HALIFAX

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Item No. 12.1.4
Transportation Standing Committee
February 22, 2018

TO: Mayor Savage and Members of Halifax Regional Council

Original Signed

SUBMITTED BY: ____
Jacques Dubé, Chief Administrative Officer

DATE: December 6, 2017

SUBJECT: Electric Bus Pilot

ORIGIN

Item 14.1.2 NSPI Partnership – Electric Bus Feasibility Study; passed at Halifax Regional Council October 4, 2016; moved by Councillor Rankin, seconded by Councillor Watts. **THAT Halifax Regional Council approve entering into a joint partnership and joint funding arrangement with Nova Scotia Power Inc. to undertake a third-party feasibility study on the usage of electric buses at Halifax Transit, in the amount of $50,000 with funding to come from CMU01095.**

LEGISLATIVE AUTHORITY

Section 79(1) of the Halifax Regional Municipality Charter provides that HRM "may spend money required by the Municipality for: … (o) public transportation services; ... (z) Acquisition of equipment, materials, vehicles, machinery, apparatus, implements and plant for a municipal purpose;

Section 75(1) of the Halifax Regional Municipality Charter provides that "The Municipality may agree with any person for the provision of a service or a capital facility that the municipality is authorized to provide."

RECOMMENDATION

It is recommended that the Transportation Standing Committee recommend that Halifax Regional Council direct staff to partner with Nova Scotia Power Inc., (NSPI) and the Canadian Urban Transit Research and Innovation Consortium (CUTRIC) as described in this report to undertake a two-year pilot of energy storage at charging stations to offset electricity costs during peak periods and determine the viability of a broader system deployment of battery electric buses in the Halifax Transit's fleet.

BACKGROUND

Halifax Transit recognizes its role in providing a safe, reliable and sustainable public transit service and has for the past number of years been seeking ways to reduce its carbon footprint. Activities supporting this mandate include:

1) In 2009 Halifax Transit procured 2-diesel hybrid vehicles as a pilot initiative jointly funded between the province and the municipality; also in the same year, all bus manufacturers moved to a more efficient diesel engine design in anticipation of federally legislated emission targets; buses built since 2009 have been built to exceed 2015 emission standards.

Although the pilot was successful, Halifax Transit has continued to procure diesel vehicles with the newer engines because diesel hybrids produced relatively the same emissions as the newer diesel engines and were much costlier to procure.

2) In 2010 a pilot project was initiated with funding from the Federal Green Fund and Municipality; the trial included the installation of EMP Mini Hybrid systems on 15 buses with engines pre-dating the new environmental regulations. These units reduce green house gas (GHG's) by reducing fuel consumption and bring older engines into compliance with 2015 standards.

   The pilot took place over a two-year period and was successful; in 2013 Regional Council approved the installation of these units in up to 99 additional vehicles. All installations are now complete; the yearly savings, from this point in time, are equal to 195,000 L of diesel fuel and 534 tonnes of equivalent CO2.

3) In 2016 Halifax Transit completed a study that explored the design/cost implications of using compressed natural gas vehicles (CNG) at the Burnside Transit facility (BTC). Halifax Transit has been presented with a business case by Heritage Gas with respect to the feasibility of operating a CNG fleet and will be undertaking a cost/benefit study with dedicated funding in 2018/19.

   Also in 2016 Halifax Transit partnered with Nova Scotia Power (NSPI) to study the feasibility of moving to electric buses, the study was issued to determine the best battery technology and infrastructure configuration for Halifax Transit's network, topography and environment.

   In the same year, Halifax Transit also partnered with Dalhousie University on a power generation project; students developed a decision matrix that will assist Halifax Transit in establishing the most appropriate mix of vehicles in its fleet; the tool allows the department to weight the importance of such factors as cost and GHG emissions.

4) In 2017 Halifax Transit included $200K in its 18/19 capital budget for a consultant's report on the optimal mix of alternative power generation technologies (Sustainable Fuel Study) such as battery electric buses, (BEB's), compressed natural gas, (CNG) or Renewable (Landfill) Natural Gas, (RNG) hybrid-diesel, hydrogen fuel cell as well as the cost/benefits/risks associated with these alternatives. This study will inform the BTC facility redesign project as well as the BEB project and establish the capital replacement/expansion strategy for Halifax Transit's fleet.

The Battery Electric Bus Feasibility Study

The Battery Electric Bus (BEB) Feasibility Study was completed by WSP on November 26, 2017 under the direction of Halifax Transit, Nova Scotia Power, and HRM Energy & Environment subject matter experts.

The purpose of the study was to:

1) Understand the battery electric bus (BEB) technology and charging infrastructure requirements
2) Identify the benefits, risks and constraints associated with adopting BEB technology in Halifax Regional Municipality (HRM)
3) Simulate power usage (state-of-charge) on combinations of BEBs, battery ranges, and charging methods on specific Halifax Transit routes; and validate results with the National Research Council, (NRC)
4) Analyze financial, environmental and strategic impacts of a full-scale BEB technology adoption
5) Recommend optimal technology for a potential BEB pilot
6) Provide technical specification guidelines for BEBs based on best practices observed in North America

All original equipment manufacturers (OEMs) of BEBs that are Canadian Motor Vehicle Safety Standards (CMVSS) certified, or are currently seeking certification were examined. The study included simulation of:

- Battery ranges between 76 KWh and 400 KWh
- End-point charging (plug-in), on-route charging, and inductive charging methodologies
- The review of four bus OEMs

The analysis of routes took into consideration seasonal changes, topography, passenger loads, electrical accessories, and duty cycles. Six Halifax Transit routes were simulated for the study and their associated “home” terminal was examined:

- Route 80 “Sackville” (Sackville Terminal)
- Route 87 “Glendale” (Sackville Terminal)
- Route 59 “Colby” (Portland Hills Terminal)
- Route 72 “Portland Hills” (Portland Hills Terminal)
- Route 41 “Dalhousie-Dartmouth” (Dartmouth Bridge Terminal)
- Route 60 “Eastern Passage” (Dartmouth Bridge Terminal)

Further detail regarding the methodology, constraints and considerations of the study can be found in Appendix A; Halifax Battery Electric Bus Feasibility Study Summary.

In addition, four case studies were reviewed (Edmonton, King County, Go-Ahead London and Antelope-Valley Transit Authority) and seven surveys were completed by transit agencies. The purpose of the survey was to uncover lessons learned and deployment challenges in adopting BEBs to eliminate or mitigate pilot risks. These transit authorities demonstrated positive outcomes of piloting and/or deploying BEB technology. All the examined properties are currently either expanding their BEB fleet or have adopted BEB technology fully.

Interviews with Halifax Transit Maintenance & Operations Management were also conducted to assess the level of change management required and identify areas of risk for a pilot project.

CUTRIC’s BEB Research Trials

In October 2016, CUTRIC, a not for profit organization focused on research and innovation in transportation sector, launched Phase I of their BEB trial; this project involved partnerships with several transit properties, bus original equipment manufacturers (OEM’s), charging infrastructure OEMs, electrical utilities and educational partners. The scope of this initiative was to demonstrate the benefits of BEBs in comparison to diesel and develop one overhead charging standard for the Canadian market. The project successfully moved into the procurement phase in September 2017 with Brampton, Translink and York as partner agencies.

In anticipation of Phase II, Halifax Transit became a partner organization of CUTRIC in March 2017.

CUTRIC kicked off Phase II of their BEB research in November 2017 with three streams of focus:

- Energy storage at on road/at terminal charger
- Plug-in Hybrid Bus Options (retro-fits) J3105 compliance
- J3068 at garage charging standardization

To date, ten transit properties (Brampton, York, BC Transit, Burlington, London, Société de Transport Laval, Winnipeg, York, TTC and Halifax Transit), as well as their associated utilities, (NSPI in the case of Halifax Transit), have put forward their intention to participate in one or more of the streams of research.

The electric vehicle market is quickly changing with recent announcements of Tesla and Cummins to the market place. Recent large scale investments in the public transit sector include 100 BEBs to New York Transit, 40 to Edmonton Transit and 30 for the Toronto Transit Commission (TTC).

DISCUSSION

Simulation Outputs and Cost Benefits

The Battery Electric Bus Feasibility Study concludes that implementing BEB technology will provide benefits to HRM such as: reduced lifecycle costs, reduced greenhouse gas emissions, improved air quality, positive perception by the public, positive driver feedback and alignment with global bus market trends.

