

Item 7



For Action

TTC Green Bus Program Update

Date: February 25, 2020
To: TTC Board
From: Chief Vehicles Officer

Summary

This report provides as an update on TTC's Green Bus Program, which was approved at the November 2017 Board Meeting. The TTC's Green Bus Program identifies a procurement strategy to transition the fleet to become zero-emissions by the year 2040. This plan is in alignment with the City of Toronto's Transform TO Action Plan and the C40 Fossil-Fuel-Free Streets Declaration.

When the entire fleet is zero-emissions in 2040, greenhouse gas emissions will have been reduced by the equivalent of approximately 250,000 tonnes of CO₂ each and every year; diesel emission will have been eliminated from bus operations thereby improving local air quality; and the total life cycle cost is estimated to be significantly lower than any currently available fuel alternative.

Recommendations

It is recommended that the TTC Board:

1. Receive this report for information.

Financial Summary

The TTC's Green Fleet Plan transitions the city bus fleet to zero emissions by using hybrid diesel-electric buses and new all-electric buses to phase out clean diesel buses.

From April 2016 to March 2020, the TTC has utilized the Government of Canada Public Transit Infrastructure Fund (PTIF) program to refresh its fleet of city buses and to start the transition of this fleet from clean diesel to zero emissions buses. Through the PTIF program, the TTC purchased 1,043 new buses. This procurement included:

- 728 clean diesel buses;
- 255 hybrid diesel-electric buses; and
- 60 electric buses and related charging infrastructure

The purchase of 728 clean diesel buses was the last procurement of this propulsion type and fuel source. The TTC's last delivery of a clean diesel bus was in December 2018.

As of December 2019, all 255 hybrid buses were delivered to TTC. These buses are the latest generation hybrid diesel-electric technology and when compared to the diesel buses replaced, reduces greenhouse gas emissions by nearly 50%.

The City approved funding for the noted procurements total \$827.6 million of which approximately \$707.5 million has been spent to the end of 2019. This report is being provided as an update to the Board on the status of the Green Bus Program.

The Interim Chief Financial Officer has reviewed this report and agrees with the financial impact information.

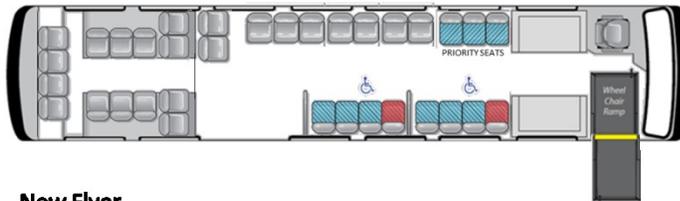
Equity/Accessibility Matters

A reliable transit network is critical for equity-seeking groups relying on the TTC's services to get to work, school, access health services, participate in recreational and cultural services, etc. Studies have shown that people who have less access to public services, including transit, typically have worse economic and health prospects. Access to transit that is equitable, accessible, safe, reliable, and that grows with or ahead of the population will help improve health outcomes, economic prosperity, and equality throughout the City of Toronto, regionally and nationally.

All buses, regardless of the propulsion technology, will be compliant with the Canadian Standards Association (CSA) D435 standard for accessible transit buses and the Accessibility for Ontarians with Disabilities Act (AODA).

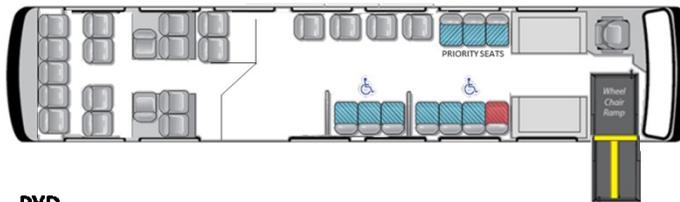
The TTC strives to exceed minimum requirements and has included the Advisory Committee on Accessible Transit (ACAT) in design reviews of our bus procurements. Through our most recent procurement of eBuses from BYD, New Flyer Industries, and Proterra we have identified three different interior configurations and seating layouts that will allow for ACAT and customer focus groups to evaluate what works best and inform future bus procurements. Shown below are the interior configurations of the three eBuses.

