BRAMPTON

Report
Staff Report
The Corporation of the City of Brampton
4/24/2024

Date: 2024-04-10

Subject: **Brampton Zero Emission Bus Implementation Strategy & Rollout Plan**

Contact: Heidi Dempster, General Manager, Transit

Report number: Brampton Transit-2024-346

RECOMMENDATIONS:

1. That the report from Heidi Dempster, General Manager, Transit to the Committee of Council Meeting of April 24, 2024, re: **Brampton Zero Emission Bus Implementation Strategy & Rollout Plan**, be received;

2. That Council endorse the *Brampton Transit Zero Emission Bus Implementation Strategy and Rollout Plan* prepared by the Canadian Urban Transit Research & Innovation Consortium to help guide the City's transition to an environmentally sustainable transit service; and

3. That Council adopt and commit to a net zero objective by transitioning to a zero emission bus fleet for Brampton Transit as early as 2040 with full fleet transition required no later than 2050, if possible; and

4. That Council consider the capital and operating financial commitments outlined in the Brampton Transit Zero Emission Bus Implementation Strategy and Rollout Plan Summary Report corporate priorities during the City's annual budget process, noting that future capital and operating requests are subject to change and require approval through the annual budget process; and

5. That the General Manager, Transit, be directed to update the *Brampton Transit Zero Emission Bus Implementation Strategy and Rollout Plan* on a five-year cycle, subject to future funding approval during the annual budget process.

OVERVIEW:

- **The purpose of this report is to provide an update on the status of the Phase 1 - eBus Trial, and two key planning studies required to transition Brampton Transit buses to a full zero emission fleet.**

- **Through this report, staff are seeking Council endorsement of the *Zero Emission Bus Implementation Strategy & Rollout Plan* (ZEB Strategy) prepared by the Canadian Urban Transit Research and Innovation Consortium (CUTRIC).**

- **Council's endorsement of the ZEB Strategy includes the adoption of and commitment to achieving a net zero objective for the Brampton Transit bus fleet as early as 2040 and no later than 2050, subject to the capital and operating commitments required.**

- **The ZEB Strategy recommends, based on existing route structure and geographic location (in relation to our local energy grid), that the City proceeds to electrify the bus fleet using a mixed fleet of Zero Emission Buses (ZEBs); both Battery Electric Buses (BEBs) and hydrogen Fuel Cell Electric Buses (FCEBs).**

- **The ZEB Strategy will be executed in a phased approach, as outlined in this report and subject to change based on the annual fleet plan, required funding and/or financing, commercial supply chain availability, technology innovation, and Energy-as-a-Service (EaaS) requirements.**

- **The transition to ZEBs will require more buses given the limited kilometer range of ZEBs that are commercially available today, compared to diesel and hybrid-electric buses.**

- **The mixed fleet transition provides for the fewest number of ZEBs within the three fleet electrification scenarios examined, and will require:**
  - **More buses: approximate 21% increase in fleet to provide same level of service as clean diesel/hybrid electric buses; and**
  - **More service hours: approximate 7% additional incremental service hours; and**
  - **More staff: increased labour expenditures to support additional service hours.**
  - **More facilities and equipment:**
    - **New Third Transit Facility: storage limits are anticipated to reach near capacity in 2034 (973 buses forecasted). Advancing Phase 2 build to support electrification is needed.**
    - **Future Additional Facilities: Further assessment will need to be completed to determine the fleet storage strategy beyond 2034, including potential for expansion and/or relocation options for**

existing facilities, and/or the need for a potential New Fourth Transit Facility.

- **The zero emission target for achieving full electrification as outlined in the ZEB Strategy is achievable, and ambitious. This target will however require significant funding and financing to achieve, as the City alone will be unable to generate sufficient funds from the tax base and current funding sources.**

BACKGROUND:

Brampton Transit is committed to achieving an environmentally sustainable transit service by electrifying its fleet. With the transportation sector being a major contributor to greenhouse gas (GHG) emissions, the electrification of Brampton Transit's fleet is crucial in achieving the City of Brampton's GHG reduction targets in support of the federal government's 2050 emissions targets.

This report provides an update on Brampton Transit's current activities related to zero emission buses and presents key findings of the City's inaugural ZEB Strategy, now completed.

History

The City of Brampton provides sustainable public transit services to over 40 million passengers per year (based on 2023 ridership) with its fleet of nearly 500 buses:

Clean Diesel Buses:

- Although clean diesel buses emit GHGs, there are significant environmental benefits in using public transit in the first place.
- One standard 12-metre (40-foot) bus at full capacity takes the place of 70 single occupancy cars[1].
- Clean-diesel buses of today (based on stringent EPA emission requirements) produces less than 1/10th the emissions per passenger than a personal vehicle.

Hybrid-Electric Buses (HEBs):

- In 2010, Brampton Transit was the first transit agency in North America to use New Flyer's clean diesel-electric hybrid (HEB) buses and currently have 133 HEBs in our Züm Bus Rapid Transit (BRT) fleet, making up about one-third of our fleet today.
- HEBs generate additional GHG savings compared to clean diesel buses and comparatively save approximately 3,400 tonnes of CO_2e per year.

[1] Toronto Transit Commission, Green Initiatives, Fun Facts

Zero Emission Bus Trials

Phase 1 - Battery Electric Bus (BEB) Trial

- In July 2021, the City fully launched its first 8 BEBs into revenue service as part of CUTRIC's Pan-Canadian BEB Demonstration and Integration Trial.
- Brampton Transit's deployment, at that time, was the largest global deployment of fully interoperable BEBs and high powered (450kW) overhead pantograph-style chargers.
- This 2.5-year trial was coordinated by CUTRIC and included Brampton Transit, York Region Transit, TransLink, ABB E-mobility, Siemens Canada, New Flyer Industries, and Nova Bus. The Phase 1 trial officially ended in December 2023.
- This $15.95M project was successfully delivered during COVID, with 70% ($11.15M) funded by Natural Resources Canada (NRCan). This project is being closed off with CUTRIC and NRCan in Q2/2024.
- During the 30-month trial period, our eight (8) BEBs accumulated over 920,000 revenue service kilometres and CUTRIC estimates savings of over 448,000 litres of diesel fuel resulting in savings of over 1,400 tonnes of GHGs (CO_2e).