Per the study, the major tangible benefits of adopting BEB technology are:

- Reduced maintenance and operating costs resulting in savings of approximately $127 Million to $163 Million over 20 years (no carbon tax savings nor potential benefits of a Cap and Trade program are included). Savings are based on current operating and fuel costs as well as a full fleet implementation.
- Reduce annual lifecycle costs by approximately $10,500 per bus (10% decrease)
- Reduce greenhouse gas emissions over 20 years by approximately 66,000 tonnes for slow adoption of BEBs (50% of every new bus purchase is electric)
- Reduce greenhouse gas emissions over 20 years by approximately 131,000 tonnes for full adoption of BEBs (if every new bus purchase is electric)
- Reduce greenhouse gas emissions by approximately 53 to 63 tonnes per year per bus
- Reduce noise pollution

All recommended battery ranges and charger combinations maintained a minimum of 20% State of Charge at the end of the day. Seasonality did not adversely affect the State of Charge and this was confirmed while surveying other transit agencies. In addition, the simulation indicated that recommended battery ranges and charging methodologies can electrify 59% to 89% of Halifax Transit's fleet; depending on the battery size selected and on-route chargers available. A battery size under 80 KWh with on-route chargers may electrify 59% of the fleet while a battery size of 250 kWh to 300 kWh with on-route chargers can electrify 89% of the fleet. These results are available in Appendix A -Battery Electric Bus Feasibility Study Summary.

It should be noted that although electric buses have a more inexpensive lifecycle costs compared to diesel; the current capital cost to purchase electric vehicles, install charging infrastructure, and retrofit facilities is higher. Therefore, a mixed fleet, or partial implementation as outlined in the report, balances out these costs. However, as battery technology improves and there is a more widespread adoption it is anticipated that the business case for full adoption will improve.

Charging Infrastructure Considerations

During the study, three Halifax Transit terminals and each garage were examined by WSP's engineering team and Nova Scotia Power representatives. It was determined that there were no foreseen issues with grid capacities and spatial requirements for the pilot project. A general layout of charging infrastructure was supplied by WSP for each terminal minimizing implementation costs.

Pilot Considerations

If Regional Council approves the recommendation, HRM will participate in a project led by CUTRIC in partnership with NSPI, focused *on "standardization of charging and energy storage to support opportunity and end-point charging"*. By acting as a research participant in this project, HRM and Provincial Department of Energy, may gain access to federal research funding that could allow Halifax Transit to expand the scope of the pilot. Applications have been made by CUTRIC on behalf of research participants to the Innovation Supercluster Initiative, Strategic Innovation Fund and Energy Innovation Program and Natural Resources Canada (NRCAN) Clean Innovation Fund If the funding becomes available, HRM will be matched the value of each bus, up to four buses. Please find application to NRCAN as well as letter of support from NSPI and Provincial Department of Energy in the appendices. If the funding becomes available, HRM will be matched the value of each bus, up to four buses.

To ensure an adequate amount research data is collected, CUTRIC is recommending a total commitment of eight BEBs; four from the municipal partner and four through federal fund matching. Halifax Transit would like to take a phased approach to piloting BEB's and take advantage of funding as it becomes available and are therefore committing to the procurement of two buses in 2018/19 with addition of others as funding opportunities become available. It should be noted that although procurement may take place in 18/19 it can take up to one year to receive the vehicles.

The benefits of conducting a pilot are:

- Obtain lessons learned and requirements for expanding BEBs within the Halifax Transit system
- Collect the public's feedback to understand challenges and perceptions regarding BEB technology
- Partnership with educational institutions to advance technology training and BEB research
- Access to resources and subject matter experts through CUTRIC to support pilot project and go-forward recommendation
- Aid in standardization of BEB charging methodologies which will increase Canadian technology development and talent attraction and provide gateway infrastructure for commercial BEB sector
- Alignment with Municipality's Integrated Community Sustainability Plan, as well as the Province's Sustainable Transportation Strategy, both of which seek to reduce the negative impacts of fossil fuels
- Partnership with NSPI may result in a solution to high energy costs during peak periods which will improve business case for electrification
- The project will enable both the Municipality and Provincial Department of Energy to study the effects of the gradual load imposed by electric buses on the power grid, providing insight to infrastructure requirements and energy certainty

A pilot would allow the collection of information to determine the feasibility of a full-deployment electrification strategy. The information that is recommended to collect and monitor during the pilot are:

- Mean Distance Between Defects
- KWh over KM
- KWh Winter over KM
- KWh Summer over KM
- Cost Per KM
- Energy Efficiency (Electrical Grid/Electrical Charge)
- Actual peak charging periods compared to forecasted periods
- Change in volume of diesel fuel delivered to depots
- Average Lead Time of parts and service
- Customer feedback (including 3-1-1 customer service requests)

Halifax Transit and NSPI and have elected to participate in energy storage at on road/terminal charging for several reasons:

- Halifax Transit's consultant's report is indicating that opportunity-based charging will maximize the uptime of vehicles while minimizing capital costs. Opportunity-based charging infrastructure now has a Canadian standard which considerably de-risks the ability to move from one bus product to another through public procurement process and mitigates the potential of being stranded with a proprietary based charging system
- Reduction of energy costs through energy storage provides for a better return on investment as well as the predictability and sustainability required for infrastructure expansion and wide scale adoption of BEB's
- Halifax Transit and NSPI have a mutual interest in reducing carbon emissions
- Investments in green infrastructure may offset cost associated with Provincial Cap and Trade

FINANCIAL IMPLICATIONS

Presently there are no financial implications with entering into this partnership. Halifax Transit will work within already approved budgets if it pursues future phases of the pilot program. At that time, potential funding opportunities will be better understood. Funding may become available via the Energy Innovation Program; Halifax Transit's letter of support is provided in Appendix C - NRCAN - Letter of Support for Pan-Canadian Electric Bus Demonstration & Integration Trial - Phase II. A recommendation to expand the scope of this pilot will be sought during the procurement phase of the BEB pilot project.

RISK CONSIDERATION

WSP through surveys concluded that many agencies positively perceived BEB from an environmental perspective. However, many flagged integration risks both from infrastructure and human resources perspective.

BEB buses and charging infrastructure are relatively new to the Canadian market place; this pilot project is a research initiative aimed at product standardization, optimization and development, therefore HRM must accept a certain level of risk. However, these risks have been determined to be acceptable and manageable.

The risks associated with conducting a Battery Electric Bus Pilot Project are:

Financial Risks

- Moderate - High capital costs of vehicles vs. CNG and diesel which may be mitigated by obtaining additional funding by partners.
- Moderate - Unforeseen redevelopment costs at terminals or at garages which are mitigated by adding contingency in the pilot budget
- Low - Optimizing routes for the buses due to variation in range (variability due to traffic, hills and elevations) may require additional funding. This can be built into the project contingency.
- Low - Savings are only obtained by achieving an 18-year lifecycle of BEBs, no North American transit agencies after this study have experienced BEBs for a full lifecycle. The average age of BEB fleets surveyed is 4 years. Contingency was included in this study and therefore, the worst-case scenario is presented.
- Low - Training and tooling costs can be higher than anticipated. This is addressed through contingency added into the pilot budget.
- Low - Pre-mature failure of battery; batteries are a high cost item. Risk associated with failure can be mitigated through warranty terms or leasing options

Safety Risks

- Moderate - High voltage electrical infrastructure and batteries; maintenance staff must be trained in proper repair procedures. No such risk is known for Bus Operators or the public.

Operational Risks

- Moderate - Reduced flexibility of buses due to state of charge constraints and BEBs must only run on routes where a charging terminal is available. CUTRIC may assist in overall strategic plan to optimize BEBs and routes.
- Low - Unavailable supply chain requirements and dealer support in Halifax which may be addressed through the procurement process.
- Low - Infrastructure issues and reliability (charger reliability and speed). A mitigation plan can be put in place during the pilot for charger downtime.
- Low - Rejection of the buses/technology by the public and/or Operators. The project must be accompanied by a change management plan engaging the public and employees to overcome resistance

COMMUNITY ENGAGEMENT

There was no community engagement undertaken during the feasibility study however, interviews with other transit authorities and internal Halifax Transit staff provided some insight on perceptions regarding BEBs. The summary of these surveys can be found in Appendix A -Battery Electric Bus Feasibility Study Summary.

