GHG EMISSION REDUCTION IMPACTS

7.2.1 BEB - 525 KWH

Based on the assumptions above, the GHG emissions from BEB operations are summarized in **Table 26** below. Over the study period, BEBs will reduce emissions by approximately 11,500 tonnes.

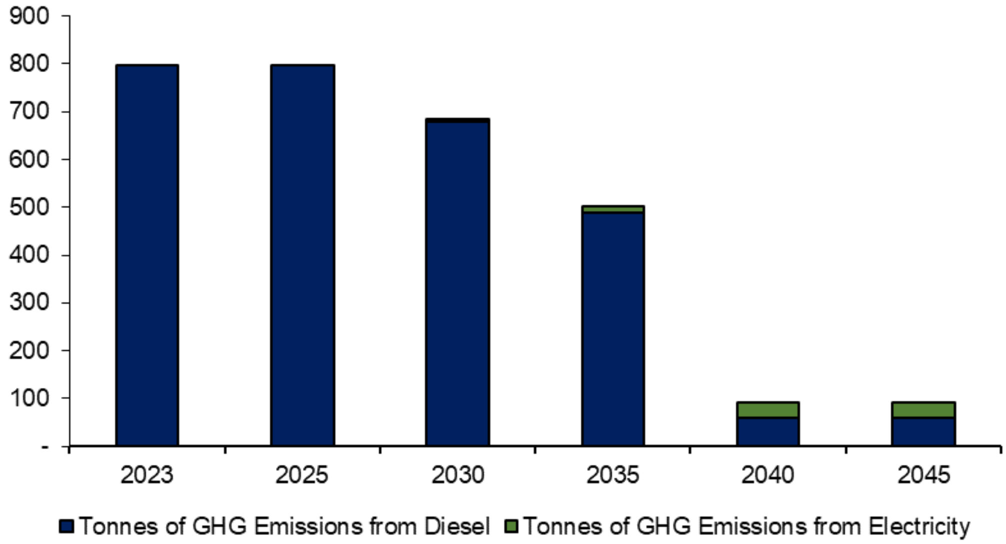
Table 26 - GHG Emissions, Baseline and BEB Scenarios, Selected Years and Total, tonnes

	2025	2030	2040	Total
Baseline	**796**	**796**	**796**	**22,296**
Diesel	796	796	796	22,296
BEB	-	-	-	-
BEB Scenario	**796**	**685**	**91**	**10,830**
Diesel	796	680	58	10,298
BEB	-	5	33	532

This reduction is due to the dramatically lower operating emissions of BEBs relative to diesel buses.

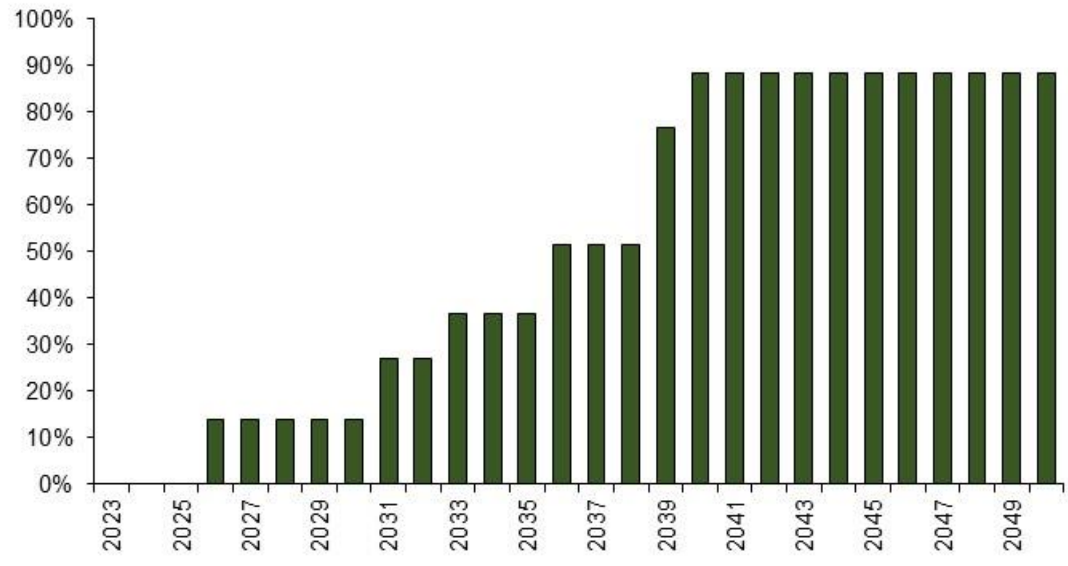
Figure 9 below shows the annual GHG emissions from operations as the fleet mix changes in the BEB Scenario. There is a substantial decline from nearly 800 tonnes of GHGs per year to 91 tonnes per year in the full build BEB Scenario.

