For Action

Green Bus Technology Plan Update (Presentation)

Date: June 12, 2018
To: TTC Board
From: Chief Service Officer

Summary

In July 2017, the City of Toronto adopted the TransformTO greenhouse gas (GHG) reduction target to reduce emissions 80% by 2050. In November 2017, the TTC Board approved staff's Green Bus Technology Plan and associated targets for procurement of only zero-emissions buses starting in 2025 and an all zero-emissions bus fleet by 2040.

The Board's approval of the Plan included procurement of the TTC's 30 all-electric buses (eBuses), which were to be delivered by March 31, 2019 in order to ensure eligibility for funding under the Government of Canada's Public Transit Infrastructure Fund (PTIF). The Board also requested that staff report back on increasing the procurement quantity from 30 to 60 if a one-year extension to the PTIF funding program was granted.

In January 2018, the federal government announced that the PTIF Phase 1 program deadline was extended until March 31, 2020. The primary purpose of this report is to obtain approval for a scope change to the eBus program: procurement of an additional 30 eBuses and the infrastructure required to begin modification of the first TTC bus garage to accommodate up to 300 zero emissions buses.

The report is structured as a status update on the work underway to implement the overall Green Bus Technology Plan, and includes rationale for the eBus program scope change in that context:

1. TTC Bus Procurement Plan

2. Program Status Update & eBus Change Request
    a) Clean Diesel Bus Procurements
    b) Hybrid Electric Bus Procurements
    c) eBus Program (eBuses and Charging Infrastructure)

3. Future Proofing Garages (including McNicoll Bus Garage)

4. Gaseous Fuel Study for Compressed Natural Gas (CNG) and Hydrogen

5. Cost Benefit Analysis and Evaluation of Potential Funding Opportunities

Recommendations

It is recommended that:

1. Staff exercise contract options to increase the procurement quantity of eBuses from 30 to 60 and work with Toronto Hydro on the design and installation of associated charging infrastructure (i.e. chargers and energy storage system), revising the project budget from $50 million to an estimated $120 million based on the following:

    a) Award of contract options will be based on negotiating an acceptable agreement, satisfactory to the TTC General Counsel with suppliers of the 30 eBuses;

    b) All 60 eBuses are to be delivered no later than March 31, 2020 in order to ensure that the buses are eligible for PTIF funding.

2. The Board delegate authority to the TTC CEO to work with Toronto Hydro in modifying one of TTC's bus garages to accommodate up to 300 zero emissions (or near zero emissions) buses through the supply of a substation and a backup generator for an estimated project cost of $18 million based on the following:

    a) Recognizing that procurement, installation, and commissioning of a substation takes approximately two and a half years, staff is to work within the PTIF guidelines to capture as much of the substation procurement cost as possible prior to the March 31, 2020 deadline;

    b) The backup generator is to be delivered no later than March 31, 2020 in order to ensure that it is eligible for PTIF funding.

3. Staff return to the TTC Board in Q1 of 2019 with an information report providing award details and a project status update with respect to Recommendation Nos. 1 and 2.

4. Staff conduct a garage-by-garage feasibility study at an estimated cost of $2 million and return to the TTC Board in Q4 of 2019 outlining preliminary estimates for the total costs, benefits, and potential funding opportunities associated with the green bus plan.

Implementation Points

TTC Bus Procurement Plan

The bus procurement plan, which was revised to reflect the Board's decisions on the Green Bus Technology Plan issued in November 2017, is as follows:

Description	PTIF Period			Remaining Capital Plan (Steady State Procurement)							10-Year Total
	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	
Clean Diesel (40 ft)	310										310
Hybrid (40 ft)	55	200		32	80	60	40				467
Hybrid (60 ft)				61							61
Zero Emissions (40 ft)	10	50		60	80	100	120	84	84	160	748
Zero Emissions (60 ft)				7				76	76		159
Total Bus Procurements	**375**	**250**	**0**	**160**	**160**	**160**	**160**	**160**	**160**	**160**	**1,745**

Figure 1: TTC Bus Fleet Plan

This plan sets out the following:

1. The number of vehicles required to procure each year in order to meet Service Planning's projected ridership through bus replacements and additions;

2. The transition towards green bus technology and the steady state procurement of only zero emissions buses starting in 2025;

3. Resulting overhaul program to maintain the fleet in a state of good repair;

4. Resulting capital budget and operating impacts, to be presented through the 2019 budget process.

<u>eBus Program</u>

Due to the complexity of the eBus program, a high level timeline is provided in Figure 2.

Timeline for 30 eBuses

Finalization of bus procurements are scheduled in June 2018; approval of detailed designs in August; and commissioning of eBuses start in December and finishing in June 2019.

Timeline for 60 eBuses, Storage System, Substation and Emergency Backup Generator

Subject to approval of this report, milestones for the infrastructure required to begin retrofit of the first TTC garage to accommodate up to 300 zero emissions buses are shown in this parallel and extended timeline, with the receipt of substation equipment and the backup generator prior to the end of Phase 1 of the PTIF program on March 31, 2020.

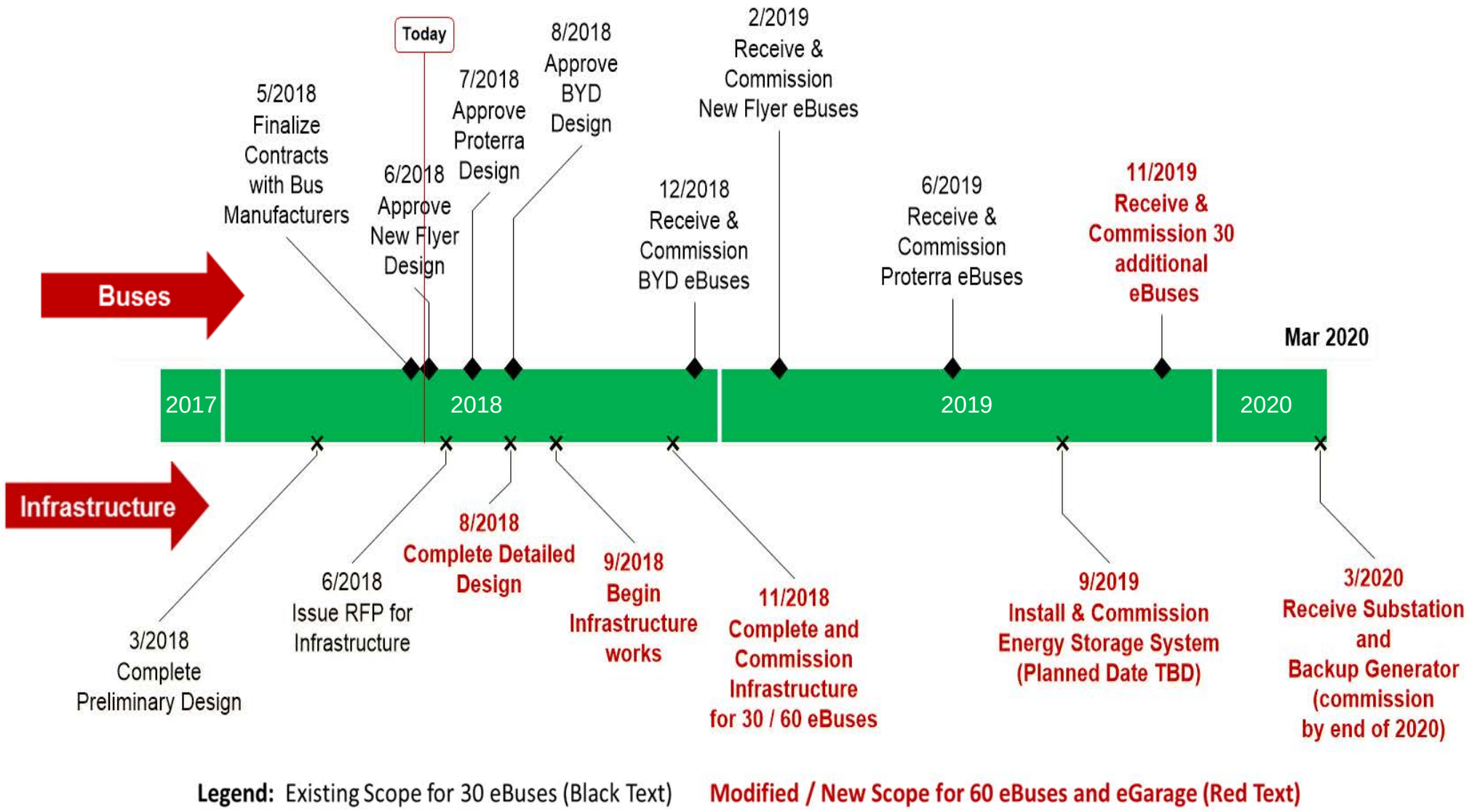

Figure 2 – eBus Program Timeline (scope in red is subject to approval through this report)

Financial Summary

This report recommends Board authority for the eBus program change request to procure an additional 30 long range electric buses and in parallel start preparations for the electrification of TTC's first all-electric bus garage to support future procurements of battery electric buses for a total estimated project adjustment of $90 million.

Under the PTIF program, capital projects commenced after April 1, 2016 and completed by March 31, 2020 may receive up to 50% funding of eligible costs. The purchase of these new buses and related infrastructure meets the criteria for funding eligibility under the program, subject to final Treasury Board approval.

In addition to the funding already spent or committed for 1,013 clean diesel, hybrid, the initial 30 eBuses and infrastructure, $90 million in capital funding will be made available for the procurement of the additional 30 electric buses and associated infrastructure.

Funding is available for this added requirement within a combination of the existing capital budget for bus procurements, under the 4.11 Purchase of Buses program, reallocated PTIF funding of $23 million and an additional $10 million from the Government of Ontario's Green House Gas (GHG) Fund.

Future cash flows from 2020 – 2023 will be accelerated for this requirement. Authority for this acceleration and offsetting deferrals will be included in the upcoming Capital Acceleration Report to the Board in July.

Additional funding for future bus procurements beyond the 1,043 buses will be identified as part of the 2019 – 2028 budget submission.

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

Equity/Accessibility Matters

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.

TTC will strive to exceed minimum requirements and will include the Advisory Committee on Accessible Transit in design reviews and evaluations of pilot vehicles.

Decision History

At its meeting on September 5, 2017 TTC Board was presented with a request for a procurement authorization of 440 low floor clean diesel buses:

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

Following this discussion, the TTC Board adopted the following member motions:

1. *The recommendations be amended to award 325 low floor clean diesel buses to Nova; and*
2. *The TTC issue an RFI for electric buses and report back on the results of the RFI in November and further bring forward the report on new technologies for buses at that time paying particular attention to the maturity of the battery power bus technology; and*
3. *That TTC staff report back on awarding Nova the additional 115 buses on the same terms if the TTC Board does not award a contract for 115 electric buses; and*
4. *That consideration be given to job creation opportunities in Toronto, Ontario and Canada in the RFI and bus technology report.*
5. *Staff report back by the December 11, 2017 meeting of the Board on any other bus fleet options that might be available to the TTC within the timelines set out in the PTIF program.*

At its meeting on November 13, 2017 TTC board was presented with the Green Bus Technology Plan along with a request for a procurement authorization of 30 long range battery electric buses and 230 new generation hybrid electric buses:

https://www.ttc.ca/About_the_TTC/Commission_reports_and_information/Commission_meetings/2017/November_13/Reports/4_Green_Bus_Technology__Plan.pdf

Following this discussion, the TTC Board adopted the staff recommendations, amended as follows:

1. *The Board delegate authority to the TTC CEO to negotiate and enter into up to three contracts for the supply of a total of 30 long range battery electric buses not to exceed the total project cost of $50M based on the following:*

a) *The award of contract(s) will be based on negotiating an acceptable agreement, satisfactory to the TTC General Counsel with the only three qualified long rang battery electric bus suppliers, New Flyer, Proterra and BYD that are compliant with Transport Canada Motor Vehicle Safety Standards; and*
b) *All 30 battery electric buses are to be delivered no later than March 31, 2019 in order to ensure that the buses are eligible for PTIF funding.*

2. *The Board delegate authority to the TTC CEO to enter into a contract(s) with up to two suppliers for the supply of 230 new generation hybrid electric buses not to exceed the total project cost of $230M based on the following:*

a. *The award of the contract(s) will be based on negotiating an acceptable agreement, satisfactory to the TTC General Counsel with the only two bus suppliers, Nova Bus and New Flyer, capable of manufacturing hybrid electric buses that are compliant with Transport Canada Motor Vehicle Safety Standards; and*
b. *Hybrid electric buses are to be delivered no later than March 31, 2019 in order to ensure that the buses are eligible for PTIF funding*
c. *TTC staff consider weighting consideration of the hybrid electric bus order to those companies who would be prepared to build an assembly facility in the City of Toronto.*

3. *Staff return to the TTC Board in Q1 of 2018 with an information report providing award details with respect to recommendations 1 and 2.*

4. *That staff be requested to consider and report back to the Board on increasing the battery electric bus procurement quantity from 30 to 60 buses based on the following conditions:*

a) *One (1) year extension to the PTIF funding program is granted;*
b) *Toronto Hydro confirms ability to support and implement electrical infrastructure upgrades required within the extended PTIF timeframe; and*
c) *Procurement is subject to availability of funding for the portion of expenses not funded through PTIF.*
d) *In the event that one or more of the three qualified suppliers is unable to meet the TTC's requirements, then the quantity of buses awarded to the remaining qualified supplier/s can be increased to achieve the approved limit.*

5. *In consideration of the Board's decision at its meeting on September 5, 2017 to award up to 325 low floor clean diesel buses to Nova, that the Board delegate authority to the CEO to negotiate a contract change with Nova Bus to maximize the number of 2nd generation hybrid electric buses that can be delivered under that contract, based on the following conditions:*

a) *All 325 buses, both clean diesel and hybrid-electric, are to be delivered no later than March 31, 2019 under the existing contract conditions in order to ensure that the procurement remains eligible for PTIF funding; and*
b) *Procurement is subject to availability of funding for the portion of expenses not funded through PTIF and negotiating an acceptable agreement with Nova Bus for the cost premium, if any, associated with the hybrid electric propulsion system.*

In addition, the Board adopted the following member motions:

Staff consider new technologies in the construction of the McNicoll Garage and any future bus garages.