ENVIRONMENTAL IMPLICATIONS

In 2015-2016, Halifax Transit's 40ft bus fleet (275 buses) drove 15.8 million kilometers and consumed 8.97 million litres of diesel fuel. With zero-emission-40ft-electric buses, tailpipe emissions are eliminated, but upstream emissions from power generation are sustained. Therefore, the annual greenhouse gas reduction is approximately 53 to 63 tonnes of equivalent CO2 per BEB purchased. This is equivalent to reducing annual greenhouse gas emissions by 59% on a per bus basis. A pilot of two vehicles (at a minimum), is estimated to save between 106 tonnes and 126 tonnes of equivalent CO2 equivalent per year.

Under the Provincial Environmental Goals and Sustainable Prosperity Act, NSPI and other electrical utilities have a mandate to reduce the use of fossil fuels for power generation by 2020. NSPI has also committed to reduce its reliance on fossil fuels for electricity production over the next decade, therefore carbon savings can be expected to increase over time as the province's grid becomes 'cleaner'.

ALTERNATIVES

1. Regional Council may direct staff to postpone the pilot of BEBs and reallocate funds available in CM000011 (Electric Bus Pilot) to future years awaiting the announcement of award of federal funding to CUTRIC's EBUS Phase II project bid and/or results of sustainable fuel study Study (see background) This alternative is not recommended as Halifax Transit may not be able to join the EBUS Phase II project in later years and may therefore not be a recipient of additional funding.

2. Regional Council may direct staff to continue to use diesel buses and reject the recommendation to pilot BEBs. This alternative does not conform to HRM's Community Sustainability Plan and does not promote environmental stewardship and leadership. Also, it is anticipated that the cost of diesel fuel will rise over time because of downstream costs associated with a provincial Cap and Trade system, and Canada's proposed Clean Fuel Standard.

ATTACHMENTS

Appendix A - Battery Electric Bus Feasibility Study Summary
Appendix B - NSPI – Letter of Intent
Appendix C - NRCAN - Letter of Support for Pan-Canadian Electric Bus Demonstration & Integration Trial - Phase II
Appendix D- DOE Letter of Support

A copy of this report can be obtained online at halifax.ca or by contacting the Office of the Municipal Clerk at 902.490.4210.

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Appendix A

HALIFAX BATTERY ELECTRIC BUS FEASIBILITY STUDY

EXECUTIVE SUMMARY

December 4, 2017

FEASIBILITY STUDY OVERVIEW

Halifax Transit is considering implementing an electric bus pilot program to understand the new technology and its implications for transitioning their fleet towards zero emissions. The deployment of an electric bus into their service would support a reduction in greenhouse gas emissions and lead to improved cost and lifecycle savings in comparison to diesel buses.

This study presents the current state of electric bus and charging technology both globally and in Canada, and analyzes various options available to the Halifax Regional Municipality. Simulations were conducted for electric bus operation using WSP's Battery Optimization Lifecycle Tool (BOLT) to model different bus manufacturers, battery sizes, and charging options, considering seasonality, passenger loading, parasitic load (electrical accessories), topography, and duty cycles.

In addition, other transit agencies across North America who have operated battery electric buses were engaged through an online survey to collect information regarding their experience using electric buses in their fleets. WSP found that many agencies and stakeholders positively perceived BEB from an environmental perspective. However, stakeholders and early adopters flagged integration risk both from infrastructure and human resourcing perspectives. It is clear there are higher upfront capital costs when adopting BEB over diesel. On the other hand, BEB have lower operating and maintenance costs per km driven. Charging and facility infrastructure decisions must be made alongside fleet purchasing decisions with BEB vehicles to ensure flexibility in roll-out and to avoid being restricted to one manufacturer's charging methodology.

FEASIBILITY STUDY SUMMARY

Environmental	Reduction of approximately 65,878 tonnes of GHGs for slow adoption of electric buses (50% of every new bus purchased is electric) and 131,062 tonnes of GHGs for full adoption of electric buses (every new bus purchased is electric) over 20-year forecast period.
	The use of an electric bus will result in approximately 62.56 tonnes GHG emissions saved, compared to using a diesel bus for one year of operation.
	Electric buses reduce noise pollution in comparison to diesel.
Financial	The optimum lifecycle scenario for an electric bus is 18 years with an annualized cost of $99,441. The optimum lifecycle scenario for a diesel bus is 13 years with an annualized cost of $109,960. If the BEB is not able to achieve a lifecycle of 18 years, the business case is not as favourable at the current state of technology.
	System-wide full adoption would result in approximately $127M saved over 20-year forecast period. System-wide partial adoption would result in $163M saved over 20-year forecast period.

Strategic Fit	Battery electric buses provide significant GHG reductions, helping to mitigate climate change in Halifax.
	Adopting electric buses is in line with the global bus market trending towards full battery electric capabilities with supporting charging infrastructure for system-wide operations.
	According to case studies and previous electric bus pilots, electric buses are capable of operating in winter conditions, where temperature has little impact on range.
	Electric buses are an innovative, future-ready transit solution that will help Halifax be viewed as an environmentally conscious city.
	Halifax internal staff demonstrated support and a positive perception of electric bus technology during a survey and interview session with senior members of the organization.

LIMITATIONS OF THE FEASIBILITY STUDY

The findings of the feasibility study were based on information and data available at the time of writing. To support the analysis, supplementary sources were used including data collected from early adopters, academic journals, and global experts.

NRC was retained to assist with model inputs and quality assurance of model parameters. The simulation was developed based on NRC methodology and assumptions were validated by NRC's own simulation analysis. The outcome of the simulation showed results within 5% of NRC's results, therefore it is within the tolerance expected by Halifax Transit. Information available from other electric bus studies and existing testing of electric buses were used to confirm and validate data and results. Test reports produced by the Altoona Bus Test Centre at the Pennsylvania Transportation Institute for electric bus evaluation were used to compare with values stated by the selected bus manufacturers.

HALIFAX TRANSIT CURRENT STATISTICS

Halifax Transit provided 2015 data for fleet information used for analysis in the study. The study considered 40ft conventional buses only for comparison purposes to 40ft electric bus options.

Halifax Transit Fleet Information (2015)

Number of Conventional buses	47 60ft 275 40ft
Number of Access-A buses	38
Diesel fuel consumed Conventional buses	10.5 million litres
Diesel fuel consumed AAB's	0.4 million litres
Total Halifax Transit Bus fleet consumed	10.9 million litres
Kms Conventional buses	18.5 million km
Kms AAB's	1.8 million km
Total Halifax Transit Bus fleet Kms	20.3 million km

ROUTE OPTIONS

Three options were specified by Halifax Transit in the RFP, which included two routes for each option, for a potential electric bus pilot. The focus of the analysis was on the six routes below to simulate electric bus operation and charging requirements for a pilot.

Option	Route	Start	End
Sackville Terminal	80	Sackville Terminal Bay 5	Upper Water St. Before Valour Way
	87	Bridge Terminal Bay 5	Sackville Terminal Bay 2
Portland Hills Terminal	59	Cole-Harbour Rd. After Cumberland Dr.	Summer St.
	72	Commodore Dr. After Countryview Dr.	Portland Hills Terminal
Dartmouth Bridge Terminal	41	Lemarchant St. Before University Ave.	Bridge Terminal Bay 7
	60	Bridge Terminal Bay 4	Samuel Danial Dr. After Cow Bay Rd.

DIRECTION OF THE INDUSTRY

The direction of the industry was reviewed to demonstrate market potential and trends for electric bus technology. It was found through research that many Canadian transit agencies are announcing plans to go fully-electric by 2025 or 2030, and pilot projects or demonstrations are being implemented in urban centres across the country including: Windsor, St. Albert, Vancouver, Montreal, Edmonton, municipalities of the GRA, and Winnipeg. The acceleration of pilot testing and adoption across the world can be attributed to advancements in battery range, cost reductions, support for environmental policy, and customer confidence in electric technology.

The advancements in electric bus powertrain and battery range capacity is making this propulsion technology a serious contender in current and future fleet renewals. Halifax Transit needs to examine how this technology can be applied to existing routes and operations, while considering advancements in the technology over the next decade and further impacts on operations.

CASE STUDIES

Four case studies were reviewed to provide examples of electric bus implementation in Canada and internationally.

