GMF Schedule F – Project Completion Report

Front-End Engineering and Design (FEED) Study for the Electrification of the St. Catharines Transit Commission's Conventional Bus Fleet

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GMF Number	18100
Name of Lead Applicant	St. Catharines Transit Commission
Siemens Technical Contact	Jordan Kamphuis, P. Eng. Solutions Engineer
Office Address	1577 North Service Road East, Oakville, Ontario, L6H 0H6
Phone	+1 (289) 455-1214
Email	jordan.kamphuis@siemens.com
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1 INTRODUCTION

a) Who was involved in doing the Feasibility Study, and what are their affiliations? Please include name, title and contact information. Those involved could include municipal staff, engineers and other consultants, a representative from a non-governmental organization, and others.

The following individuals contributed to the completion of this Feasibility Study:

St. Catharines Transit Commission

Tim Luey, C.P.A., C.A.
Manager of Transportation
905-685-4228, ext. 229
tluey@yourbus.com

Neil Waldick
Manager of Maintenance
905-685-4228, ext. 247
nwaldick@yourbus.com

Adam Arbour
Manager of Customer Experience
aarbour@yourbus.com

Siemens Canada Limited

Ray Little, CMA, CMC, MBA, PMP
Zero Emissions Mobility Expert
705-323-4155
ray.little@siemens.com

Jordan Kamphuis, P.Eng.
Solutions Engineer
289-455-1214
jordan.kamphuis@siemens.com

Jordan Hebbert
Microgrid Engineering Specialist
905-580-2876
jordan.hebbert@siemens.com

Brent Cameron
Engineering Project Manager
365-996-2695
brent.cameron.ext@siemens.com

Alectra Utilities

Daniel Carr
Head, Smart Cities, GRE&T Centre

647-388-8241
Daniel.Carr@alectrautilities.com

Curtis Leishman
Project Lead, Smart Cities, GRE&T Centre
437-246-6916
curtis.leishman@alectrautilities.com

Rodrigo Frigotto, P.Eng, M.Sc
Supervisor, Distribution Design – ICI & Layouts
437-229-8952
Rodrigo.Frigotto@alectrautilities.com

Ketan Patel
Engineering Technologist
905-798-2748
Ketan.Patel@alectrautilities.com

Alectra Energy Solutions

Ammar Nawaz, P.Eng., LL.M.
Vice President - Distributed Energy Solutions
437-249-6972
ammar.nawaz@alectrasolutions.com

Helen Papachronis
Director E-Mobility
416-318-3359
helen.papachronis@alectrasolutions.com

Ricardo Macasaet, C.E.T.
Design Technologist, Power Services
416-618-0366
ricardo.macasaet@alectrapowerservices.com

CBRE Limited

Pat Furney
Facility Manager
289-686-2098
patricia.furney@cbre.com

Wood Plc

Naeem Farooqi
Global Technical Director- Zero Emission Mobility
416-816-6786
naeem.farooqi@woodplc.com

Jamal Nureddin
Engagement Lead, Zero Emission Mobility
289-812-8792

jamal.nureddin@wsp.com

Norman Hendry
Zero Emissions Mobility Lead - Canada
780-233-4718
norman.hendry@woodplc.com

Matthieu Goudreau, M.Sc.E.
Consultant, Zero Emission Mobility
matthieu.goudreau@woodplc.com

WalterFedy

Nick Angeloff, BASc, P.Eng.
Senior Engineer, Practice Lead, Electrical Associate
289-799-3547, ext. 497
nangeloff@walterfedy.com

Marc Moubarak, P.Eng, MBA
Senior Structural Engineer
289-799-3547, ext. 453
mmoubarak@walterfedy.com

Kevin Chen
EIT, Electrical
519-576-2150, ext. 215
kchen@walterfedy.com

2 THE FEASIBILITY STUDY

a) Describe the process that you undertook to make this feasibility study a reality, from concept, to council approval, to RFP, to final deliverable.