Figure 9 - Annual GHG Emissions, BEB Scenario, tonnes



The cumulative reduction in GHG emissions is shown in **Figure 10** below. The reduced emissions grow substantially over time as the diesel fleet is converted to BEBs. When the full transition from diesel to BEBs is complete, there is approximately a 90% reduction in GHG emissions.

Figure 10 - Cumulative GHG Reductions in BEB Scenario, percentage



7.2.2 BEB – 675 KWH

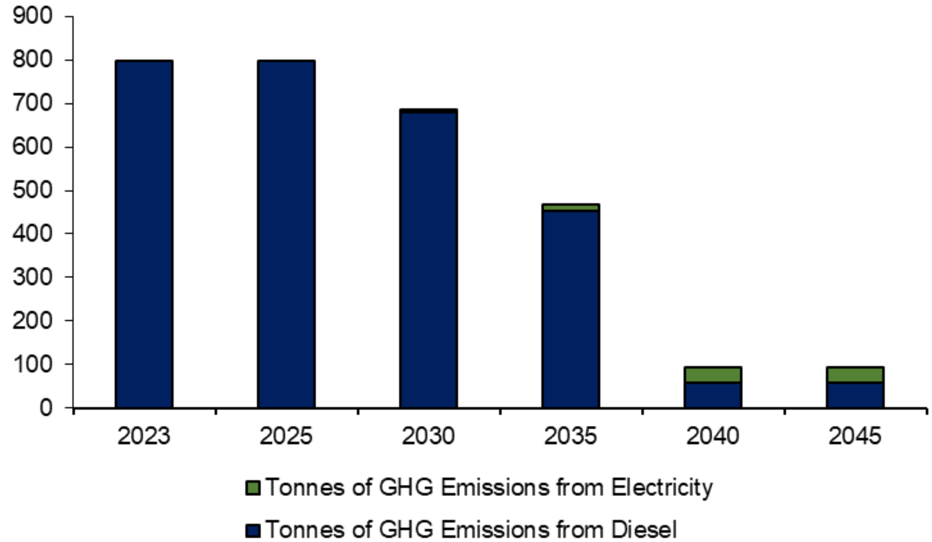
Based on the assumptions above, the GHG emissions from BEB operations are summarized in **Table 27** below. Over the study period, BEBs will reduce emissions by approximately 12,000 tonnes.

Table 27 - GHG Emissions, Baseline and BEB Scenarios, Selected Years and Total, tonnes

	2025	2030	2040	Total
Baseline	**796**	**796**	**796**	**22,296**
Diesel	796	796	796	22,296
BEB	-	-	-	-
BEB Scenario	**796**	**685**	**93**	**10,338**
Diesel	796	680	58	9,906
BEB	-	5	35	432

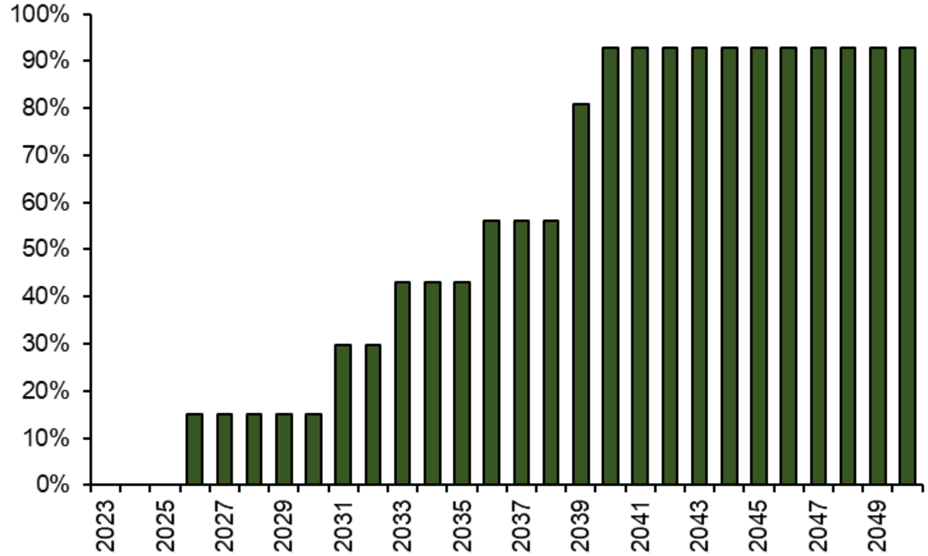
This reduction is due to the dramatically lower operating emissions of BEBs relative to diesel buses. **Figure 11** below shows the annual GHG emissions from operations as the fleet mix changes in the BEB Scenario. There is a substantial decline from nearly 800 tonnes of GHGs per year to 91 tonnes per year in the BEB Scenario.