Case Study	Key Finding
Edmonton Transit Service *Edmonton, Alberta, Canada*	Tested three electric buses during a pilot evaluation in the winter. With acceptable performance on Edmonton's hills and routes, the testing concluded no anticipated performance issues for Edmonton's climate/routes.
King County Metro *Seattle, Washington, USA*	Currently scaling up electric bus adoption after a successful 1-year pilot. Found that electric buses exceeded expectations for charge duration and range requirements.
Go-Ahead London *London, United Kingdom*	Converted garage to fully electric operation, the first of its kind in UK. Maintained nearly 100% operational mileage during the conversion project. Proactively consulted with the community and drivers and experienced no major issues.
Antelope Valley Transit Authority *Los Angeles County, California*	Transitioning fleet to all-electric after a successful pilot of an articulated electric bus. Plans to combine depot and on-route charging, as well as incorporating wireless charging technology. Experienced less maintenance costs than that of their newest diesel buses.

MAINTENANCE COSTS

The study compared the expected maintenance requirements and costs of battery electric buses relative to diesel buses.

Advantages of electric buses (relative to diesel)	Disadvantages of electric buses (relative to diesel)
- Annual brake maintenance is expected to be lower for electric buses. Electric buses have regenerative braking, which reduces the use of the brake system and extends its life. Early adopters have seen brake life extended by 3 to 4 times of that on diesel buses. - Electric buses have direct drive train through traction motors, which negate the need for internal combustion engine, transmission, and differential. This reduces the maintenance cost for these components, which comprise a significant portion of the preventative maintenance cost for diesel buses. - Bulk fluids such as transmission and engine oil are no longer needed in electric buses. This can reduce costs and the environmental footprint of spillage. - There are no annual costs related to exhaust system and cranking system maintenance for electric buses. - No alternator related charging system maintenance is required on electric buses as such a system is not present. - There is minimal expected hydraulic maintenance and costs related to electric buses, but this is dependent on specific systems of the selected electric bus. - No annual ignitions system maintenance nor oil changes on electric buses as compared to diesel buses. - Tire costs are comparable to diesel.	- Maintenance costs may be higher for body and exterior for electric buses, depending on specific parts requirements and procurement specification. - Steering related costs are expected to be higher for electric buses due to a typically more expensive power steering motor. - Electrical accessories and electrical modules/ relays/wiring related maintenance costs will be higher for electric buses due to more complex systems. - Mechanics and maintenance staff need to be trained to work with a greater amount of electrical systems, and training costs will be incurred. Furthermore, there will be some familiarization time required before maintenance staff is comfortable with electric bus maintenance and troubleshooting. - One OEM uses an external diesel heater which would result in higher costs related to the HVAC system. If this OEM is chosen for electric bus procurement, this would be taken into consideration.

LIFECYCLE ANALYSIS METHODOLOGY

The lifecycle analysis utilized various stages of asset lifecycle from Halifax Transit's historical data including purchase history, work orders, operating costs and disposal (salvage value). This information was used to compare diesel bus lifecycle costs to electric bus lifecycle costs. The analysis included the following elements:

Procurement: Historical value of purchase (Halifax Transit 2016 purchase price for diesel); electric bus price average price from BEB manufacturers.

Operate & Maintain: Costs of parts, mechanical labour cost, fuel cost, bulk fluids, towing cost, and warranty recovery (provided by Halifax Transit for diesel), electric bus data using surveys and BEB manufacturers.

Overhaul: Mid-life cost affiliated with re-building powertrain, body and major components. (Halifax Transit provided for diesel); electric bus overhaul built with BEB OEM discussion.

Disposal: Salvage value for buses obtained from Halifax Transit for diesel and BEB manufacturers for batteries on electric buses.

Lifecycle analysis including the above considerations rendered the following conclusions:

- The optimum lifecycle scenario for an electric bus is 18 years with an annualized cost of $99,441.
- The optimum lifecycle scenario for a diesel bus is 13 years with an annualized cost of $109,960.
- If the BEB is not able to achieve a lifecycle of 18 years, the business case is not as favourable at the current state of technology.

ELECTRIC BUS PILOT PERCEPTIONS

Halifax internal staff were interviewed to understand their perceptions regarding the benefits and potential challenges of implementing an electric bus pilot project. The following perceptions were noted:

Benefits / Positive Perceptions	**Potential Challenges / Negative Perceptions**
— Predict a positive response from residents with regards to electric buses since they are cleaner and quieter. — Cap and Trade in Nova Scotia an important factor when considering acquiring electric buses. — Pilot program will help prove the benefits of the technology and highlight potential issues in larger fleet adoptions (expect pilot to run for 1-2 years).	— Concerns with regards to supply chain requirements - would require dealer support in Halifax. — Other alternative fuel technologies could be considered as well such as compressed natural gas (CNG) or hydrogen fuel cell technology.

TRANSIT AGENCIES SURVEY

An online survey was conducted to collect information pertaining to the use of relevant OEM electric buses in operation by various transit agencies across North America. The following major benefits and challenges were observed:

Major benefits of adopting electric buses, as reported by other transit agencies.	**Major challenges of adopting electric buses, as reported by other transit agencies.**
• Positive perception by the public. • Lower overall operations cost. • Quiet operation. • Environmental and air quality benefits (CO2 reductions). • Easier maintenance of vehicles. • Generally positive driver and customer feedback.	• Optimizing routes for the buses due to variation in range (variability due to traffic, hills and elevations). • Driver training. • Infrastructure issues and reliability (charger reliability and speed). • Safety training for staff working with high voltage electrical infrastructure and batteries.

SYSTEM-WIDE ELECTRIC BUS SIMULATION

The study analyzed a fleet of electric bus's performance across all blocks on Halifax's transit network to understand the opportunity to achieve full electrification, based on technology currently available. All block analysis was completed for different electric buses from small battery capacity to large. The simulation was run where parasitic loads were the highest. The analysis assumed the electric bus must not drop below a 20% state-of-charge as a safety for operation. It was assumed that each terminal station would have multiple overhead chargers, with one charger at each bay.

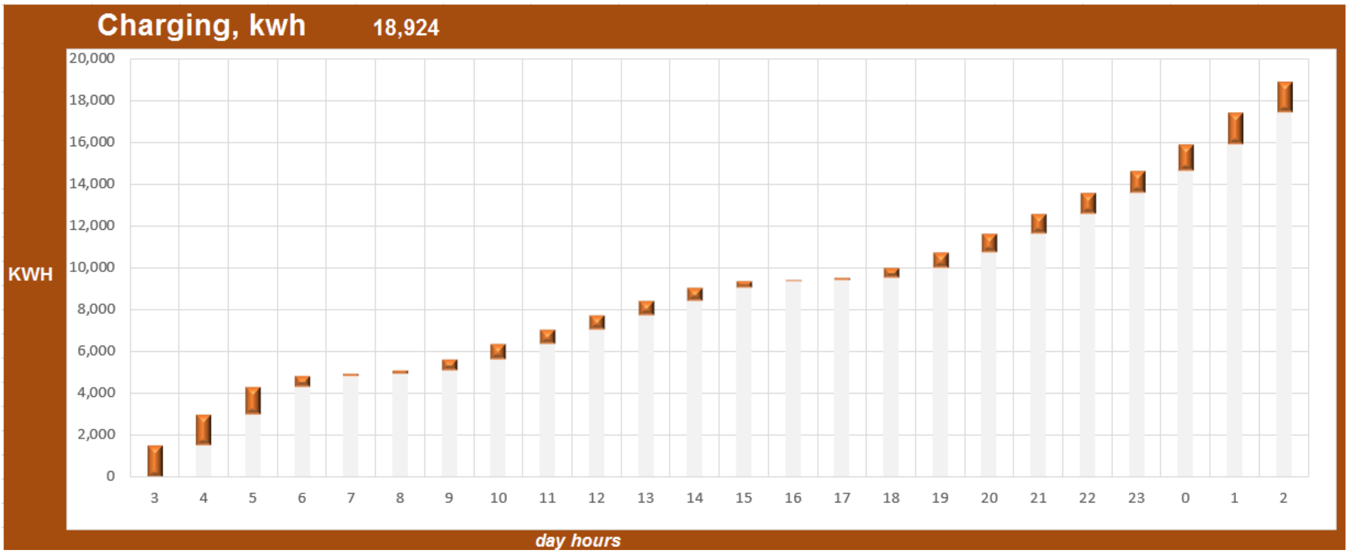
The results of the all block analysis are presented below. This analysis considers the energy consumption of a fleet of electric buses, the energy drawn from the grid from on-route chargers, and the energy needed to charge up the BEBs at the garage. The Electrifiable Index (EI) was calculated for each scenario to show the percentage of the network that could be serviced with each BEB vehicle based on today's charging and battery technology. The percentage of total service hours that would be electrified is also estimated. If the electrifiable index is high, but the percentage of service hours electrified is low, this means that the bus can complete a high number of blocks, but these blocks are actually short in duration and length, relative to other blocks in Halifax's network.