That staff report back in one year on the transition from end-of-life diesel buses to CNG to ensure a mix of vehicle fleet energy types into the future.

Issue Background

By its nature, mass transit is green. Subways and streetcars are powered by electricity and even the diesel bus produces less than 1/10 the emissions per passenger than the personal automobile.

With the evolution of diesel bus technology over the past 30 years, air quality standards have forced industry innovation and today's buses emit 99% fewer Oxides of Nitrogen (NOx) and 95% less particulate matter (Source: US Environmental Protection Agency). That said, while the latest "clean diesel" buses are much cleaner than the conventional diesel buses they replace, much more can be done.

The City of Toronto's TransformTO Climate Change and Clean Air Action Plan targets the reduction of GHGs 80% by 2050 (from 1990 levels). As such, we need to begin adopting new technology now and work closely with industry to build on our mutual experience and to make improvements in zero emissions bus technology.

As approved by the Board in November 2017, the TTC's target for steady-state procurement of zero emissions buses is 2025, in line with the C40 Fossil Fuel Streets Declaration. C40 is a network of the world's megacities committed to addressing climate change. Signatories of the Declaration include Mayors of Paris, London, Los Angeles, Vancouver and others. Since the November report several other major cities have pledged to go all-electric by 2040, including New York which has the largest bus fleet in North America. With the TTC targeting the procurement of only zero-emissions buses from 2025, we would also have an all emissions free fleet by the end of 2040.

The TTC has been an early adopter of new technology in the past. It has had an early version of the trolley bus, articulated bus, low-floor bus, CNG bus, bio-diesel fuel bus, and more recently the beta version of the diesel hybrid-electric bus. Some technologies proved more reliable and more cost efficient than others. What is clear from this institutional experience is that when adopting new technology it is prudent to take measured steps to limit risk to the base fleet of vehicles – the bus replacement program. Adopting technology too fast can result in decades of poor system reliably, low customer and operator satisfaction, and/or a high cost of maintenance and operation. That said, the TTC operates the largest bus fleet in Canada and the third largest in North America and so we have a role to play in the advancement of technologies that promise to offer significant safety, environmental, vehicle reliability, lower life-cycle costs, and customer focused improvements.

Comments

In July 2017, the City of Toronto adopted the TransformTO GHG reduction target to reduce emissions 80% by 2050. In November 2017, the TTC Board approved staff's Green Bus Technology Plan and associated targets for procurement of only zero-emissions buses starting in 2025 and an all zero-emissions bus fleet by 2040.

The Board's approval of the Plan included procurement of the TTC's first 30 eBuses, which were to be delivered by March 31, 2019 in order to ensure eligibility for funding under the Government of Canada's PTIF. The Board also requested that staff report back on increasing the procurement quantity from 30 to 60 if a one year extension to the PTIF funding program was granted.

In January 2018, the federal government announced that the PTIF Phase 1 program deadline was extended until March 31, 2020. The primary purpose of this report is to obtain approval for a scope change to the eBus program: procurement of an additional 30 eBuses and the infrastructure required to begin modification of the first TTC bus garage to accommodate up to 300 zero emissions buses.

The report is structured as a status update on the work underway to implement the overall Green Bus Technology Plan, and includes rationale for the eBus Program scope change in that context:

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    c) eBus Program (eBuses and Charging Infrastructure)

3. Gaseous Fuel Study for Compressed Natural Gas (CNG) and Hydrogen

4. Future Proofing Garages (including McNicoll Bus Garage)

5. Cost Benefit Analysis and Evaluation of Potential Funding Opportunities

1. TTC Bus Procurement Plan

The bus fleet plan, which was revised to reflect the Board's decisions on the Green Bus Technology Plan issued in November 2017, is as follows:

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Figure 3: TTC Bus Procurement Plan

This plan sets out the following:

1. The number of vehicles required to procure each year in order to meet Strategy and Service Planning's projected ridership through bus replacements and additions;

2. The transition towards green bus technology and the steady state procurement of only zero emissions buses starting in 2025;

3. Resulting overhaul program to maintain the fleet in a state of good repair; and the

4. Resulting capital budget and operating impacts, to be presented through the 2019 budget process.

Further to Item #2 (above), as we move towards the 2025 target for procurement of only zero emissions buses (i.e. 60 in 2021, 80 in 2022, 100 in 2023, and so on), it would be inefficient to continue modifying existing garages to accommodate only 20 buses each, even though potential sunk cost of the capital investment is low.

To stay ahead of the bus procurements and to ensure efficient use of resources for the preparation of garages, electrical capacity must be added through the installation of substations and resiliency must be added through backup generators.

The benefit of pursuing this additional scope now, besides the potential use of PTIF funding and the fact that our existing garages will have to be modified starting in 2021/2022 regardless, is that the modification is future proof. Whether the future of our fleet is comprised of all-electric, hydrogen fuel cell, CNG buses, plug-in hybrid, or a mix of these technologies, the substation and backup generator is required.

2a) Status of Clean Diesel Orders

2018 – 2020 Bus Procurements													
		2018				2019				2020			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Clean Diesel Bus	Actual	40	2*							NO PROCUREMENTS IN 2020			
	Vs Scheduled	40	78	104	88								
	Cumulative Actual	40	42*										
	Vs Cumulative Scheduled	40	118	222	310	310	310	310	310				

In Q1 2018, 40 clean diesel buses were received from Nova Bus completing the order originally scheduled to end in 2017.

Between Q2 and Q4 2018, Nova is scheduled to deliver 270 clean diesels (and 55 hybrids – see Hybrids below for explanation).

The 310 Clean Diesels planned to be delivered within the remaining PTIF period are expected to provide the following benefits:

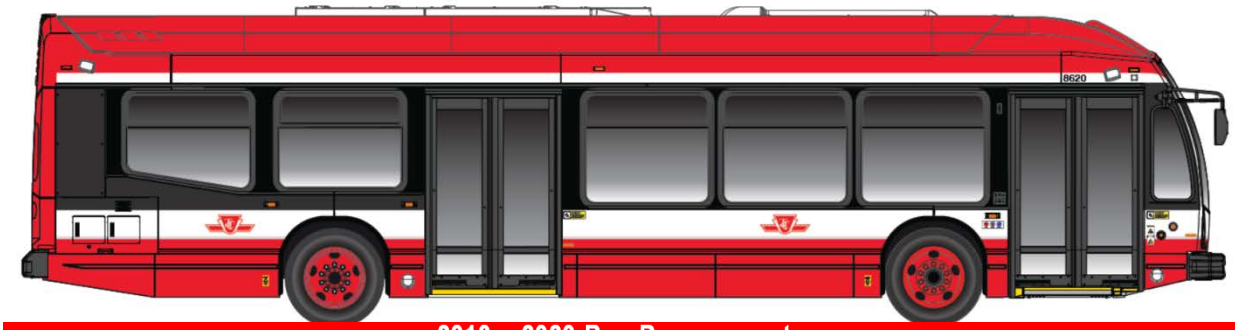
- Environmental Impact:
  - GHG emissions reduction of approximately 49.6 tons CO_2e per bus per year – total 15,400 tons CO_2e per year

- Service Impact (vehicle reliability):
  - Mean Distance Between Failures 28,000km versus 17,000 for the vehicles they replace – average improvement of 65%.

- Financial Impact (fuel savings only):
  - Diesel fuel savings of approximately $15,600 per bus per year – total $4.8 million per year

- Other Key Benefits:
  - Electric doors
  - Engine idle stop technology
  - Active obstacle detection on front doors

2b) Status of Hybrid Orders



2018 – 2020 Bus Procurements													
		2018				2019				2020			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Hybrid Electric Bus	Actual									NO PROCUREMENTS IN 2020			
	Vs Scheduled			1	54	115			85				
	Cumulative Actual												
	Vs Cumulative Scheduled			1	55	170	170	170	255				

As directed by the Board in November 2018, staff have completed negotiations and issued awards for hybrid electric buses as follows:

1. Maximize the number of 2nd generation hybrid electric buses that can be delivered on the existing contract for 325 clean diesel buses.

   Results:
   - In January 2018, TTC issued a contract change with Nova changing 54 clean diesel buses to hybrid electric buses at a total cost of $15.9 million;
   - In May 2018, Nova advised that they could schedule the production of one additional hybrid bus, for a total of 55, at a cost of $ 295,000. At the time this report was being written the contract change was pending internal approval.

2. Award a contract(s) for 230 hybrid electric buses under delegated authority based on negotiating an acceptable agreement with the only two bus suppliers, Nova Bus and New Flyer.

   Results:
   - Given staff was preparing to recommend procurement of an additional 30 eBuses, in line with TTC Board direction, the number of hybrids was revised from 230 to 200 in order to re-allocate the associated funds;
   - In March 2018, New Flyer pulled out of the competition due to limited production capacity and a belief that, as with the previous clean diesel procurement, they would not be able to compete with Nova commercially;
   - On May 19, 2018, Nova Bus was awarded a contract for 200 next generation hybrids to be delivered in 2019 and at a cost of $178 million.

As originally described in the November 2017 staff report on the Green Bus Technology Plan, the new generation hybrid electric buses serve as a transition technology to the all-electric bus.

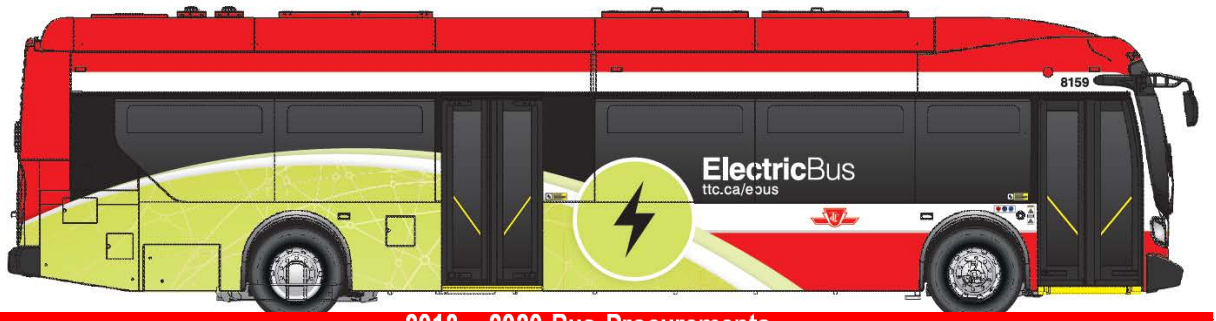
The 255 Hybrid Electric Buses planned to be delivered within the remaining PTIF period are expected to provide the following benefits:

- Environmental Impact:
  - GHG emissions reduction of approximately 75.6 tons CO2e per bus per year – total 19,300 tons CO2e per year

- Financial Impact (fuel savings only):
  - Diesel fuel savings of approximately $25,600 per bus per year – total $6.5 million per year

- Other Key Benefits:
  - an all-electric vehicle mode for up to 5km for zero emissions operations at the garage and/or along routes to improve local noise and air quality levels;
  - engine stop/start technology to prevent idling in traffic and at bus stops;
  - all electric accessories, including doors, HVAC, power steering, and air compressor systems;

2c) Status of eBus Program (eBuses and Charging Infrastructure)



2018 – 2020 Bus Procurements

		2018				2019				2020			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Battery Electric Bus (eBus)	Actual									NO PROCUREMENTS IN 2020			
	Vs Scheduled				10	10		10	30**				
	Cumulative Actual												
	Vs Cumulative Scheduled				10	20		30	60**				

The Board's approval of the Green Bus Technology Plan included procurement of the TTC's first 30 eBuses, which were to be delivered by March 31, 2019 in order to ensure eligibility for funding under the Government of Canada's PTIF.