Figure 11 - Annual GHG Emissions, BEB Scenario, tonnes



The cumulative reduction in GHG emissions is shown in **Figure 12** 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 will be reduced by approximately 93%.

Figure 12 - Reductions in Annual GHG Emissions in the BEB Scenario, percent



8 SOLAR FEASIBILITY ANALYSIS

HDR prepared a solar feasibility analysis to assess the cost effectiveness of installing solar photovoltaic (PV) units on various Stratford transit properties. **Table 28** below contains the general assumptions used in the solar feasibility analysis. The annual solar generation estimates in kWh were produced by HDR.

Table 28 - Solar Analysis Assumptions

General Inputs	Value	Notes/Source
Base Year	2023	
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 (Cdn Source)	$2,242	Natural Survey Report of PV Power Applications in Canada suggests value of $2.10 per Watt (W)
$/kW CapEx (US Source)	$2,641	Sensitivity - US Data converted to CAD and inflated; Index | Electricity | 2022 | ATB | NREL
$/kW OpEx	$27.80	Index | Electricity | 2022 | ATB | NREL
2020 USD/CAD Conversion	1.3415	Annual exchange rates - Bank of Canada
2022 Average Electricity Price	$0.10	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 are four options considered in the analysis including two at the Transit Garage and one at Cooper Terminal:

- Transit Garage (Option 1): Under this option, new solar panels are installed to cover available surface area of the facility roof, including the barn. Approximately 2,200 square meters would be available for solar panels, allowing for a nameplate capacity 327.6 kilowatts (kW). Annual generation would be approximately 408,000 kWh.
- Transit Garage (Option 2): Under the second Transit Garage option, new solar panels are installed on the available roof space only. The installed capacity would be about 200.7 kW, and occupy a space of approximately 1,300 square meters. Annual generation would be approximately 250,000 kWh.
- Cooper Terminal: Under the Cooper Terminal option, new solar panels are installed on a new overhead gantry structure above the bus loop area. The installed capacity would be about 163.4 kW, and occupy a space of 1,100 square meters. Annual generation would be approximately 204,000 kWh.

A summary of assumptions by project is shown below in **Table 29**.

The capital and annual O&M costs were calculated using the $/kW values in **Table 28** above.

Table 29 - Project-Specific Assumptions

Variable	Transit Garage (1)	Transit Garage (2)	Cooper Terminal
Capital Cost ($)	$734,601	$450,044	$366,404
Annual O&M ($)	$9,108	$5,580	$4,543
BEB Demand (kWh)	710,707	710,707	274,532
Solar Generated (kWh)	408,098	250,017	203,674
Grid Energy Required	302,609	460,690	70,858
Net Capacity Factor	14.2%	14.2%	14.2%
Construction Year	2023	2023	2023
Nameplate Capacity (kW)	327.6	200.7	163.4

8.1 METHODOLOGY

The analysis defined 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 was 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 assumed 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 assumed a degradation factor on installed solar PV output of 0.5% per year, compounding. The total costs under the No Build case were compared against the total costs under the Build case to determine whether there are cost savings.

8.2 RESULTS

The estimated benefits are presented for each scenario below, using the calculated present value of costs to estimate the benefit cost ratio (BCR).

Table 30 - Solar Feasibility Analysis Results (2022$, millions)

	Transit Garage (1)	Transit Garage (2)	Cooper Terminal
Energy Cost Savings (PV)	$576,999	$353,492	$287,969
Capital Costs (PV)	$734,601	$450,044	$366,404
O&M Costs (PV)	$142,366	$87,218	$71,009
NPV	-$299,968	-$183,771	-$149,444
BCR	**0.59**	**0.59**	**0.59**

Under Transit Garage (Option 1), the discounted electricity cost savings are $0.6 million over the study period. The total capital costs are $0.7 million. The NPV of this option is -$0.3 million, and the project has an estimated cost-benefit ratio of 0.59. For every dollar spent on constructing the project, the project will only yield 59 cents of savings, discounted.