Phase 2 – Additional eBuses

- 2024 BEB Procurement:
  - On January 15, 2024, a Purchase Order was issued to Nova Bus Inc. (RFP2023-011) for the supply and delivery of the City's next ten (10) BEBs ($16M). Pre-production meetings are underway and these new BEBs are anticipated for delivery in early 2025 based on the suppliers manufacturing window.
  - Additional BEBs will be ordered as per the ZEB Strategy, and annual budget process, and phased into the annual fleet plan (for scheduled replacement and growth buses) during the early and mid-phases of the fleet transition.
  - Although not part of an official trial with CUTRIC, the empirical data from these 10 BEBs (and any others procured by the City) will continue to be monitored and reported by CUTRIC on a quarterly basis until June 2025.

- Fuel Cell Electric Bus (FCEB) Trial:
  - Brampton Transit remains interested in undertaking a small FCEB trial of 1-2 buses, although significant challenges currently exist regarding the supply chain of hydrogen in Ontario that would not support the use of FCEBs.
  - Based on industry engagement the availability of low carbon hydrogen is anticipated to become more readily available within the next 1-3 years.
  - FCEBs may be procured as per the ZEB Strategy, associated facility, fuel, and dispensing infrastructure required, and annual budget process.
  - Based on the ZEB Strategy, FCEBs may be phased into the annual fleet plan (for scheduled replacement and growth buses) during the latter phase of the fleet transition, beginning service in 2034.

- Clean Diesel to Battery Electric Bus Conversion Trial:
  - A Request for Information (RFI2023-010) was issued in early 2023, limited responses (two) were received.
  - Staff have prepared the technical and business requirements and following recent Council approval (on February 28, 2024) of the required Begin Procurement Report, a competitive public Request for Proposals (RFP2024-112) is to be issued.
  - At the time of authoring this report, only one other transit agency in Canada (Milton Transit) has initiated a similar project.
  - Dependent on the success of Brampton's conversion trial, this innovative approach to transitioning our existing diesel fleet to fully electric may result in an ability to advance some of our fleet transition timelines.

Feasibility Studies

- The required feasibility studies have been completed by CUTRIC which assessed the feasibility of using ZEBs across the entire Brampton Transit route network.
- In July 2022, Brampton welcomed investments from the Government of Canada and the Federation of Canadian Municipalities (FCM) to support the prerequisite feasibility studies, which are required prior to commencement of the ZEB Strategy.
- This is a requirement of the federal government prior to submission and consideration of any Zero Emission Transit Fund (ZETF) capital project applications.

Implementation Strategy & Rollout Plan

- The Government of Canada selected CUTRIC as the National ZEB Planning service.
- Following completion of the Feasibility Studies, Council approved further engagement with CUTRIC to undertake the comprehensive ZEB Strategy. The ZEB Strategy will guide the City on how to electrify the Brampton Transit fleet using ZEBs.
- This strategy has been conducted based on information available now. Given the rapid innovation in this space (both bus and charging equipment), based on CUTRIC's guidance, staff are recommending the strategy be refreshed every five (5) years to track progress. The strategy will also need to:
  - coexist with and support the Brampton Transit Business Plan (also on a five (5)-year cycle).
  - influence existing and future corporate strategic priorities (such as Community Energy & Emissions Reductions Plan, Brampton Grow Green Environmental Management Plan, Mobility Plan, etc.).
- Key findings of the strategy are presented within this report.

CURRENT SITUATION:

Strategy Overview

1. Overview of 3 scenarios for electrification

The ZEB Strategy as developed by CUTRIC lays out a pathway towards a zero emissions future for Brampton Transit achieving 100 per cent fleet electrification as early as 2040, subject to securing the funds and electrification supply chain required.

As part of this study, Deloitte was engaged by CUTRIC to complete the full life cycle economic analysis component. This analysis considered 15-year and 18-year life cycle options, both with and without supplementary heating.

Under this study CUTRIC has assessed our base case along with three (3) potential scenarios for Brampton Transit's fleet electrification as follows:

- Base Case: ongoing procurement of diesel and HEBs for growth and replacement to 2041 ("base case")
- Scenario 1: full transition to BEBs ("full BEB solution")
- Scenario 2: full transition to FCEBs ("full FCEB fleet")
- Scenario 3: full transition to a mixed fleet of BEBs and FCEBs ("mixed fleet").

a) Support for mixed ZEB fleet option:
   - Through the findings of this study, CUTRIC supports an approach to full fleet decarbonization that prioritizes Scenario 3 (mixed BEB/FCEB solution).
   - This solution balances the advantages and disadvantages of both BEB and FCEB technologies to deploy a flexible future fleet.
   - CUTRIC's recommendation is based on their comprehensive analysis, inclusive of total cost of ownership and the full lifecycle economic analysis undertaken by Deloitte under each scenario.
   - Leveraging both BEB and FCEB technologies will provide the greatest flexibility as rollout occurs and enable Brampton Transit to pivot as required based on future federal and provincial policy and industry innovation and supply chain considerations.
   - Staff support and recommend adoption of the Mixed ZEB Fleet approach for Brampton Transit's electrification pathway.

b) Vehicles:
   - One of the major challenges in achieving fleet electrification is that the ZEBs commercially available today present a significantly shorter range when compared to diesel and HEBs.
   - Another major challenge is supply chain. Currently there are only two original equipment manufacturers (OEMs) manufacturing and supplying BEBs to the Canadian public transit industry, and only one supplying FCEBs.