In addition to many of the benefits listed for Clean Diesel and Hybrids, the 30 eBuses are expected to provide the following key benefits:

- Environmental Impact:
  - Zero tailpipe emissions
  - GHG emissions reduction of approximately 149.2 tons CO2e per bus per year – total 4,500 tons CO2e per year

- Financial Impact (fuel savings only):
  - Diesel fuel savings of approximately $56,000 per bus per year – total $1.7 million per year

Timeline for 30 eBuses

Figure 5 includes key milestones for the first 30 eBuses, which include the finalization of bus procurements in June 2018; approval of detailed designs by August; and commissioning of eBuses starting in December of 2018 and finishing in April 2019.

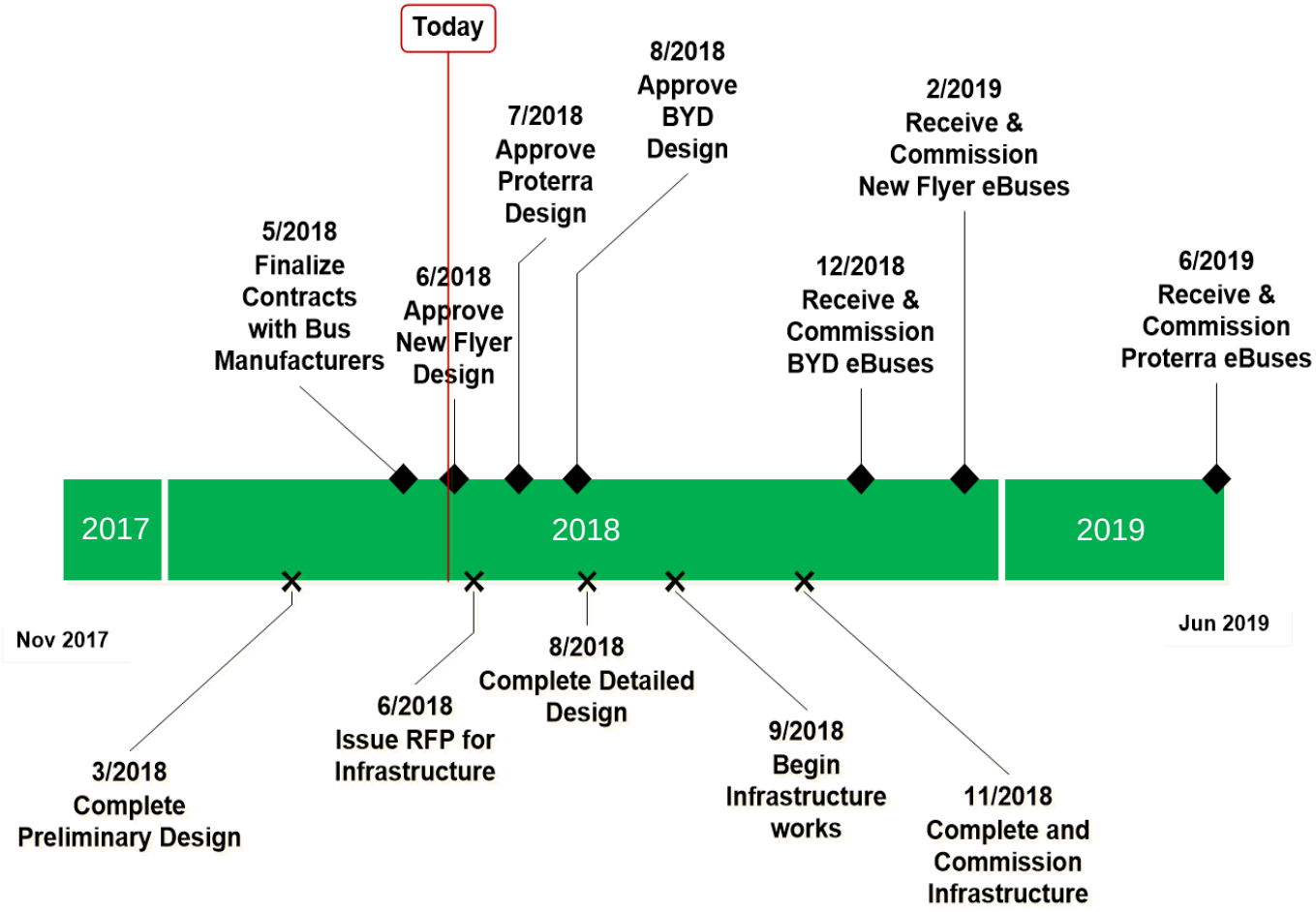


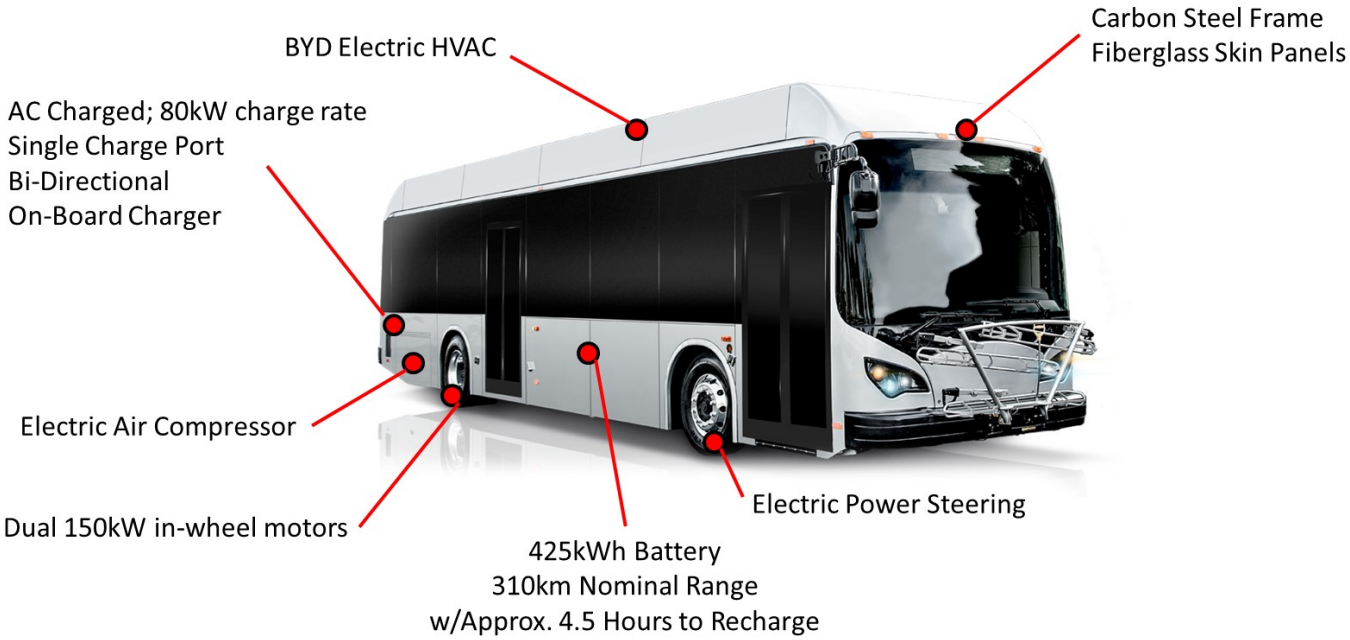
Figure 5: Timeline for first 30 eBuses

As of the writing of this report on May 28, 2018, orders have been issued with BYD and New Flyer for 10 eBuses each. Negotiation with Proterra continues, and so as not to jeopardize TTC staff's negotiating position, the results of all procurements will be reported to the Board publically through a future CEO report.

Head-to-Head Comparison between BYD, New Flyer and Proterra

Offered below for the interested reader, in particular for our peer agencies, are a few technical details that distinguish the buses we are currently working to procure.

<u>BYD's eBus</u>



BYD is the world's largest manufacturer of all-electric buses, having delivered over 25,000 electric buses worldwide. They are the only eBus manufacturer that develops and produces its own battery technology.

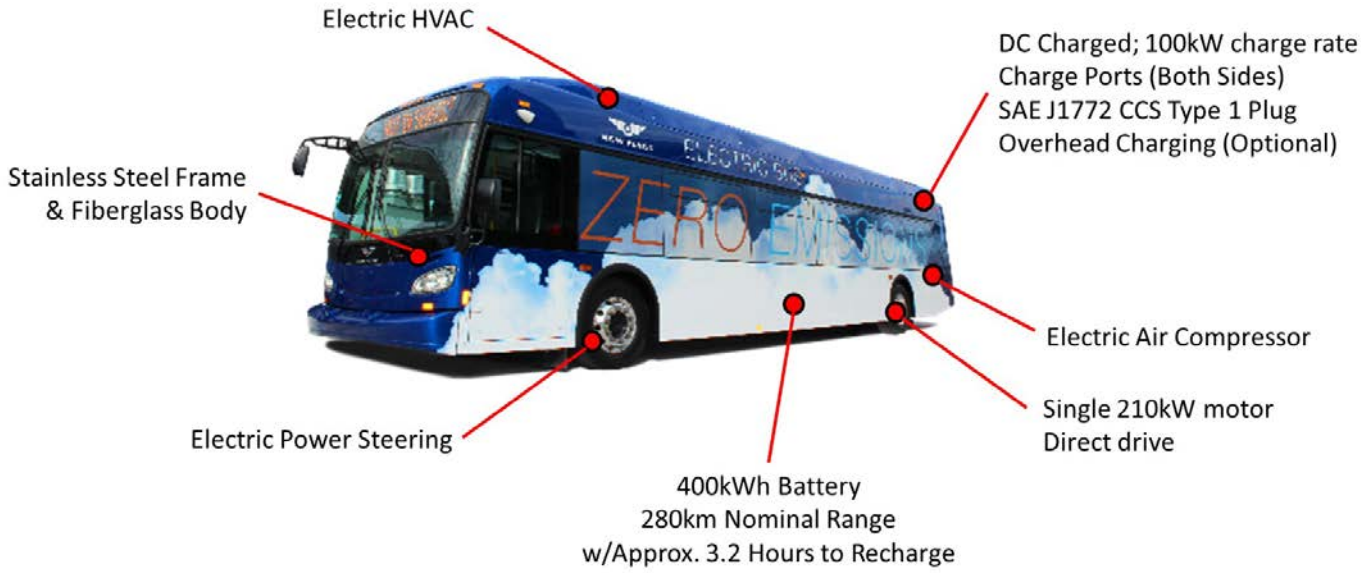
The bus proposed for this procurement by BYD is the K9M 40-foot model with a 425kWh battery. The on-board battery uses Lithium Iron-Phosphate chemistry batteries (LiFePO4) that are100% recyclable and reportedly require minimal thermal management.

BYD's charging interface also differs from other eBus charging equipment in that AC to DC power conversion occurs on-board the vehicle instead of at the charging point with a charge rate of 80kW using the BYD AC Direct Charging Power Interface receptacle. This architecture makes Vehicle to Grid, Vehicle to Vehicle, and Vehicle to Load charging possible with little additional infrastructure required.

The electric drive system utilizes twin wheel-hub liquid-cooled three-phase 150kW permanent magnet synchronous traction motors and eliminates the need for transmissions, differentials, and drive shafts. In addition, the HVAC system, doors, power steering and air compressor are all electrically powered.

It is estimated that utilizing 90% of the 425kWh battery capacity will provide a driving range of 310km (FTA Altoona test average) and will take approximately 4.5 hours to recharge.