Proterra



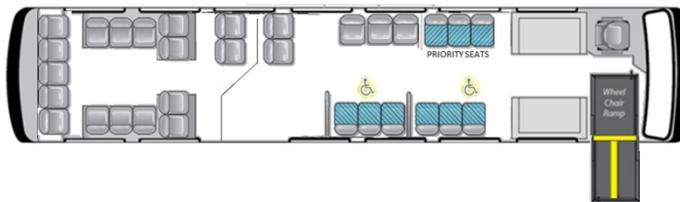
- 34 Seats
- 2 Wheel Chair Positions
- 2 Attendant Seats
- Perimeter Seating (lower & upper deck)

New Flyer



- 31 Seats
- 2 Wheel Chair Positions
- 1 Attendant Seat
- Passenger Facing ADA Stop Requests
- Yellow Guide Stripe on Ramp

BYD



- 31 Seats
- 2 Wheel Chair Positions
- Above Seat ADA Stop Requests
- Perimeter Seating (lower and upper deck)
- Yellow Guide Stripe on Ramp

The layouts were determined in consideration of physical constraints of each bus and through consultation with ACAT.

All buses have the Vision system for audible and visual announcements of stops and diversions. The Bus Announcement System interfaces with the internal and external speakers to provide audio announcements to passengers as well as a visual announcement to the Customer Next Stop Screen that provides information such as Next Stop, Route and Destination, Stop Requests and Public Service Announcements.

A comprehensive review will be undertaken with ACAT, customer focus group(s), and an independent AODA expert. The results of this evaluation will be included in the head-to-head evaluation of all three eBuses in Q4 2020.

Decision History

September 5, 2017: The TTC Board granted authorization to award the contract for 325 low floor clean diesel buses to Nova and requested further updates on the issuance of a Request for Information (RFI) for electric buses and information on new technologies with a focus on battery power technology.

Report:

[https://www.ttc.ca/About the TTC/Commission reports and information/Commission meetings/2017/September 5/Reports/9 PA Purchase 440 Low Floor Clean Diesel Buses.pdf](https://www.ttc.ca/About%20the%20TTC/Commission%20reports%20and%20information/Commission%20meetings/2017/September%205/Reports/9%20PA%20Purchase%20440%20Low%20Floor%20Clean%20Diesel%20Buses.pdf)

November 13, 2017: The TTC Board delegated the authority to the TTC CEO to negotiate and enter into the following:

- Up to three contracts for the supply of 30 long range battery electric buses with BYD, New Flyer and Proterra with a total project cost of up to \$50 million.
- Up to two contracts for the supply of 230 new generation hybrid electric buses with Nova Bus and New Flyer and a total project cost of up to \$230 million.
- All vehicles are to be delivered no later than March 31, 2019 to be eligible for PTIF funding.

Report:

[https://www.ttc.ca/About the TTC/Commission reports and information/Commission meetings/2017/November 13/Reports/4 Green Bus Technology Plan.pdf](https://www.ttc.ca/About%20the%20TTC/Commission%20reports%20and%20information/Commission%20meetings/2017/November%2013/Reports/4%20Green%20Bus%20Technology%20Plan.pdf)

June 12, 2018: Staff presented an update on the Green Bus Technology Plan to the TTC Board. The Board delegated the authority to the CEO to procure an additional 30 long range battery electric buses with BYD, New Flyer and Proterra, to be delivered no later than March 31, 2020 to ensure eligibility for PTIF funding. In addition, staff were directed to begin preparations for the electrification of the TTC's first all-electric bus garage to support future procurements of battery electric buses for a total project cost of \$90 million.

Report:

[https://www.ttc.ca/About the TTC/Commission reports and information/Commission meetings/2018/June 12/Reports/27 Green Bus Technology Plan Update.pdf](https://www.ttc.ca/About%20the%20TTC/Commission%20reports%20and%20information/Commission%20meetings/2018/June%2012/Reports/27%20Green%20Bus%20Technology%20Plan%20Update.pdf)

The Board also requested the following:

- To review the operations of the 75 Sherbourne Bus and on other routes with similar issues (noise and air quality) to see how electric buses and other measures could minimize the impacts along the residential neighbourhoods through which they operate.
- To report on the eBus roll-out plan including details on charging stations and infrastructure requirements and consider the feasibility of prioritizing the use of electric buses on routes that run on local and collector roads.
- TTC confirm its target for procurement of only zero emissions propulsion technology starting in 2025 and define zero emissions propulsion technology as fossil fuel free.