ELECTRIC BUS WITH BATTERY SIZE OF 50 TO 80 KWH

Electrifiable index	59.2%
Percentage of service hours electrified	35.3%

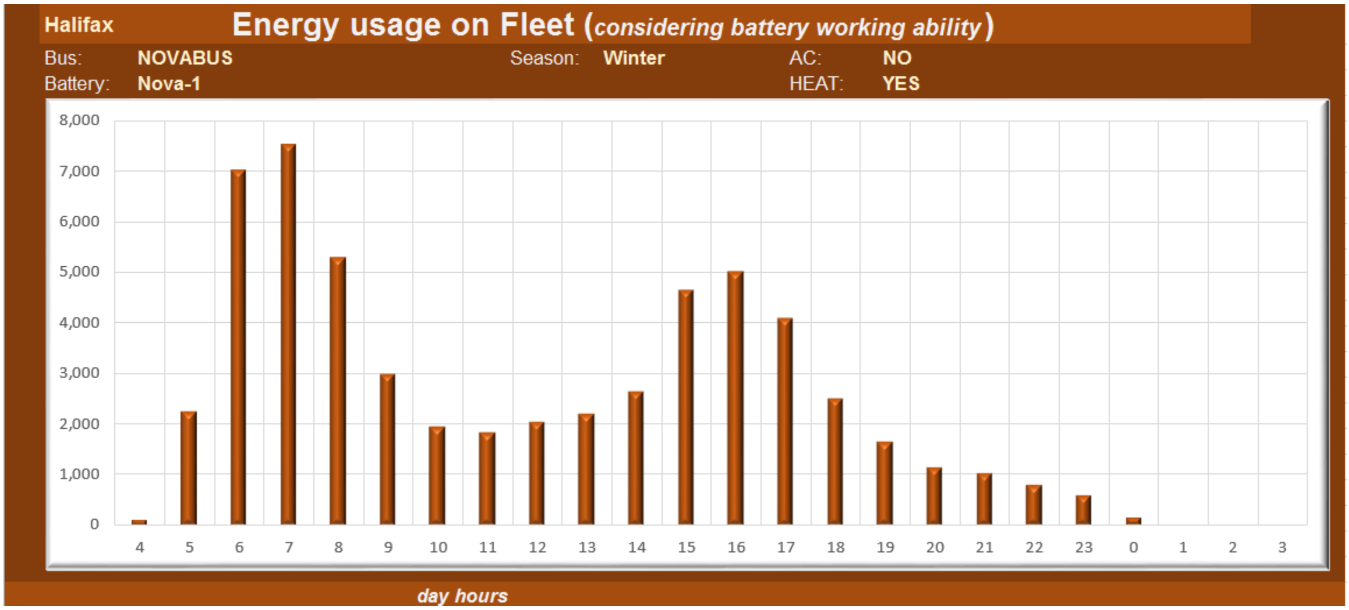
GARAGE CHARGING

This graph shows the cumulative amount of energy drawn from the grid at the garage to charge up the electric buses over 24 hours. These buses would draw a total of 18,294 kWh over 24 hours.



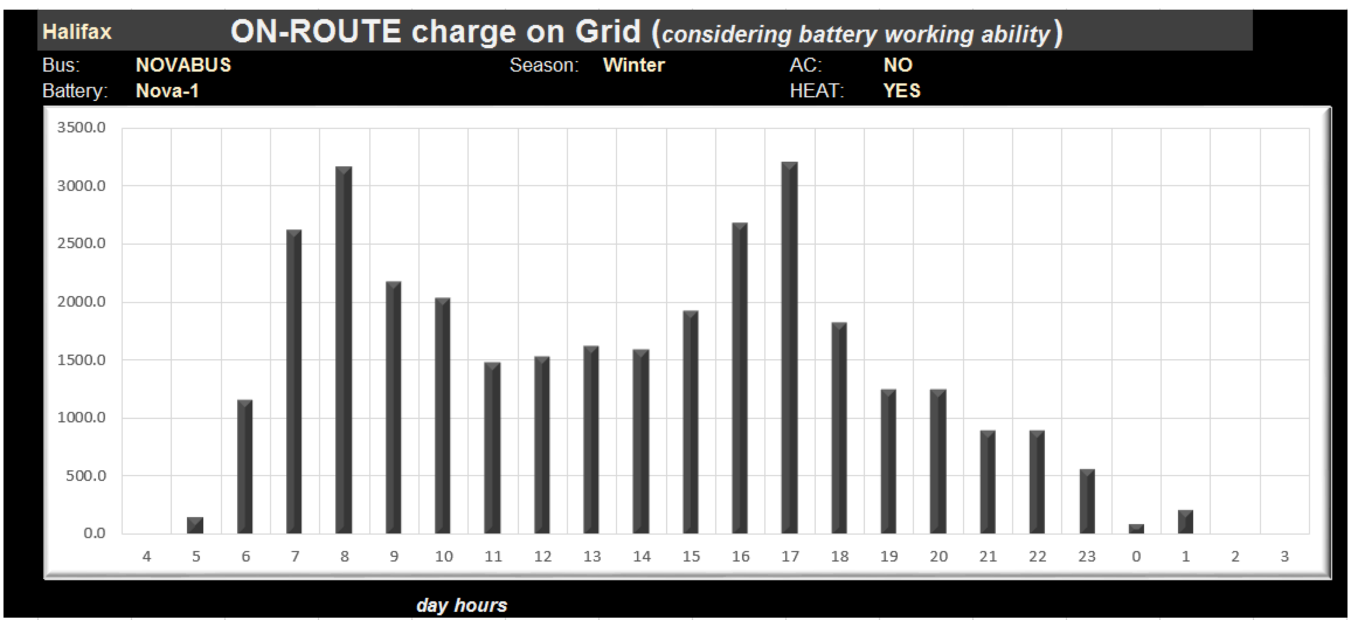
ENERGY CONSUMED BY FLEET

This graph shows the amount of energy the fleet of electric buses is consuming in operation across the 24-hour period. The peak energy consumed occurs at 7am with a draw of approximately 7,500 kWh.



ENERGY DRAWN BY CHARGERS

This graph shows the amount of energy drawn from the grid by on-route chargers during the 24-hour operating period. Peak draw is at 7am and 5pm of approximately 3,500 kWh each.



NUMBER OF ON-ROUTE CHARGERS

Charger Terminals	Address	Chargers
Bridge Terminal	24 Nantucket Ave, Dartmouth, NS	16
Cobequid Terminal Bay	50 Cobequid Road	2
Highfield Terminal Bay	Highfield Terminal, Dartmouth, NS B3A 4V1	2
Lacewood Terminal	320 Lacewood Dr., Halifax, NS B3M 3P6	13
Micmac Terminal	21 Micmac Blvd, Dartmouth, NS B3A 4N3	2
Mumford Terminal	7010-7004 Mumford Rd.	3
Sackville Terminal	7 Walker Avenue, Sackville, Nova Scotia B4C 0A3	5
Water St Terminal	1781 Upper Water Street	1
Woodside Ferry Terminal	9 Atlantic Street, Dartmouth	4
Penhorn Terminal	866 Portland Street	7
Portland Hills Terminal	Dartmouth, Nova Scotia B2V 1P3	7