New Flyer's eBus

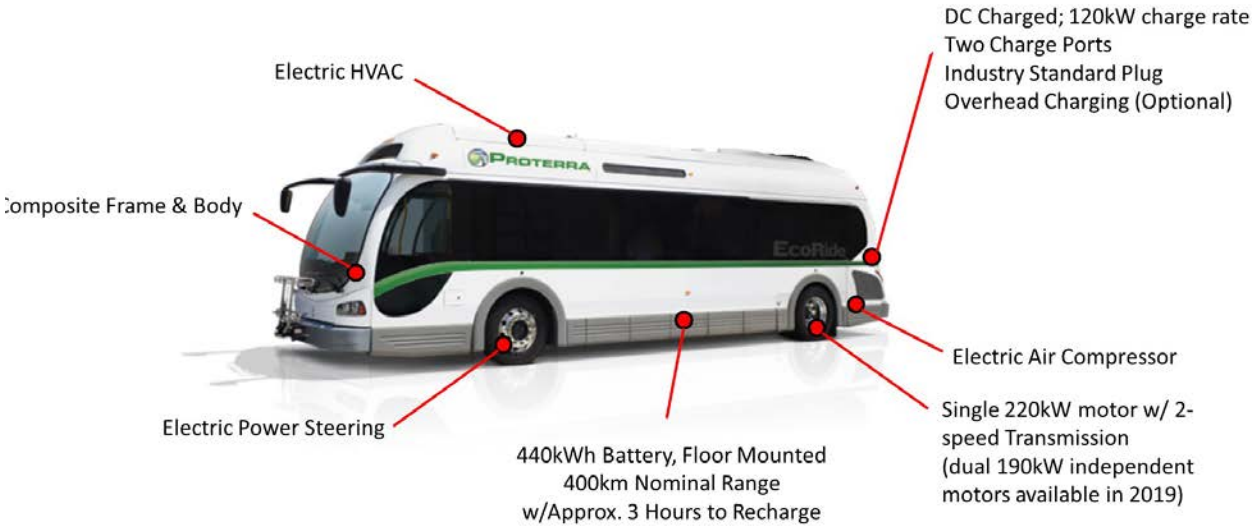


The eBus proposed by New Flyer for this procurement is the Xcelsior CHARGE^{TM} XE40 with a 400kWh battery. The on-board battery uses lithium-ion Nickel Manganese Cobalt chemistry that is 100% recyclable and is manufactured by XALT Energy. Battery packs are located in the engine bay area and roof. The 400kWh ESS is liquid cooled and monitored by a battery management system. Plug in charging strategy will be used with a maximum allowable charge rate of 100kW using a CCS Type 1 receptacle and SAE J1772 standards.

The electric drive system consists of a Siemens high-efficiency permanent electromagnetic traction motor with 190kW of peak power and 2,500Nm peak torque. It is direct drive and does not utilize a transmission thereby reducing cost, weight, maintenance, and propulsion complexity. In addition, the HVAC system, doors, power steering and air compressor are all electrically powered.

This translates to approximately 3.2 hours to charge from 10% State of Charge to 90% SOC. It is estimated that the 400kWh battery will provide a driving range of 280km (FTA Altoona test average).

Proterrra's eBus



Proterra's buses differ dramatically from the other two manufactures. They have been designed from the ground up as an electric vehicle. Other manufactures must work within the constraints of a design for diesel propulsion systems which requires the placement of heavy high voltage batteries in multiple locations (typically in what was the engine bay and on the roof). Proterra buses are designed with a lightweight carbon fiber-reinforced composite body that optimizes battery placement below the floor for the passenger compartment and is highly resistant to corrosion.

The bus proposed by Proterra for this procurement is the Catalyst E2 40-foot model with 440kWh battery. The battery uses proprietary high energy density battery chemistry that falls into the broader category of lithium-ion batteries. Plug in charging strategy will be used with a maximum allowable charge rate of 120kW using a CCS Type 1 receptacle and SAE J1772 standards.

The electric drive system consists of single 220kW permanent magnet drive motor and 2-speed automatic shift gearbox. In addition, the HVAC system, doors, power steering and air compressor are all electrically powered.

This translates to a charge time less than 3 hours and it is estimated that the 440kWh ESS will provide a driving range of 400km (FTA Altoona test average).

Infrastructure

The remaining sections of this report include high level, but sometimes quite technical detail necessary to justify the additional scope and funding recommended. The simple explanation to keep in mind is that there is a great deal of complexity ahead and we need to both advance our understanding and the required civil and electric work in order to realize the TTC's Green Bus Plan. Lastly, this information is also intended to keep our peer agencies informed of our journey towards a zero emissions bus fleet in a collaborative effort to share strategy and lessons learned.

eBus Home Garage Selection

The electric bus industry today does not have standardized charging ports, charging port locations, plugs or receptacles. BYD, for example, uses a unique system that includes an on-board inverter and a receptacle particular to that bus. Proterra and New Flyer on the other hand use receptacles standardized by the Society of Automotive Engineers with the inverter included as part of the external charging station.

Lack of standardization between bus manufacturers, and a limit on the number of buses that can be charged at any one garage, led to the allocation of BYD, New Flyer, and Proterra buses at three separate garages.

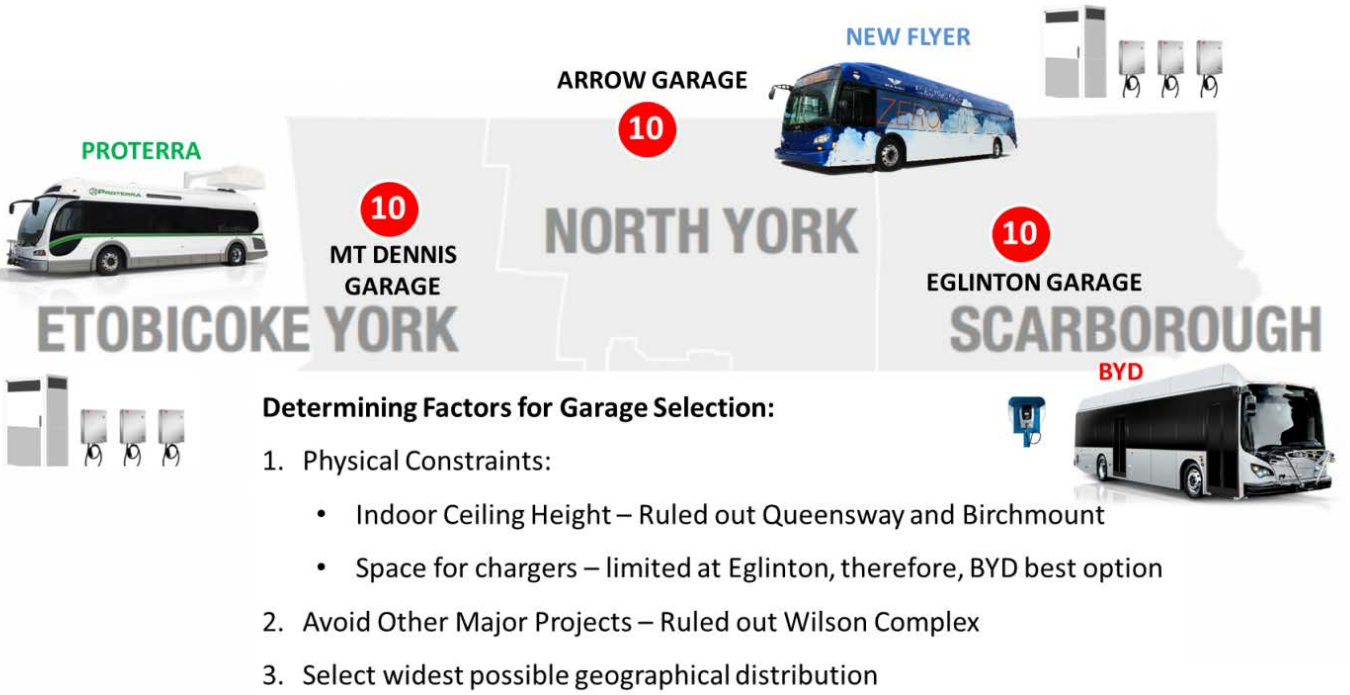


Figure 6: eBus Home Garage Locations

The head-to-head comparison in performance is not just between unique buses but between unique systems that include bus and charging infrastructure. This will facilitate understanding of the infrastructure requirements and limitations, understanding of charging technologies and the technology constraints associated with each manufacturer.

In determining which garages should become home locations for the respective buses, several factors were considered:

- Physical constraints including indoor ceiling heights and available space for chargers
- Avoidance of other major capital infrastructure projects
- Geographical location
- Local staff experience with hybrid electric technology

After reviewing all bus divisions, Mount Dennis, Arrow Road and Eglinton divisions were selected as optimal candidates to support the TTC eBus program. Assuming all negotiations are successful, Mount Dennis will be home to Proterra, Arrow Road to New Flyer and Eglinton to BYD.

Lastly, since 20% of TTC bus fleet today is stored outdoors, four of 10 eBuses at each division will be stored and charged solely outdoors to assess environmental impacts.

eBus Home Garage Limitations

Existing garages have a 600V electrical distribution fed from a 1500kVA transformer owned by Toronto Hydro, with the exception of Arrow Road which is fed from a 1000kVA transformer that needs to be upgraded to a 1500kVA unit. Historical billing data from all garages indicates peak demand in the range of 650 to 885kVA occurring overnight and in winter months. With bus charging rates between 80 and 150kW per bus, the energy available for eBus charging is determined by the difference between the existing peak demand and the allowable continuous load. This limitation is driven by the fact that both the facility and charging demands have coincident peaks. To allow for the first 10 eBuses at home garages, an energy management system (software) will be used to curtail charger output in response to plant load and total vehicle demand.

The energy management system alone, however, cannot accommodate a larger number of buses. To allow for more than 10 eBuses at any one garage, an energy storage system (ESS), which is essentially a large battery system, is required to help managing peak loads to within the 1500kVA limitation and to spread the charging window without exceeding the operational/infrastructure limit.

Scope Change: 60 eBuses, Storage System, Substation, & Backup Generator

In the time since the November Board meeting, TTC and Toronto Hydro have worked closely together as an integrated project team to strategize and design solutions for expanding the zero emissions fleet. Technical solutions not clear to the team only six months ago are now mature and reflect an approach to the charging infrastructure that is modular, resilient, and capable of being scaled up to fleet wide implementation.

As reported in November, the limit for any one garage is 10 eBuses; however we now understand that with an ESS, the limit can be extended to a maximum of 20

eBuses/garage. This model, described previously, is scalable and provides an opportunity to prove the design, maintenance and operations of an all-electric bus garage. Furthermore, the investment is almost entirely reusable as all of the equipment can be repurposed as garages are eventually converted over to support an all zero emissions fleet.

As we move towards the 2025 target for procurement of only zero emissions buses, it would be inefficient to continue modifying existing garages to accommodate only 20 buses each, even if the potential sunk cost of the capital investment is very low. To stay ahead of the bus procurements and to ensure efficient use of resources for the preparation garages requires, electrical capacity must be added through the installation of a substation and resiliency must be added through a backup generator.

The other benefit of pursuing this additional scope now, besides the potential use of PTIF funding and the fact that our existing garages will have to be modified starting in 2021/2022 regardless, is that the modification is future proof. Whether the future of our fleet is comprised of all-electric, hydrogen fuel cell, CNG buses, plug-in hybrid, or a mix of these technologies, the substation and backup generator is required.

Recommendation No. 1: Minimum Required to Accommodate an Additional 30 eBuses

In addition to the procurement of an additional 30 eBuses, chargers, training for operators and maintenance staff, special tools and maintenance equipment, etc. an ESS is required to manage the additional loads.

An additional 10 eBuses at each garage would exceed facility peak energy limits. On a daily basis, the number of eBus service kilometers available is a function of the on-board battery capacity and the amount of energy that can be drawn from the grid. By examining hourly power demands at our garages, there is a reserve capacity that is not being used. ESS could be added to the existing electrical system and charged slowly during the day using existing spare capacity. These batteries could then be discharged supplement energy drawn from the grid, charging more buses than would be possible if the system relied on the grid alone and staying within the operational/infrastructure limit.

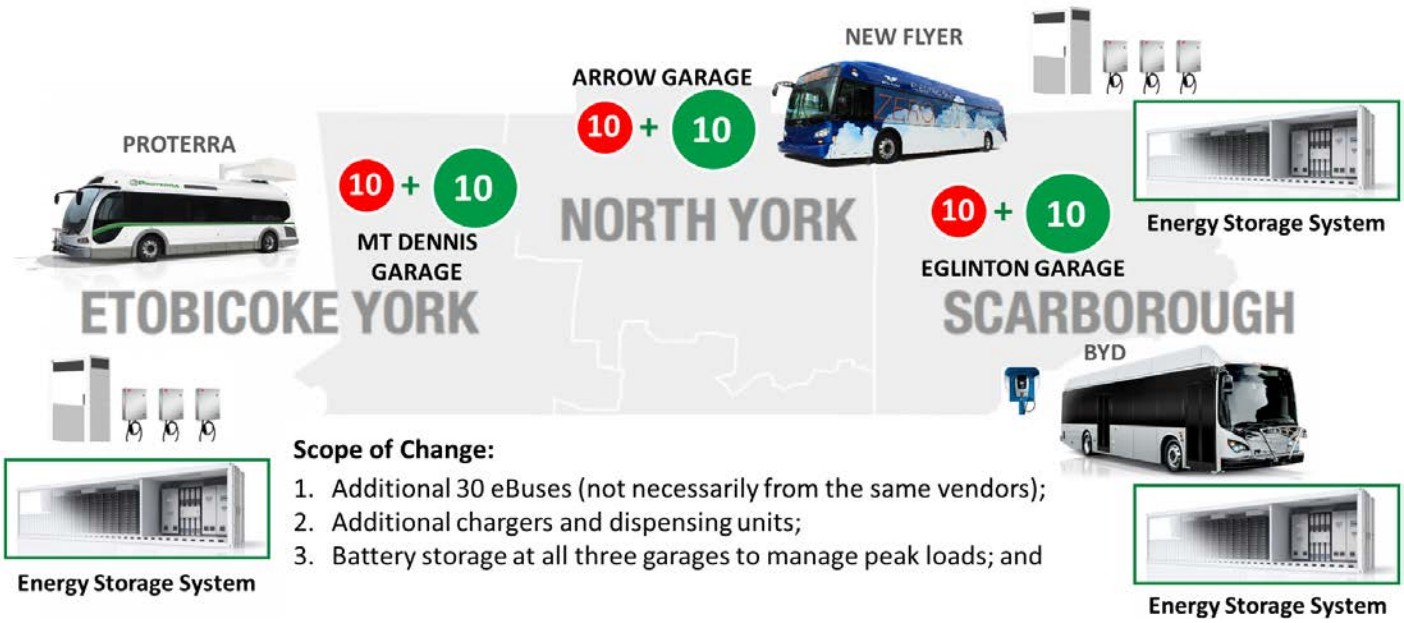


Figure 7: eBus Home Garage Locations with a Total of 60 eBuses and ESS

This concept is explained in Figures 8 through 10. Preliminary analysis shows that each selected eBus home garage can draw enough energy during the day to charge a fleet of 20 buses once per day – with an ESS.

