Report to
Rapport au:

Transit Commission
Commission du transport en commun
16 June 2021 / 16 juin 2021

and Council
et au Conseil
23 June 2021 / 23 juin 2021

Submitted on June 7, 2021
Soumis le 7 juin 2021

Submitted by
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Ward: CITY WIDE / À L'ÉCHELLE DE LA VILLE

File Number: ACS2021-TSD-TS-0009

SUBJECT: ZERO-EMISSION BUSES FOR OC TRANSPO

OBJET: AUTOBUS À ZÉRO ÉMISSION POUR OC TRANSPO

REPORT RECOMMENDATIONS

That the Transit Commission recommend that Council approve:

1. That the City purchase zero-emission buses for all future transit bus fleet needs, on the basis that buses are available to meet the City's operational needs and subject to financial arrangements on terms and conditions acceptable to the City

so that the purchase, transition, operation, and support is affordable under the City’s Long Range Financial Plan (LRFP) for Transit;

2. The selection of battery-electric buses with in-garage charging as the suitable zero-emission bus technology for the years from 2022 to 2027, with a review of available technologies to be carried out in 2026 for the next phase of fleet conversion;

3. That, as part of the annual capital budget each year, staff recommend to Council the number and size of buses to be purchased, whether current buses of that size are available as zero-emission buses, and whether appropriate financing is available;

4. That the General Manager, Transportation Services, be delegated the authority to negotiate and enter into an appropriate agreement with Hydro Ottawa Holding Inc. and/or its subsidiaries, as described in this report, for energy supply, the provision of backup power, and the supply and operation of charging infrastructure for the battery-electric buses;

5. That the General Manager, Transportation Services, be delegated the authority, with the concurrence of the City Treasurer, to negotiate and enter into an acceptable long-term financing arrangement with the Canada Infrastructure Bank (CIB), together with executing any amendments or supplementary agreements consistent with the terms outlined in this report and as described in this report, to have no net effect on the transit LRFP, subject to stacking rules and acceptable risk transfer;

6. That the General Manager, Transportation Services, be delegated the authority, with the concurrence of the City Treasurer, to negotiate and enter into a funding agreement for a minimum of 35 percent of implementation costs with Infrastructure Canada and any related parts of the federal government, together with executing any amendments or supplementary agreements consistent with the terms outlined in this report and as described in this report, to have no net effect on the transit LRFP, subject to stacking rules and acceptable risk transfer; and

7. That the General Manager, Transportation Services, and Chief Procurement Officer be authorized to conduct a procurement process for the multi-year provision of up to 450 battery-electric buses, as outlined in this report, with

annual orders being subject to approval by the Transit Commission and Council in the annual capital budget.

RECOMMANDATIONS DU RAPPORT

Que la Commission du transport en commun recommande au Conseil d’approuver :

1. L’achat d’autobus à émission zéro par la Ville pour tous les besoins futurs du parc de véhicules de transport en commun, au motif que les autobus répondent aux besoins opérationnels de la Ville et sous réserve d’entente financière dont les conditions sont acceptables pour la Ville de façon à ce que l’achat, la transition, la mise en service et le soutien soient abordables dans le cadre du plan financier à long terme pour le transport en commun de la Ville;

2. La sélection d’autobus à batterie électrique avec bornes de recharge dans le garage comme technologie convenable d’autobus à émission zéro pour la période de 2022 à 2027. Un examen des technologies disponibles sera effectué en 2026 pour la prochaine phase de conversion du parc de véhicules;

3. Que chaque année, dans le cadre du budget d’immobilisations annuel, le personnel recommande au Conseil le nombre d’autobus à acheter et leur taille, si des autobus à émission zéro de cette taille sont disponibles et si le financement acceptable est disponible;

4. Que soit délégué au directeur général, Service des transports le pouvoir de négocier et de conclure une entente appropriée avec la Société de portefeuille Hydro Ottawa inc. et ses filiales, conformément au présent rapport, pour l’alimentation électrique d’urgence ainsi que l’alimentation et l’opération d’infrastructure de recharge pour les autobus à batterie électrique;

5. Que soit délégué au directeur général, Service des transports et au trésorier municipal le pouvoir de négocier et de conclure une entente de financement à long terme acceptable avec la Banque de l’infrastructure du Canada (BIC) ainsi que d’apporter toute modification et de conclure toute entente supplémentaire correspondant aux conditions énoncées dans le présent rapport et comme décrit dans le présent rapport de façon à n’avoir aucun effet net sur le Plan financier à long terme du transport en commun, sous réserve de règles de cumul et de transfert des risques acceptables;

6. Que soit délégué au directeur général, Service des transports, avec l’accord du trésorier municipal, le pouvoir de négocier et de conclure une entente de

financement pour un minimum de 35 % des coûts de mise en service avec Infrastructure Canada et tout autre secteur contigu du gouvernement fédéral ainsi que d'apporter toute modification et de conclure toute entente supplémentaire correspondant aux conditions énoncées dans le présent rapport et comme décrit dans le présent rapport de façon à n'avoir aucun effet net sur le Plan financier à long terme du transport en commun, sous réserve de règles de cumul et de transfert des risques acceptables;

7. Que le directeur général, Service des transports, et le chef de l'approvisionnement soient autorisés à entamer un processus d'approvisionnement pour l'achat sur plusieurs années de jusqu'à 450 autobus à batterie électrique, comme indiqué dans le présent rapport, les commandes annuelles étant assujetties à l'approbation de la Commission du transport en commun et du Conseil dans le budget d'immobilisations annuel.

EXECUTIVE SUMMARY

Council approved the Climate Change Master Plan (ACS2019-PIE-EDP-0053) on January 29, 2020, to document the City's plans to reduce greenhouse gas (GHG) emissions, the leading cause of climate change, by 100 percent of 2012 levels by 2040. To support this goal, Council directed staff to introduce electric buses to the OC Transpo fleet, examine approaches for conversion to a full low-emission fleet, develop a transition plan, and pursue funding opportunities to achieve this goal. This report outlines the results of this work.

The focus of this report is on the immediate five-year period. As technology evolves and moves forward, staff will update the findings in this report to ensure the transition to zero-emission buses meets the City of Ottawa's needs and delivers the highest quality service to OC Transpo customers.

Evaluating Zero-Emission Technologies for Ottawa

Staff and specialist consultants evaluated a variety of energy systems for zero-emission buses based upon real world experiences across North America. Following this initial evaluation, two technologies were selected for more detailed analysis. Compressed natural gas buses, hybrid electric buses, and trolley buses were not selected for more detailed analysis due to the reasons identified below and explained in greater detail within this report. Hydrogen fuel cell and battery-electric buses were chosen for the more detailed analysis.

Compressed natural gas (CNG) is an internal combustion fuel technology that burns cleaner than diesel powered buses and while not zero-emission is often considered as a transition fuel, reducing GHG emissions as true zero-emission technology emerges. A variant of CNG is renewable natural gas (RNG) which can be used interchangeably with CNG and is a biogas produced from organic waste, agricultural production, and wastewater treatment which will be produced regardless of the need for the RNG. CNG vehicles are a proven technology running between 10 and 20 percent cleaner than standard diesel buses and do not have significant range restrictions. However, CNG buses are not zero-emission and require heavy gas tanks increasing the weight of buses reducing their operating efficiencies. Furthermore, federal funding programs supporting the transition to zero-emission buses are not applicable to the purchase of CNG buses.

Hybrid electric buses are systems that use diesel generators to charge batteries which supply the electric motor which drives the bus. These hybrid buses reduce both GHG emissions and diesel consumption without introducing any significant range restrictions nor is there a need for charging infrastructure as the batteries are charged through operation. However, hybrid electric buses are more expensive than diesel buses and do not achieve zero-emissions. OC Transpo previously ran hybrid buses between 2008 and 2019 and retired these buses with the opening of O-Train Line 1 due to their high operating costs. Again, as these buses are not zero-emission they are not eligible for federal funding programs.

Trolley buses are electrically-powered buses relying on an overhead contact wire system (OCS). Newer trolley buses draw power from both the OCS and a small battery allowing for short distances of off-wire travel. Trolley buses are zero-emission with reduced weight and do not require refueling or recharging. The installation and maintenance of the OCS along with the higher cost of the buses would make a trolley bus system in Ottawa more expensive than diesel buses and more expensive than battery-electric buses. Furthermore, the OCS system limits the use of buses and reduces flexibility in changing bus routes as the city evolves. This system also places hindrances on road use due to height restrictions and can be considered visually intrusive.

Hydrogen fuel cell buses use onboard tanks to carry hydrogen, which then reacts with oxygen in the fuel cell to produce electricity, which powers the electric motor and all bus systems in an emission-free system. These buses have a lower range than diesel buses and their heavy tanks reduce overall capacity and can limit the roads on which they may operate. It is the availability of hydrogen that is the biggest challenge with this bus type.

With no local source it would need to be shipped in from outside the region or produced on-site at great expense.

Battery-electric buses are powered by an electric motor that draws electricity from onboard batteries which require periodic charging and can be susceptible to reduced capacity on the coldest days. Charging of the batteries requires returns to the garage or on-route chargers installed at strategic points. Based on route profiles and operational needs most of the charging will be concentrated to low-use periods such as overnight. The battery capacity, frequency of charges, charge speed, and route profiles will determine how long it takes for a battery to charge and the number of times it needs to charge per day. Battery-electric buses are quieter than diesel buses and produce no emissions aside from small diesel heaters required on the coldest days. This is a more common zero-emission technology with the greatest variety of bus type available from multiple manufacturers with faster development of technology and greater levels of research compared to alternative zero-emission options. Despite the presence of the small diesel heater, battery-electric buses remain eligible for federal funding programs. Battery capacity limits the range of these buses between charges, resulting in operational limitations. Adding charging infrastructure to existing garages requires the building to be upgraded. St-Laurent Garage has the capacity to store the 40-foot battery-electric buses expected to be purchased by 2027, however, beyond that year other solutions may be needed, depending on the outcome of industry research and experience with outdoor storage of battery-electric buses in cold climates.