- As reported by CUTRIC through the study, Table 1 provides a comparison between 12-metre (40-foot) diesel, diesel hybrid electric, BEB and FCEB technologies according to the manufacturer data available in Canada today*.

	Fuel capacity	Fuel efficiency	Range
Diesel	400 L	60 L/100km	600-700 km
Diesel Hybrid	400 L	45 L/100km	800-900 km
BEB	500 kWh	1.7 kWh/km	200-300 km
FCEB	35 kg	10 kgH2/100km	300-400 km

** Note: These values are approximate averages as specific circumstances and local operating conditions result in variability (including the number of passengers on board, weather, road conditions. etc.)*

*Table 1: National averages for 12-metre bus comparison fuel capacity, fuel efficiency, and range**

- Incremental capital and operating cost increases must therefore be anticipated to occur with the transition to ZEBs:
  - Capital – more ZEBs will be required to perform the same amount of service kilometers that our current fleet of clean diesel and HEBs perform today.
  - Operating - additional ZEBs will require additional service hours, over and above growth related service hours, that will be required to allow for on-route charging, refuelling and block splitting. Future budget requests for increased service hours tied to growth will now also denote those required for electrification. This is discussed further in Section 5 of this report.

- Supplemental Heating
  - To maximize the range of BEBs and minimize the total number of BEBs required in the fleet, supplementary heating using self-contained diesel fired auxiliary heaters (DFAH) are utilized.
  - According to CUTRIC:
    - the use of DFAHs on BEBs can reduce the energy consumption rate (as less energy is drawn from the battery required for propulsion) from approximately 12 per cent to 25 per cent.
    - Employing DFAH on BEBs assigned to on-route charging blocks can also help decrease the amount of service (block) splitting between two vehicles.
    - The overall effect is to reduce the system's total energy consumption and the minimum number of vehicles required to electrify the system.
    - With the use of DFAHs, the estimated BEB growth fleet will be reduced by approximately 5%.
  - BEBs with DFAHs are fully recognized as ZEBs. DFAH use a very small amount of clean diesel and there are zero tailpipe emissions with use of DFAHs.

- The DFAH are programmed and will not operate above an ambient temperature of 4.5 degrees Celsius.
- Therefore, it will be the City's approach to continue procuring BEBs equipped with DFAH, as this is typical practice for transit agencies operating in Canada today to maximize capital investment and BEB range, while minimizing additional incremental operating costs.

c) Environmental and Operational GHG reductions:

- Transit electrification builds on Council's Climate Emergency declaration in support of building a Green City and helps to achieve the goals established by the Government of Canada including the goal of becoming net zero emissions by 2050.
- As part of the ZEB Strategy, CUTRIC has calculated both operational and lifecycle emissions for the base case and each of the transition scenarios.
  - Operational emissions are directly controlled by Brampton Transit and are proportional to the distances travelled and the energy/fuel consumed.
  - The environmental lifecycle analysis (LCA), also known as "well to wheel", is more comprehensive capturing aspects not controlled by Brampton Transit, such as vehicle and infrastructure manufacturing.
- As Brampton Transit generates about 70% of total corporate operational GHG emissions, the electrification of our transit fleet is a critical milestone in the City of Brampton's plan to reduce community-wide emissions by 50% from 2016 levels by 2041 and establish a pathway to reduce emissions by at least 80% by 2050 to meet or exceed federal and provincial targets.
- Based on the current fleet (base case), refer to Table 2 which provides a comparison of operational and fuel GHG emissions estimated for each scenario, with DFAH. These values represent the emissions that the current clean diesel fleet would emit under full fleet electrification.

	Base Case (Diesel Fleet)	Scenario One (full BEB solution)	Scenario Two (full FCEB solution)	Scenario Three (Mixed Solution)
BEBs with DFAH	55.67	2.49	Green H2: 5.40 Blue H2: 18.01 Grey H2: 36.01	Green H2: 3.02 Blue H2: 6.20 Grey H2: 10.73

Note: Scenario Three (mixed green flee solution) considers emissions from both BEBs and FCEBs. The hydrogen production method is used to analyze emissions across different categories; however, the full impact of BEBs is included with each type of hydrogen.

Table 2: Operational and Fuel GHG emissions by scenario for current fleet per year ($KtCO_2eq$)

- Based on the projected fleet growth requirements to 2041, the operational GHG emissions, with DFAH, are estimated to reach the following levels:
  - Base case –
    - existing diesel/HEB fleet increased to forecasted future fleet of 938 buses.

        - existing diesel/HEB operational GHGs estimated to increase by 98%, from approximately 56 $ktCO_2e$/year (or about 13,000 passenger cars[2]) to approximately 111 $ktCO_2e$/year (or about 26,000 passenger cars[1]).
    - Scenario 1 – Full BEB Solution:
        - Emissions estimated to be about 3 $ktCO_2e$/year, or about 97% reduction compared to future fleet GHGs (or about 25,400 passenger cars[1]).
    - Scenario 2 – Full FCEB Solution
        - Emissions using green H_2 estimated to be about 16 $ktCO_2e$/year, or about 85% reduction compared to future fleet GHGs (or about 22,250 passenger cars[1]).
    - Scenario 3 – Recommended BEB/FCEB Mixed Fleet Solution
        - Like the emission reduction results under the full BEB solution, the mixed BEB/FCEB solution, using green H_2, mixed fleet emissions are estimated to be about 5 $ktCO_2e$/year, or about 95% reduction compared to future fleet GHGs (or about 24,800 passenger cars[1]).
- Based on the proposed mixed fleet solution, estimated GHG reductions during the following time periods are estimated:
    - Short term: 2025 – 2030 = 25%
    - Medium term: 2031 – 2035 = 95%
    - Long-term: 2036 – 2050 = 130%
- Refer to Chart 1, which depicts the number of buses per year anticipated, and the potential GHG reductions.