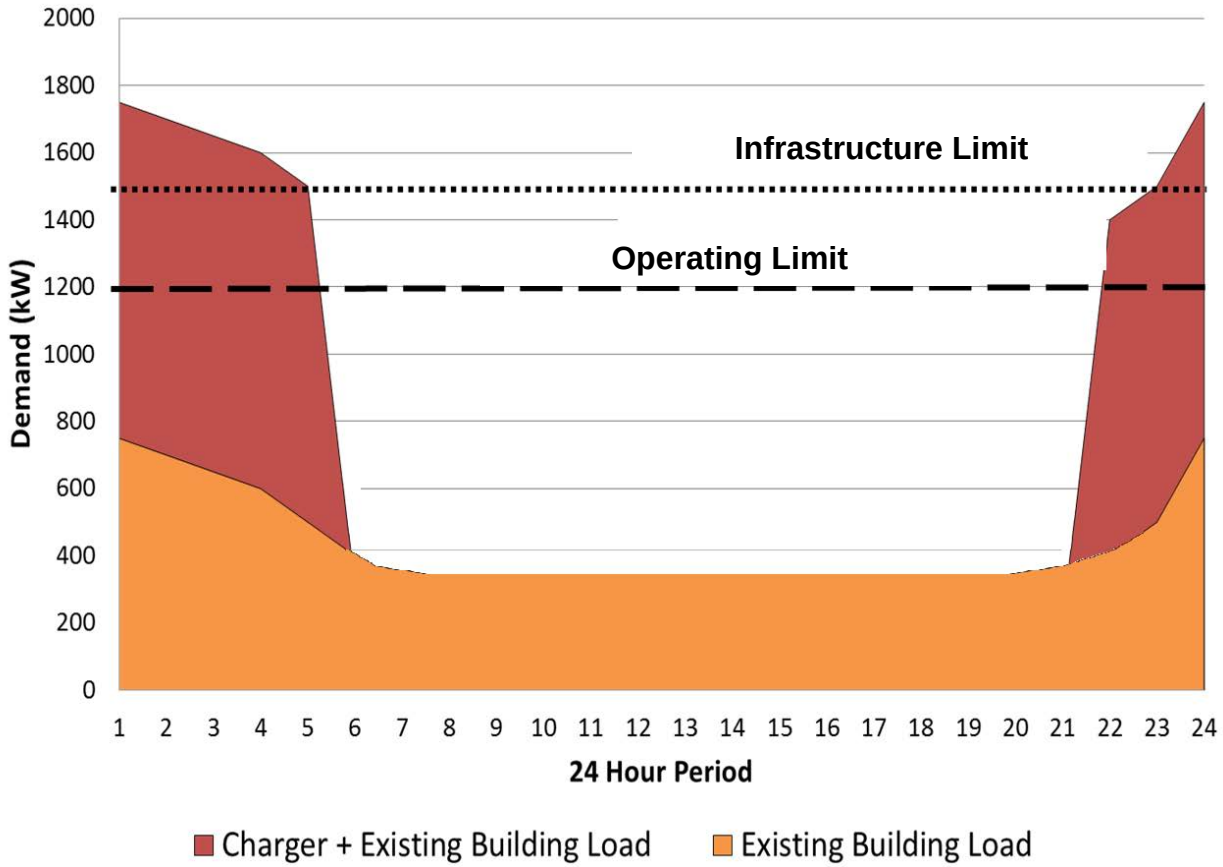


Figure 8 – Building & Charger Electrical Loads

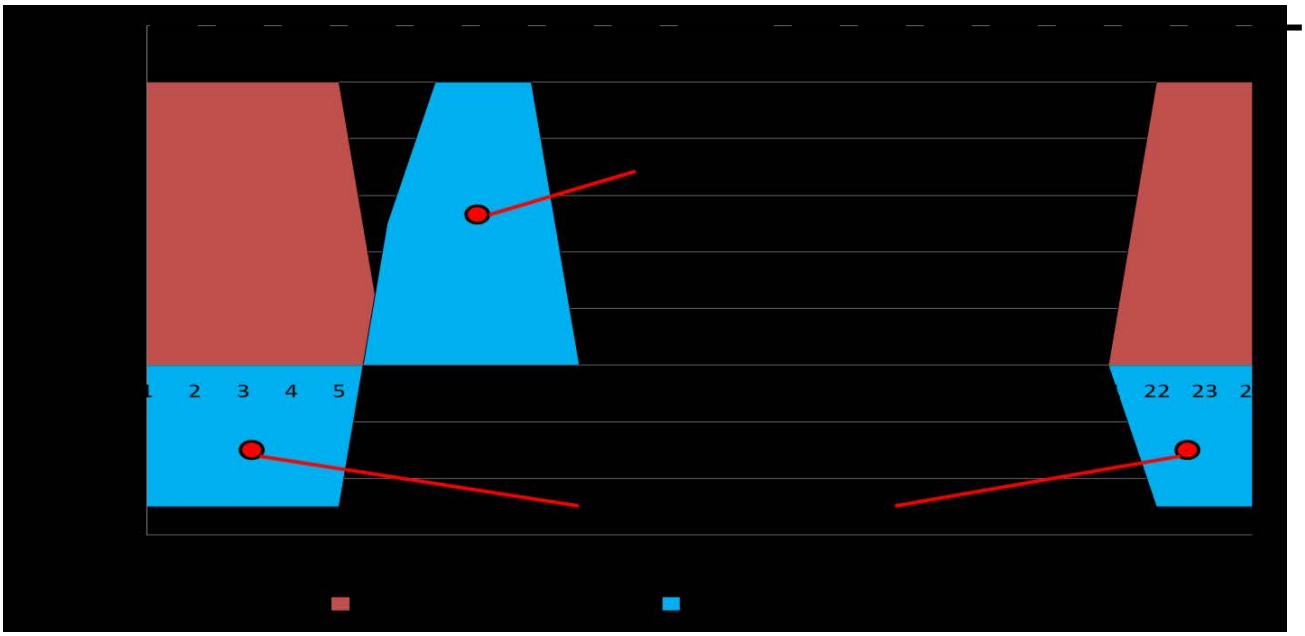


Figure 9 – Charging Profile with Energy Storage

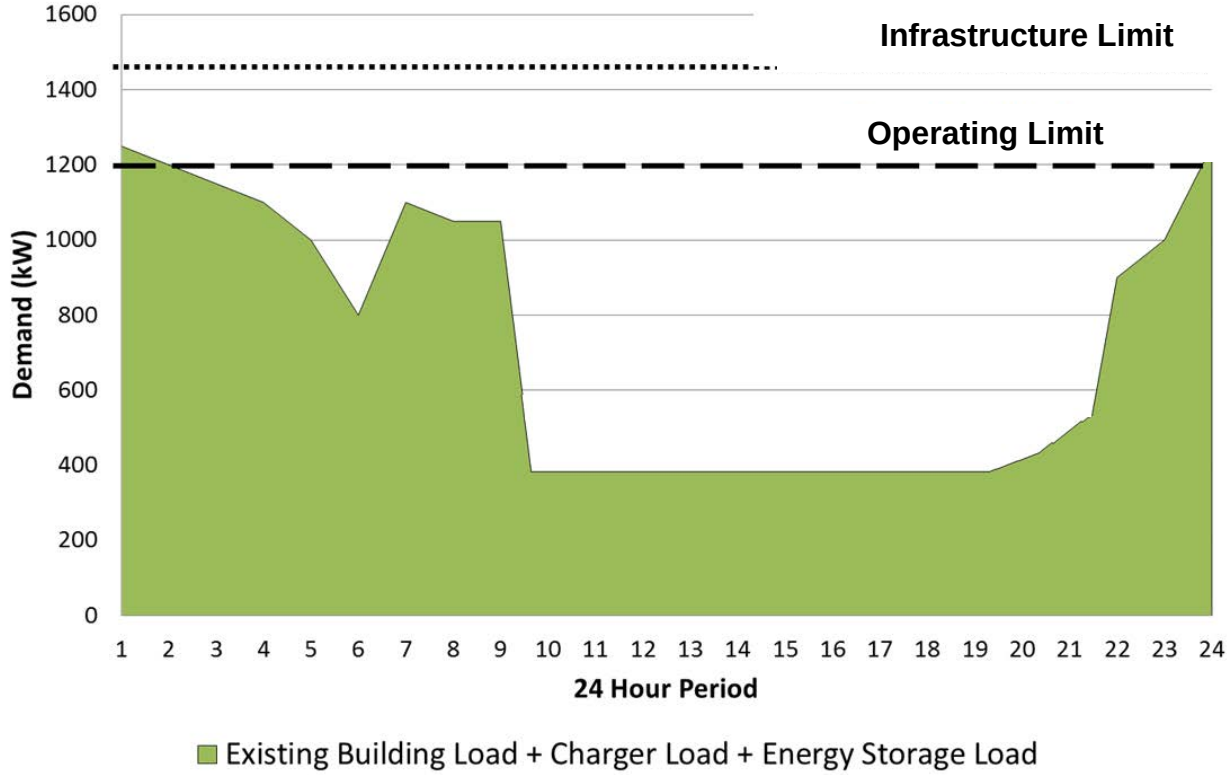


Figure 10 – Resultant Energy Profile with Energy Storage

In addition, to mitigate the need for infrastructure upgrades, the on-site ESS would also provide facility and charging back-up power during short duration power outages. Long term power outages would still require backup power generation.

New protection and control will be required for the main breakers due to the permanently connected power sources inside the garage. This may include transfer trip depending on feeder load. From a construction perspective, the ESS is the only major addition to the scope required to accommodate an additional 30 eBuses; the other relatively minor, such as alterations to transformer and switchboard sizes. Although limited, space is available at all sites for ESS containers.

Recommendation No. 2: Supply of a Substation and Backup Generator

Substation

In order to accommodate more than 20 eBuses at a garage, even with ESS, more power must be drawn from the grid. The minimum rating of such a service would be 2500kVA which exceeds the secondary (e.g. 600V) offerings from Toronto Hydro and so a TTC owned substation is required – similar to what is in place for Streetcar and Subway operations. This option requires the addition of the following equipment:

- New 27.6kV switchgear with new feeder entry from Toronto Hydro
- New TTC-owned transformers to step the voltage down to 600 and 480 V
- New cabling to connect to the existing garage service entrance and to the new eBus charging equipment

This system will also benefit from the advantages of the ESS proposed under Recommendation No. 1; however the sizing may be different. Recommendation No. 2 will require additional time for construction and time to coordinate the necessary approvals.

Backup Generator

There are three internal combustion solutions with various fuels available for backup energy generation. Diesel generators are the most common and can pick up loads within 10 seconds. Bi-Fuel generators that run on 30% diesel and 70% natural gas can also pick up loads quickly but are dependent on the ability to supply the bus garage with natural gas. Lean burning 100% natural gas generators are the cheapest to operate and emit the least amount of GHG emissions but can take between 4 to 10 minutes to start and take load and occupy a larger space footprint in comparison to diesel and bi-fuel options. Lastly, the use of backup generation power can also assist in curtailing global adjustment charges from the local utility company through peak energy shaving. A 5MW backup diesel generator costs approximately $5 million and additional $3 million for every 5MW added thereafter.

As noted previously, both the substation and the backup generator will be required at all existing garages regardless of the future (non-diesel) technology. To keep up with zero emission bus procurements, the first garage must be ready in 2021 and additional garages must be retrofitted at a rate of approximately one every 1.5 to 2 years.

3. Future Proofing Garages (including McNicoll Bus Garage)

Consulting with peer agencies and working with our entire team at Toronto Hydro and Enbridge, staff and consultants are designing a micro-grid (see Figure 11) that can be utilized for both retrofit of existing garages and for new construction. The design would facilitate any one of a number of possible future technologies; all-electric, hydrogen fuel cell (electrolyzer + compression), CNG (compression), and/or plug-in hybrid buses.