Battery-electric buses hold key advantages over their hydrogen fuel cell counterparts including, cost, variety, and availability. Hydrogen fuel cell buses, however, have advantages in range and in avoiding battery degradation over time. Both battery-electric buses and hydrogen fuel cell buses will require infrastructure to be installed at garages, however the charging infrastructure for battery-electric buses is cheaper and more practical than the fuelling infrastructure for hydrogen fuel cell buses. Both types of buses require additional training of staff and changes to schedules and bus deployment. Charging and fuelling are different between the two, as battery-electric buses can be charged where they are parked, while hydrogen fuel cell buses would require more service lanes to refuel than diesel buses currently do. Both bus types have similar environmental impacts with negligible emissions, apart from a scenario in which hydrogen must be trucked into Ottawa from outside the region.

Based on the above, staff recommend battery-electric buses as the selected technology for the years 2022 to 2027, with a re-evaluation at that time. Overhead pantograph chargers in bus garages are the preferred charging solution as they allow for more efficient charging and space management within the garage. Battery-electric buses are available in Canada from numerous providers including some that currently supply OC Transpo with diesel buses. The higher capacity 60-foot articulated and double-decker buses are not yet widely available with long-range battery-electric technology, but staff will continue to monitor industry trends in order to make updated recommendations at a future date. Similarly, minibuses for Para Transpo service are also not yet widely available or proven in daily operation, and staff will continue to monitor industry development to make future recommendations on how to transition the Para Transpo fleet to zero-emission.

Planning and Procuring the Future Bus Fleet

OC Transpo's bus fleet plan receives regular updates and reflects current ridership trends and projections as well as changing service levels as it outlines current and future bus needs. With a gradual phase out of diesel buses OC Transpo can achieve a zero-emission bus fleet by 2036. The next buses to be purchased, according to the fleet plan, are 74 40-foot buses to be ordered in 2022 and delivered in 2023.

Following the recommendations in this report, staff will start a procurement process for the 450 battery-electric buses required over the five years from 2022 to 2027, with annual orders being subject to approval by the Transit Commission and Council as part of the annual capital budget. The first buses to be ordered would be 74 40-foot buses for delivery in 2023. The recommendations for the annual orders will be shaped by the continued development of battery-electric bus technology and the market availability of high-capacity and paratransit buses.

The first five years of transition to electric buses will be a multi-year project with costs close to $1 billion, therefore staff will include in the capital recommendations for Transit Commission and Council the funds needed to establish and operate a program management office and the funds to engage specialist legal, financial, and technical resources.

Zero-Emission Buses – Transition and Operational Considerations

To ensure a successful and complete transition to a zero-emission fleet, staff will review and refresh this plan periodically and will bring policy and funding recommendations to the Transit Commission and Council for consideration. To begin the transition, maintenance facilities will need to be upgraded to support the upkeep of the new fleet. A comprehensive training plan will be developed for all staff affected. Integration of energy management systems will ensure that energy supply and battery use are managed in integration with operational systems. Over time, as the transition to battery-electric buses nears its end, the removal of infrastructure, tools, and spare parts that support diesel buses will need to occur.

In planning for the charging of batteries, load balancing will allow for a more efficient charging scheme and can either shift peak demand to reduce energy costs or flatten peak energy demand for a more consistent power draw. Energy costs are typically lowest overnight which coincides with the lowest operational demand for buses therefore allowing for alignment of these low-cost times and bulk charging. Beyond this, midday charging for some of the fleet will be required to provide service all day long.

To manage battery degradation buses can be stored with lower states of charge and by avoiding their maximum range every day. For planning purposes, the effective range of the 40-foot battery-electric bus is 286 km, an estimation that will help preserve battery life and covers approximately 60 percent of the current schedule blocks for 40-foot buses. Battery degradation, operational needs, and technological advances will all be monitored to ensure that as more battery-electric buses come into service OC Transpo can meet its operational needs and service level commitments.

Financing the Transition to Zero-Emission Buses

Converting the bus fleet to zero-emission comes with a significant cost for the buses, infrastructure upgrades, and transition requirements to support them. The cost to convert to a zero-emission bus fleet as well as the infrastructure was not included in the City’s last long range financial plan (LRFP) for transit and is not affordable without new funding from senior orders of government. The federal government has announced two funding programs to support the transition to zero-emission bus fleets, a loan program through the Canada Infrastructure Bank and grant funding through the Transit Fund. The recommendations in this report are based upon taking advantage of these programs in combination with the bus fleet replacement and growth funding identified in the transit LRFP.

The unit cost of a 40-foot battery-electric bus is approximately $1.3 million. The cost of charging equipment is approximately $20 million for the first year’s order of buses or $83 million for the first five years. Charging equipment for buses can be purchased and installed as the electric bus fleet grows in size. Upgrades to the on-site electrical elements at St-Laurent garage will cost approximately $48 million. The one-time cost of grid and substation upgrades at St-Laurent garage is approximately $25 million. A natural gas powered backup generator is also needed to ensure service continuation during power grid disruptions and is estimated to cost $14 million. The total program cost between 2022 and 2027 for 450 zero-emission buses and their supporting charging infrastructure is estimated to be $986 million.

The transit LRFP includes the cost of planned diesel bus purchases through 2048. This money would be put towards electric buses with federal funding covering the added capital costs, to ensure the City is kept whole. The Canada Infrastructure Bank loan program will cover the additional costs of the electric buses above and beyond the costs associated with diesel buses, with the loan amount repaid through operational savings. The report recommends that staff be given the delegated authority to enter into the appropriate agreements for this loan.

In early 2021 the federal government announced a new grant program to further support the transition to zero-emission public transit. Following approval of this report, staff will apply for this federal funding, aiming for it to cover a minimum of 35 percent of the cost of the full program.

The total cost savings from maintenance of a battery-electric bus is difficult to estimate as no North American transit agency has long term data on this due to how new the technology is. However, operating and maintenance costs are expected to be lower for battery-electric buses when compared to diesel. This allows OC Transpo to achieve the savings required to pay back the Canada Infrastructure Bank loan for the acquisition of buses and charging infrastructure. Based on the experiences of other transit agencies, staff forecast the cost to maintain a 40-foot battery-electric bus to be about 65 percent of the cost to maintain a diesel bus. Charging the battery-electric buses will cost about 40 percent of the cost to fuel diesel buses. The anticipated lifecycle of the battery-electric buses is expected to be the same as diesel buses at 15 years, though the batteries are currently expected to last only 12 years.

Risk and Mitigation

With no data on the long-term reliability of battery-electric buses there is a risk that these buses will not perform as anticipated in the later years of their serviceable life. This can impact service, however by phasing the full fleet transition over 15 years this risk can be mitigated. If continued advancements in battery technology are not realised, there is a risk that the battery-electric buses would not be able to service all of OC Transpo’s existing schedule blocks, which would require shorter blocks to be scheduled, and higher operating costs as buses return the garage more often, or require in-field charging. There are also currently only limited options for battery-electric 60-foot articulated and double-decker buses. If options for these high-capacity buses to meet OC Transpo’s service needs do not come to market, a higher number of 40-foot buses could be used to provide the same capacity, at a higher operating cost. There is also a risk that federal government policy may shift over the 15 years required to complete the transition of the entire fleet, leaving a funding shortfall. The recommendations related to financing are based on conditions not yet fully finalised with Infrastructure Canada and the Canada Infrastructure Bank.

Conclusions

Transitioning to zero-emission buses can have several benefits including improved air quality, lowered corporate GHG emissions, lower noise pollution, and improved working conditions for OC Transpo staff. Zero-emission buses can also lead to significant operating and maintenance cost savings, which will offset the higher purchase price and the conversion costs. To meet the goals of the City's Climate Change Master Plan, the full electrification of public transit is necessary, and the transition to a full fleet of battery-electric buses by 2036 along with expansion of the O-Train system moves the City in this direction.

BACKGROUND

On June 12, 2019, Council directed staff to:

- Introduce electric buses to the OC Transpo fleet within this term of Council,
- Continue to monitor research conducted by various agencies such as the Canadian Urban Transit Research and Innovation Consortium (CUTRIC) and ongoing alternative energy pilot projects in other Canadian municipalities,
- Start working on a plan in this term of Council to further expand the number of buses that rely on cleaner sources of energy by 2025, and,
- Pursue funding opportunities dedicated to transit and environmental initiatives that may arise at other levels of government to help fund this transition to cleaner sources of energy.

Council approved the *Climate Change Master Plan* on January 29, 2020, as the City's overarching framework to reduce greenhouse gas (GHG) emissions and respond to the current and future effects of climate change. The *Climate Change Master Plan* identifies short, medium, and long-term GHG reduction targets based on 2012 levels: a 30 percent reduction by 2025, a 50 percent reduction by 2030 and a 100 percent reduction by 2040.

The Transit Services 2020 Business Plan approved by the Commission on February 19, 2020 identifies the Alternative Fuels Program for the OC Transpo fleet as one of the 12 priority projects for 2020.

In 2020, the City purchased four 40-foot battery-electric buses for delivery and entry into service in 2021.