Minutes:

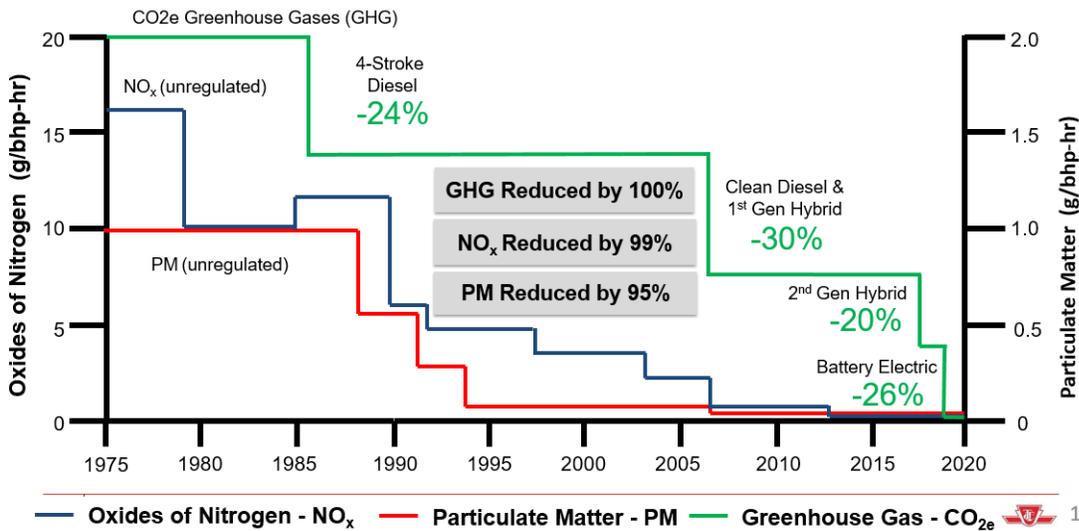
[http://www.ttc.ca/About the TTC/Commission reports and information/Commission meetings/2018/July 27/Minutes/Minutes.jsp](http://www.ttc.ca/About%20the%20TTC/Commission%20reports%20and%20information/Commission%20meetings/2018/July%2027/Minutes/Minutes.jsp)

Issue Background

Summary of Transit Bus Emissions

The chart below illustrates how changes in bus propulsion technology has resulted in improvement to air quality through the reduction in particulate matter, nitrogen oxides and greenhouse gas (GHG) emissions.

Chart 1: Path to Zero Emissions



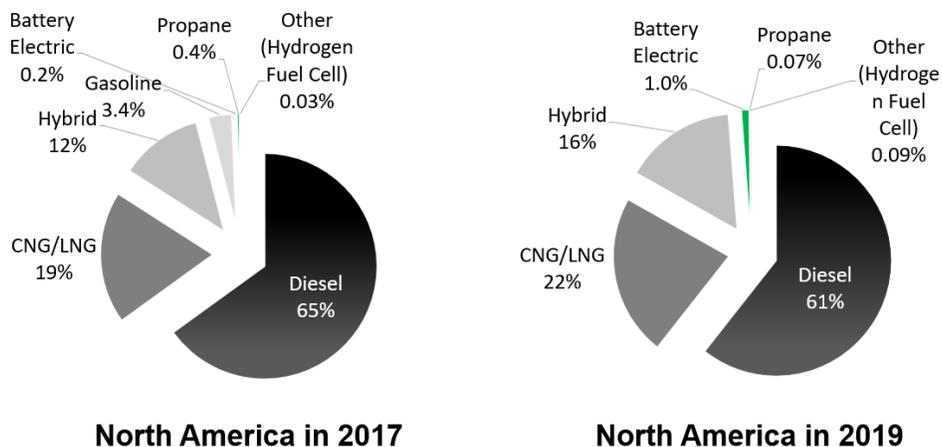
Since 1980, increasingly strict environmental regulations have forced the industry to improve technology in order to reduce emissions of particulate matter and nitrogen oxides. By 2006, both particulate matter and nitrogen oxides were reduced by 95%.

By 2005, more focus was placed on lowering fuel consumption and GHG emissions. New technology such as hybrid-electric, hydrogen fuel cell, and battery electric technology will have a 50 to 100% reduction of GHG tailpipe emissions.