Under Transit Garage (Option 2), the discounted electricity cost savings are $0.4 million over the study period. The total capital costs are $0.4 million. The NPV of this option is -$0.2 million, and the project has an estimated cost-benefit ratio of 0.59.

Under the Cooper Terminal option, the discounted electricity cost savings are $0.3 million over the study period. The total capital costs are $0.4 million. The NPV of this option is -$0.1 million, and the project has an estimated cost-benefit ratio of 0.59.

9 SUPPLEMENTARY 10-YEAR CAPITAL PLAN TABLES

This section illustrates a more detailed capital purchase plan under the BEB Scenario, and supplemental charts to illustrate the impact on the fleet mix. As noted above in the BEB Scenario sections, figures shown in the tables and figures below are representative of the scheduled retirement of diesel vehicles.

9.1 525 KWH SCENARIO

Table 31 contains an annual breakdown of capital purchases from 2023-2032.

Table 31 - Capital Purchase Assumptions, 2023-2032

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Diesel	-	-	-	-	-	-	-	-	-	-
BEB	-	2	-	-	-	-	2	-	2	-

Figure 13 contains the total fleet composition from 2023-2032, indicating the changes to fleet mix based on the purchase schedule presented in **Table 31**.

Figure 13 - Total Fleet Composition, 2023-2033

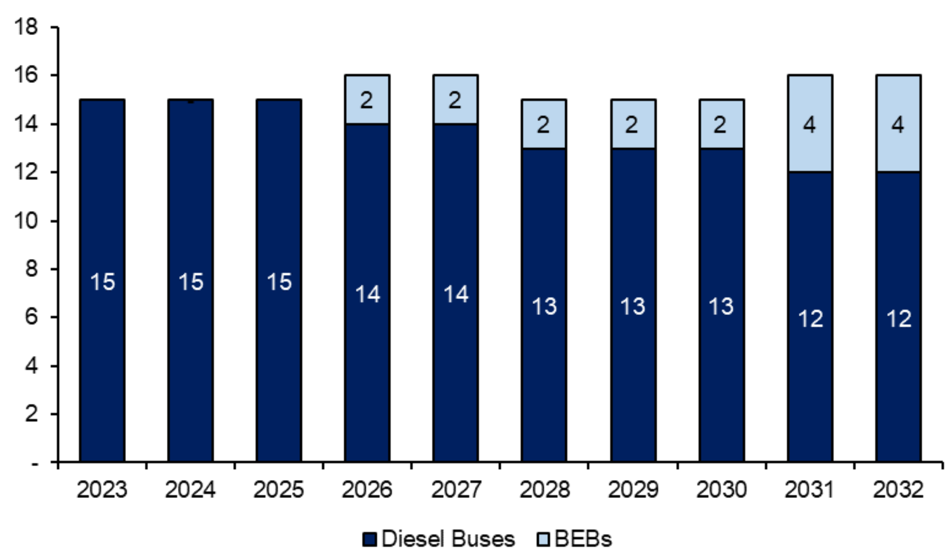


Table 32 applies the assumed capital costs to the capital purchase schedule presented above.

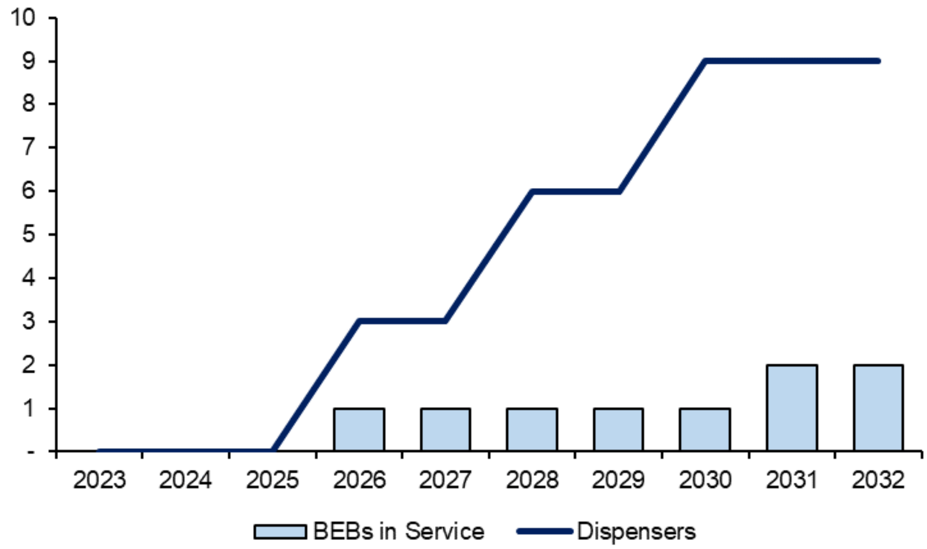
Table 32 - Capital Cost Assumptions, 2023-2033, YOE$ millions