DISCUSSION

This report presents the results of research and analysis to answer the questions that staff were asked to address on the subjects of alternative energy sources, the advisability of a fleet-wide conversion to zero-emission buses, the practical aspects of such a conversion, and the financial and risk considerations. The report also presents recommendations for policy decisions for the consideration of the Transit Commission and Council.

In preparing this report, staff have worked with three external firms. Dillon Consulting has been the zero-emission bus technology subject matter experts. Envari Energy Solutions, a subsidiary of Hydro Ottawa, has provided information on the work required to upgrade OC Transpo bus garage sites in order to charge battery-electric buses, along with the associated cost estimates. Deloitte has consulted on the development of the financial models and risk analysis.

The report also builds on the experience of other Canadian transit systems who have operated battery-electric buses or have evaluated zero-emission buses. Staff have used information from the transit systems in Durham Region, Edmonton, Halifax, Québec City, Saskatoon, Toronto, and Winnipeg, and thank all these agencies for their assistance.

The discussion section of this report is divided into six major sections:

1. Evaluating Zero-Emission Technologies for Ottawa
2. Planning and Procuring the Future Bus Fleet
3. Zero-Emission Buses – Transition and Operational Considerations
4. Financing the Transition to Zero-Emission Buses
5. Risks and Mitigation
6. Conclusions

Bus technology is changing, responding to market demands as transit systems increasingly purchase zero-emission buses, and responding to research and evolution of zero-emission technologies. The conclusions of this report will need to be refreshed in the years to come. The recommendations in this report are for bus acquisition, transition of operations, and the supporting infrastructure for approximately the next five years.

1. Evaluating Zero-Emission Technologies for Ottawa

Staff retained Dillon Consulting, a consulting engineering company with substantial expertise in the area, to evaluate the different energy sources and technologies available for zero-emission buses and to assess their applicability and feasibility for the OC Transpo system and for the Ottawa climate.

The project team completed an industry scan of projects and reports from transit agencies across North America to identify any potential, realistic options for reduced or zero emissions energy systems for buses. The following different energy sources were evaluated to determine which to carry forward for detailed assessment and consideration for the OC Transpo bus fleet.

1.1. Compressed Natural Gas (CNG) and Renewable Natural Gas (RNG)

CNG is an internal combustion engine technology that burns compressed natural gas instead of gasoline or diesel. While CNG is a fossil fuel, producing greenhouse gas and other emissions, it is considered cleaner than other internal combustion propulsion technologies. This is because burning natural gas produces fewer air pollutants and carbon dioxide (CO_2) emissions than burning coal or petroleum products to produce an equal amount of energy. Due to its cleaner nature, it is often considered a transition fuel that can help reduce fleet emissions as zero-emission technology matures and is implemented.

A variant of CNG is Renewable Natural Gas (RNG). As a fuel, RNG is functionally the same and can be used interchangeably with CNG. However, RNG is derived from biogas that is captured from sources such as organic waste, agricultural production, and wastewater treatment. Since the biogas would have been produced regardless, RNG is produced using renewable sources rather than extracted from the environment like CNG is. In this way, while local vehicle emissions remain, the overall greenhouse gas emission impact is reduced.

1.1.1. Benefits of CNG buses:

CNG vehicles are an existing and proven technology. Buses powered by CNG are between 10 and 20 percent cleaner than standard diesel bus technology. There are no significant range restrictions as compared to diesel buses.

1.1.2. Limitations of CNG buses:

CNG buses are not zero-emission as they produce local vehicle emissions, even when using RNG, including toxic substances beyond greenhouse gases. Additionally, access to RNG depends on geography and RNG can be significantly more expensive (as much as seven times more) than conventional CNG. Heavy gas tanks result in CNG buses being around 1,300 kg heavier than diesel equivalents.

Funding from Infrastructure Canada and the Canada Infrastructure Bank does not apply to CNG or RNG buses as they are not zero-emission technology.

1.2. Hybrid Electric

This technology uses a combination of a diesel engine and electric batteries to power the bus, thereby reducing diesel consumption and local vehicle emissions as compared to a traditional diesel bus. While there are two main hybrid systems, modern hybrid buses are series systems. The internal combustion engine is used to generate electricity and the bus is constantly powered by electric motors, with no mechanical transmission connected to the engine. The engine can operate at any time to ensure that enough electricity is available and stored in the batteries for use when needed.

1.2.1. Benefits of hybrid electric buses:

Reduced local emissions and diesel consumption compared to standard vehicles. There are no significant range restrictions as compared to diesel buses. Unlike fully electric buses, no charging infrastructure is required as batteries are charged during operation.

1.2.2. Limitations of hybrid electric buses:

Hybrid buses are more expensive than diesel buses and are not zero-emission.

OC Transpo operated hybrid buses between 2008 and 2019. All of the hybrid buses were retired following the opening of O-Train Line 1 because of their high operating costs. The hybrid buses had first-generation electric batteries and were purchased between 2008 and 2010. Battery technology has improved since then.

Funding from Infrastructure Canada and the Canada Infrastructure Bank does not apply to hybrid buses as they are not zero-emission technology.

1.3. Trolley Buses

Trolley buses are 100 percent electrically-powered vehicles that use an overhead contact wire system (OCS) to supply the electricity. The OCS requires two wires – one each for the positive and negative currents and, as a result, trolley buses feature distinctive twin trolley poles.

Most new trolley buses are designed to draw power from the overhead wire system as well as an on-board battery to accommodate off-wire travel for detours or to extend the service. The battery capacity is typically much smaller than on a dedicated battery-electric bus, sometimes enough for just a few kilometres. Operating connected to the overhead wire allows trolley buses to have, theoretically, an infinite range. This makes trolley buses potentially suitable for those routes or corridors where buses have scheduled work blocks that are longer than the range of battery-electric or hydrogen fuel cell buses.

1.3.1. Benefits of trolley buses:

Trolley buses produce zero local emissions, and the energy is as clean as the electricity supplied to the grid. The weight and maintenance are reduced since there is no requirement to carry bulky batteries or an internal combustion engine on board. No fueling or recharging infrastructure is required.

Within the OCS system, there is effectively no range limitation. Trolley buses are also quieter than diesel or CNG buses.

1.3.2. Limitations of trolley buses:

The capital costs of a trolley bus system are much higher than diesel buses due to multiple costs including the vehicles, the OCS, and ongoing OCS maintenance.

These buses can only operate where OCS has been installed, limiting day-to-day and long-term flexibility, and requiring replacement with other vehicles during detours that exceed the range of the small battery pack. The OCS itself has several limitations. It must be supplied by electricity from a network of substations across the transit system, it imposes height restrictions for all vehicles on roads with an OCS, and it can be considered visually intrusive.

CNG and hybrid electric buses were not carried forward into the second phase of the study because they are not zero-emission technologies. Trolley buses were not carried forward into the second phase because of their very high cost and limited applicability in Ottawa.

The two technologies that are included in the second phase of the study, the detailed assessment of technologies, are hydrogen fuel cell buses and battery-electric buses.

1.4. Hydrogen Fuel Cell Buses

Hydrogen fuel cell is a technology that is used to power 100 percent electric buses. Instead of storing energy in batteries, hydrogen is carried onboard and then converted to electricity by reacting with oxygen in the fuel cell. The drive train and all bus systems are electrically powered and the only local emission from the vehicle is water vapour.

1.4.1. Benefits of hydrogen fuel cell buses:

Hydrogen buses have zero local emissions and energy is as clean as the hydrogen supply. In limited areas, hydrogen is available as a by-product of industrial processes at a low cost.

1.4.2. *Limitations of hydrogen fuel cell buses:*

Hydrogen fuel cell buses have a lower range than conventional diesel buses. They also have heavy tanks that result in the buses being approximately 4,500 kg heavier than diesel equivalents. This reduces capacity and can lead to high axle loads, restricting the buses from being able to operate on some streets.

The most significant limitations come with obtaining the necessary hydrogen. Hydrogen must either be sourced externally and shipped to the garage site or manufactured on site, and both options are more expensive and less convenient than using the direct energy supply to charge battery-electric bus batteries. Hydrogen is not currently available locally in Ottawa and would need to be transported from outside the region. Some Canadian options are located in Bécancour, Québec, Magog, Québec, or Sarnia, Ontario. The two locations in Québec are roughly 330 km from the St-Laurent bus garage, while Sarnia is about 700 km away. There would be transportation costs to move the hydrogen to Ottawa, as there are currently for diesel fuel, and emissions generated by the transportation.

1.5. Battery-Electric Buses

Battery-electric buses are primarily powered by electricity stored onboard in batteries. Electric motors are used to propel the bus and the batteries are primarily charged from outside sources when the buses are out of service at the garage. Some systems also install chargers at terminals of bus routes, to allow buses to charge during the day. As battery capacity is currently limited, on the coldest days of the year, some heating is provided by a small diesel heater.

These buses must return to the garage to recharge and the frequency of this is dictated by the capacity of the onboard batteries and the nature of the routes operated. This is similar to diesel buses, which return to the garage to refuel. Generally, low-speed, low-draw charging technology is used, subject to the number of buses at the garage and the amount of out of service time available. With most buses on the road during the day during peak periods, charging demand will be concentrated to the garage during low use periods, like overnight, with some buses available to be charged during the middle of the day.

Charging infrastructure installed in the garages consists of charging packs that receive the electricity from the distribution network in the garage and connections between the charging packs and the buses themselves. The connections can be either cables from ground-mounted charging packs that plug into a connection point somewhere on the bus, or overhead pantographs with charging packs that connect to receiving points on the roof of the bus.