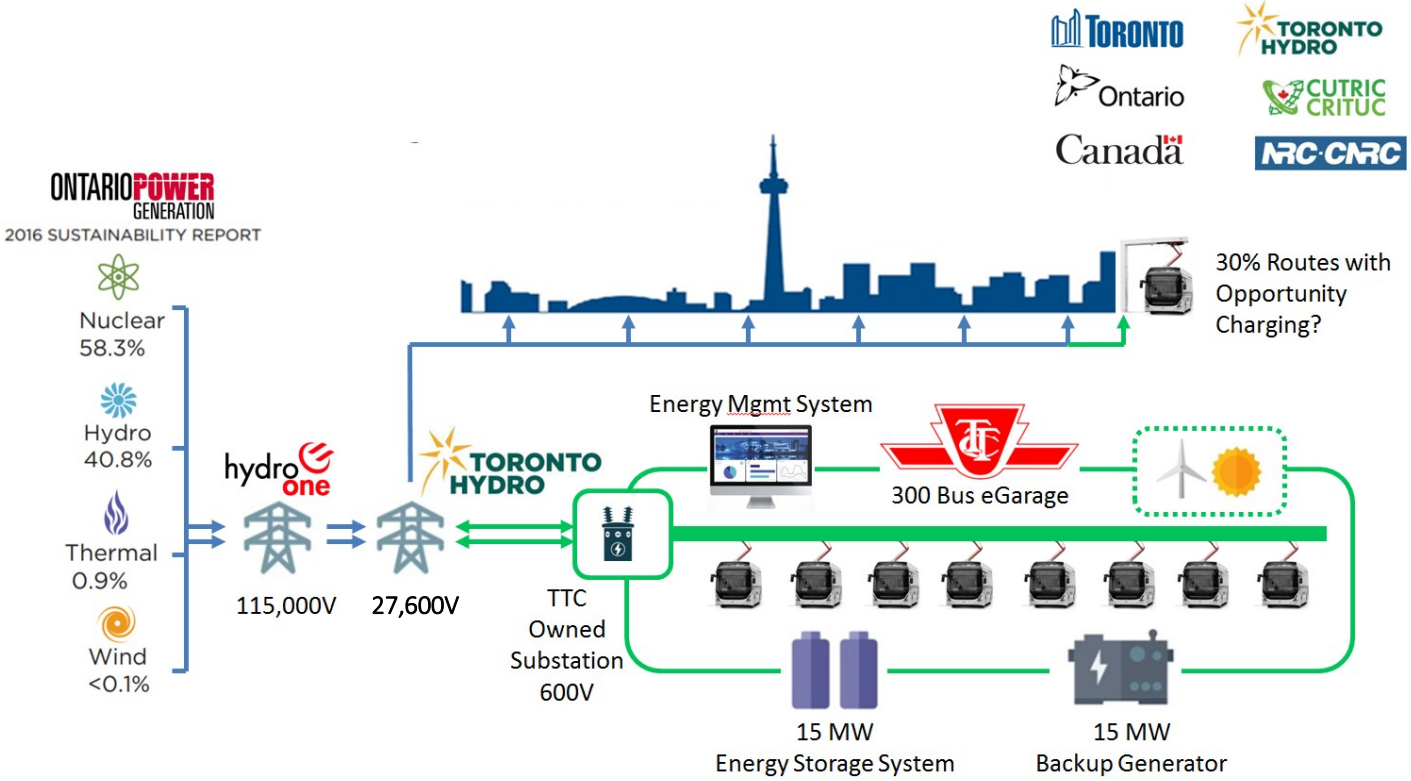


Figure 11 – TTC / Toronto Hydro Integrated Microgrid

Significant power upgrades are necessary for electrification of a full bus garage – whether for all-electric buses or other zero emissions technology. For example, a 300 electric bus garage, each bus with a 440kWh battery and a 100kW charge rate with charging events spread over two equal shifts would result in a power draw of approximately 15MW. These numbers are conservative given there would never be a situation where all buses would need to be charged concurrently (due to maintenance spares, vehicles in service, mix of technologies, mix of long range and on-route charging, etc.).

Important to note is that the micorgrid depicted above is required for a resilient fleet of CNG buses, hydrogen fuel cell buses, plug-in hybrids, or battery electric eBuses.

Given a lead time to plan, design and construct the Microgrid (i.e. substation, ESS, and emergency backup generator), the TTC needs to start this work immediately in order accommodate further electric buses in 2021 and beyond.

McNicoll Bus Garage Electrification Study

Stantec Consulting Ltd. (Stantec) was engaged to study the feasibility of adding eBuses to McNicoll Bus Garage (MBG). Stantec assembled a team with specific experience within transit operations, electrical grid design and performance, ESS renewable energy, facility electrical design, vehicle charging infrastructure, and design of maintenance facilities. This was a high-level study conducted in early 2018 that focussed on two scenarios:

1. Identifying the number of buses that could be accommodated at the facility based on the current design

2. Identifying infrastructure required to accommodate a full fleet of eBuses at a future date, and considering whether some of this infrastructure could be provided now via changes to the current Design-Build contract.

It should be noted that the equipment and planning required to accommodate eBuses at MBG would likely be similar at most existing TTC facilities.

Both scenarios described below are based on a set of assumptions confirmed by Stantec in discussion with stakeholders including Toronto Hydro, TTC Vehicle Programs Department staff, TTC Plant Maintenance Engineering staff, and the McNicoll Project Team.

Scenario 1 – Accommodating eBuses at MBG as Currently Designed

MBG is designed with a 2000kVA transformer with 15% spare capacity. Employing this spare capacity may charge up to two eBuses at a time over the course of three to four hours. Charging would ideally be achieved through overhead pantograph-style chargers, which also require charging cabinets weighing approximately 1500kg each. This equipment would require space either within the bus storage lanes, or on the roof with a potential corresponding need to strengthen the roof structure.

Scenario 2 – Accommodating a Future 100% eBus Fleet

To support a 100% electrification strategy at MBG, the following additional equipment would be required:

- 160 overhead pantograph charger units, each weighing approximately 165kg, plus a 49kg control box for each charger

- 80 charge station enclosures, each weighing approximately 1500kg

- 15,000 kVA transformer capacity, broken into six modular transformer units of 2500kVA each (owned by TTC) to allow stepped capacity increases as the eBus fleet is added over time. Note the current design includes only a single 2000kVA capacity transformer owned and maintained by Toronto Hydro.

- 27.6 kV switchgear lineup to feed the above 6 transformers, plus 480VAC switchgear at the secondary of the transformers to feed the charge station enclosures

- 15 MW / 60MWh ESS, broken into six modular enclosures of 2.5MW / 10MWh each

- 10-to-15MW backup generator capacity to charge the eBuses in the event of an extended power outage

Further study is required to consider:

- Identifying locations to place the above equipment on an already space-constrained site. The sum of new transformers, switchgear and energy storage equipment constitute a footprint similar to a utility substation.

- Assessment of the roof structure to determine if additional reinforcement is required to accommodate the weight of any equipment proposed to be located to the roof. Note that erection of structural steel at MBG has already begun.

- Permitting challenges, and potential public resistance, associated with the installation of 10-to-15MW generators on the site

- Fire suppression system requirements for the BESS, and for the eBus fleet. It is important to note that these requirements may vary depending on the type of ESS selected and the particular bus models deployed at the facility. A thorough Code Review and Hazard Classification is anticipated to be required.

- The amount of funding to be approved and allocated to assess all bus garage locations and to develop a cost estimate in support of a further business case.

Conclusions:

1. Existing capacity at MBG would allow charging of only two eBuses at a time. Any marginal benefit gained by adding two eBuses would not be sufficient to justify the potential schedule and budget impacts to the current construction.

2. To fully electrify MBG further study and detailed design would be required. It is believed that any retrofit solution developed for existing garages could be applied to MBG at some point in the future. As with Conclusion No. 1, it is believed that any further work to prepare MBG to accommodate eBuses at this time would cause significant unacceptable delay and budget impacts to the design-build contract, which is already in progress.

Figure 12: McNicoll Bus Garage Under Construction, May 2018

4. Gaseous Fuel Study for CNG and Hydrogen

There is currently a gaseous fuels study underway in partnership with Enbridge to determine the cost and time required to modify garages, shop, and stations to accommodate CNG buses and or hydrogen fuel cell buses.

The intent of this evaluation is to examine the impacts of adopting the methane based fuels (CNG, RNG) and Hydrogen given TTC's requirements (below), for which the underlying motivation was the November 13, 2017 TTC Counsel accepted motion *"That staff report back in one year on the transition from end-of-life diesel buses to CNG to ensure a mix of vehicle fleet energy types into the future.*"

TTC's request to Enbridge:

a. Resiliency – provide an assessment of reliable busing through extended weather, energy and market events;
   Backup generation option with Natural Gas vs Diesel (What are the pros and cons)

b. Performance Requirements – provide flexible wheeled vehicle solutions in high demand neighborhoods with long routes and infrequent refueling;

c. Organizational and Operational Impacts of Alternative fuels – the report will include a section that evaluates potential requirements for change management, technical training, health and safety as well as changing codes and standards for the alternative fuels.

d. High Level implementation plan (e.g. If a decision is made to go CNG, what is the construction timeline? Permittings? Commissioning?)

e. Financial Considerations (Class 5 Estimate[i]):
   - Cost Benefit Analysis which includes comparisons of:
     i. Building Modification options and all other related facilities
     ii. Different CNG Station Ownership Models – Fixed unitized fuel cost vs Utility Rental program vs TTC Station Ownership
     iii. Model cash flow and potential liabilities to determine which combination of adopted fuel systems meet requirements a, b, c and d.
        1. Use TTC's diesel Lifecycle costs
     iv. Vehicle Maintenance
        1. Costs associated with CNG buses
        2. Comprehensive preventative and on-going maintenance interval schedules
     v. CNG Station Maintenance
        1. Costs for turn-key scenario
        2. Costs for TTC ownership scenario
   - Optimize public funding sources

i. PTIF Phases 1 and 2

ii. Other sources of Capital (eg. Federation of Canadian Municipalities, MCIP Green Transportation fund, Green ON)

iii. NRCan Standing support for Canada's Objectives, re: Roadmaps for Natural Gas and Renewable Natural Gas

- Time Sensitivity and Opportunity Costs
    i. Report should identify the risks of policy and funding risks with adopting or not adopting gaseous fuels.

Enbridge will work with TTC to render a report that provides recommended course of actions and best practices for the TTC to adopt gaseous fuels to deliver a resilient path from high carbon vehicles to low/zero carbon vehicles. Deliverables would include business case which includes life cycle costs, capital costs, Operating and Maintenance costs and any related cost avoidances.

5. Cost-Benefit Analysis and Evaluation of Potential Funding Opportunities

In addition to the promise of significant environmental benefits and potential life-cycle cost savings, a future that includes all-electric, hydrogen fuel cell, CNG buses, plug-in hybrid, or a mix of these technologies also presents alternate funding opportunities that must be explored.

A list of potential, but yet to be confirmed and evaluated, funding opportunities is as follows:

- Bus manufacturers: All eBus manufacturers offer lease programs. Options include lease of the entire bus or lease of the on-board batteries which can comprise as much as half of the total bus cost;

- Enbridge: The gas utility is offering a turnkey solution for a CNG compressor station(s) that would have them finance, build, and maintain the station;

- Toronto Hydro: the electrical utility is pursuing incentive applications pursuant to federal and provincial smart grid programs; and

- Third-Party Investors: potential investors in technology and capital have approached TTC staff with offers to discuss potential funding opportunities.

The next step is to confirm with interested parties what they are offering (e.g. shared cost-benefit arrangement, cost of capital financing, etc.) and to consider whether there is value in pursuing these opportunities given the comparatively low rates at which the City of Toronto secures its capital. Through discussion with all relevant stakeholders in City Finance, Legal, Procurement, and others, a strategy is to be developed and then

presented back to the TTC Board for approval. As per Recommendation No. 4, this report is targeted for Q4 2019.

A Note on Procurement Costs Referenced in this Report

Please note that in order to avoid jeopardizing staff's negotiating position with the bus manufactures, the bus procurement costs provided through this report do not include other project costs such as the contract change allowance, project management and engineering costs, or contingency.

Contact

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mike.macas@ttc.ca

Signature

Collie Greenwood
Chief Service Officer (Acting)

Attachments

Presentation

TTC Green Bus Program

Status Update and eBus Change Request

TTC Board Meeting June 12, 2018
Bem A. Case, TTC Head of Vehicle Programs

City / TTC Emissions Targets

TransformTO Target:

Reduce greenhouse gas (GHG) emissions 80% by 2050

TTC Target:

Steady-state procurement of zero-emissions buses by 2025 in line with the C40 Fossil-Fuel-Free Streets Declaration, and an all zero-emissions bus fleet by 2040.