Recent Shift Toward Green Bus Propulsion Technology

As illustrated in Chart 2 there is an increasing shift towards greener technology. In just the last two years, the number of diesel buses procured has decreased by 4%. This reduction is being offset with more demand for cleaner technology. For example, from 2017 to 2019 the number of battery electric buses increased five fold.

Chart 2: Shift Towards Green Propulsion Technology



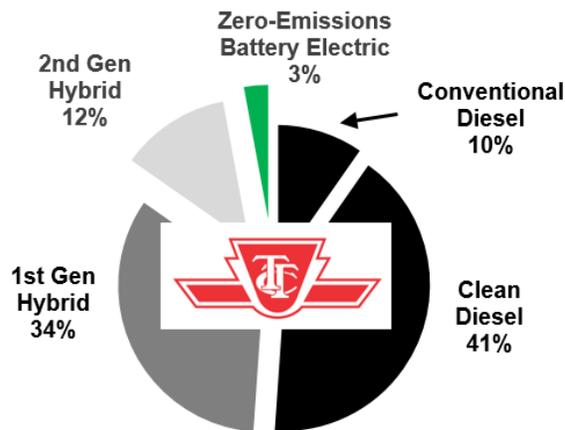
The TTC's Path to Zero Emissions

Driven by the TTC's Corporate Plan and the City of Toronto's TransformTO Climate Change and Clean Air Action Plan, TTC developed the Green Bus Program.

This program was approved by the TTC Board in November 2017, with the target of procuring only zero-emission buses starting in 2025 and achieving an entirely zero-emissions bus fleet by 2040.

The following chart identifies the make-up of the TTC bus fleet as of 2019.

Chart 3: TTC's Bus Fleet 2019



Today's TTC bus emits:

- **16%** less GHG than average
- **14%** less than it did in 2017
- **41%** less than it did in 1990

Since approval of the Green Bus Program, the TTC has reduced bus fleet emissions by:

- 14% compared to the TTCs 2017 levels;
- 16% compared to the 2019 North American fleet average; and
- 41% compared to the TTCs 1990 levels.

Comments

This section provides a status update on the Green Bus Program, and provides a snapshot of our involvement in industry to learn, adopt, and share what works best for the environment, our operations, and our customers.

The current scope of the Green Bus Program includes the following:

1. Bus procurements
 - a. Clean Diesel buses
 - b. Hybrid diesel-electric buses
 - c. Electric buses (eBuses)
2. eBus Charging System Infrastructure

Since the TTC Board's approval of the Green Bus Program in November 2017, the TTC has procured 310 of the latest Clean Diesel buses, 255 of latest generation hybrid-electric buses, the City of Toronto's first 60 battery-electric eBuses, and retrofitted three of our eight garages with the required eBus charging systems infrastructure.

As part of these bus procurements the following design upgrades were included:

Safety:	Electric doors for improved detection of obstacles prior to bus movement;
Accessibility:	ACAT approved seating layout including 3 flip down seats on the street side to improve passenger flow and remove barriers;
Noise and Local Emissions:	Engine Idle stop technology for reduced noise and tailpipe emissions at bus stops and in stations;
Customer Communications:	Vision System including 2 large 29" infotainment screens for audible and visual announcements of both stops and diversions; and
Customer Convenience:	12 USB charging ports throughout the bus for customers to charge their devices.

These upgrades will be incorporated into the TTC bus design specifications for future procurements.

Clean Diesel Buses

In 2018, three hundred and ten (310) clean diesel buses were procured under the PTIF program. These buses included diesel particulate filters (DPR) and selective catalytic reduction (SCR) systems to comply with stricter EPA standards. When compared to the conventional diesel buses the new clean diesels reduced greenhouse gas emissions by 30% and resulted in fuel savings of \$12.6 million in 2019. The purchase of these clean diesel buses is the last procurement of this fleet type and energy source.

Hybrid Diesel-Electric Buses

Between 2018 and 2019, a total of two hundred and fifty-five (255) of the latest generation hybrid diesel-electric buses were procured under the PTIF program.