On-route charging is also possible with battery-electric buses. Infrastructure is required at strategic points along routes instead of being concentrated at the garage. High speed, high draw charging is required to minimize the time stopped on route. The result is more frequent, smaller charges and requires buses to wait longer at charging stops than would otherwise be required. On-route charging facilities can limit the possibility of adjusting routes, are expensive to install, and the space required along routes can be difficult to find.

1.5.1. Benefits of battery-electric buses:

Battery-electric buses have almost zero emissions as the only emissions come from the small diesel heater. The absence of a large internal combustion engine means battery-electric buses are quieter than diesel buses.

Battery-electric buses are more common in the transit industry, with more size options available from more manufacturers, compared to hydrogen fuel cell buses. Therefore, infrastructure and technologies tend to be developing faster with greater cohesion between suppliers and infrastructure companies, and more research being undertaken than other energy systems.

1.5.2. Limitations of battery-electric buses:

Battery-electric buses are not 100 percent zero emission; a small diesel heater is needed to assist with heating during cold weather, while cooling is provided by an electric air conditioner. The diesel heater is supplementary to the main electric heater and is only used during periods of extreme cold. Without a diesel heater, the bus range would be reduced as energy from the battery would be directed towards heating. Despite the diesel heater, the Canada Infrastructure Bank and Infrastructure Canada consider a battery-electric bus to be zero-emission and the buses qualify for federal funding.

Battery capacity limits result in a shorter range than other bus types, resulting in operational limitations. As buses are procured for use in different cities, transit systems specify the trade-offs between bus weight and bus range, and manufacturers configure their product to achieve the specified targets.

Low daily hours of bus downtime can make the required garage charging problematic. Charging is focussed on the time between the morning and afternoon peak periods and overnight.

Batteries are heavy, resulting in buses being around 2,700 kg heavier than the diesel equivalent.

Charging infrastructure can also pose problems. Some charging infrastructure may not be able to be accommodated at existing garages and is potentially expensive to retrofit, potentially requiring garage rebuilding. Charging at garages requires significant electrical grid capacity upgrades, adding to the cost.

Storing energy at garages in the case of a supply failure is currently more expensive than storing diesel fuel and is not feasible based on space requirements. This function would require a storage battery to be located on-site. A storage battery with enough power to fully charge 200 buses would be very large, similar in size of a football field. A feasible alternative is to install a local backup power generator that will be used to charge batteries during a power outage.

There is limited experience with outdoor storage of battery-electric buses in cold climates, and staff will be monitoring developments in this area.

1.6. Comparison of Hydrogen Fuel Cell with Battery-Electric

1.6.1. Vehicles:

When considering the bus itself several factors were considered including cost, availability of sizes, range and range degradation, and reliability.

Battery-electric buses hold many advantages over fuel cell buses. Battery-electric buses are currently generally less expensive than hydrogen fuel cell buses. Battery-electric also holds the advantage in availability of sizes, as standard 40-foot buses, articulated buses, and double-decker buses are all available, although the articulated and double-decker models currently available do not have as much range as the 40-foot buses. Forty-foot and articulated hydrogen fuel cell buses are also available in North America, but double-decker hydrogen fuel cell buses are rare. There are more manufacturers of battery-electric buses in North America than there are manufacturers of hydrogen fuel cell buses, indicating that the bus manufacturing industry appears more optimistic that battery-electric bus technology will advance at a faster rate than hydrogen fuel cell bus technology. This has already been seen, as battery-electric technology has surpassed hydrogen fuel cell on several key factors.

There are some advantages to hydrogen fuel cell buses. Hydrogen fuel cell buses currently have a higher maximum range than battery-electric buses, meaning that there is less potential requirement for scheduling adjustments and active energy management with hydrogen fuel cell buses. Hydrogen fuel cell and battery performance and range both decline over time, but the impact on performance and range for fuel cell buses is likely less than battery-electric buses.

1.6.2. Infrastructure:

Infrastructure considerations include fueling and fuel storage infrastructure, potential on-route infrastructure, and cost, availability and source of energy.

Battery-electric buses have many advantages over hydrogen fuel cell buses when charging/fueling infrastructure is considered. For hydrogen fuel cell buses, the most significant hurdle is obtaining the hydrogen. It must either be sourced externally and shipped to the garage site or manufactured on site, and both options are more expensive and less convenient than using the direct energy supply to charge battery-electric buses. Sourcing hydrogen externally and having it trucked to the site is less convenient and more expensive long-term than using the direct energy supply for charging batteries. This can be mitigated by producing the hydrogen on site, but this requires high amounts of electricity and grid supply upgrades. The infrastructure cost of getting electricity to the garage site for charging or creating hydrogen is greater for the hydrogen fuel cell option because of the necessity to construct an electrolyzer to create the necessary hydrogen. Creating hydrogen requires about 40 percent more electricity than is required to charge battery-electric buses, while electricity is directly available from the grid (with necessary grid supply upgrades) for battery-electric buses. Battery-electric buses also have the option of on-route charging in order to provide operational flexibility. This is not practical for hydrogen fuel cell buses.

Charging for battery-electric buses will require extensive overhead or ground-based infrastructure throughout the garage facility while hydrogen fueling can be accommodated in the same daily service lanes being used for today’s diesel fleet. However, hydrogen fueling may take longer than diesel fueling and may need to be undertaken more frequently than diesel fueling, which could result in increased demand on the daily service lanes and/or the need for additional service lanes. The ventilation systems in OC Transpo garages would need to be inspected and would likely need to be upgraded if hydrogen fueling takes place.

1.6.3. Operations:

Factors to consider that impact operations include impacts to scheduling and staff, fleet size implications, and impacts to the fueling process.

Training is required for operators and maintenance staff for both battery-electric and hydrogen fuel cell buses. The fleet size can remain the same with both technologies. However, modifications to the schedules that dictate how buses are deployed on the roads would be required to maintain the fleet size with either technology. Both technologies have a similar impact on scheduled work blocks (successive bus route trips run by the same bus and bus operator), as most blocks can be operated within the current range of hydrogen or battery-electric buses.

The fueling process for hydrogen fuel cell buses is similar to the process for diesel buses, but more service lanes would be required as the range of the buses is lower than diesel buses. Creating more service lanes would necessitate the capital costs of expanding the garage. Charging battery-electric buses requires building charging infrastructure to the bus parking lanes, but reduces the time spent by each bus in the service lanes, as fuelling is not required.

With both technologies, the hope is that range will increase and battery or fuel cell degradation will be reduced as the technologies improve. Overall, it is currently more likely that battery-electric will show greater improvement, as there are more battery-electric buses in service today.

1.6.4. Environmental Aspects:

The local environmental aspects of battery-electric and fuel cell are similar. For both, energy is sourced from the main electrical grid. Vehicle emissions are negligible compared to diesel and both technologies produce less noise than diesel buses. While the recycling for both technologies is unproven, it is likely to improve in the future as each technology matures. As noted earlier, there would be an environmental impact if hydrogen were transported to Ottawa.

1.7. Recommended Technology: Battery-Electric Buses

Based on the above, staff are recommending that battery-electric buses be the selected technology for the years from 2022 until 2027. This is influenced by the variety of available bus sizes, greater potential for range and battery capacity improvements, and the charging advantages that battery-electric has over the fueling process for hydrogen fuel cell buses. Knowing that there are more battery-electric buses on the road today, and the general optimism in the industry that battery-electric bus technology will continue to improve have also influenced this decision. Staff will carry out a review of the state of energy sources and energy delivery technology about five years from now to inform the next phase of fleet conversion.

Overhead pantograph chargers in bus garages are the preferred choice for charging the buses, as the space required for ground mounted chargers will reduce the bus storage space available in the garage. Plug-in chargers with ceiling mounted retractable cords is an option, but this would create many hanging cords and would require more staff attention to manage. An advantage of overhead pantographs is the automated connection process. The charger connects with the bus once the bus is parked in the charging location, removing the need for staff to connect and disconnect charging cords. Overhead pantograph charging allows for one power pack to charge two buses sequentially overnight without the need for any manual switching between the buses and without a need for the buses to be moved. One power pack can be connected to two pantographs, with each pantograph connected to a separate bus. The power pack will charge the first bus, then automatically switch to the second bus when the first bus is charged.

Several other Canadian cities are in the process of procuring zero emission buses to begin the transition of their bus fleets. Edmonton Transit put 40 battery-electric buses into service in 2020. In Montréal, the STM has seven on-route charging electric buses on the road today, and they are also procuring 30 slow-charge buses. The TTC in Toronto has 60 battery-electric buses on the road, with the first one put into service in 2019. York Region Transit purchased six battery-electric buses in 2019. Brampton Transit put eight battery-electric buses into service in early 2021. Winnipeg Transit is deploying a test fleet of 16 zero-emission buses with a mix of battery-electric and fuel cell buses of different sizes.

1.8. Battery-electric bus availability

1.8.1. Buses for conventional OC Transpo bus routes:

An industry scan conducted by Dillon Consulting in late 2020 showed that battery-electric buses suitable for use in Canada are currently available from Alexander Dennis, BYD, New Flyer, Nova Bus, and Proterra.

The OC Transpo fleet currently has diesel buses from Alexander Dennis, New Flyer and Nova Bus. BYD and Proterra battery-electric buses are currently in use in other Canadian cities, including Toronto.

High-capacity 60-foot articulated and double-decker buses are not yet widely produced. As over half the OC Transpo bus fleet is made up of high-capacity buses, staff will be following industry trends in this area closely, in order to be able to make recommendations to the Transit Commission and Council.

