Toronto Transit Commission/ PowerON Energy Solutions

Zero-Emission Medium and Heavy Duty Vehicle Adoption Case Study

December 2024

CLEAN ENERGY CANADA

Tell us a little bit about the Toronto Transit Commission's ("TTC") current fleet.

The TTC has a large and diverse fleet with various vehicle types and classes. As of December 2024, the TTC has approximately 2,000 buses. Out of these, **75 are battery electric buses (BEBs or eBuses) and 591 are the latest generation hybrid buses.**[1] The vast majority of the buses are 40-foot buses, along with 220 60-foot buses. TTC also has 250 Wheel-Trans buses which are class 2. In addition, TTC has approximately 1,000 vehicles which are used to support TTC operations, such as supervisor cabs, SUVs, and pickup trucks. These vehicles range from class 1 to class 8.

TTC also has 75 non-revenue rail work cars that are a mix of diesel-powered and electric-powered, and 235 streetcars and 848 subway cars that are fully electrified.

Based on the TTC's current fleet of streetcars, subway, eBuses, and hybrid buses, the TTC's low- to zero-emission fleets cover 70% of all customer boardings.

When did the TTC start their fleet electrification journey and why did they choose to begin electrifying their fleet?

In November 2017, the TTC Board approved **the TTC's Green Bus Program, which identified a procurement strategy to transition the fleet to zero-emissions by the year 2040.** This aligned with the City of Toronto's TransformTO Net Zero Strategy and the C40 Cities Fossil-Fuel-Free Streets Declaration. The TTC's Green Bus Program includes the procurement of hybrid-electric buses as a transition technology until the steady-state procurement of only zero-emissions, battery-electric buses.

Hybrid:

In June 2018, with support from the Government of Canada's Public Transit Infrastructure Fund (PTIF), TTC received the first of its current fleet of 255 hybrid-electric buses along with additional clean diesel buses. On February 28, 2022, the TTC awarded contracts for 336 hybrid-electric buses which were delivered in 2023 and 2024. The last hybrid bus was delivered in July 2024. All future procurements will be zero-emissions buses.

Battery Electric:

In early 2018, the TTC entered negotiated procurement with three different manufacturers of eBuses, BYD, New Flyer Industries, and Proterra. Subsequently, in June 2018, the TTC Board authorized the purchase of an additional 30 eBuses to increase the procurement quantity to 60 eBuses. This investment was made possible by the federal PTIF program.

The intention was to have the three eBus types evaluated through the TTC's head-to-head testing program. The TTC's objectives were to evaluate all three types in the TTC's operating environment, leverage lessons learned to inform eBus technical and commercial specifications for future procurements, and share findings with the broader transit community through an open exchange of best practices to assist with eBus planning and adoption.

In April 2022, the TTC presented a comprehensive report to the TTC Board on the head-to-head eBus pilot program. **No significant obstacles were identified that would prevent the TTC from transitioning to a zero-emissions bus fleet.**

The same month, the TTC posted a Request for Proposal (RFP) for the procurement of eBuses. The RFP was structured into three stages.

Stage 1: Pass/Fail Requirements

Stage 2: Commercial Confidential Meetings (CCMs) of the procurement process, which allows for dialogue between the TTC and the proponent(s) on general conditions and technical requirements.

Stage 3: Final Submission, which included the evaluation of both non-price rated criteria and pricing.

The TTC awarded contracts were awarded for the supply and delivery of 340 eBuses as follows:

- A contract for 204 40-foot buses to New Flyer Industries; and
- A contractor for 136 40-foot buses to NOVA Bus Inc.

These deliveries have commenced, and all buses are expected to be received by the end of 2025.

In February 2022, with the TTC Board's approval, the TTC contracted PowerON, a subsidiary of Ontario Power Generation, to deliver all of the TTC's electrification infrastructure. Through a Principal Agreement between TTC and PowerON, both parties co-invest in, undertake, and manage the design, construction, and operation of the charging infrastructure and related electrical infrastructure to support electrification of the TTC fleet and facilities.

[1] A mild hybrid vehicle is a conventional gasoline or diesel engine with a low voltage battery and an electric motor which is typically used to power electric components such as air conditioning and the radio. Mild hybrids may employ regenerative braking and some level of power assist to the internal combustion engine.

What have been the best things about going electric?

The TTC Board's motivation to go zero-emission was really pushed by the massive emissions reductions offered by eBuses. The TTC Board strongly desired zero or low-emission solutions. **When the entire fleet is zero-emissions, greenhouse gas emissions will be reduced by approximately 275,000 tonnes of CO2 annually. The cumulative benefits of implementing the Green Bus Program from 2024-2040 are anticipated to be 2.7 million metric tonnes of greenhouse gas emissions avoided compared to a 2017 baseline.**

In addition to the environmental benefits of eBuses, there is real public health benefit through improved air quality for Torontonians. In 2019, the TTC conducted a study with C40 Cities and public health that found **an estimated three premature deaths could be avoided each year with the electrification of the entire city fleet.** The TTC recently estimated that the implementation of the Green Bus Program would result in approximately 1.1 metric tonnes of avoided criteria air pollutant emissions[2] and **$25M in avoided healthcare costs.** The TTC is intentionally deploying eBuses in communities where the local community has historically been exposed to lower air quality from diesel fumes, and where significant immediate benefits are anticipated.