Hybrid diesel-electric buses are equipped with both a clean diesel engine and an electric generator/motor. The on-board batteries which drive the electric traction motor are charged by the generator driven by the diesel motor and supplemented by the recovery of braking energy through regenerative braking. The clean diesel engine used on the hybrid buses is smaller in size compared to the engines used in the clean and conventional diesel buses. In addition, these buses have all-electric accessories such as electric power steering, air compressor, power steering, etc. All these features result in reduced fuel consumption and in turn, reduced tailpipe emissions

This latest generation of hybrid buses results in a 50% reduction of greenhouse gas emissions and a fuel savings of \$3.3 million in 2019 when compared to the conventional diesel buses they replaced. These hybrid buses play a critical role in the TTC's transition towards a zero-emissions fleet and this technology provides maintenance staff, operators, and our customers the experience of an all-battery electric bus.

It should be noted that under certain operating conditions, these buses are also capable of operating in electric vehicle (EV) mode. When in EV mode the diesel engine is not used and the vehicle can travel up to five kilometres without charging the batteries. This results in a quieter, zero emissions operations. The TTC is currently studying all the parameters that must be met in order to enable EV mode and will develop a strategy to deploy this technology.

All-Electric eBuses

At the November 2017 Board Meeting, TTC staff was authorized to purchase 30 eBuses for a pilot program. TTC entered into negotiated procurement with three different manufacturers of eBuses (BYD Canada, New Flyer Industries and Proterra). Subsequently, in June 2018, the TTC was authorized to purchase an additional 30 eBuses to increase the procurement quantity to 60 eBuses.

Unlike the hybrid diesel-electric bus, a battery electric bus does not rely on a diesel power plant to charge the batteries. The batteries are charged by energy from the hydro-electric grid either by slow charging at the garage (long range buses) or fast charging using on-route charging stations (short range buses). In both charging methods, complex charging infrastructure is required.

Although there are a number of battery electric buses in operation throughout the world the technology is relatively new and still evolving. The TTC chose the garage charge option (long range buses) for the following reasons:

- PTIF timelines;
- the amount of time that would have been required to design and install on route charging stations; and
- to allow the operational flexibility of deploying these buses on various routes.

As a result of this decision, the only three manufacturers (BYD Canada, New Flyer Industries, and Proterra) of long-range battery electric buses approved under Transport Canada's Commercial Motor Vehicle Safety Standards were selected to participate in the TTC's head to head eBus pilot program.

The TTC's head-to-head evaluation of these buses over the next two years will include assessment of both vendor performance and vehicle performance. Vendors will be assessed against criteria such as adherence to the contract schedule, production quality, and customer support. Vehicle performance metrics will include vehicle reliability, rate of energy consumption, charger reliability, ride quality, serviceability, maintainability, accessibility and ergonomics. Throughout the procurement, production, delivery and warranty phases of these contracts TTC has been, and will continue, providing each vendor with formal performance reviews.

The vehicle head-to-head evaluation will begin when each vendor has a minimum of 10 buses available for service. We expect this to commence by Q2 2020, when all buses will be delivered and in service.

The following are some high level data for vendor and vehicle performance for eBuses already received as of January 2020:

BYD Canada

BYD is one of the world's largest manufacturer of all-electric buses, having delivered over 40,000 electric buses worldwide. They are the only eBus manufacturer that develops and produces its own battery technology.

Schedule Adherence: The first BYD eBus was received by the TTC on January 21, 2020, which was 347 days past the original contract schedule date of February 8, 2019.

As of February 7, 2020, a total of 4 buses were delivered and 0 have been commissioned for revenue service.

Production quality and vehicle performance data is not available as the first bus has not yet completed its post delivery inspection.

New Flyer Industries

New Flyer has over 50 years of experience manufacturing zero-emissions buses, and has delivered over 6,400 buses powered by electric motors and batteries in North America.

Schedule Adherence: The first New Flyer Industries eBus was received by the TTC on April 15, 2019, which was 22 days past the original contract schedule date of March 25, 2019.

As of February 7, 2020, a total of 15 buses were delivered and 10 commissioned for revenue service.

Post Production Quality: There were an average of 30 quality issues identified by TTC during post delivery inspection of the first 10 buses, which took an average of 45 days for New Flyer Industries to correct.

Vehicle Performance: The fleet accumulated a total of 176,000 km in 2019, with a MDBF of 19,500 km

Average energy consumption was approximately 1.40 kWh/km, which is below the target of 1.5 kWh/km and has resulted in a GHG impact equivalent of 298,400 kg of carbon dioxide.