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Diesel	-	-	-	-	-	-	-	-	-	-
BEB	-	$2.5	-	-	-	-	$2.9	-	$3.0	-

Figure 14 contains the necessary purchase schedule for dispensers relative to the number of BEBs in service. Both items were assumed to be purchased 2 years ahead of entering service. Dispensers are introduced based on a 4 stage phasing plan. The number of dispensers installed in each phase was

determined in line with the implementation of BEBs and fleet facility plans developed by HDR. This ensures that introductions of BEBs in subsequent years will have sufficient access to in-depot charging.

Figure 14 - Peak BEBs and Dispensers in Service, 2023-2032



9.2 675 KWH SCENARIO

Table 33 contains an annual breakdown of capital purchases from 2023-2032.

Table 33 - Capital Purchase Assumptions, 2023-2032

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Diesel	-	-	-	-	-	-	-	-	-	-
BEB	-	2	-	-	-	-	2	-	2	-

Figure 15 contains the total fleet composition from 2023-2032, indicating the changes to fleet mix based on the purchase schedule presented in **Table 33**.

Figure 15 - Total Fleet Composition, 2023-2032

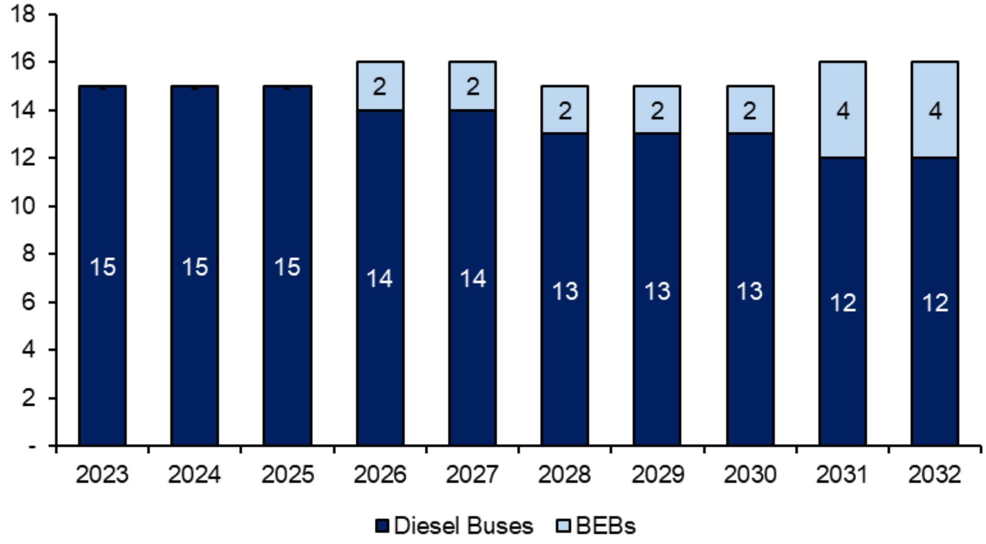


Table 34 applies the assumed capital costs to the capital purchase schedule presented above.

Table 34 - Capital Cost Assumptions, 2023-2032, YOE$ millions

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Diesel	-	-	-	-	-	-	-	-	-	-
BEB	-	$2.9	-	-	-	-	$3.4	-	$3.6	-

Figure 16 contains the necessary purchase schedule for dispensers relative to the number of BEBs in service. Both items were assumed to be purchased 2 years ahead of entering service. Dispensers are introduced based on a 4 stage phasing plan. The number of dispensers installed in each phase was determined in line with the implementation of BEBs and fleet facility plans developed by HDR. This ensures that introductions of BEBs in subsequent years will have sufficient access to in-depot charging.

Figure 16 - Peak BEBs and Dispensers in Service, 2023-2032