Another benefit has been demonstrating to other large fleet owners/operators that transitioning to zero-emissions is possible and doable.

Finally, the TTC has calculated the cost savings associated with implementing the Green Bus Program compared to a 2017 baseline of a fossil fuel-based fleet. Between 2024 and 2040, avoided operational costs are anticipated to be between $2 billion to $3 billion (from the projected changes in diesel and electricity costs, and maintenance costs). This did not include capital costs.

What have been the challenges?

1) **Costs and consistent cash flow risk.** Currently, the cost per bus is about $1.6M. This is about 60% higher than the cost of a hybrid electric bus, although even considering that incremental cost and the cost of the charging infrastructure, the TTC conservatively projects reaching a break-even point in the mid-late 2040s , including all buses purchased, infrastructure, electricity and maintenance due to avoided operational and fuel costs. The TTC also assumes with cost reductions in BEB technology, this cost will come down over time to be comparable to a hybrid electric bus by 2034. Intergovernmental partners have been supportive of electrification initiatives to date, but a predictable and sustainable funding source for fleet electrification is needed to ensure that this work continues.

2) **Expertise and capacity constraints during procurement.** Navigating the numerous complex procurement contracts in the beginning was a very time-intensive process. The TTC commissioned PowerON to provide charging infrastructure to help mitigate risk and help with capacity constraints. The contract with PowerON took two years to be finalized, but once done, helped mitigate many of these risks.

3) **Change management and building a convincing case to transition to BEBs.** The TTC has had challenges in the past when moving to new systems—with examples being the slotted rail terminal, which was a unique technology at the time, and the compressed natural gas fleet which did not perform well and had technical issues with the filling station. There were also older versions of hybrid buses that were not performing very well and were maintenance intensive.

   Building trust was key to building a convincing case. Staff working on the transition plan found ways to mitigate risks with high-level solutions. They started by evaluating all available propulsion technology at the time—clean diesel, hybrid vehicles, hydrogen, and battery-electric—and weighed the pros and cons from a life cycle analysis, operational and reliability perspective. It was decided to pursue eBuses, with hybrid-electric buses as part of the transition to fully zero-emission. This was partly because there is not great availability of hydrogen fuel and it is very expensive.

How did you understand the right infrastructure for your project?

We were aware that we had a number of choices to make. Some agencies were going with on-route or depot charging, some were choosing to plug buses, while others were using automatic pantographs to connect chargers to buses.

As the initial pilot fleet of 30 eBuses were all long-range buses and depot charging with pantographs was relatively unheard of at the time, the choice to use sequential, plug-in chargers was relatively straightforward. Power and energy calculations were performed by internal TTC staff and verified by the

[2] Inclusive of carbon monoxide, nitrogen oxides, sulphur oxides, particulate matter, and volatile organic compounds

infrastructure vendor, Toronto Hydro. These calculations identified that the electrical systems at the time would be capable of supporting 10 buses per garage with some limitations, but that it would not be necessary to install customer-owned substations or other long-lead, high-cost solutions. These calculations demonstrated that the order could be increased to 60 buses if stationary battery storage were added to each garage to provide additional overnight energy for charging.

While the pilot project was under construction, we commissioned feasibility studies to determine the infrastructure requirements of a full fleet of eBuses at each garage. These studies indicated that significant roof reinforcement, infrastructure, and costs would be required for a 1:1 ratio of in-service buses to pantographs. Following these studies, a general maturing of project cost projections, good experience with plugs, and industry concerns about cost/reliability of pantographs, it was determined that a mix of plugs and pantographs would likely be required for depot charging.

The TTC undertook a proof-of-concept project to gain experience with pantographs and trial new, more compact, central-rectifier charging systems that can charge 20 buses from a single large charging system. The project showed that pantograph charging can be generally reliable but that the central rectifier charger was prone to single points of failure that raised reliability concerns. In addition, a new generation of distributed chargers has half the energy footprint of the chargers installed for the pilot. Feedback from this project as well as ongoing operational experience with plug-in charger operations and costs shows a preference towards use of plugs; however, our existing garages do not have sufficient space between tracks of buses to allow plug-in connections. Thus, plugs will be used where buses park against walls or where outdoor charging islands can be located, but some indoor buses will require plugs.

It is also possible that portions of the future fleet will require pantographs to provide higher charge rates to maintain reasonable charging times when battery capacities are significantly higher. Additional infrastructure direction has come from two large route modelling and fleet transitions studies performed in 2022/2023. These indicated that portions of the fleet may be best converted to BEBs with on-route charging to provide top-up charging during operations. We are planning an on-route charging pilot to understand and solve operational issues related to on-route charging of high-frequency routes at compact, urban terminal stations.