Contents

1. TTC Bus Procurement Plan
2. Program Status Update & eBus Change Request
   - Clean Diesel Bus Procurements
   - Hybrid-Electric Bus Procurements
   - eBus Program (eBuses and Charging Infrastructure)
3. Future Proofing Garages
4. Gaseous Fuel Study
5. Cost Benefit Analysis and Evaluation of Potential Funding Opportunities
6. Recommendations

TTC Bus Procurement Plan

Pending 2019 Budget Approval

Garage Infrastructure Upgrades Required

Description ($Millions)	Last diesel buses received in Q4 2018	PTIF Period			Remaining Capital Plan (Steady State Procurement)							10-Year Total
	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	
Clean Diesel (40 ft)	310										310
Hybrid (40 ft)	55	200		32	80	60	40				467
Hybrid (60 ft)				61							61
Zero Emissions (40 ft)	10	50		60	80	100	120	84	84	160	748
Zero Emissions (60 ft)				7				76	76		159
Total Bus Procurements	**375**	**250**	**0**	**160**	**160**	**160**	**160**	**160**	**160**	**160**	**1,745**

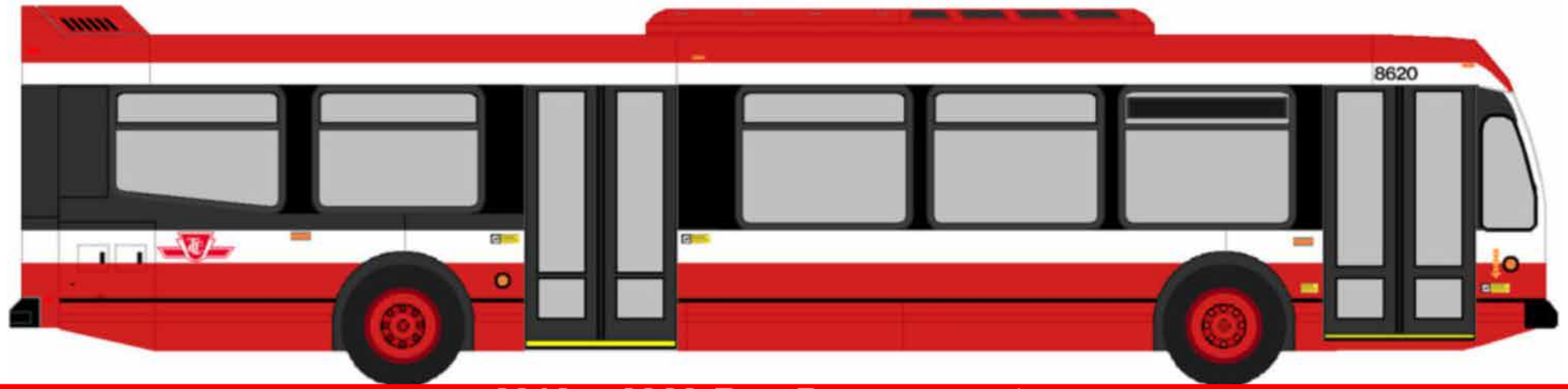
Hybrids: Reliable Technology for SOGR

Transition to Zero Emissions Buses

All Zero Emissions

Clean Diesel Bus Procurement Update

Status of Deliveries



2018 – 2020 Bus Procurements

		2018				2019				2020			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Clean Diesel Bus	Actual	40	2*										
	Vs Scheduled	40	78	104	88								
	Cumulative Actual	40	42*										
	Vs Cumulative Scheduled	40	118	222	310	310	310	310	310				

Last all diesel bus to be received in Q3 2018

Clean Diesel Bus Procurement Update

Expected Benefits

- **Service Impact:**
  - All 128 remaining conventional diesel buses will be replaced by Q3 2018
  - 65% increase in reliability from 17,000km MBDF and 28,000km
- **Environmental Impact:** Reduce GHG emissions by 30% or 49.6 tons / bus / yr.
- **Financial Impact:** Reduce fuel consumption by approximately 39% or $15,600 per bus/yr.
- **Other Key Benefits:**
  - Active obstacle detection on front doors starting in Q2 2018
  - Twelve (12) USB ports
  - Three (3) additional external cameras
  - Engine idle-stop feature
  - Customer infotainment screens

Hybrid-Electric Bus Procurement Update

Status of Deliveries

2018 – 2020 Bus Procurements

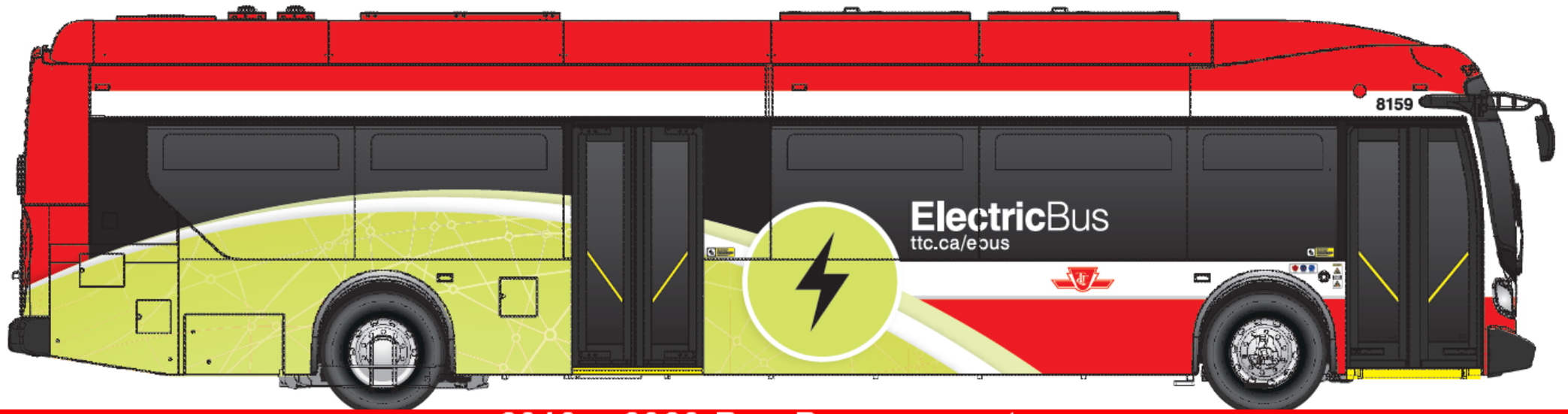
		2018				2019				2020			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Hybrid Electric Bus	Actual									NO PROCUREMENTS IN 2020			
	Vs Scheduled			1	54	115			85				
	Cumulative Actual												
	Vs Cumulative Scheduled			1	55	170	170	170	255				

Hybrid Diesel-Electric Procurement Update

Expected Benefits

- **Service Impact:**
  - Average of 65% increase in reliability
- **Environmental Impact:**
  - Reduce GHG emissions by 39% or 75.6 tons/bus/yr.
- **Financial Impact:**
  - Reduce fuel consumption by 39% or $25,600/bus/yr.
- **Other Key Benefits:**
  - An all-electric vehicle mode for up to 5 km for zero emissions operations at the garage and/or along routes to improve local noise and air quality levels;
  - Engine stop/start technology to prevent idling in traffic and at bus stops; and
  - All electric accessories, including doors, HVAC, power steering, and air compressor systems.

eBus Program Status Update



2018 – 2020 Bus Procurements

		2018				2019				2020			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Battery Electric Bus (eBus)	Actual									NO PROCUREMENTS IN 2020			
	Vs Scheduled				10	10		10	30**				
	Cumulative Actual												
	Vs Cumulative Scheduled				10	20		30	60**				

eBus Program Status Update

Expected Benefits / Proposed Organizational KPIs (by OEM)

Bus Fleet Availability*		Bus Reliability		Energy Consumption	
XX%	80%	XX MDBF	12,000 MDBF	XX kWh/km	1.35 kWh/km
ACTUAL	TARGET	ACTUAL	TARGET	ACTUAL	TARGET

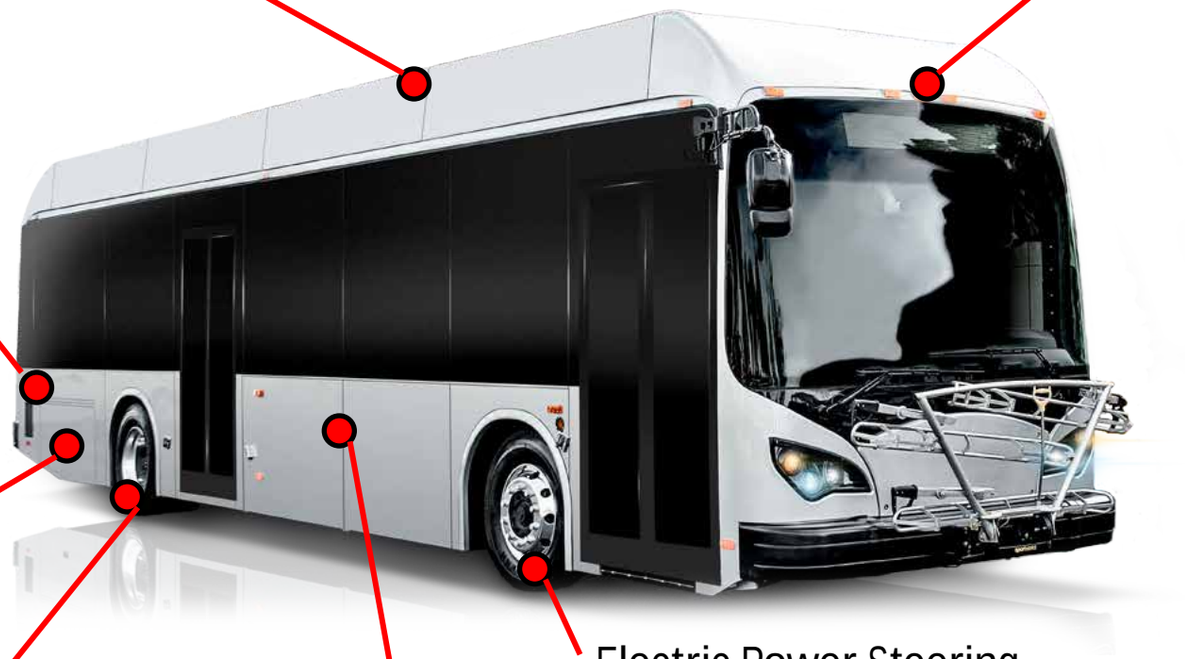
Annual Reduction in GHG** Emissions		Annual Reduction in Fuel Consumption		Net Annual Reduction in Fuel Cost	
XX TONS	149 TONS	XX THOUSAND LITERS	13.8 THOUSAND LITERS	$X	$56,000
ACTUAL PER BUS	FORECAST PER BUS	ACTUAL PER BUS	FORECAST PER BUS	ACTUAL PER BUS	FORECAST PER BUS

Total Life Cycle Cost (calculated)		Capital Budget Impact (calculated)		Operating Budget Impact (calculated)	
$2.02/km	$2.39/km	$1.44/km	$1.33/km	$0.58/km	$1.06/km
CURRENT	ORIGINAL BASELINE***	CURRENT	ORIGINAL BASELINE	CURRENT	ORIGINAL BASELINE

*** Daily average number of buses available for service divided by the total number of buses in the fleet**
****GHG stands for Greenhouse Gas and is measured in CO_{2e}**
*****Original baseline as reported at November 13, 2017 TTC Board Meeting**

eBus Program Status Update

BYD x10 Planned Delivery by December 2018



eBus Program Status Update

New Flyer x10 Planned Delivery by February 2019

Electric HVAC

DC Charged; 100kW charge rate
Charge Ports (Both Sides)
SAE J1772 CCS Type 1 Plug
Overhead Charging (Optional)