Proterra

Since 2004, Proterra has sold more than 900 electric buses to 100 communities across North America.

Schedule Adherence: The first Proterra eBus was received by the TTC on Aug 23, 2019, which was 47 days past the original contract schedule date of July 8, 2019.

As of February 7, 2020, a total of 10 buses were delivered and 10 commissioned for revenue service.

Post Production Quality: There were an average of 45 quality issues identified by TTC during post delivery inspection of the first 10 buses, which took an average of 59 days for Proterra to correct.

Vehicle Performance: The fleet accumulated a total of 13,250 km in 2019.

With only 13,250 km of revenue service, reliability and average energy consumption cannot be estimated with any level of confidence. To ensure fairness among all three vendors, we will report these metrics only after their buses exceed 150,000 kms of revenue service.

Ultimately, the purpose of this first phase of the TTC's adoption of eBuses is to evaluate all 3 eBus types in the TTC's operating environment and leverage our findings in the areas of design, reliability and maintainability to develop an electric bus specification for future procurements. The TTC will also be sharing our findings with the broader transit community to assist them with electric bus planning and adoption.

In addition to monitoring operational performance using metrics like those above, the head-to-head testing will consist of loading a test eBus from each manufacturer with 12,000 lbs of ballast to represent a fully loaded bus and operating them in simulated service on a minimum of 40 different routes through winter and summer seasons. Energy consumption, energy regenerated, ride quality, heating and cooling efficiency data will be collected and analyzed to understand which system configurations are the best for our operations and our customers.

Performance and reliability of the different types of charging systems will also be evaluated. Further, each of the three eBus home garages has a minimum of 4 outdoor chargers so the effects of the environment on charging efficiency, charge time, and charger reliability will be measured and evaluated.

eBus Charging Systems

For this pilot, three garages were retrofitted with depot charging systems to accommodate charging up to 25 eBuses per location. This infrastructure was designed within the electrical energy constraints of each garage. Future adoption of electric buses will require a feasibility study to understand energy requirements, facility constraints and

the potential need for on route charging throughout the City. Increasing the fleet by more than 25 eBuses at each garage will require significant infrastructure upgrades both internally and from the utility provider.

Ongoing Industry Engagement

As part of the Green Bus Program, the TTC is collaborating with numerous stakeholders including; bus manufacturers, peer transit agencies, Canadian Urban Transit Association (CUTA), American Public Transit Association (APTA), Canadian Urban Transit Research and Innovation Consortium (CUTRIC), Zero Emissions Bus Resource Alliance (ZEBRA) and service providers (Toronto Hydro).

The TTC chairs a bi-monthly call to discuss technical and operational challenges including lessons learned. Interest in this bi-monthly call continues to grow. Currently the list of participants are as follows:

- Association du Transport Urbain du Québec;
- King County Metro (Seattle);
- Los Angeles Metro;
- New York City Transit Authority; and
- Société de Transport de Montréal;

The next call is planned for March 3, 2020 and will also include representation from Brampton Transit, York Region Transit, Chicago Transit Authority, Edmonton Transit, Southeastern Pennsylvania Transportation Authority, Washington Metro Area Transit Authority, Portland Transit, and Massachusetts Bay Transportation Authority.

At this year's Ontario Transportation Expo and Trade Show (April 2020), the TTC will bring industry peers to see different types of charging systems at TTC and York Region Transit bus garages. Attendees will have the opportunity to ride on the TTC's eBuses.

The TTC plans to host a Peer-to Peer eBus Summit for interested transit agencies across North America. The focus of this summit will be to discuss in detail topics such as:

1. Factors for Success: Commitment, Partnerships and Resources
2. Bus Systems Engineering
 - i. Operations Planning and Delivery
 - ii. Charging Systems Infrastructure Design, Procurement and Construction
 - iii. Bus Specification, Procurement and Performance
 - iv. Performance Optimization
3. Vendor Performance
4. Lessons Learned

In addition, to eBus technology, TTC staff is working with industry to identify and evaluate alternative technologies for lowering GHG emissions from our current fleet of diesel buses (i.e hydrogen injection technology).

Contact

Bem Case, Head – Vehicle Programs
416-397-8375
bem.case@ttc.ca

Signature

Rich Wong, Chief of Vehicles
416-393-3564
rich.wong@ttc.ca