1.8.2. Minibuses for Para Transpo service:

The results of an industry scan have shown that alternative energy technologies for transit vehicles for paratransit service are lagging behind conventional vehicles. Today, there are no large-scale implementations of zero-emission vehicles in paratransit service. Though some manufacturers have announced their plans for paratransit vehicles, they are to this point largely untested in regular transit service conditions. Staff will be monitoring the progress of the transit industry closely, in order to be able to make future recommendations to the Transit Commission and Council on how best to convert the Para Transpo fleet to zero-emission technology.

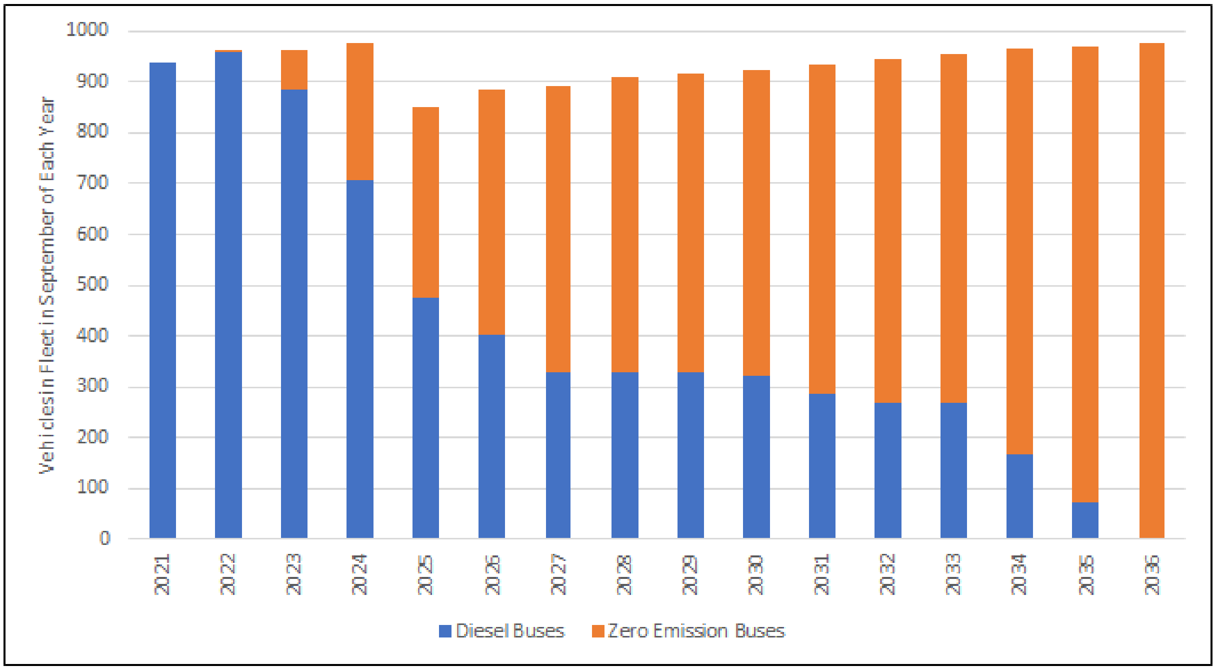
2. Planning and Procuring the Future Bus Fleet

2.1. OC Transpo Bus Fleet Plan

OC Transpo’s fleet plan is regularly updated to respond to changes in actual and forecasted ridership levels, to reflect the retirement of buses from service as they age, and to take into account any other necessary considerations when planning for future bus needs. The fleet plan contains information on the number and type of buses currently in service and projects the number and types of buses to be purchased, with projections currently out to 2048.

Figure 1, below, shows the projected transit fleet composition. With the gradual phase-out of diesel buses as they reach their end of life, and their replacement with zero-emission buses, OC Transpo could achieve a fully zero-emission bus fleet by 2036. This is based on one-to-one replacement of all bus types and is contingent upon the availability of suitable buses to purchase, and that the buses be purchased at no net additional cost to the city.

Figure 1: Projected Overall Transit Fleet Composition



New bus purchases and projections for future years have historically been based on projected ridership, overall capacity, and maintenance requirements. They also take into account Stage 2 expansion of the O-Train network and the replacement of buses by trains. (The effects of the future Stage 3 would be included in future revisions of the plan, one the implementation dates are known.)

Table 1, below, shows the number of new bus purchases per year until 2036, broken down by bus type. Replacement buses are purchased to replace older buses that have reached the end of their service life. Growth buses are purchased to accommodate projected increases in ridership that come from the City’s travel demand forecasting model and long-range financial plan for transit. The table shows that the next buses to be purchased are 74 40-foot buses to be delivered in 2023, followed by 42 40-foot buses, 66 60-foot articulated buses, and 82 Para Transpo minibuses in 2024.

Following consideration of the recommendations in this report, staff would bring a recommendation to the Transit Commission and Council as part of the 2022 capital budget to purchase 74 40-foot battery-electric buses and the supporting electrical charging and supply infrastructure. Staff would bring further recommendations for the purchase of 40-foot battery-electric buses in the capital budgets for future years.

Following procurement, manufacturing, and testing and commissioning, buses are expected to be in service the year after the capital budget in which they are approved. For example, buses approved by Council in the 2022 capital budget would normally be in service and carrying customers in 2023.

As noted earlier, minibuses for Para Transpo service and high-capacity, long-range double-decker and 60-foot articulated buses are not yet widely available or tested to meet the operating requirements for Ottawa. Staff will continue to engage with potential suppliers, other transit agencies, and transit industry associations to follow emerging trends and to develop recommendations for the consideration of the Transit Commission and Council. Some options to be considered for high-capacity buses may include purchasing shorter-range buses with on-route charging for operation on major Transitway routes, a two-part procurement allowing manufacturers to bid with either diesel or zero-emission buses, or changing the fleet composition to use more 40-foot buses and fewer high-capacity buses. Options for Para Transpo minibuses will depend on developments in the market.

Table 1: Number of New Bus Purchases per Year

Fleet Acquisition
Vehicles available for service for September of each year
Capital funding requests to come one year in advance

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Total new 40-foot buses required	**74**	**42**	**42**	**42**	**14**	**9**	**4**	**5**	**5**	**6**	**7**	**87**	**96**	**78**
for replacement	74	42	42	21	-	-	-	-	-	-	-	82	81	74
for growth	-	-	-	21	14	9	4	5	5	6	7	5	15	4
Total new 60-foot articulated buses required	**-**	**66**	**66**	**67**	**12**	**6**	**4**	**3**	**4**	**3**	**4**	**5**	**2**	**2**
for replacement	-	66	66	52	-	-	-	-	-	-	-	-	-	-
for growth	-	-	-	15	12	6	4	3	4	3	4	5	2	2
Total new double-decker buses required	**-**	**-**	**-**	**-**	**55**	**-**	**-**	**6**	**38**	**17**	**-**	**19**	**-**	**-**
for replacement	-	-	-	-	55	-	-	6	37	17	-	19	-	-
for growth	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Total new Para Transpo minibuses required	**-**	**82**	**-**	**-**	**-**	**-**	**-**	**-**	**82**	**-**	**-**	**-**	**-**	**-**
for replacement	-	82	-	-	-	-	-	-	82	-	-	-	-	-
for growth	-	-	-	-	-	-	-	-	-	-	-	-	-	-

2.2. Procurement

The City’s first four battery-electric buses are currently being manufactured, for delivery and entry into service later in 2021. A request for proposals (RFP) for heavy-duty battery-electric low-floor transit buses was issued by the City in 2020. The design requirements included in the RFP were for a 40-foot bus with a minimum seating capacity for 36 customers, including two personal mobility device locations.

This report recommends that a procurement process be launched for the provision of 450 buses over the years from 2022 to 2027, with the annual orders being subject to approval by the Transit Commission and Council in the annual capital budget. This would be a new competitive procurement process, and not an add-on to any existing contract. Staff will explore the possibility of a joint procurement with other transit systems, such as through Metrolinx or CUTRIC. (Procurement of diesel 40-foot buses in recent years has been through a province-wide joint procurement organized by Metrolinx.)

As described more fully later in this report, the specifications for buses in future years will require a longer range (the distance that a bus can cover from one charge to the next). Staff will ensure that the procurement process allows for the specifications to be adjusted based on the expected continuous improvements in battery and power technology and based on the availability of all four bus types used in the OC Transpo system.

Following budget approval by Council, the process to order, manufacture, deliver, and commission buses can take 12 to 18 months, so buses ordered in early 2022 should be ready for service during 2023.

For the charging infrastructure, this report recommends that the City enter into an agreement with Hydro Ottawa to procure, supply, install, and operate for the City the electrical equipment and charging equipment initially in St-Laurent bus garage, and later if necessary in other locations. Funding for these works would also be included in the annual capital budgets for approval by the Transit Commission and Council.

It is possible that, prompted by the federal funding programs, the demand for battery-electric buses will result in longer lead times for manufacturing. Staff will seek to mitigate this by reviewing the possibility of long-term contracts.

2.3. Program Management

The multi-year program to convert the City's bus fleet from diesel to zero-emission will be a major City program, with capital costs of close to $1 billion in the first phase alone, and with many aspects that will require new knowledge and expertise. Staff will include in the capital budget recommendations for Transit Commission and Council sufficient funds to establish and operate a program management office, and also sufficient funds to engage the specialist legal, financial, and technical consulting resources that will be required.

Specialist legal and financial advisors will also be needed to complete the recommended agreement with the Canada Infrastructure Bank and Infrastructure Canada, as described more completely below.

3. Zero-Emission Buses – Transition and Operational Considerations

3.1. Transition

Making the transition from an all-diesel bus fleet to an all zero-emission bus fleet will be a major program for the City. Some aspects of the transition will need to be in place as the first four battery-electric buses enter into service later this year, and some aspects will come with time, as more and more of the current fleet is replaced by zero-emission buses. Some aspects of the transition will depend on future technology decisions which cannot currently be known. Staff will review and refresh this plan as needed and will bring policy and funding recommendations to the Transit Commission and Council for consideration.