Siemens engaged in multiple discussions with the St. Catharines Transit Commission (SCTC) surrounding battery electric buses (BEB) and the feasibility of implementing this technology within SCTC's fleet. SCTC is aware of the opportunity for emissions reductions via the implementation of such a fleet, thus supporting the strategy of becoming a sustainable community while reducing ongoing operating costs. However, SCTC was unsure of the best path forward from both a planning and implementation perspective. A Battery Electric Bus (BEB) fleet requires the adoption of a completely new skill set for the St. Catharines Transit Commission, from both an operation and maintenance point of view. In addition, early engagement with a variety of stakeholders is required, including the Local Distribution Company (LDC), which in this case is Alectra Utilities. SCTC was also made aware of potential opportunities to reduce the cost and increase the resilience of a BEB fleet through the use of Distributed Energy Resources (DERs) such as Battery Energy Storage Systems (BESS) and solar photovoltaic (PV) generation. However, determining the feasibility, sizing, and business case of these potential new assets was key to assessing the value of them and presenting said value to stakeholders at various levels of government.

Bearing these various aspects in mind, the Siemens team proposed that SCTC engage with our eMobility consulting group, to aid in the required planning process for bus electrification. Two primary phases of the consultation were proposed, as follows:

Phase 1: Preliminary feasibility study for fleet electrification.

Phase 2: Technical solution to evaluate grid architecture and electrical infrastructure required. This phase would include the overall project foreseeing all components from project planning and kickoff to implementation plan.

Further details regarding the exact deliverables proposed and agreed to will be described later in this report.

As part of this work, Siemens also made SCTC aware of potential funding available through the Federation of Canadian Municipalities' (FCM) Green Municipal Fund (GMF), which provides financial support for feasibility assessments such as the one proposed. While FCM was engaged to provide funding for the second phase of this study, the first phase is also discussed in this report as they are integrally linked together.

The St. Catharines Transit Commission saw the value in performing this Feasibility Study work and made the decision to proceed with Siemens as the selected consultant. Since that decision was made, the Siemens team has conducted the Feasibility Study over the course of 12 months, with the Final Deliverables being completed in October 2022.

b) What were the objectives of the Feasibility Study (what was it seeking to determine)?

The first phase of the Feasibility Study was primarily focused on assessing the possibility of implementing a battery electric bus (BEB) fleet within the City of St. Catharines, based on currently available vehicle and charging technologies. This included determining the possibility of using battery electric buses to replace their diesel counterparts, while maintaining the same level of service and using the same overall number of vehicles. As part of this work, different variables were modelled including seasonal effects on BEB performance, the impact of on-route chargers at the Downtown Terminal, reduction in bus battery capacity over the life of the vehicle, and the impact of using diesel heaters. In addition, Alectra Energy Solutions, in partnership with Alectra Utilities, was to complete a preliminary review of the required feeder upgrades which would be necessary to support the charging of an electric bus fleet. The phase one study would also seek to determine fuel cost savings and Greenhouse Gas (GHG) reductions, which would result from the use of electric buses.

Once the feasibility of BEB implementation was confirmed in phase one, the goal of the second phase of the study was to examine the infrastructure requirements as well as the operational and financial implications in much greater detail. This would include creating a BEB pilot study, which SCTC could adopt as a blueprint to guide the initial electrification of its fleet and to gauge the initial performance of these new vehicles. The team would provide detailed bus charging load profiles, which were optimized using proprietary simulation algorithms from Siemens. In addition, a software from Siemens known as PSS DE® or "Energy Twin" was used, to determine whether there would be a benefit to implementing DERs such as batteries, solar, or other assets at each of the SCTC sites. Once this work was complete, 30% electrical, civil, and structural engineered drawings would be completed, to prepare SCTC for a potential infrastructure RFP. A high-level Class D estimate and major equipment procurement schedule would also be provided, for the purposes of supporting future funding applications to the Zero Emission Transit Fund (ZETF). The procurement schedule and associated implementation plan were to be designed to match St. Catharines Transit's predetermined diesel bus retirement plan, thus resulting in a phased rollout of infrastructure as well as BEBs. From the vehicle perspective, a detailed Battery Electric Bus specification would be developed, which would include guidance for maintenance policies pertaining to these new types of vehicles. In addition to this, a diesel bus retirement plan and BEB procurement schedule would be shared with SCTC. Finally, a 12-year financial operating model would be developed. All the outputs from these various focus items are described within the Final Deliverable resulting from this Feasibility Study.

c) What approach (or methodology) was used in the Feasibility Study to meet these objectives?