To provide time for operating groups to acclimatize to eBuses as well as for battery capacities and bus efficiencies to improve, the initial deployment of buses and infrastructure at each garage will be similar to the pilot. We will add 30-50 buses and associated infrastructure behind the existing electrical infrastructure. Due to the high cost of installing customer-owned substations, and to match the expected block-compatibility of the buses, phase 2 installations will be up to 50% eBuses at each location.

During the pilot, it was noticed that the original 2:1 sequential charger systems and 1:1 bus:plug ratio was resulting in underutilized infrastructure. The pilot, as well as further investigation by internal teams, indicated that based on our patterns of service and operating practices, three sequential plugs could be connected to each 150 kW charger and those three plugs could serve four buses with minimal limitations. For the newly available 300 kW chargers with four parallel plugs, five buses can be served from each charger.

A moderate amount of backup generation will be provided for phase 2, although the current intention is not to provide 100% backup power, but to rely on operational contingency planning.

As of Spring 2024, the TTC has 80 charge points in place, with 70 plug-in with rated power outputs of 150 kW and an additional 10 pantograph chargers that are rated at about 75 kW.

Did you hire any new staff or did current staff change their day-to-day operations for this transition?

The TTC approached this as a transition rather than a switch. There was an intentional focus on hybrid-electric buses as a transition technology to help maintenance staff be more aware of the high voltage components of the vehicle. A key part of the training was having the OEM present as part of the support stream for the vehicle maintenance.

From an operator safety perspective, there is a joint health and safety committee that has worked on training staff on how to plug and unplug the chargers as well as on their safety mechanisms. Regarding pantographs, training has been delivered on how to get the bus in and out of the charging space so that the charger is working correctly. Maintenance staff have also been trained.

Once the TTC transitions the charging infrastructure over to PowerON, they will be responsible for the maintenance and corrective operations for the vehicles going forward.

What programs and incentives did you use?

The TTC has had substantial intergovernmental support when it comes to the electrification of our fleet.

By 2019, the TTC had procured 255 hybrid-electric buses after **the Government of Canada and the City of Toronto invested $370 million as part of the federal Public Transit Infrastructure Fund ("PTIF"). The TTC also procured 60 eBuses through an investment of $140 million made by the Government of Canada and the City of Toronto under PTIF.**

In 2023, the TTC secured $349 million in matching federal funding for the procurement of 340 eBuses and 248 charge points under the Government of Canada's Zero Emission Transit Fund. This funding has enabled the TTC to procure previously unfunded buses needed for replacement to the end of 2025.

In 2019, Natural Resources Canada also provided the TTC with $2.5 million through the Government of Canada's Electric Vehicle Infrastructure Demonstration program to develop an energy management system.

Finally, the TTC has looked at the federal Clean Fuel Regulations (CFR) in detail. The TTC has received internal approval to participate in the program and has commissioned program administration to PowerON (who owns the charging infrastructure asset for TTC), which includes competitively procuring the services of a third-party aggregator of credits under the program. Revenue generated from the CFR program will be re-invested.

What insights would you pass on to other fleets looking to electrify?

1) **Consider conducting feasibility studies to understand how zero-emission vehicles will work within your current fleet.** The TTC conducted feasibility studies to understand how service levels would be impacted by the transition to eBuses. They know that an eBus is not going to be out there for 26 hours straight. But from their own studies they know that they can split the time the bus is in service into two 13-hour blocks rather than a full 26-hour block. Eventually, the TTC might have to look at hydrogen options for some blocks they are not able to solve, but **currently their eBuses are operating fine using only depot charging. In the future, there may be consideration of developing on-route charging.**

2) **If possible, consider partnering with a third party that can help navigate the transition.** The TTC has partnered with PowerON who will be owning, operating, and maintaining the charging infrastructure assets going forward. They have been helpful in navigating different charging infrastructure options and procurements, and understanding incentives/programs like the CFR and the benefits those can provide. While there is a cost, it is helpful to weigh the cost of the additional time that would be spent by your own staff versus using a third-party provider with existing expertise.

3) **Engage with your utility early and often.** The TTC has been in regular contact with Toronto Hydro over the course of this project. This will be important in ensuring the second phase of their work, which will require substantial upgrades to the substation, is aligned with Toronto Hydro's plans. The Ontario Energy Board can also take time to ensure the necessary infrastructure is there to meet the TTC's needs. Therefore, planning ahead and engaging early can help mitigate some of these longer timelines.

4) **It will be a transition, not a switch—plan for change management within your organization and help mitigate internal risks.** The TTC has taken steps to phase in the charging infrastructure deployment and routes that are well suited for early adoption. The next phase will focus on depots that will require service upgrades. In addition, working through the transition plan with key decision makers to have all actors on board will be important. Part of this is to understand and validate the concerns of those decision makers and create a risk mitigation plan to address concerns.