3.1.1. Maintenance Facilities:

Facility upgrades will be necessary, beyond the upgrades required for charging infrastructure. Bus maintenance areas will need to be modified to safely maintain electric buses. Cranes, platforms, and fall arrest systems will need to be installed in order to remove rooftop batteries. The roof structures at garages will need to be modified so the pantographs can be supported. Storage areas will need to be added to store batteries, tools and equipment. The bus bays will need modifications such as hoists, arc flash guards, and new signage.

3.1.2. Training and staffing:

Training OC Transpo staff is an important consideration. The majority of training costs will be associated with operators and mechanics. They will be trained on how the new technology works and how to safely work with it. Some training will be needed for other staff, such as training on how to safely work in an area where high voltage charging takes place. A full training plan will be developed for OC Transpo. Portions of the plan will likely involve training from the original equipment manufacturer while other portions of the plan will call for OC Transpo employees to be pulled from normal duties, requiring replacements to cover those duties. This will be captured in the training plan.

In addition to the program management office described above, there may be a need to add new specialist staff to the OC Transpo maintenance team, and it is expected that there will be changes in the nature of the work that the bus technicians do, given the new technologies of battery-electric buses. A staffing plan will be developed and implemented as part of the program.

3.1.3. Integration of Energy Management Systems:

Battery-electric buses and the charging infrastructure associated with them will require work by OC Transpo staff to ensure that energy management systems are integrated with our operational systems. This ties into the load balancing mentioned below. This system integration will involve IT-related commissioning, including required connectivity from devices to the back-office management system, and potentially, interfaces to the control centre and bus parking management systems. The energy management application software will require hosting services and data storage capabilities within the City's IT infrastructure. Maintenance of the software, servers, networks and databases will be required continuously to ensure the system remains up to date and secure for reliable and efficient operations.

3.1.4. Eventual Removal of Diesel Equipment:

OC Transpo will eventually need to remove diesel infrastructure from our garages. This includes gas storage tanks, fuel lines, gas pumps, tools and spare parts that are used on diesel buses but won't be needed for battery-electric buses. Proper decommissioning or disposal of these items will need to be examined as more battery-electric buses come into service.

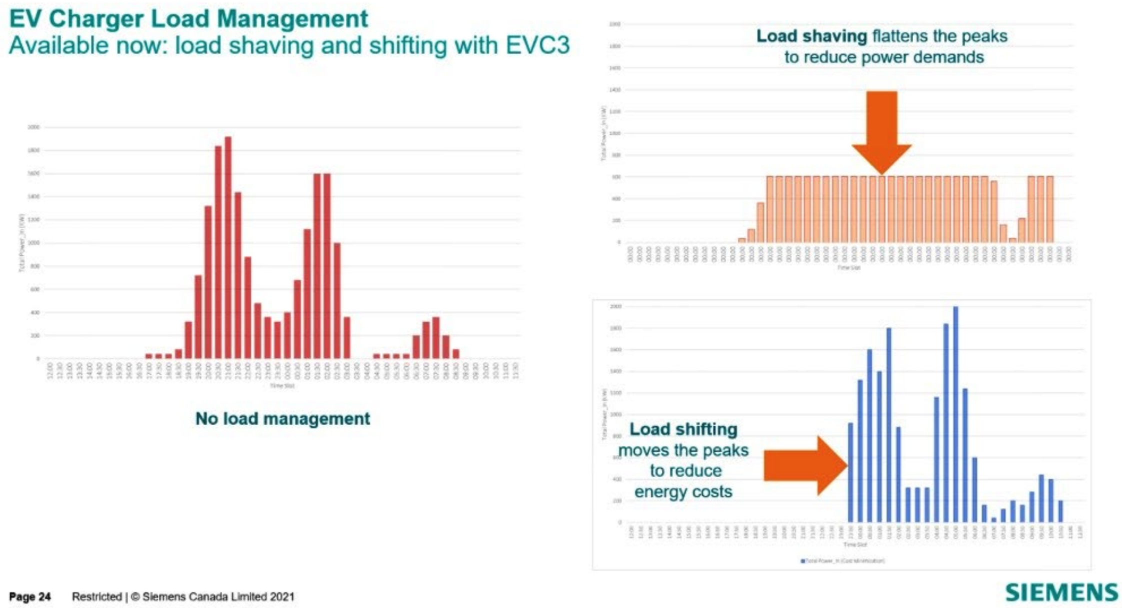
3.2. Energy Management

Energy management will play a critical role in operating a zero-emissions bus fleet, to ensure that buses are being charged at times that do not coincide with the times of peak electricity consumption in the province. Most bus charging will be done overnight, when power demand is at its lowest.

3.2.1. Load Balancing:

It will be important to mange bus charging efficiently, to take full advantage of the buses and the charging infrastructure, and to moderate the peak electrical requirements of the system. Battery chargers can be integrated into a charger network and charger management software can monitor, report, optimize and control networked charging infrastructure. This software can control power distribution to chargers and automatically adjust the distribution based on parameters set by OC Transpo in cooperation with Hydro Ottawa, including fixed power limits, bus schedules, and energy pricing. This is known as load balancing and load shifting and can ensure that charging is done as efficiently as possible. Figure 2 shows a visual representation of load shaving and load shifting from one potential supplier.

Figure 2: Load Shaving and Load Shifting (source: Siemens)



3.2.2. Midday and overnight charging:

Focussing charging time outside of peak energy price time windows will help to reduce load on the electrical system and overall energy costs. Fortunately, the lowest energy demand occurs overnight, coinciding with the time that the highest number of buses are parked in the garage. Doing most of the charging overnight makes sense operationally and financially.

Where battery-electric buses do not have enough range to complete a full day-long scheduled block of work, they will also return to the garage between the morning and afternoon peak periods to be charged. Staff will manage the midday charging so that buses are not being charged at the time when provincial electricity demand is at its highest, normally hot summer afternoons.

If charging needs increase at peak times of provincial energy demand as more battery-electric buses are brought into the fleet, staff will evaluate other methods for charging to avoid drawing more utility-supplied electricity from the grid. These could include on-site storage units, which could be charged during off-peak periods and subsequently used to charge buses during peak periods.

3.3. Battery Capacity, Degradation, and Lifespan

The capacity of batteries declines as they age. This battery degradation will need to be monitored closely to ensure maximum bus range during the entire lifecycle of the battery. There are two tactics that can be taken to slow the rate of battery degradation; reducing the maximum range of travel and storing buses with the battery at a low state of charge.

The effective life of the batteries currently available is estimated by the suppliers to be 12 years. The economic life of the other major components of a bus is normally 15 years. Staff will need to plan how to manage the shorter life of a battery within the longer life of a bus, to ensure that all assets are used to their full potential.

The theoretical maximum range of the four 40-foot battery-electric buses that are being received in 2021 (New Flyer model XE40 with 528 kWh of energy storage) is 381 km. Operating battery-electric buses at this maximum range every day would lead to accelerated battery degradation, resulting in a lower maximum range during the later years of the battery’s lifecycle.

The practical maximum range of the 40-foot battery-electric buses is 286 to 305 km. This is based on experience of other transit agencies and modelling conducted by Dillon Consulting. Scheduling for this range results in an average maximum battery discharge of 80 percent, leading to a slower rate of battery degradation and allows the bus to operate at the maximum practical range for the entire lifecycle of the battery.

The amount of charge during storage also degrades battery life. The manufacturer’s guidance is that buses be stored at 25 percent charge or lower. The buses are expected to take four hours to charge and reducing total capital costs by having each charger charge two buses sequentially overnight means that some buses will be stored for several hours with greater than the recommended charge in their batteries.

These considerations reduce the best range for the buses to a level lower than the maximum possible range. For planning purposes, the effective range for a battery-electric bus like the first four is approximately 286 km. Approximately two-thirds of the current schedule blocks for 40-foot buses are within this range.

In the early years, the initial battery-electric buses will be assigned to the two thirds of scheduled work blocks that match the range of the buses. In later years of the fleet-wide conversion, another solution will need to be found. As battery and power technology improves, it may become possible to purchase buses with a longer range. Returning buses to the garage more frequently or adding on-route charging stations, for instance at major Transitway stations, are other possible options, but both would have operating cost implications as they would increase unproductive time.

Decisions in this area and regular management of the batteries will be assisted by energy management software that will be integrated with the current bus fleet management systems.

4. Financing the Transition to Zero-Emission Buses

Converting the OC Transpo bus fleet to zero-emission buses will create significant capital costs that are much higher than if the current diesel bus fleet were maintained. The buses themselves are more expensive than their diesel counterparts. The onsite charging infrastructure, electrical elements and the grid and substation upgrades that are necessary also introduce new, significant one-time costs.

The City’s long range financial plan (LRFP) for transit, last updated in 2019, is a look forward for several decades, to ensure that the projected capital and operating costs of the transit system are and remain affordable, without the need for disproportionate fare increases, tax increases, or service cuts. The current transit LRFP showed that the Stage 2 expansion of the O-Train system was affordable along with the lifecycle capital costs of the current system, the operating costs of the current system, and the capital and operating costs to encourage and respond to City growth and growth in transit ridership. This is based on the understanding that continuous annual increases are made to transit fares and property taxes that support transit, that development charges continue to be collected as permitted, and on the basis that funding for O-Train expansion would be provided by senior levels of government. Other future projects, such as the Stage 3 O-Train extensions to Barrhaven and Kanata/Stittsville and Transitway projects on Baseline Road, March Road, and in Stittsville and Cumberland, were shown to not be affordable without increased funding from senior levels of government. The cost of converting the bus fleet to zero-emission buses was not included in the 2019 transit LRFP and is similarly not affordable without new funding from senior levels of government. Staff are currently updating the transit LRFP as input to the 2022 transit budget to better reflect the most recent operating and financial trends that could have an impact on longer-term affordability.