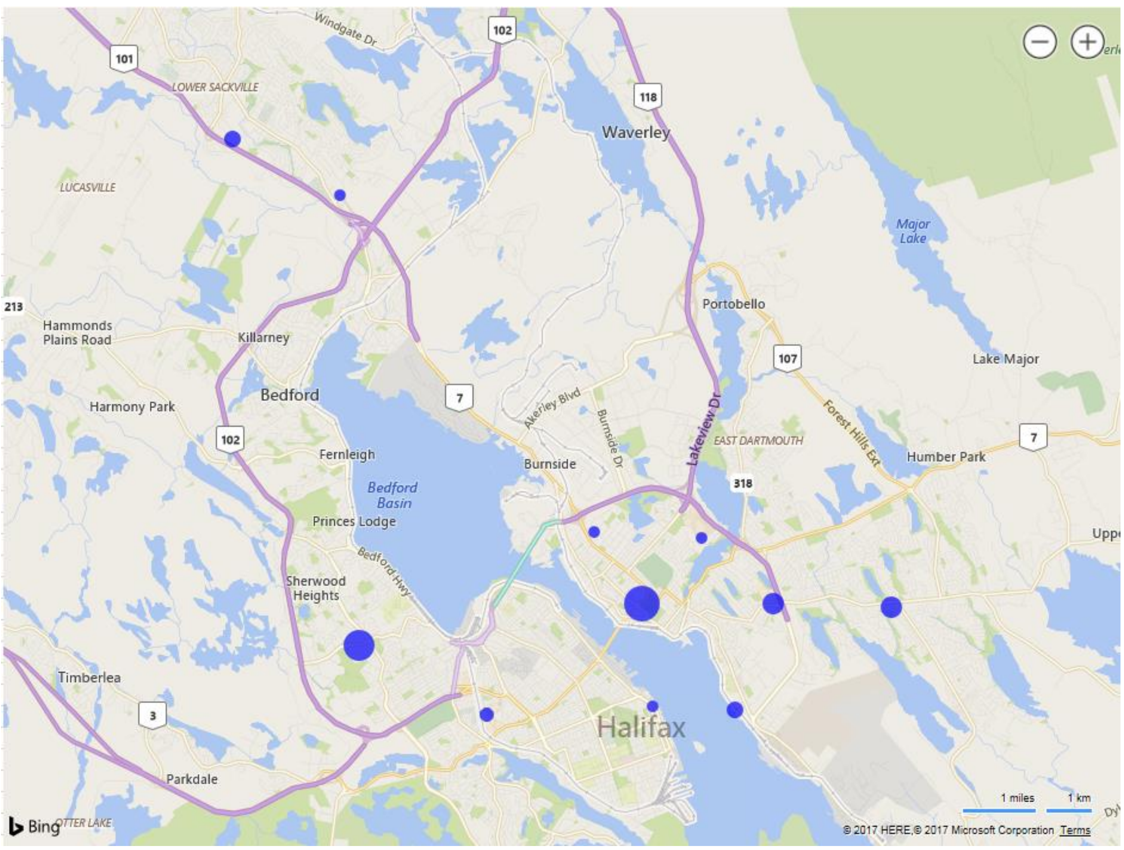


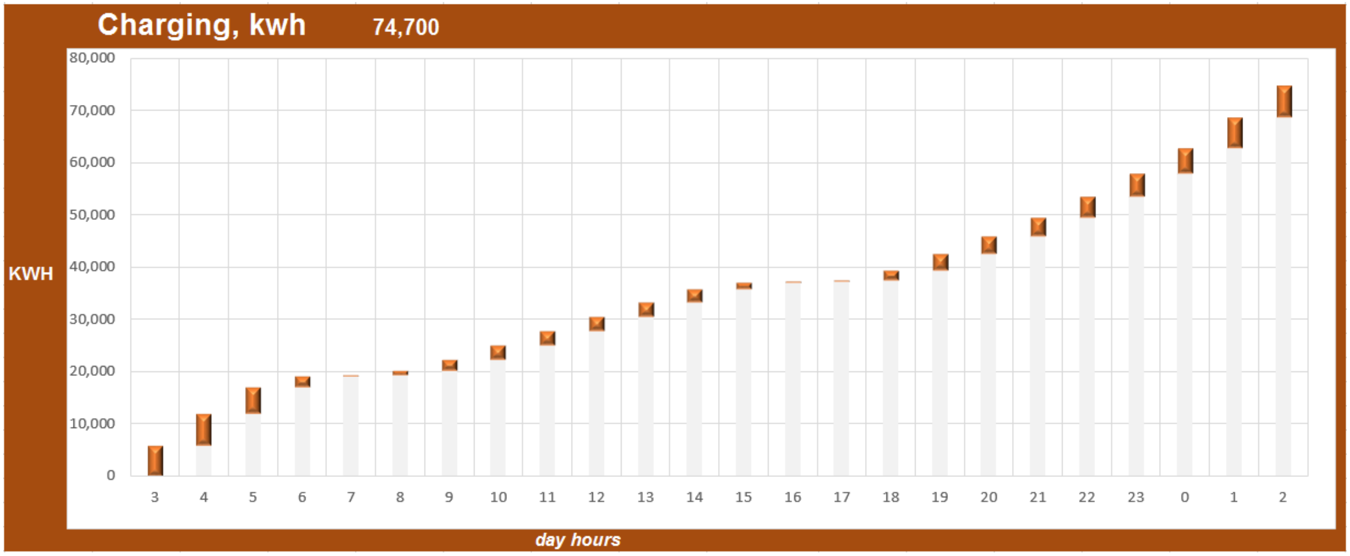
Figure 1: Block analysis charger locations.

ELECTRIC BUSES WITH BATTERY SIZE OF 250 TO 350 KWH

Electrifiable index	88.9%
Percentage of service hours electrified	75.0%

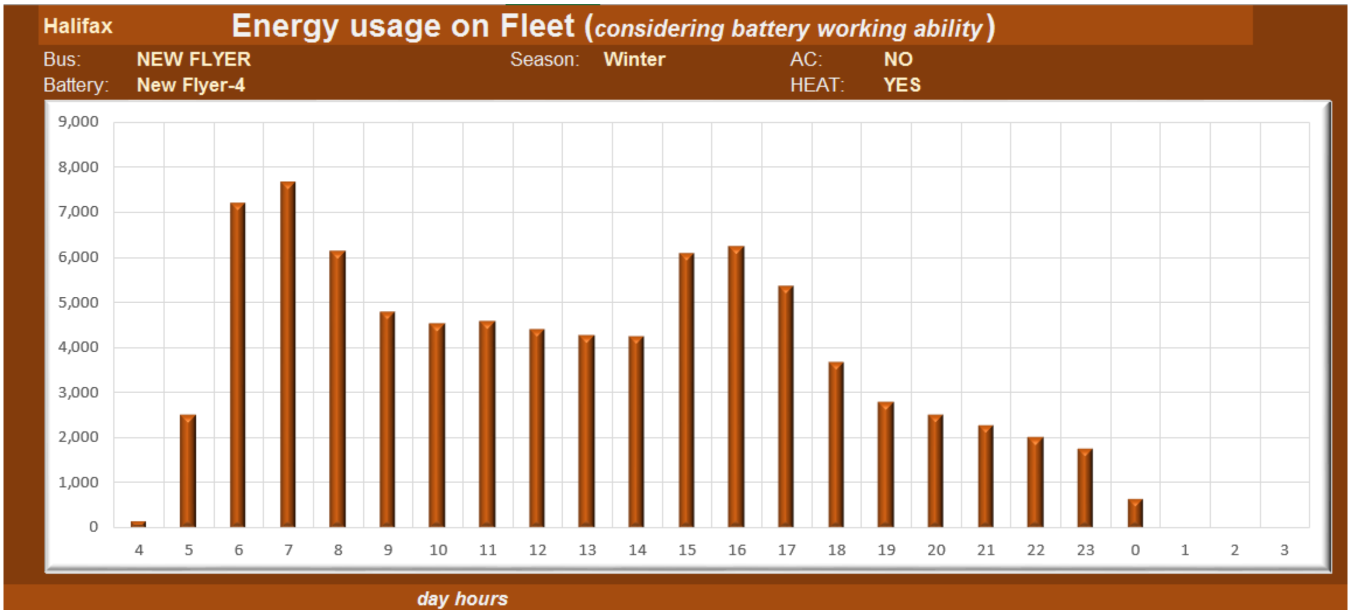
GARAGE CHARGING

These buses would draw a total of 74,700 kWh over 24 hours at the garage.