The Siemens team employed a concept known as the Front-End Engineering Design (FEED) process to complete this Feasibility Study. FEED is an engineering design approach which is used to provide clients with a complete plan for infrastructure upgrades, prior to releasing RFPs for equipment supply and installation. By planning out the work ahead of time through the creation of design drawings and reports, the client ensures that they will receive competitive proposals from contractors at time of RFP. This helps to control costs and keep the overall Capital Expenditures (CAPEX) lower during the construction and installation phase of the project. As the cost of performing a FEED is quite small relative to the cost of capital infrastructure, there is tremendous value in performing this work to reduce the overall investment required for the client. The FEED process also requires the use of a structured, project-oriented approach. What this means is that an engineering project manager is engaged to manage the overall process and maintain an active Gantt chart throughout the course of the work. Underneath the project manager can sit engineers and technical specialists from a variety of disciplines. In the case of this study, specialists who were engaged included, but were not limited, to zero emission bus modelling experts, DER simulation specialists, as well as electrical and structural engineers.

It should also be noted that the Siemens consulting team prides itself on employing a transparent and collaborative communication approach, when conducting these studies. What this means is that SCTC was regularly engaged to review preliminary results at different stages of the study. During these engagements, SCTC was given the opportunity to share feedback, ask questions, and provide guidance on whether the results were meeting expectations.

Finally, the Siemens team made a strategic decision to engage with Alectra Energy Solutions as a partner, during the process of completing this FEED. The reason for this is that the utility grid upgrades and connection implications are a fundamental requirement for supporting the electrification of an entire bus fleet. By working with Alectra from the start, the Siemens team was able to ensure a coordinated approach to investigating the grid upgrade requirements and subsequently presenting the proposed solutions to the client.

d) Please describe any public consultations conducted as part of the Feasibility Study and their impact on the Study.

No public consultations were conducted as part of the Feasibility Study. However, the benefits to the public of converting diesel to battery electric buses have been well studied and are quite clear. These benefits are comprised of reductions in air pollutants including GHGs, quieter streets resulting from lower noise levels emitted by the buses, as well as a more comfortable ride for passengers.

3 FEASIBILITY STUDY FINDINGS AND RECOMMENDATIONS

a) What were the environmental findings related to the options explored in the Feasibility Study? Please provide quantitative results and summary tables of these results (or the page numbers from the Feasibility Study report).

The consulting team determined the following when assessing the environmental impact of switching from diesel to battery electric buses:

- For a 40-foot diesel bus using the average fuel economy confirmed by SCTC of 0.62L/km, the CO2 emissions are estimated to be 1.631 kg/km. This is based on the CO2e emissions factor for Heavy-Duty vehicles using Diesel (B4) fuel, which is 2.63 kg of CO2e emissions per litre.
- The average annual fleet utilization for St. Catharines Transit is 58,000 km per bus.
- It is envisioned that the final state of the SCTC fleet will comprise 58 conventional 40-foot buses in daily operation.
- Auxiliary diesel heaters are planned for these battery electric buses, as they greatly expand the range of the buses and enable the service delivery capability of a bus fleet with 100% electric powertrains operating in colder climates. As can be seen below, the GHG reduction potential is still significant, equivalent to removing emissions from 1,046 gasoline-powered passenger vehicles per year, even with the use of auxiliary heaters.
- The Grid Emissions Factors used for all calculations in this section have been pulled from Annex C of the "Zero Emission Transit Fund - The GHG+ Plus Guidance Modules", found here: https://www.infrastructure.gc.ca/zero-emissions-trans-zero-emissions/ghg-modules-ges-eng.html.

With the above assumptions in mind, we can now complete the following calculations to estimate the total diesel fuel and GHG reductions which can be achieved, once all 58 of SCTC's operational buses are electrified. Note that emissions are stated in metric tons, or tonnes, of CO2 equivalent emissions. In addition, the grid emissions factor reflects the predicted values for 2031, when SCTC would have 58 BEBs in operation.