Stainless Steel Frame
& Fiberglass Body

Electric Air Compressor

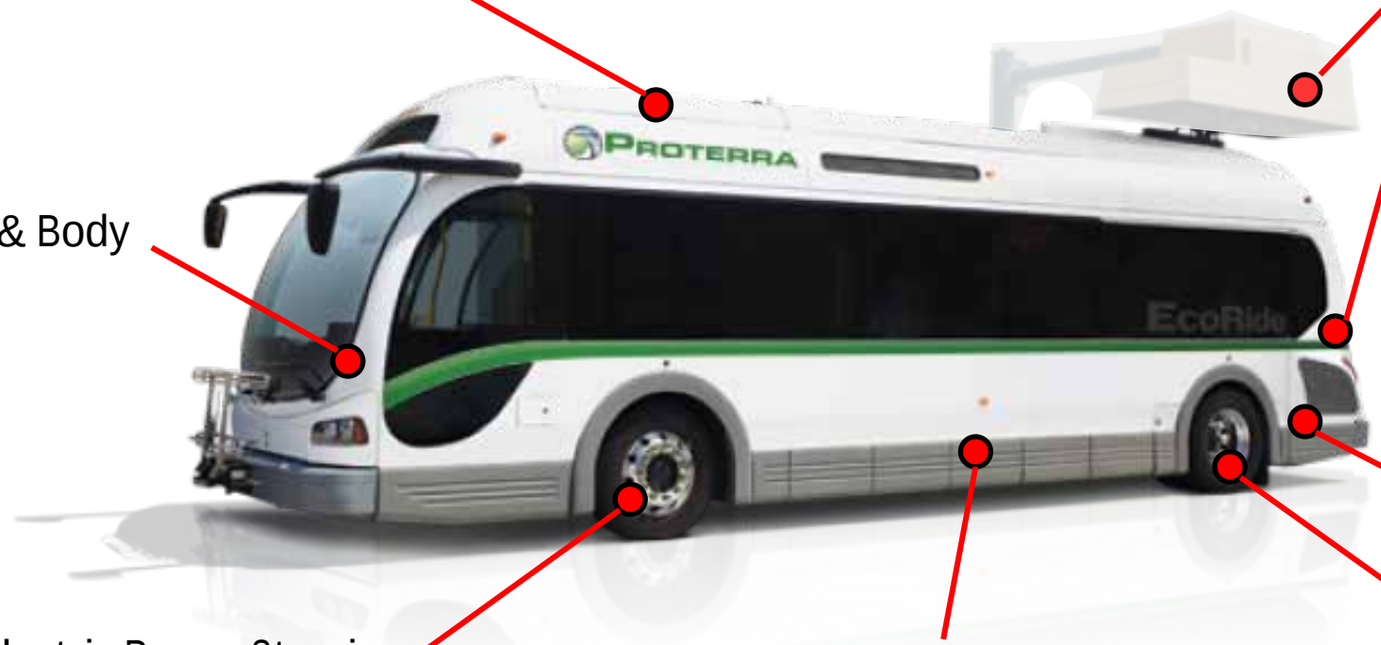
Single 210kW motor
Direct drive

Electric Power Steering

400kWh Battery
280km Nominal Range
w/Approx. 3.2 Hours to Recharge

eBus Program Status Update

Proterra x10 Planned Delivery by June 2019



Electric HVAC

DC Charged; 120kW charge rate
Two Charge Ports
Industry Standard Plug
Overhead Charging (Optional)

Composite Frame & Body

Electric Air Compressor

Electric Power Steering

440kWh Battery, Floor Mounted
400km Nominal Range
w/Approx. 3.2 Hours to Recharge

Single 220kW motor w/ 2-speed Transmission
(dual 190kW independent motors available in 2019)

eBus Program Status Update

Infrastructure

NEW FLYER

ARROW GARAGE

10

PROTERRA

10

MT DENNIS GARAGE

NORTH YORK

10

EGLINTON GARAGE

ETOBICOKE YORK

SCARBOROUGH

BYD

Determining Factors for Garage Selection:

1. Physical Constraints:
   - Indoor Ceiling Height – Ruled out Queensway and Birchmount
   - Space for chargers – limited at Eglinton, therefore, BYD best option
2. Avoid Other Major Projects – Ruled out Wilson Complex
3. Select widest possible geographical distribution

eBus Program Change Request

Infrastructure

NEW FLYER

ARROW GARAGE

10 + 10

Energy Storage System

PROTERRA

10 + 10

MT DENNIS GARAGE

NORTH YORK

10 + 10

EGLINTON GARAGE

ETOBICOKE YORK

SCARBOROUGH

Energy Storage System

Scope of Change:

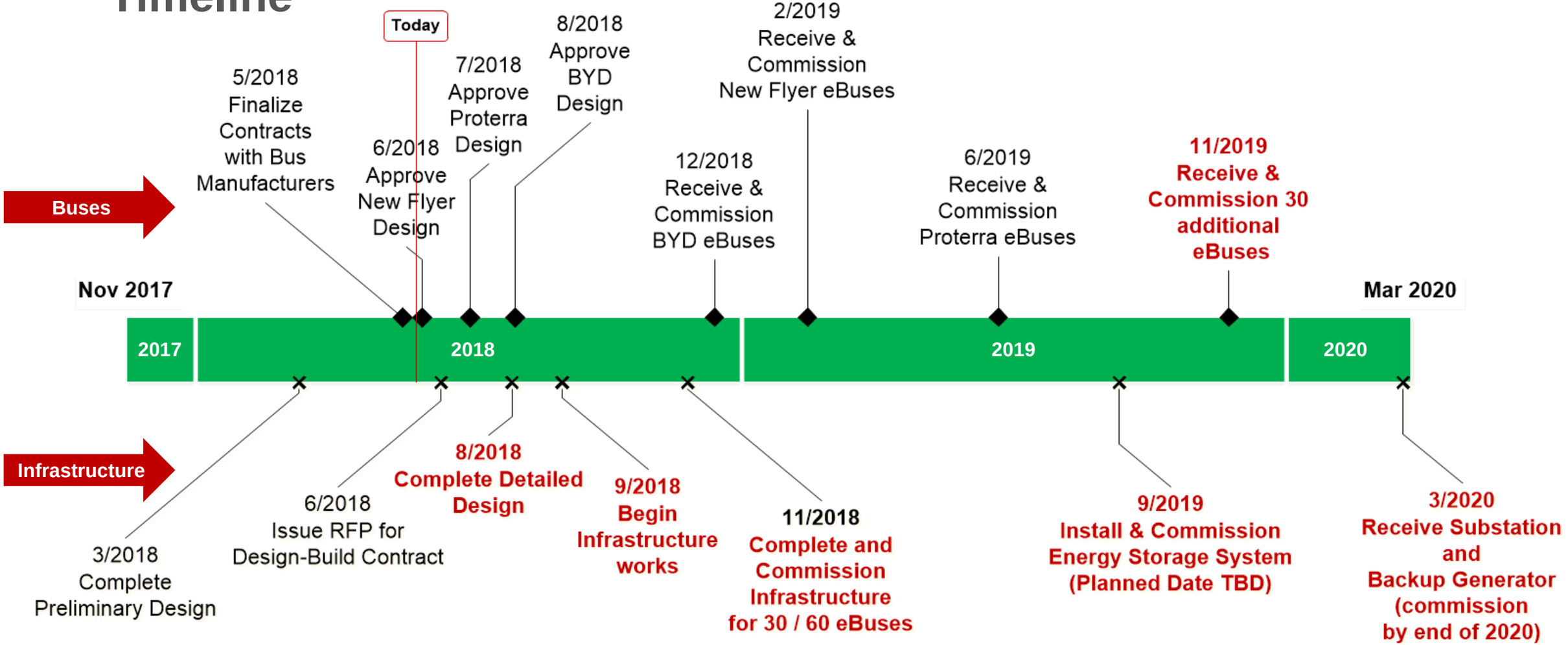
1. Additional 30 eBuses (not necessarily from the same vendors);
2. Additional chargers and dispensing units;
3. Battery storage at all three garages to manage peak loads; and

BYD

Energy Storage System

eBus Program Change Request

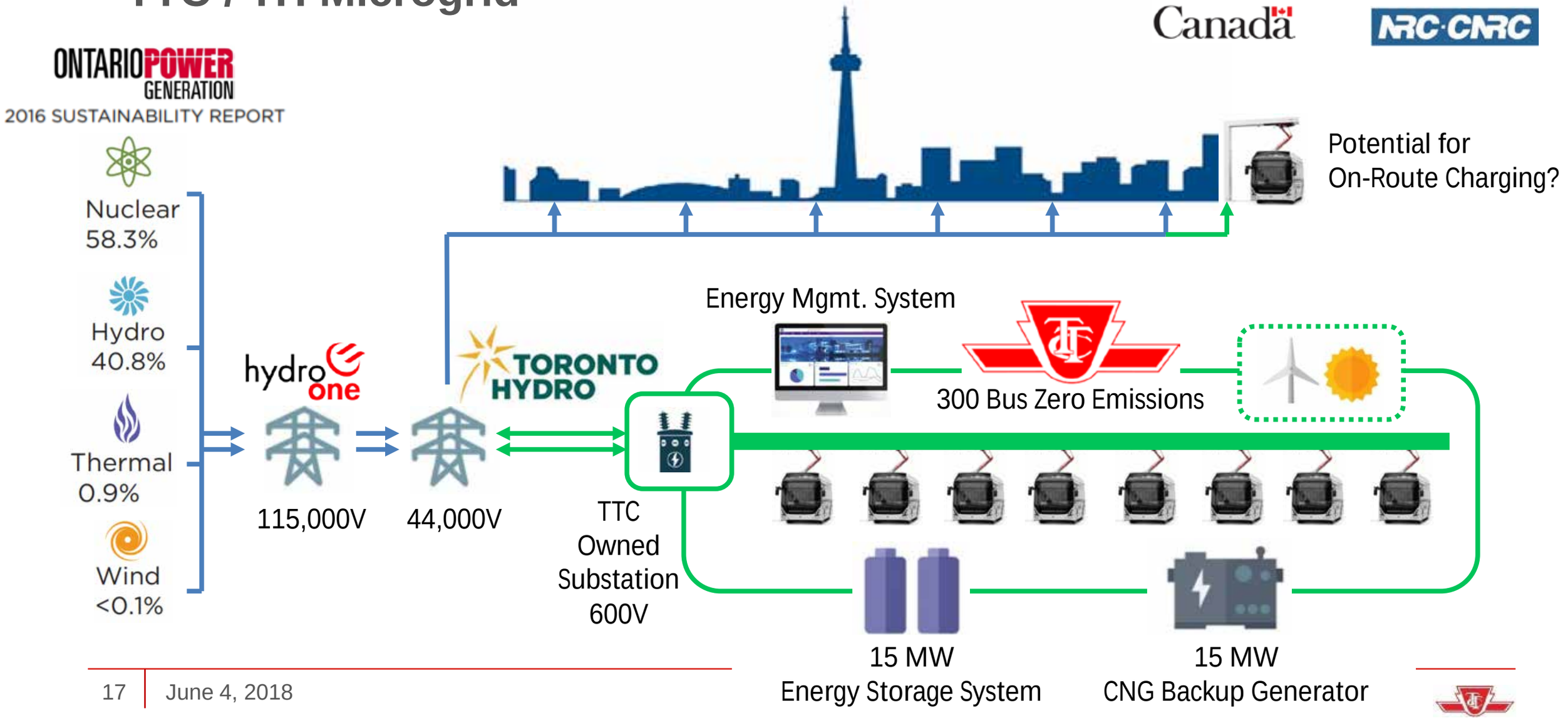
Timeline



Legend: Existing Scope for 30 eBuses (Black Text) **Modified / New Scope for 60 eBuses and eGarage (Red Text)**

Future Proofing Garages

TTC / TH Microgrid



Future Proofing Garages

McNicoll Bus Garage Electrification Study

As detailed in the report, Stantec Consulting conducted an impact study for retrofit of McNicoll Garage and found that work required accommodate eBuses at this time would cause significant unacceptable delay and budget impacts to the design-build contract.

Gaseous Fuel Study for CNG and Hydrogen

CNG Buses, Backup Generators, and Hydrogen Fuel Cell Buses

There is currently a gaseous fuels study underway in partnership with Enbridge to determine the cost and time required to modify garages, shop, and stations to accommodate CNG buses and or hydrogen fuel cell buses.

In Q4 2018, staff will report back with an report that provides recommended course of actions and best practices for the TTC to adopt gaseous fuels to deliver a resilient path from high carbon vehicles to low/zero carbon vehicles.

Deliverables would include a business case with life cycle costing, capital costs, operating and maintenance costs and any opportunities for cost avoidances through alternate financing.

Cost, Benefits, and Potential Funding Opportunities

Total Cost, Funding, Payback Period, Financing Options, etc.

In addition to the promise of significant environmental benefits and potential life-cycle cost savings, a future that includes zero emissions buses, in particular all-electric buses, presents alternate funding opportunities that should be explored.

With approval of recommendation No. 4 of this report staff will report back to the TTC Board with a detailed costing study, quantification of benefits, and assessment of potential funding opportunities.

eBus Program Status Update

Recommendations

1. Increase the procurement quantity of eBuses from 30 to 60 eBuses and work with Toronto Hydro on associated infrastructure, revising the project budget from $50 million to an estimated $120 million;

2. Work with Toronto Hydro to modify one of TTC's bus garages to accommodate up to 300 zero emissions (or near zero emissions) buses through supply of a substation and a backup generator for an estimated project cost of $18 million;

3. Return to the Board in Q1 of 2019 with award details and a project status update with respect to Recommendation Nos. 1 and 2; and

4. Conduct a garage-by-garage feasibility study for an estimated cost of $2 million and report back in Q4 2019 with a comprehensive draft report on costs, benefits, and potential funding opportunities associated with the green bus plan.