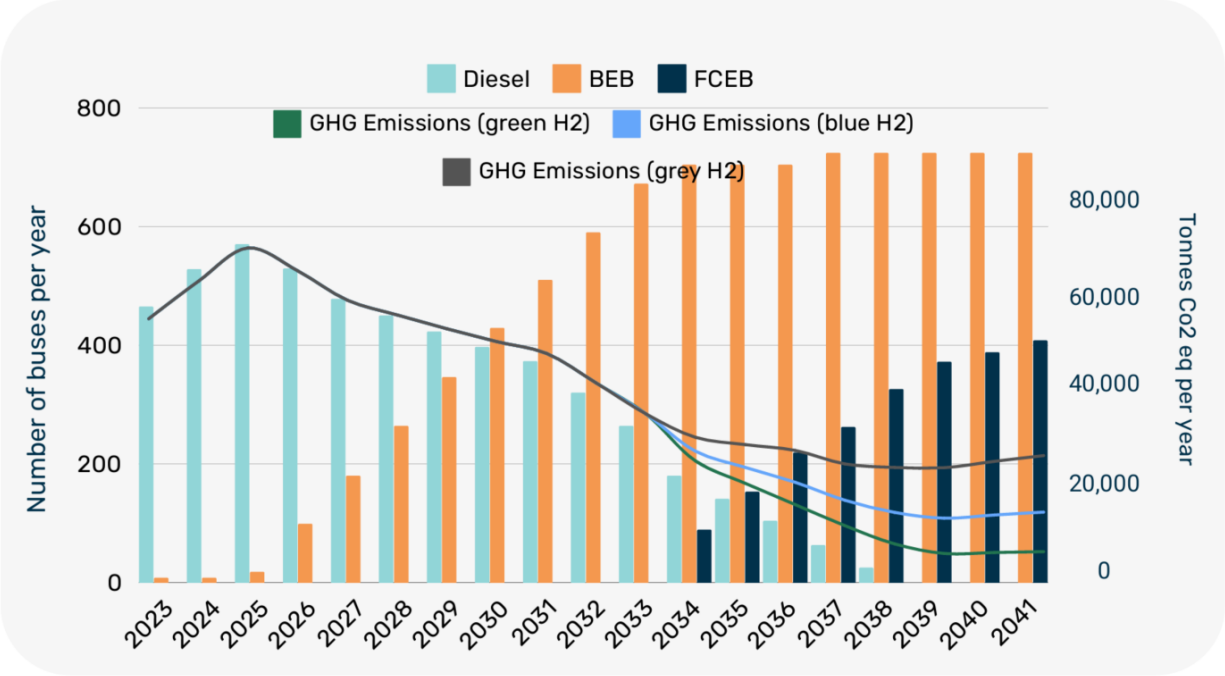

Chart 1 – Rollout and operational GHG emissions profile – Mixed Fleet

[2] Brampton Transit Zero Emission Bus Implementation Strategy & Rollout Plan, Volume 1 – Strategic, CUTRIC, 2024. *"Assuming that the typical Canadian passenger car consumes 8.6 L/100km and travels approximately 15,200 km/year, considering that the energy density of gasoline is 46MJ/kg and the volumetric density of gasoline is 0.743 kg/L. Therefore, the average Canadian cars emit approximately 4.24 tCO_2e/year"*

d) Phased in approach:
   - ZEBs will be introduced into the fleet under normal replacement & growth bus acquisition schedules. Replacing diesel or HEBs prior to the end of useful life, without significant additional funding, is not recommended.
   - Diesel to BEB conversion trial project to begin procurement in 2024 will inform future potential of zero emission conversions during diesel bus mid-life refurbishments.

2. Charging Strategy for Mixed Fleet

- In planning the fleet transition using BEBs each transit agency must carefully consider and decide on the appropriate charging strategy which is driven by the type of service the bus is expected to perform.
- This decision must be made prior to procurement of the BEBs as part of each order of buses purchased; there are two distinctly different strategies (which are outlined below); a) In-Depot Charging and b) On-Route Charging.
- The recommended mixed fleet solution leverages both in-depot and on-route charging for BEBs, as well as hydrogen fuelling on-site, to ensure a high level of service and minimal disruption to service frequency.

a) BEB Charging Strategy 1 – In-Depot:
   - Primary focus during short term rollout (2025-2030). Deployment may continue into the medium term (2031-2035).
   - Preferred BEB charging strategy to be fully utilized to the extent operationally possible.
   - When combined with high-capacity long range, BEBs will yield the lowest electricity prices (currently about $0.14/kWh or 50% less than on-route charging).

b) BEB Charging Strategy 2 – On-Route (Opportunity):
   - Through a charger optimization analysis, CUTRIC has determined the need for eight optimal locations, including the on-route chargers already in operation as part of the Phase 1 BEB trial, for a total of an additional 18 on-route chargers.
   - As the primary focus during the short and medium term rollout will remain in-depot charging, these potential on-route chargers would need to be considered also during the medium term and most likely the longer term (2036-2050), dependent on overall operational demands and scheduling requirements.
   - On-route charging is currently about twice the cost (approximately $0.31/kWh). This is due to the high demand charges.

c) FCEB – On-Site Fuelling:
   - A mixed fleet solution can leverage grey hydrogen supplies in Ontario while shifting toward increasingly lower carbon intense (green) hydrogen supplies by 2040.

- Based on the recommended fleet rollout plan discussed in the next section of this report, the first order of FCEBs is expected to enter revenue service in 2034.
- Requirements for FCEB on-site fuelling may be considered during the latter part of the short term rollout (for planning/design) and early part of the medium term rollout plan (for construction/commissioning).