$$Diesel\ Fuel\ Elimination = \ Annual\ Utilization * Fuel\ Economy$$

$$Diesel\ Fuel\ Elimination\ = 58{,}000km * \left(0.62\frac{L}{km}\right) = 35{,}960\frac{L}{year}\ per\ 40'Diesel\ Bus$$

$$Downstream\ CO2\ Reduction = \left(\frac{1.631kg}{km}\right) * (58{,}000km) = \sim 94.6\ tonnes/bus/year$$

$$BEB\ Auxiliary\ Heater\ CO2\ Ouput = \sim 6.8\ tonnes\ per\ bus, per\ year$$

$$BEB\ Electricity\ Grid\ Factor\ CO2\ Output = \ \sim 2.5\ tonnes\ per\ bus, per\ year$$

$$Total\ BEB\ Scope\ 1\ and\ Scope\ 2\ Emissions = \sim 9.3\ tonnes\ per\ bus, per\ year$$

$$Net\ Downstream\ CO2\ Reduction = 94.6 - 9.3 = \sim 85.3\ tonnes\ per\ bus, per\ year$$

$$Total\ Net\ Downstram\ CO2\ Reduction = 85.3\ tons * 58\ BEBs = \sim 4{,}947\ tonnes\ per\ year$$

The assessment above includes consideration for reduced auxiliary diesel heater usage throughout the year for winter months, as well as emissions from the electricity grid.

In the following table, a slightly different perspective is provided by the Siemens Energy Twin simulation team. They estimated the magnitude of CO2 reductions over a 10-year period, which considered the bus electrification plan outlined in the Final Deliverable, as well as each of the different Distributed Energy Resource (DER) scenarios which were proposed. For clarity, the values you see below are for years 0-10 of SCTC's fleet electrification project. As will be discussed later in the report, the SCTC team is planning to proceed with "Scenario 1" for project implementation. Scenario 1 entails the installation of a Battery Energy Storage System at the First St. Louth garage, along with utilization of the existing onsite generator, and no new DER assets at the Downtown Terminal. The other scenarios are described further in deliverable "10. Energy Twin Study – 06.29.2022".

Carbon Overview (10 Year)

Scenario	Overall CO2 Reduction over 10 years (tons)
Reference: Diesel Buses	-
Scenario 0: Grid + Generator	25,727
Scenario 1: Grid, Generator + BESS	25,719
Scenario 2: Grid, Generator, BESS + PV	25,774
Scenario 3: Grid, Large Generator, BESS + PV	25,775
Scenario 4: Grid, Generator + Large BESS	25,720

Table 1 -Total Net Carbon Reductions Resulting from Years 0-10 of SCTC's Fleet Electrification Project

b) What were the financial findings related to the options explored in the Feasibility Study (for example, results of a cost-benefit analysis, financial savings identified, and so on)? Please provide quantitative results and summary tables of these results (or the page numbers from the Feasibility Study report).

The complete financial analysis for this project is outlined in the file titled "17. SCTC Fleet Electrification - 12 Yr. Financial Model Summary - 10.28.2022", which comprises part of the Final Deliverable resulting from this consultation. However, there are a few key points worth highlighting within this report as well. First, it was identified that the estimated fuel cost savings which SCTC will see as a result of electrifying their fleet under Scenario #8.3 will be $2,816 CAD per day, per page 4 of "3. Battery Electric Bus Route Study – Final Scenario – 01.07.2022". In addition, per page 2 of the financial operating model, it was determined that the total electric bus lifecycle costs would be $542,859 CAD per vehicle, in comparison to $1,012,880 CAD per diesel bus, representing a lifecycle cost savings of $470,021 CAD per vehicle over a 12-year period. These numbers reflect Lifecycle Analysis Scenario #2 from the aforementioned financial analysis, which considers a side-by-side comparison of diesel and electric buses, in the scenario that they are both purchased at the same time. Meanwhile, Lifecycle Analysis Scenario #1 reflects greater savings, because it considers the existing fleet of SCTC, which is comprised of a number of older diesel buses requiring a higher level of maintenance. Finally, per page 12 of "10. Energy Twin Study – 06.29.2022", using the Siemens Energy Twin simulation tool, the team identified that the estimated payback period for the Battery Energy Storage System (BESS) at the First St. Louth Depot was 2.78 years, which would be achieved through Global Adjustment charge mitigation. Additional operational savings from Global Adjustment mitigation would continue to be incurred on a yearly basis following this initial payback period, as well.

c) Based on the environmental and financial findings above, what does the Feasibility Study recommend?