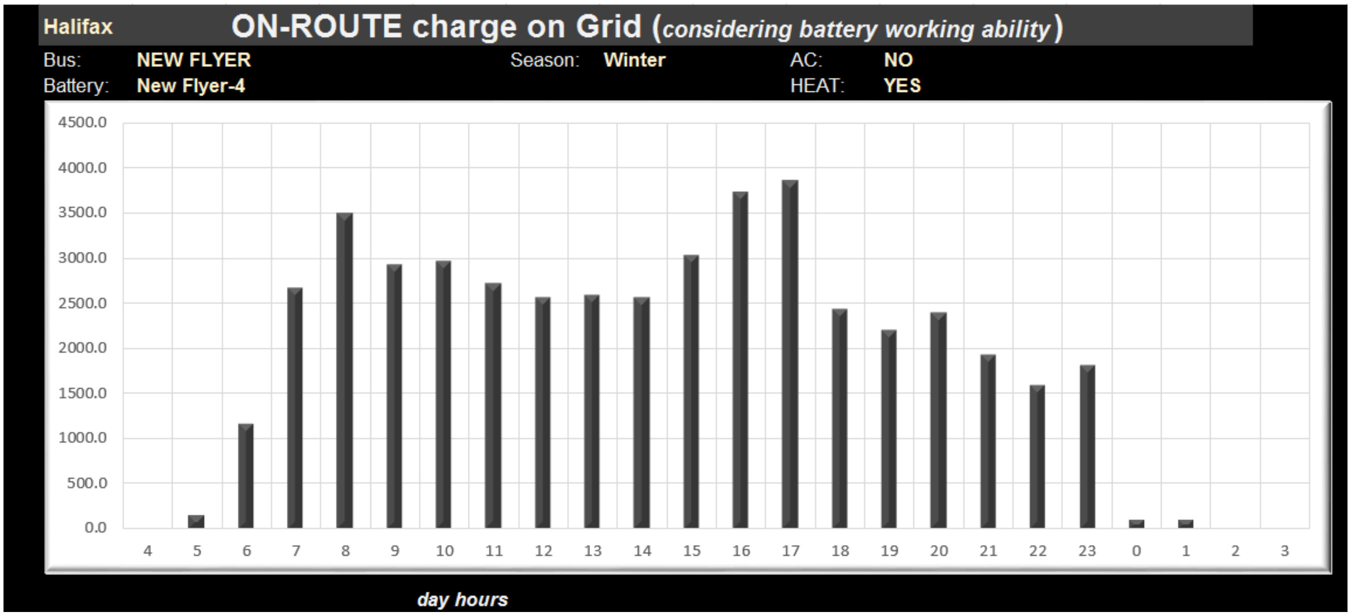
ENERGY CONSUMED BY FLEET

The peak energy consumed occurs at 7am with a draw of approximately 7,500 kWh.



ENERGY DRAWN BY CHARGERS

Peak draw is at 8am and 5pm of approximately 3,500 kWh and 3,800 kWh respectively.



NUMBER OF ON-ROUTE CHARGERS

Charger Terminals	Address	Chargers
Bridge Terminal	24 Nantucket Ave, Dartmouth, NS	16
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Lacewood Terminal	320 Lacewood Dr., Halifax, NS B3M 3P6	13
Micmac Terminal	21 Micmac Blvd, Dartmouth, NS B3A 4N3	2
Mumford Terminal	7010-7004 Mumford Rd.	3
Sackville Terminal	7 Walker Avenue, Sackville, Nova Scotia B4C 0A3	5
Water St Terminal	1781 Upper Water Street	1
Woodside Ferry Terminal	9 Atlantic Street, Dartmouth	4
Penhorn Terminal	866 Portland Street	7
Portland Hills Terminal	Dartmouth, Nova Scotia B2V 1P3	7

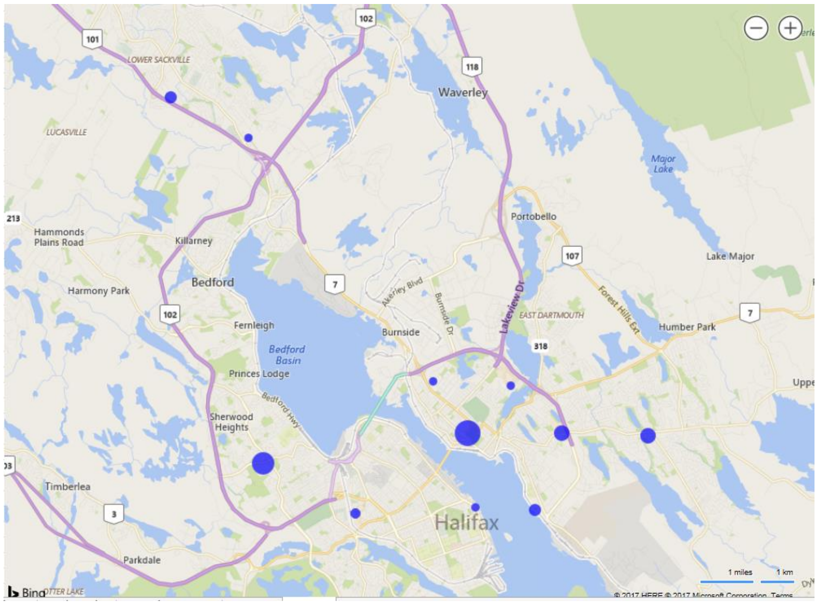


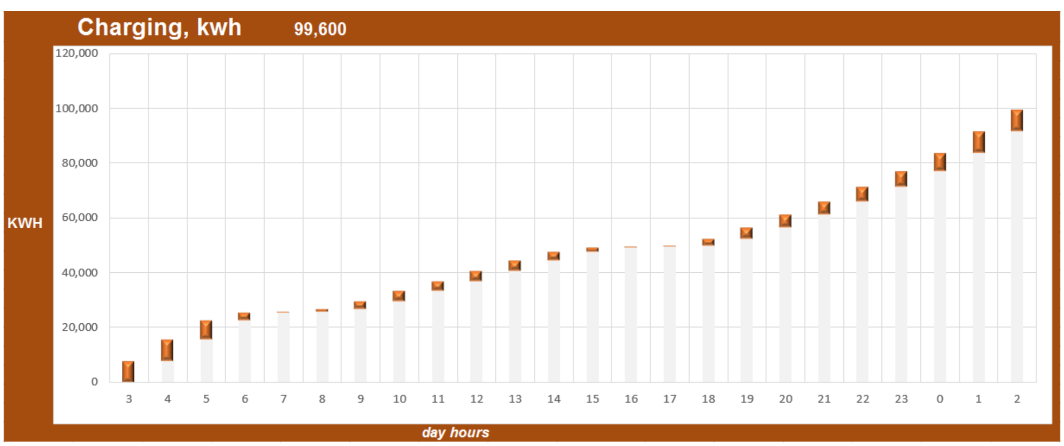
Figure 2: Block analysis charger locations.

ELECTRIC BUSES WITH BATTERY SIZE OF 300KWH TO 450KWH (WITHOUT ON-ROUTE CHARGERS)

Electrifiable index	72.5%
Percentage of service hours electrified	40.4%

GARAGE CHARGING

These buses would draw a total of 99,600 kWh over 24 hours at the garage.



ENERGY CONSUMED BY BUSES

The peak energy consumed occurs at 7am with a draw of approximately 7,900 kWh.

RECOMMENDATIONS

Six routes were modelled as options for an electric bus pilot program: 80 and 87 (Sackville Terminal), 59 and 72 (Portland Hills Terminal), and 41 and 60 (Dartmouth Bridge Terminal). These routes were grouped into options available to Halifax Transit based on their capital budgetary constraints for a pilot program.

The first scenario for a budget of $3 million includes purchasing a 40FT 400 kWh BEB and a 40FT 300 kWh BEB, to run on routes 41, 60, and 87, with an OppCharge 300 kW located at the Bridge terminal. The second scenario for a budget of $4.5 million was divided into options 2A and 2B. Option 2A consists of purchasing a 40FT 400 kWh BEB, a 40FT 300 kWh BEB, and a 40FT 76 kWh BEB, with an OppCharge 450kW at the Bridge Terminal, to run on routes 41, 60 and 87. Option 2B consisted of purchasing a 40FT 400 kWh BEB, 40FT 200 kWh BEB, and 40FT 76 kWh BEB, with a 450 kW OppCharge at Bridge Terminal and a 300 kWh OppCharge at Sackville Terminal, to run on routes 41, 60, 80, and 87.