3. Recommended Fleet Rollout Plan

- The proposed mixed fleet solution will be implemented in the following time periods:
  - Short term: 2025 – 2030
  - Medium term: 2031 – 2035
  - Long-term: 2036 – 2050
- Additionally, within the strategy CUTRIC has developed three groups for determining the prioritization of routes be electrified with ZEBs, as follows:
  - Group 1: routes that only deploy BEBs using Charging Strategy 1 (depot-only charging).
  - Group 2: routes that deploy BEBs using both Charging Strategy 2 and Charging Strategy 2 (depot and on-route charging) but do not deploy FCEBs.
  - Group 3: routes that deploy both BEBs and FCEBs.
- The classification scheme above considers that routes requiring FCEBs are the hardest to electrify given Ontario's currently undeveloped hydrogen fuel supply chain for transit applications.
- It also considers that routes requiring BEBs charging on-route are more challenging (and more costly) to electrify than routes for which BEBs charging only at the depot suffice.

a) Base Case:
   - During the eighteen (18) year period from 2024-2041, to sustain anticipated system growth and associated ridership pressures, Brampton Transit is projecting estimated increases of:
     - 76% total fleet size (from 533 buses in 2024 to 938 buses in 2041); and
     - 14% of 18-metre (60-foot) articulated buses within the fleet.

b) Recommended Mixed Fleet (BEB/FCEB) Rollout Plan, with DFAH:
   - A mixed fleet requirement of 1,132 ZEBS in 2041 is projected:
     - Estimated 724 BEBs and 408 FCEBs, this ratio is subject to change as the ZEB landscape evolves.
     - Refer to Chart 2 below which illustrates the proposed phasing of the bus fleet decarbonization rollout plan under the preferred Scenario 3 Mixed BEB/FCEB fleet, based on 18-year useful life, with DFAH:

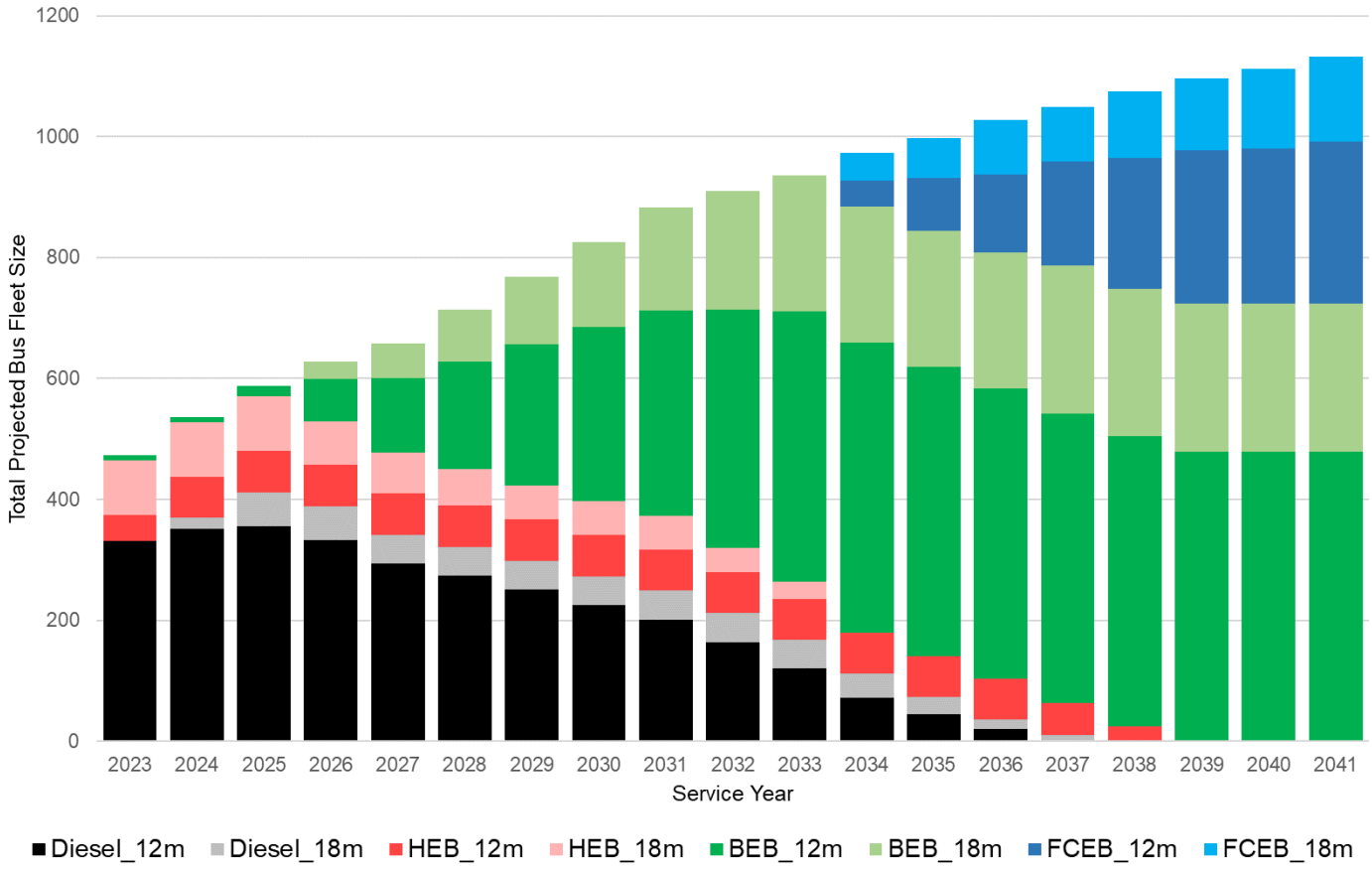

Chart 2 – Proposed Mixed Fleet Decarbonization Rollout Plan

c) Costs (Operating and Capital):