As a result of the positive GHG reductions and Operational Expense (OPEX) savings identified through this Feasibility Study, the team recommends that the St. Catharines Transit Commission proceed with an application to the Zero Emissions Transit Fund (ZETF) under the Capital Stream, which provides government funding for both battery electric buses as well as the required infrastructure to support them. Following application submission and confirmation of funding, it is recommended to initiate separate procurements for battery electric buses and infrastructure. The bus procurement process is one which SCTC is quite familiar with and one of the deliverables provided through this study was a BEB procurement specification, thus enabling SCTC to release an RFP with relative ease. Meanwhile, it is recommended that SCTC procure the infrastructure upgrades and charging equipment via an Energy as a Service (EaaS) model, where SCTC would pay for unfunded costs on a $/kWh basis throughout the lifecycle of the project, thus avoiding any upfront CAPEX. In addition to CAPEX reduction and/or elimination, using an EaaS model for infrastructure would lessen the administrative burden, as well as the implementation risk profile, for SCTC. It would also allow SCTC to stipulate certain performance requirements within the contract, to ensure that the correct level of infrastructure uptime is provided by the successful vendor.

On a separate note, it is also recommended that St. Catharines Transit consider an additional consultation for the software systems and associated integration required to facilitate a battery electric bus fleet. To ensure that this is a successful electrification project, Siemens recommends the optimization of existing SCTC software systems, as well as the potential implementation of other commercially available tools, which may also require integration to communicate with each other. It is foreseen that these tools and the associated integration between them will ensure optimal operation of battery electric buses at the First St. Louth garage.

From an electrical infrastructure perspective, the first layer of software which will support the reduction of both CAPEX and OPEX is the Charge Management System, otherwise known as a CMS. The CMS will support a variety of functions including real-time status reporting of the charging, detailed charge transaction information, notifications for errors and other events which occur at site, as well as load management. CMS load management capabilities vary widely between vendors and can have simple or more sophisticated approaches to load management. Simple solutions include setting power limits for the site and ensuring that vehicles follow a pre-set strategy, such as First-In First-Out. On the other hand, these systems can also consider many additional operational factors including vehicle schedules, cost of energy, pre-conditioning requirements, and vehicle to route allocation. As we go down the path of more advanced optimization algorithms, the required data inputs from other systems also continues to grow and this is discussed in further detail, below. To round out the management of electrical infrastructure, a microgrid controller (MGC) and its associated intelligence is also required. The MGC is discussed in detail within the Energy Twin study, however, suffice to say that it manages the operation of Distributed Energy Resources such as Battery Energy Storage Systems, PV installations, generators, as well as the facility and charging loads.

It was mentioned in the previous paragraph that more advanced load management algorithms require data from other telematics systems operated by the transit agency, including the CAD/AVL system, vehicle scheduling software, and depot management system. The transfer of this data can be facilitated via the use of Application Programming Interfaces (APIs), which in layman terms allow different software systems to speak with each other. In addition to these systems, a connection with the microgrid controller is also highly beneficial, as the additional sources of energy supply from the DERs can be accounted for, to provide optimal energy "operation" at site. Figure 1 below helps to illustrate the concept of such an integrated software solution, for the reader's benefit.

The Siemens team has assessed that a key aspect of any integrated software solution for a fully electrified bus garage must include a depot management system, in combination with a Real Time-Locating System (RTLS). Depot management systems are provided by several bus telematics software providers and support automatic vehicle-to-block assignment and vehicle parking within the depot, among other things. Meanwhile, the RTLS consists of wireless "gateways" placed throughout the garage, which are monitoring for signals received from active transponders on each bus. By combining the intelligence of a depot management system with the real-time positioning information of each bus, the integrated software solution for a given site can ensure that the right bus parks at the right dispenser for charging, thus enabling the bus to leave for its route on time. This is key since the time for bus fuelling dramatically increases in comparison to diesel and there are various charging processes to consider, such as sequential charging with multiple dispensers and pre-conditioning. With this in mind, it is crucial that information such as vehicle position, State of Charge (SOC), and route assignment is exchanged and optimized in real-time. With fast and efficient transfer of data between its various software systems, SCTC can ensure that operations at the First St. Louth Garage will be intelligently managed.

As a next step, the Siemens team recommends that SCTC conduct a follow-up consultation, for software solutions to support BEB garages. This study would help SCTC to better understand whether its current software systems will be able to support the needs of BEB operations, or if additional capabilities will need to be developed to ensure a smooth transition to this new bus technology.