The federal government has announced two programs to provide financial support to municipalities and transit systems to encourage and support the conversion to zero-emission buses across Canada. In 2020, the federal government announced that the Canada Infrastructure Bank (CIB) would make $1.5 billion available for bus fleet conversion through a loan program. In early 2021, the federal government announced that, as part of the Permanent Transit Fund, Infrastructure Canada would make available $2.75 billion in grant funding for fleet conversion.

The recommendations in this report are based on taking full advantage of the Infrastructure Canada and CIB programs to supplement the capital funding for bus fleet growth and replacement identified in the LRFP, with all of these funding sources working together to make possible the conversion to a zero-emission bus fleet.

All of the costs in this report are preliminary and will be confirmed through the procurement and program management work that are described in the report. Some costs, especially those related to electricity supply and electrical equipment, may be highly variable, and could fluctuate by plus or minus 25 percent.

4.1. Capital Costs

OC Transpo’s project for the first four battery-electric buses has solidified some costs that are being used in financial models. The current unit price per 40-foot battery-electric bus is approximately $1,300,000. In-garage charging infrastructure for one bus consists of a power pack and a dispenser. The dispenser is similar to a fuel nozzle or extension cord as it is the piece that connects to the bus. The dispenser can either be a floor-mounted pedestal charger or an overhead pantograph descending from the garage ceiling. The power packs cost approximately $200,000 each while both options for the dispenser are about $50,000 each.

On-site electrical elements that distribute the power throughout the garages include an on-site substation, on-site distribution system, on-site transformer, and a main switchboard. The price of this varies by the size of the garage and the number of buses to be charged. For example, at St-Laurent Bus Garage, the cost estimate to distribute enough power to charge the 78 buses that would be in the fleet by 2023 is $22 million. For the 450 buses that would be in the fleet by 2027, the cost estimate is $48 million.

Upgrades to the electrical grid and off-site substations will also be required. These upgrades vary by garage site, but not by the number of buses expected to be charged at the garage. For example, the estimated cost for the necessary upgrades to feed St-Laurent Garage is $25 million. This is the case for both 78 and 450 buses.

The purchase and installation of the charging equipment will be an ongoing cost as more buses are purchased. This includes the power pack and overhead pantographs. Envari estimates a cost of $20 million to accommodate the purchase of 74 buses in 2022-23.

Hydro Ottawa has confirmed that they are able to deliver the required energy to the St-Laurent bus garage. Despite the large cost to perform the necessary upgrades, St-Laurent is the best option for electrification when compared to OC Transpo's other garage sites. Merivale Garage on Colonnade and Pinecrest Garage on Queensview both would require more infrastructure upgrades. Industrial Garage, near St-Laurent, would not require those upgrades, but is not configured to maintain 40-foot buses.

The recommended staging plan is to build the full electrical and garage upgrades to support the eventual full fleet of buses at St-Laurent Garage and to stage the purchase and installation of the charging equipment as the battery-electric bus fleet expands from 2023 to 2027. Envari has estimated that full site electrification at St-Laurent will cost $73 million. This includes upgrades to grid and substation elements and on-site electrical elements. The exact sizing of the electrical capacity and the location of the investment will depend in part on the future availability of high-capacity buses and minibuses.

In addition, backup power generation will be required in case there is a need to charge the buses during an extended power outage. Without backup power generation, OC Transpo risks not being able to provide its full transit service during power outages. Providing a natural gas powered generator for the necessary backup power generation at St-Laurent is estimated to cost $14 million.

There is very limited experience with outdoor storage in cold climates with the current battery-electric bus technology, and manufacturers have noted that cold temperatures affect battery performance. St-Laurent Garage has adequate indoor capacity to store the 40-foot battery-electric buses that are expected to be purchased by 2027, but some buses will need to be stored outside eventually. If battery technology does not improve, alternative solutions would need to be found in the future. This could include providing more protection from the weather, identifying other ways to keep batteries warm, or a reconfiguration of bus storage and charging areas.

Table 2, below, summarises the sharing of costs for the 450-bus conversion of the fleet between 2022 and 2027.

Table 2: Approximate Cost Share for 450-bus Zero-Emission Bus Program, 2022 to 2027

Cost components		
Battery-electric buses	$760 M	77%
Charging infrastructure	$204 M	21%
Transition costs	$22 M	2%
Total	$986 M	100%
Sources of funds		
Infrastructure Canada	$345 to $493 M	35% to 50%
City Share		
From Savings, through CIB Loan Program	$400 M	41%
Capital Funding	$93 M to $241 M	9% to 24%
Total City Share	$493 M to $641 M	50% to 65%
Total	$986 M	100%

4.2. Sources and Uses of Funds

4.2.1. City capital funding:

The transit LRFP includes the cost of planned diesel bus purchases through to 2048. This money would be put towards the purchase of battery-electric buses, with the federal funding covering the additional capital costs. This existing City funding is not sufficient to pay for the higher costs of zero-emission buses and the charging infrastructure required. It is only because of the funding programs described below that the conversion of the bus fleet is financially feasible.

4.2.2. Canada Infrastructure Bank loan:

The Canada Infrastructure Bank has $1.5 billion available to help transit agencies purchase zero-emission buses and related infrastructure. This funding is to be provided as loans, to cover the difference between the cost of a diesel bus and the cost of a zero-emission bus, plus the related charging or fueling infrastructure. The loans are to be paid back over the life of the bus from the operating cost savings – energy and maintenance – that are expected with zero-emission buses.

Through this program, the City would pay what it would normally have paid if diesel buses were purchased and the loan from the CIB will pay the difference. This money is being provided as a loan to be paid back with 1 percent interest. The loan is to be paid back from the operational savings OC Transpo realizes by having battery-electric buses on the road instead of diesel buses. This will come from savings on energy (with electricity replacing diesel fuel) and maintenance (with no engine and fewer parts to maintain). Repayment is the lesser of the loan or the savings achieved.

This report recommends that the General Manager, Transportation Services, be given the delegated authority to negotiate and enter into the appropriate agreements for this loan.

4.2.3. Infrastructure Canada grant:

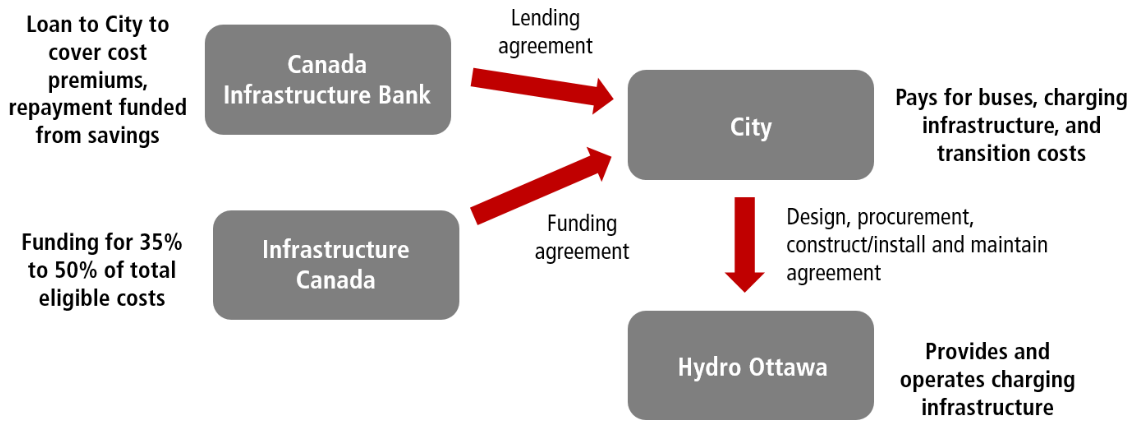
In early 2021, the federal government announced an investment of $2.75 billion in grants over five years to support the purchase of zero-emission public transit and school buses. This money can be accessed starting in 2021. Further details of the eligible costs and the process to apply are expected from the federal government in the months to come.

This report recommends that the General Manager, Transportation Services, be given the delegated authority to apply for this federal funding and to negotiate the terms of the funding agreement.

Upon approval of this report, staff will apply for this federal funding as soon as is possible.

Figure 3, below, illustrates the roles and funding relationships between the participating agencies.

Figure 3: Roles and funding relationships between participating agencies



4.2.4. Next steps:

Figure 4, below, shows the timeline of decisions and other actions required over the rest of 2021 so that procurement of the 74 new buses can start at the beginning of 2022.