- Scenario 3, the recommended mixed fleet solution requires the fewest ZEBs and is the most financially viable overall, costing less than Scenario 1 (full BEB solution) or Scenario 2 (full FCEB solution).
- Refer to Attachment 1, Section 08 pertaining to the total cost of ownership and economic analysis completed by CUTRIC and Deloitte, respectively.
- The economic analysis completed by Deloitte for preferred scenario 3 mixed fleet, 18-year life cycle, using BEBs with DFAH (which is the preferred approach) is summarized in net present value as follows:

CAPEX:	$3.40 billion	OPEX:	$5.71 billion
Residual:	$(161 million)	TOTAL:	$8.94 billion

d) Land acquisitions:

- Some property acquisition may need to be considered to permit the possible locating and operation of the on-street chargers.
- Other transit agencies (GO Transit, MiWay) would need to be consulted to identify potential shared charging locations. Approvals and agreements may be required for charging operations within their terminals.

- As part of the study CUTRIC conducted a real estate assessment of the various land parcels necessary for Brampton Transit to implement the proposed electrification solution using BEBs and on-route charging considering the current service levels.
- Given on-route charging is being considered in the latter phases of electrification, expanding the scope of this study to consider future service levels with the potential inclusion of new routes and/or terminal stations where on-route charging will be necessary would be beneficial.
- A total estimated market value of $0.51 million ($2023) to potentially acquire lands required are identified for future consideration.

4. Facilities Requirements

As the ZEB evolution continues, transit agencies must be flexible in their approach to full electrification to adopt new facilities standards to support the storage and maintenance of ZEBs.

There are currently no specific standards for the design of facilities when considering transition to ZEBs. The Canadian Standards Association (CSA) is currently working collaboratively with the public transit industry to develop two new standards that will support the storage and maintenance of ZEBs in the short term:

- CSA B401.3 – Hydrogen Vehicle and Trailer Maintenance Facilities Code
- CSA B401.4 – Battery Electric Vehicle Maintenance and Storage Facility Code

Capital costs presented in the ZEB Strategy are not inclusive of the considerations above. The need for additional capital funding and/or financing will need to be considered at the appropriate time to follow future codes and safety standards.

a) Sandalwood Transit Facility Retrofit (2026):

- Based on the Class C Reference Concept Design (75% design) CUTRIC estimates for the proposed Scenario 3 mixed fleet:
    - $86 million total retrofit cost, for further review and adjustment by staff to include ancillary project costs (such as legal, project management, etc.) that would need to be included.
        - Note: this estimate does not presently include the facility enhancements that would be required to store and maintain FCEBs inside this facility.
        - Additional engineering assessment required will result in higher capital costs, to be confirmed per the rollout plan timing to support FCEBs.
    - 20,000 kg of hydrogen storage capacity
    - 17 MW of installed charging power and 11 MW of estimated peak service demand.

    - This is the equivalent energy to power approximately 17,000 residential homes per year in Ontario[3].
- $60 million electrification retrofit Expression of Interest (EOI) was previously submitted to Infrastructure Canada through the Zero Emission Transit Fund (ZETF) in 2021.
- With the strategy now complete, staff will proceed to re-engage INFC and submit the required capital application reflective of the increased Class C estimate prepared by CUTRIC along with any adjustments by staff.

b) New Third Transit Facility & Electrification Retrofit (2027)
- For the fleet transition to occur, it is imperative that the New Third Transit Facility (base) be constructed and operational in 2027 to support eventual BEBs (and possibly FCEBs) in the future.
- Additionally crucial is the funding required to complete the electrification of this facility (retrofit to base) also for operational readiness in 2027 to support the operation of large quantities of BEBs.
- $150 million capital application has been submitted to Infrastructure Canada through the Zero Emission Transit Fund for the electrification of this facility.
- Between 2026 and 2033, the average number BEBs anticipated per year (subject to funding approvals) are as follows:
    - 53 (12-metre) and 28 (18-metre) for a total of about 80 BEBs per year between 2026 through 2033.

c) Clark Transit Facility Retrofit (Beyond 2028):
- Based on the Class C Reference Concept Design (75% design) CUTRIC estimates for the proposed Scenario 3 mixed fleet:
    - $46 million total retrofit cost, for further review and adjustment by staff to include ancillary project costs (such as legal, project management, etc.) that would need to be included.
        - Note: this estimate does not presently include the facility enhancements that would be required to store and maintain FCEBs inside this facility.
    - Additional engineering assessment required will result in higher capital costs, to be confirmed per the rollout plan timing to support FCEBs.
    - 10,000 kg of hydrogen storage capacity.
    - 7 MW of installed charging power and 5 MW of estimated peak service demand.
    - This is the equivalent energy to power approximately 7,000 residential homes per year in Ontario[2].
- $60 million electrification retrofit Expression of Interest (EOI) was previously submitted to Infrastructure Canada (INFC) through the Zero Emission Transit Fund (ZETF) in 2021.

[3] Canada Energy Regulator

- With the strategy now complete, staff will proceed to re-engage INFC to submit the required capital application at the appropriate time, reflective of the revised Class C estimate prepared by CUTRIC and any adjustments by staff.

d) Additional facilities:

- Based on the preferred Scenario 3 mixed fleet and rollout to 2041, the proposed fleet size of 1,132 cannot be accommodated within the indoor storage capacities of the Brampton Transit facilities, shown in standard bus equivalents (SBEs) as follows:
  - Sandalwood Transit Facility: 371
  - Clark Transit Facility: 178
  - New Third Transit Facility
    - Phase 1: 250
    - Phase 2: 183

  Total: 982
- Storage limits at the New Third Transit Facility are anticipated to reach near capacity in 2034 (973 buses forecasted).
- Further assessment will need to be completed to determine the fleet storage strategy beyond 2034, including potential for expansion and/or relocation options for existing facilities and/or the need for a potential New Fourth Transit Facility.