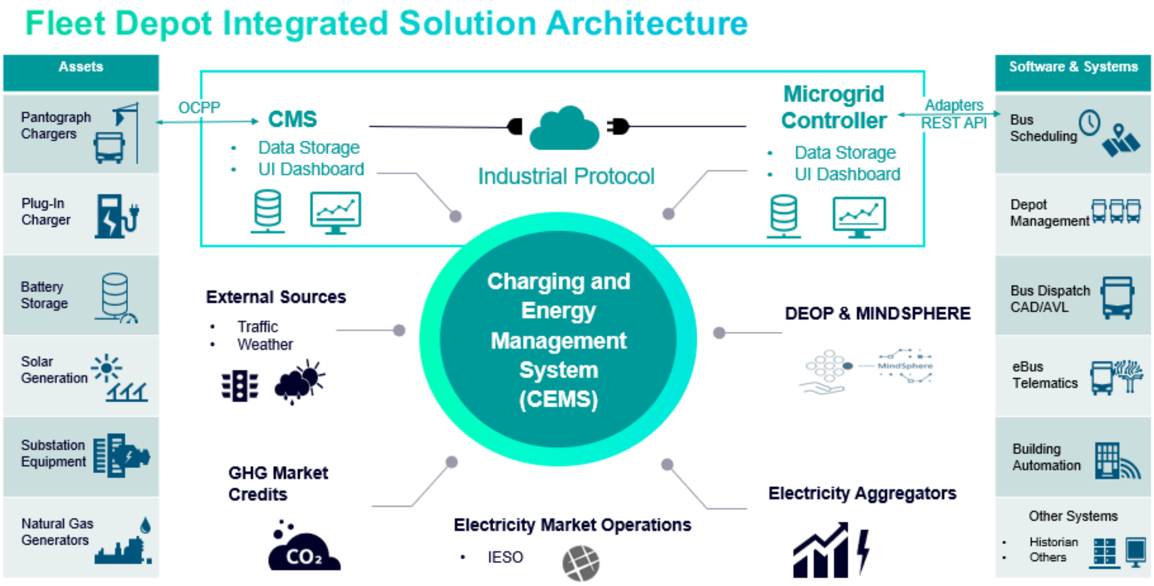

Figure 1 - Example of Integrated Software Solution for an Electrified Fleet

4 LEAD APPLICANT'S NEXT STEPS

a) Taking the Feasibility Study's recommendations into account, what next steps do you as the municipality plan to take? What potential benefits or internal municipal improvements would result from these next steps?

The next planned steps by SCTC would include an application to the Zero Emissions Transit Fund (ZETF), to support the procurement of battery electric buses and the required supporting infrastructure. All the deliverables resulting from this Feasibility Study will act as useful inputs into said application and will make the process easier for SCTC. It's worth noting that a submitted ZETF application will be reviewed by both Infrastructure Canada and the Canadian Infrastructure Bank, to ensure that the maximum amount of available funding as well as financing can be made available to the applicant. These sources of funding would greatly ease the financial burden of electrifying SCTC's fleet and potentially remove the requirement for any upfront CAPEX spending by SCTC.

Pending availability of funding, SCTC would also plan to engage in an eBus pilot study, following the guidance provided by the Feasibility Study team in "8. BEB Pilot Study & KPIs – 04.08.2022". This would include the deployment of a limited number of electric buses on a set of defined routes, which have a lower operational risk. SCTC would also implement a defined training program focused on the transition to BEBs, including programs for operators, mechanics, and support personnel. An electrical engineer and electrician would need to be brought on staff, and a total of twelve 310T technicians would be trained on BEBs within the first two years. Specific maintenance and training programs would be included within the scope of the bus and infrastructure RFPs, to ensure a strong layer of support from the OEMs in the initial years with these new technologies. As the fleet continues to electrify, the plan would be to transition the capabilities of the SCTC staff to be self-sufficient with management of an electric bus fleet.

Overall, the benefits to conventional bus fleet electrification are clear and as a result, proceeding with the above noted next steps is strongly recommended.

5 LESSONS LEARNED

a) What would you recommend to other municipalities interested in doing a similar Feasibility Study? What would you do differently if you were to do this again?

The St. Catharines Transit Commission would recommend that any municipality who is interested in electrifying their conventional bus fleet engage in a Front-End Engineering and Design (FEED) study, to ensure that they are prepared both for the required funding applications as well as subsequent infrastructure RFPs. Having an infrastructure design in place prior to RFP will ensure that the municipality receives competitive and intelligent proposals from interested bidders. This will save the municipality significant money in the long run, by ensuring that unnecessary cost contingencies and/or overruns are avoided during both the procurement as well as execution phases of the project.

b) What barriers or challenges (if any) did you encounter in doing this Feasibility Study? How did you overcome them?