Two scenarios were modelled for system-wide adoption. Partial adoption proposes a slow transition to electric where half of new bus purchases are electric. Full adoption proposes a transition to electric where every new bus purchased is electric. At the current state of technology, it was found that the slow transition to electric represents the highest value for Halifax Transit, however as battery technology continues to improve, Halifax could ramp up the transition to electric in the coming years.

From an energy consumption perspective, Nova Scotia Power suggests that there will be little impact to the grid requiring electric grid improvements for a pilot program or system-wide adoption scenarios. The electric buses suggested for each pilot option was analyzed across all blocks in Halifax Transit’s network to determine their performance system-wide, with an Electrifiable Index (EI) indicating the percentage of routes that can be serviced by an electric bus. It was found that of the electric buses considered for the pilot options, the 300 kWh BEB has the highest EI, indicating 88.9% of Halifax Transit’s network can be serviced by this bus with 450 kW OppCharge infrastructure in place at terminal stations.

Nova Scotia
POWER
An Emera Company

Halifax Transit
c/o Wendy Lines, Manager Bus Maintenance Halifax Transit
200 Ilsley Ave, Dartmouth, NS

January 26th, 2018

Re: Letter of Support for the Battery Electric Bus Pilot Project in Partnership with Halifax Transit and Canadian Urban Transit Research Consortium

Dr. Wendy,

Please accept this letter as formal indication of our desire to support the Halifax Transit's Battery Electric Bus (BEB) Pilot Project. Nova Scotia Power Inc. alongside Halifax Transit and the Canadian Urban Transit Research Consortium (CUTRIC) would like to create a collaborative research environment among transit, industry and academic stakeholders in Nova Scotia, which will promote a sustainable environment for BEB's and foster Canadian technology development and talent attraction to the region.

Our company is also very focused on the environment. We currently supply close to 30% of the electricity in Nova Scotia from renewable sources, and that figure will grow to 40% by 2020. From this perspective, we see collaboration in this program as a great opportunity to gain a better understanding of the opportunity to reduce transportation emissions.

As part of our commitment to this initiative Nova Scotia Power Inc. will contribute project resources; either in the form of a monetary contribution or expert knowledge on the electrical system and potential impacts of a pilot project. Our commitment will be solidified when project scope and federal funding support becomes known.

NSPI is committed to working with Halifax Regional Municipality in supporting the viability of the business case for electrification of the Halifax Transit fleet through the reduction of energy rates and support the Municipality's carbon reduction efforts.

Please do not hesitate to contact us if you have any questions about our involvement in this exciting project.

Sincerely,

ORIGINAL SIGNED

Shawn Connell
Director, Customer Solutions
Nova Scotia Power

Energy Innovation Program
Electric Vehicle Infrastructure Demonstrations
Natural Resources Canada (NRCan)
Government of Canada
Ottawa, ON

February 7, 2018

RE: Letter of Support for Pan-Canadian Electric Bus Demonstration & Integration Trial Phase II (2018 – 2020)

Dear Natural Resources Canada colleagues,

Please accept this letter of support from Halifax Transit as formal indication of our organization's commitment to the Pan-Canadian Electric Bus Demonstration & Integration Trial Phase II (2018 – 2021), which forms part of the application to the Electric Vehicle Infrastructure Demonstration Phase II being led by the Canadian Urban Transit Research & Innovation Consortium (CUTRIC) on behalf of a community of private and public-sector stakeholders.

Industry background

Halifax Transit is an innovative and forward-thinking transit operator. It intends to address its dynamic and pressing transit needs along with the over-arching drive to become a clean, zero-emission transit. Halifax Transit has met those needs by adopting new technologies, integrating new systems solutions, and looking to the use of data to improve our operational performance. Halifax Transit currently operates a fleet of approximately 380 vehicles and employs over 900 personnel in the operation of its service.

Trial engagement & investment

The Pan-Canadian Electric Bus Demonstration & Integration Trial is crucially important from the point of view of demonstrating and optimizing electric vehicle charging system infrastructure within a Canadian transit context. As a transit agency, heavily reliant upon diesel bus technologies today, Halifax Transit is keen to explore opportunities to shift towards zero-emissions propulsion technologies– a shift that feeds into the Government of Canada's Pan-Canadian Framework on Clean Growth and Climate Change (published in 2016).

More generally, Canada's transit agencies need to take a leadership role in contributing to the research, development and demonstration (RD&D) associated with cutting edge technologies that are high-risk and high-cost for the purposes of enabling the decarbonization of the transportation system and the environment overall. The overarching challenges associated with electric buses in Canada today have much to do with the lack of international standards for charging systems and energy storage. To overcome this significant technological hurdle, Halifax Transit is supporting the proposed demonstration trial with the explicit goal of helping manufacturers develop standardized storage charging infrastructure that can be integrated effectively and safely into the electrical grid system.

However, the lack of neutral, third party analysis, which transit agencies can use in assessing the value of zero-emissions electric bus systems in Canada, constitutes a major challenge for Halifax Transit in terms of proceeding with public procurements of electric bus technologies. We recognize transit systems and utilities need to work together and in tandem with private sector providers to integrate, demonstrate and optimize electric charging solutions to support the shift to zero-emissions transportation networks in the near-term and immediate future. The proposed Trial would constitute a global first in providing transit systems and utilities with *in situ* (real-time) experimental trial data associated with plug-and-play standardized charging stations for on road vehicular fueling. The trial will put Canada on the innovation map as the first demonstration trial to integrate multiple competing manufactured goods and services related to both the charging systems with integrated storage systems and the e-buses.

This trial will also support future training and skills building for the next generation of technical experts for both transit agencies and utilities in Canada. As part of this trial, Halifax Transit is committed to delivering the following investments in cash and in kind, subject to approval from Halifax Regional Council:

1. A commitment of up to $500,000 CAD for each electric bus procured for this trial in Halifax
   - Halifax Transit expects to invest in 8 electric buses, contingent on supplementary funding for the purposes of this trial, with delivery of those vehicles scheduled for 2019
2. A commitment of up to $150,000 in kind over three years in expert staff in supporting the development of Phase II of the trail as it expands to include several additional electrified transit systems and as it seeks to integrate artificially (AI) controls for vehicle-to-grid communications and charging system-to energy storage device communications.

In committing cash and in-kind investments to this trial, Halifax Transit recognizes that it is absorbing several risks associated with ongoing unknowns and untested variables allied to electric buses and electric charging stations in Ontario. Despite these risks, Halifax Transit believes this trial will serve not only as a technology testbed but also as a nexus for economic growth nationally, and it will create environmental and social benefits for Canadians. If NRCan has any questions about Halifax Transit's commitment to this project or about the investments and valuations outlined in this document (or any attached appendices submitted by Halifax Transit), please free to contact.

Sincerely,

Original Signed

Dave Reage
Director, Halifax Transit
(902) 490-5238
reaged@halifax.ca

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Energy

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Appendix D

February 8, 2018

Dear Natural Resources Canada Colleagues:

Re: Letter of Support for Pan-Canadian Electric Bus Demonstration & Integration Trial Phase II (2018 – 2020)

Please accept this letter from the Nova Scotia Department of Energy in support of Halifax Transit's participation in the *Canadian Urban Transit Research & Innovation Consortium's (CUTRIC) Pan-Canadian Electric Bus Demonstration & Integration Trial Phase II (2018 – 2021)*, and their application to the *Electric Vehicle Infrastructure Demonstration Phase II Program*.

The Government of Nova Scotia shares the federal government's goal of achieving deep decarbonization in all sectors of our economy. The electrification of transportation is at the center of both provincial and federal greenhouse gas (GHG) emission reduction strategies.

As the largest public transit provider in Nova Scotia, Halifax Transit is well positioned to contribute significant GHG emission reductions in our province through the electrification of their bus fleet.

The timing is right to take advantage of the research and learning opportunities that this pilot program will provide. By studying the effects of gradual increase in load from EV buses onto our power grid, and potential energy storage opportunities our provincial electric utility, Nova Scotia Power, will be able to better take advantage of our renewable resources and reduce our reliance on imported fossil fuel.

We strongly support Halifax Transit's proactive participation in this initiative. We look forward to working with Halifax Transit in advancing this initiative.

Yours truly,

ORIGINAL SIGNED

Keith Collins, Executive Director
Sustainable & Renewable Energy Branch