5. Operating Costs

a) Service hour increases:

- Table 3 on the following page shows that with projected service levels to 2041, preferred Scenario 3 (mixed BEB/FCEB fleet solution) will require an incremental net increase in service hours of approximately 7% (210,000 annual service hours) over the base case.
- This increase is directly tied to the range limitations associated with ZEBs, and the need to provide additional time to charge BEBs operating while on-route; operating costs will increase.
- As a result, the need for additional ZEBs (approximately 21% increase over base case) along with the incremental service hours noted above, for both revenue and non-revenue, are identified to achieve performance success of the ZEBs.
- These additional service hours are required to sustain the ZEB transition and will require additional labour hours, resulting in an 18-year total NPV for increased operations and maintenance labour expenditures of approximately $237 million for the mixed fleet solution to 2041 when compared to the base case.
- The mixed fleet solution requires the fewest number of additional vehicles to achieve a net zero solution as early as 2040.
- Refer to Table 3 for a summary of estimated annual service hours required for fleet electrification across the various scenarios, with DFAH:

		Base Case (Diesel Fleet)	Scenario 1 (full BEB solution)	Scenario 2 (full FCEB solution)	Scenario 3 (Mixed BEB/FCEB)
BEBs (with DFAH)	Current Service	1.58	1.70	1.61	1.70
	Growth Fleet (2041)	2.79	3.00	2.83	3.00

Table 3 – Annual required service hours (million hours)

- The service hours required by Brampton Transit will be impacted in two ways; the expected service growth and the transition to ZEBs.
- These two service pressures create new scheduling design challenges for Brampton's ZEB fleet.
  - The total number of current service hours for the base case (diesel buses) is approximately 1.58 million.
  - Current Service: with electrification under recommended scenario three (mixed green fleet), using BEBs equipped with DFAH, the total service hours to cover the current service levels would be 1.70 million (+7% over base case).
  - Growth Fleet 2041: However, by the time Brampton Transit achieves full electrification, the service will have grown by an additional 76%, resulting in approximately 3.00 million service hours in total (+7% over base case).

b) Energy costs:

- As CUTRIC outlines in the ZEB Strategy, both BEB and FCEBs are expected to allow for savings in maintenance costs over the long-term and both technologies will save overall operational costs in any future defined by carbon pricing mechanisms at national or sub-national levels by eliminating the most carbon intense fuel (diesel) used for propulsion.
- Using general averages for Canada, CUTRIC shows an average comparative diesel fuel consumption of 50 L/100 km and an average electrical energy cost of $0.35/kWh. This results in energy costs per kilometer as shown in Figure 1:

Figure 1 – National average cost per kilometre for energy/fuel types

c) Potential Savings (Fuel and Maintenance Costs) - Mixed Fleet Solution:

- The mixed fleet solution over the expected 18-year life cycle for ZEBs and utilizing the DFAH for BEBs is the most financially viable option (at $8.94 billion total net present value) costing less than the full BEB solution ($8.95 billion) or the full FCEB solution ($9.85 billion).

6. Energy-as-a-Service (EaaS)

- EaaS is a business model in which a service company provides electricity and related energy products and supporting services, typically for a recurring monthly fee.
- With an EaaS arrangement, the service provider may be a publicly owned entity or a privately held entity.
- The service provider may contribute financing, installs the equipment, ensures that the equipment is operating effectively, and takes on the performance risk associated with any upgrades.
- The EaaS model shifts the responsibility of development, delivery, financing, ownership, and operation from the organization to an experienced asset owner through a long-term agreement (i.e., five to 20 years).
- Options may exist so that after the EaaS contract expires the customer can purchase the equipment at fair market value (accounting for depreciation), extend the contract or return the equipment.
- As Brampton Transit pursues full fleet decarbonization, consideration should be given to having an EaaS partner.
- This EaaS partner will be expected to provide the necessary co-investment, financing, ownership, design, build, operations, and maintenance of energy infrastructure for electricity in the immediate short term, and well positioned to provide options in the medium to long term to support hydrogen supply for the growing zero emissions transit fleet.
- The EaaS partner may also provide the necessary staffing, knowledge, expertise, project and program management, and engineering services required to fulfill our electrification goals.
- Monthly EaaS fees are typically made up of fixed (such as capital and operating) and variable (such as electricity usage) components.
- These EaaS fees would be additional operating expenses separate from the other operating expenses noted in this report.
- EaaS can allow customers to implement energy projects with minimal upfront capital required and long-term leasing and financing arrangements that can vary by provider.
- The EaaS model allows organizations to focus on their core business and mission while having energy responsibilities handled by an accredited third-party expert that could provide critical service level agreements and equipment uptime guarantees to ensure that our ZEB fleet is never left without power.

a) EaaS Commercial Partnership:

- Establishing an EaaS commercial partnership would assist the City in meeting the aggressive 2040 all-electric fleet transition objective.
- Some key elements of potential EaaS engagement include risk transfer, investment, competitive procurement, and long-term partnership.
- With a commercial EaaS partner on board the City would realize many advantages over trying to implement this massive change on its own, for example:

- risk sharing, capacity, energy demand management/pricing, capital investments, guaranteed supply of services and required uptime, ongoing operation, maintenance and support, implementation support and planning, transition readiness, competitive procurement, and ownership of infrastructure.

7. Funding & Financing

The funding allocated to this study by the Government of Canada has enabled CUTRIC to complete Brampton's first-ever comprehensive ZEB Strategy; a necessary step in our electrification journey, which is the most significant technological change for bus operations in the history of Brampton Transit.