A key challenge examined during the Feasibility Study was that of retrofitting existing infrastructure designed for diesel buses, to accommodate their battery electric equivalents. To minimize the CAPEX spend as well as disruptions to existing operations, it was always the intention of SCTC to use existing facilities for Battery Electric Buses (BEBs). The challenge with this is that there are significant electrical and structural upgrades required to accommodate the charging infrastructure to support these BEBs. At the First St. Louth depot, new transformers would be required, and additional electrical distribution equipment would have to be installed. This included the potential addition of a Battery Energy Storage System, which has a significant footprint in and of itself. Finally, the desired method of charging dispensers was with pantographs, thus necessitating structural upgrades to the roof. Through close collaboration with Siemens and its partners, the team was able to come up with a sensible plan for these upgrades which required no building expansions or other major changes to the site. However, as mentioned in a previous section, it is recommended that SCTC consider a follow-up consultation pertaining to software systems which are necessary to support an electric bus fleet, since it is more challenging to operate than a diesel fleet. At the Downtown Terminal, a similar process was undertaken as was done for First St. Louth. One topic at this site that should be highlighted, was the potential requirement for an upgraded medium voltage distribution switch. While not mandatory for the installation of charging systems, it was noted by Alectra that the existing switch should be replaced, to ensure maximum reliability at the site. As the upgraded switch would have to be installed in a new location on the Downtown Terminal property, communication between multiple parties including Alectra, CBRE, SCTC, and the City of St. Catharines had to be facilitated by the consulting team. By enabling open and transparent dialogue on this topic, the parties were able to agree on a suitable location as well as timeline for the installation of the new switch. It should be noted that there would be a benefit to installing a BESS and/or natural gas generator at the Downtown Terminal as well, for the purposes of resiliency and Global Adjustment charge mitigation, however there was no space available for such assets. It is recommended that SCTC continue to evaluate going forward whether any adjacent properties could be purchased or leased, to enable the installation of such assets in the future.

6 KNOWLEDGE SHARING

a) Is there a website where more information about the Feasibility Study can be found? If so, please provide the relevant URL.

At this point in time, a website does not currently exist where the Feasibility Study is stored. This could be further discussed with FCM, at a later date.

b) In addition to the Feasibility Study results, has your Feasibility Study led to other activities that could be of interest to another municipality (for example, a new policy for sustainable community development, a series of model by-laws, the design of a new operating practice, a manual on public consultation or a measurement tool to assess progress in moving toward greater sustainability)? If so, please list these outcomes, and include copies of the relevant documents (or website links).

This study was completed in alignment with the St. Catharines Strategic Plan, Climate Adaptation Plan, and other existing policies supporting decarbonization within the City of St. Catharines. Links to the first two plans mentioned above are provided below, for the reader's reference:

https://www.stcatharines.ca/en/council-and-administration/st-catharines-strategic-plan.aspx

https://www.stcatharines.ca/en/council-and-administration/climate-adaptation-plan.aspx

7 APPENDIX

In addition to the information provided in previous sections, the following documents comprise the Final Deliverable for this project and are attached to this Completion Report:

1. Battery Electric Bus Route Study – Final Presentation – 09.27.2021
2. Preliminary Feasibility Study Final Report – 12.10.2021
3. Battery Electric Bus Route Study – Final Scenario – 01.07.2022
4. Final Utility Report – 12.08.2021
5. Downtown Terminal – Final Charging Load Profile – 03.29.2022
6. First St. Louth Garage – Final Charging Load Profile – 03.29.2022
7. Bus Procurement & Retirement Schedule – 23.02.2022
8. BEB Pilot Study & KPIs – 04.08.2022
9. Battery Electric Bus Specification – 06.09.2022
10. Energy Twin Study – 06.29.2022
11. Microgrid Controller Solution - 29.08.2022
12. 30% Electrical Drawings, First St. Louth – 14.09.2022
13. 30% Electrical Drawings, Downtown Terminal – 14.09.2022
14. 30% Structural & Civil Drawings – 14.09.2022
15. Major Equipment Procurement Schedule – 09.29.2022
16. SCTC Fleet Electrification – Class D Estimate – 09.30.2022
17. SCTC Fleet Electrification - 12 Yr. Financial Model Summary - 10.28.2022