Based on CUTRIC's research, Brampton's ZEB Strategy represents the most in depth zero emission bus implementation strategy completed in Canada to date.

The zero emission target of achieving full electrification as outlined in the ZEB Strategy is achievable, and ambitious. This target will require significant funding and financing to achieve that the City will not be able to generate from the tax base and current funding sources alone.

Available Funding & Financing

Canada Infrastructure Bank or "CIB" (Federal)

- The City has secured up to $400M through the CIB to support the purchase of up to 450 Battery Electric Buses (BEBs) by the end of 2027.
- To date, the City has ordered 10 BEBs which will utilize this financing.
- The amount of financing available through this program is derived from the calculated savings of operating BEBs instead of diesel buses, over their useful life.
- While the CIB financing is a valuable tool for Brampton to leverage to electrify the transit fleet, the City must continue to advocate for and secure funding for the base cost of diesel buses, as the CIB will only provide financing towards the incremental cost of BEBs.
- Based on the first 10 BEBs ordered that will leverage the program, CIB financing will support approximately 50% of the total cost per BEB.

Zero Emission Transit Fund or "ZETF" (Federal)

- Funding program for Transit electrification projects (5 years ending March 31, 2026).
- Up to 50% funding contribution towards capital projects.
- Staff submitted an expression of interest (EOI) to Infrastructure Canada for capital projects totaling $790M of estimated project costs ($395M federal share).

- The completion of the ZEB Strategy satisfies the requisite planning required by Infrastructure Canada to progress capital funding applications.
- Subject to Council approval of this strategy, staff may proceed to submit capital funding applications for these electrification projects.

Future Funding Support

Permanent Transit Fund or "PTF" (Federal)

- Funding anticipated to become available starting in April 2026.
- While the framework of the Permanent Transit Fund is still under development, it is anticipated that the program will be administered under several sub-streams.
- These sub streams may include allocation based capital funding to municipalities and direct, application based, funding to municipalities.
- Both potential funding streams could support the City's electrification transition.

Funding Constraints

- Despite significant federal investment towards transit electrification, municipalities (especially in Ontario) are still facing a substantial funding gap.
- Federal programs like the ZETF will provide up to 50% funding towards eligible capital costs associated with municipal electrification projects. Furthermore, financing available through the CIB will support the incremental cost of BEBs.
- However, while this is a big step in the right direction, municipalities are not able to fund the other 50% of large-scale infrastructure projects (like facility electrification/retrofit projects), required to implement additional electric buses.
- Municipalities require additional support from the provincial government and/or other funding/financing partners.
- It is also critical that the parameters of current and future funding/financing programs (cost eligibility, program start/end dates, stacking restrictions, etc.) are complimentary to one another for municipalities to effectively plan and execute the projects required to support their electrification transitions.

8. Immediate Next Steps

- EaaS:
  - Determine the appropriate pathway required to execute commercial agreement(s) with an Energy-as-a-Service partner for the electrical and charging infrastructure required to support further electrification, including the possibility of hydrogen in the future.
  - This EaaS partnership is required to complete design, build, and assume operations and maintenance of electrical services and charging infrastructure

and equipment required for facility retrofits to support electric buses (Sandalwood Facility, Clark Facility and New Third Facility).

- ZETF applications to advance capital projects.
- Gap Funding:
  - Despite significant federal investments towards transit electrification, municipalities are still facing a significant funding gap to initiate full fleet electrification.
  - As part of coordinated industry government relations efforts, continue to advocate for funding from the various levels of government for ZEB related deployments (including BEBs, FCEBs, facilities and EV-related infrastructure).
  - Predicable, sustainable, flexible, and easily accessible funding is required to assist municipalities to fund these large infrastructure projects.
- Continue industry engagement including active participation on Zero Emission Bus Committees:
  - Provincial: Ontario Public Transit Association (OPTA)
  - National:
    - Canadian Urban Transit Association (CUTA)
    - Canadian Urban Transit Research & Innovation Consortium (CUTRIC)
  - North America: American Public Transit Association (APTA)

CORPORATE IMPLICATIONS:

Currently, there are no direct corporate, financial, legal, purchasing or communications impacts associated with this report. The capital and operating cost burden outlined within the economic analysis and total cost of ownership of this report are significant and will need to be considered as part of the City's annual budget process and governmental relations discussions moving forward.

STRATEGIC FOCUS AREA:

This report builds on Brampton's commitment to Environmental Resilience & Sustainability by enhancing energy and climate resilience. Additionally, the Zero Emission Bus Implementation Strategy & Rollout Plan directly supports Transit & Connectivity by providing a pathway towards adopting a sustainable all-electric zero emission bus fleet as early as 2041: significantly reducing the City's GHG emissions and carbon footprint and protecting our environment for a sustainable future.

CONCLUSION:

Brampton is a Green City, and the City of Brampton is committed to greening our transit fleet and keeping Brampton's residents moving with the safe, reliable, and sustainable service they depend on.

For the City of Brampton, transitioning to an all-electric zero-emission bus fleet in the future is a crucial and necessary step towards reducing harmful emissions, combatting

air pollution, mitigating the impacts of climate change, and contributing to achieving established GHG reduction targets.

Ultimately, transitioning to a zero-emission bus fleet is a transformative step towards creating a cleaner, healthier, more resilient, and sustainable City of Brampton for generations to come.

Authored by:	Reviewed by:
Scott Gillner, Manager, Sustainability & Innovation	Ivana Tomas, Director, Transit Services
Approved by:	Approved by:
Heidi Dempster, General Manager, Transit	Marlon Kallideen Chief Administrative Officer

Attachments:

Attachment 1:
ZEB Implementation Strategy & Rollout Plan, Summary Report, CUTRIC, March 2024