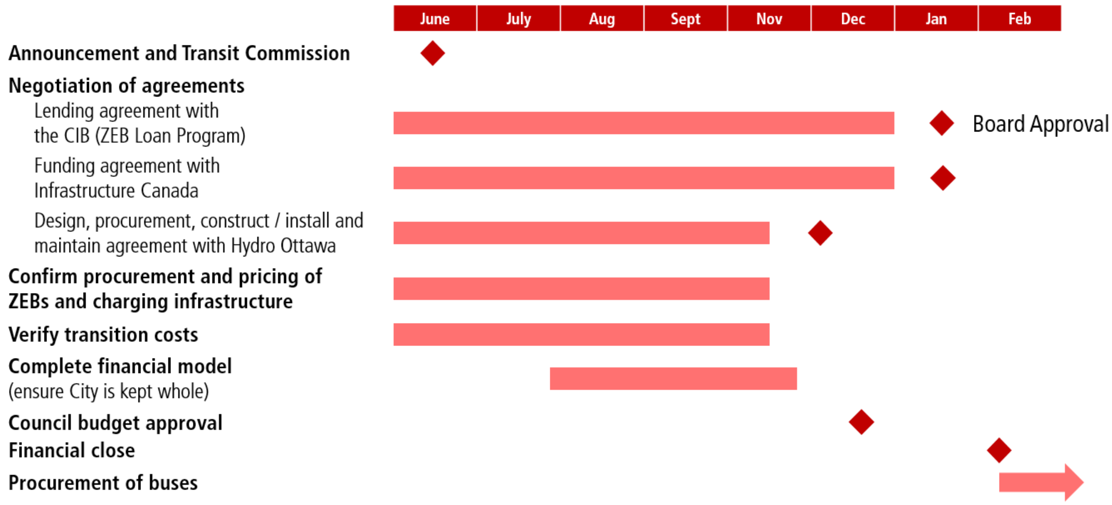
Over the next several months, City staff will engage with the Canada Infrastructure Bank and Infrastructure Canada. Negotiations will take place toward a lending agreement with the Canada Infrastructure Bank and a funding agreement with Infrastructure Canada.

All costs will be further developed and assembled into a recommendation later in 2021 to the Transit Commission and Council for input to the 2022 capital budget and operating budget.

Expected milestones in 2022 would be financial close of the lending and funding agreements, the procurement of buses, and an agreement with Hydro Ottawa and/or Envari on electrical supply and equipment maintenance.

The new buses would be expected to enter into service during 2023.

Figure 4: Timeline of 2021-22 decisions and actions for procurement of 74 new buses



4.3. Operating and Maintenance Costs

Operating costs – in particular, energy costs and maintenance costs, are expected to be lower for battery-electric buses than they are for diesel buses. This is a fundamental part of the recommended approach to funding the capital costs, as the CIB loan program is designed to address that point in particular: that municipalities and transit systems need a way to fund higher up-front costs and pay back the difference from long-term savings.

4.3.1. Operational assumptions:

A key consideration when comparing diesel to battery-electric buses is expected annual maintenance costs. The loan payback to the Canada Infrastructure Bank will be financed by maintenance savings. This consists of planned maintenance, including major overhauls, and unplanned maintenance. The expectation is that battery-electric buses will result in a cost savings due to reduced maintenance when compared to a diesel bus.

Another item that will finance the loan repayment is savings realized on energy costs. Diesel fuel is more expensive per kilometre than electricity as an energy source for transportation. As more battery-electric buses are purchased, OC Transpo's reliance on diesel will go down and fuel savings will be realized.

Overall, the expectation is that the cost to maintain a 40-foot battery-electric bus will be roughly 65 percent of the cost to maintain a diesel bus. This is based on the experience of other transit agencies and on forecasts of future distance travelled per year, the cost of diesel, and the cost of electricity.

4.3.2. Maintenance cost components:

OC Transpo diesel buses are operated on a 15-year lifecycle. Battery-electric buses are expected to be able to be in service for 15 years as well. Since the technology is new, there is as yet no experience with this in North America. Maintenance savings were calculated based on forecast fuel and electricity costs, planned maintenance costs, and major overhaul costs over a 15-year lifecycle.

OC Transpo's 40-foot diesel buses and the actual cost of diesel fuel was used to calculate the average cost of diesel per bus. To account for impacts of lower distance travelled from March to June 2020, the kilometres travelled during those months were increased to reflect service levels that were scheduled pre-pandemic. This average figure of kilometres operated was then used to predict the cost to charge the same number of battery-electric buses. Envari provided an estimate on the unit cost of electricity. Overall, OC Transpo expects that charging battery-electric buses will cost roughly 40 percent of the cost to fuel diesel buses.

Battery-electric buses have fewer moving parts than diesel buses. This is expected to lead to savings on maintenance costs. Maintenance costs can be divided into three main categories: major overhaul, planned maintenance and unplanned maintenance.

To determine expected cost savings on major overhaul costs, Canadian transit agencies that already have battery-electric buses in their fleet were canvassed to determine what cost savings they are seeing or projecting due to the switch from diesel to battery-electric. On a diesel bus, the major overhaul costs consist of structural body work and engine and transmission replacement. Battery-electric bus major overhaul costs include structural body work and traction motor overhaul. This is difficult to predict, as major overhaul costs occur later in the lifecycle of a bus and battery-electric buses in Canada are not old enough yet.

The same process was used to determine the expected cost savings for planned maintenance and unplanned maintenance. Planned maintenance includes tasks such as tire changes and system inspections. Unplanned maintenance occurs when a bus operator notices something wrong with a bus while out in service. It could be anything from flat tires, heating/cooling system issues, or propulsion issues.

Based on information received from other transit agencies and from battery-electric bus manufacturers, an average expected savings of 33 percent was determined. This was applied to OC Transpo’s known planned maintenance costs for diesel vehicles to arrive at an expected annual cost of maintenance for battery-electric buses.

4.3.3. *Maintenance risk observations:*

Estimating maintenance costs for battery-electric buses is difficult. Since the technology is still new there is a lack of data on long-term maintenance costs. The unplanned maintenance is particularly difficult to estimate, as that can vary widely from year to year. Major overhauls occur later in the bus lifecycle and are costly. Since no North American transit agency has battery-electric buses that have been on the road long enough to undergo a major overhaul, there are no good data to use when estimating costs. Actual maintenance costs might be different from what has been estimated, impacting OC Transpo’s long term maintenance costs and the repayment to the Canada Infrastructure Bank.

A major source of cost savings with battery-electric buses is the cost of electricity compared to diesel fuel. Electricity prices could increase and diesel prices could drop. This would result in reduced cost savings and projected maintenance savings not being achieved. It will be critical in negotiations with the Canada Infrastructure Bank to clarify the eligibility of cost savings to be used as the basis for the repayment of the loan. If those savings are not achieved then the loan repayment amount is also reduced and Canada Infrastructure Bank is assuming the repayment risk.

4.4. Financing Summary

Funds from the Canada Infrastructure Bank would go towards the purchase of battery-electric buses and the charging infrastructure that will be installed in the garages. Buses would be purchased with a combination of City funds and money received from the Canada Infrastructure Bank. The City will contribute what would be spent on a diesel bus with the Canada Infrastructure Bank providing money to cover the extra cost of the battery-electric bus.

Funds from Infrastructure Canada would go towards garage improvements, required electricity supply upgrades, and other transition costs such as required training and program management. As shown in Table 2, above, the funding from Infrastructure Canada will need to be for 35 to 50 percent of the total program cost in order for the program to be cost neutral for the City.

Total estimated cost for transition costs is $18 million for 450 buses. This includes modifications to St-Laurent garage, training for OC Transpo staff, and program management. These costs are included as eligible costs under the Infrastructure Canada grant program.

5. Risks and Mitigation

5.1. Fleet expansion risks

As the battery-electric bus fleet grows, a potential risk is fleet unreliability. Battery-electric buses have not been on the road for long enough to be able to fully understand the long-term performance. There are no good data on how a battery-electric bus fleet will age, and how much down time can be expected per bus. There will be risks of missed service due to buses being down with no diesel bus ready to fill in. Phasing out the full fleet conversion over 15 years can help mitigate some of this risk, as manufacturers can make improvements as necessary before OC Transpo has a fully zero-emission bus fleet.

Assuming continued improvements is another inherent risk that transit agencies including OC Transpo need to take if the goal is to have a 100 percent zero-emission bus fleet. Current practical range projections for a 40-foot battery-electric bus is 286 to 305 km, which covers approximately two thirds of OC Transpo's bus blocks that require a 40-foot bus. The expectation within the industry is that battery-electric bus range will continue to improve, but this is not a guarantee. If range does not improve as expected changes may be necessary to make existing blocks shorter and to maximise bus charging opportunities, at a higher operating cost.

As the battery-electric bus fleet grows, OC Transpo will eventually need to purchase 60-foot articulated and double-decker battery-electric buses. While there are several manufacturers that offer 40-foot battery-electric buses, there are currently only two that offer both 60-foot articulated and double-decker battery-electric buses and there are few battery-electric buses of this size operating in North America. There is little relevant in-service experience that can be drawn from. OC Transpo is planning on purchasing 60-foot articulated buses in 2024 and double-decker buses in 2026, providing some time for viable battery-electric versions to become available. If no viable options are available, OC Transpo can consider deferring these purchases if the technology seems to be attainable in one or two years. If this is not possible or practical, service levels could be increased on some routes, at a higher operating cost, to provide the same capacity with the smaller 40-foot battery-electric buses, or diesel options could be required.

Risks can also come from the need to eventually store battery electric buses outdoors. Depending on experience and on further technological improvements, there may be a need to develop alternative approaches.

5.2. Capital Risk Observations

Details of the agreement with the Canada Infrastructure Bank will be worked out over the coming months. Several factors need to be finalized. One factor is to detail the role that the Canada Infrastructure Bank will play to oversee the achievement of the actual operational savings and compare that to the forecasted savings arrived at through the financial modeling exercise carried out by Deloitte.

Specific details on the level of funding from the Canada Infrastructure Bank and Infrastructure Canada also need to be finalized. Agreements will be formalized that break down what components of converting to battery-electric buses will be covered.

OC Transpo will face challenges related to pricing of buses and associated infrastructure in the coming years. It will be important to limit cost inflation. This may be difficult, as the money that is available from the federal government will increase demand for battery-electric buses and related infrastructure, possibly leading to price increases that are above typical inflation.

5.3. Financing Risks

The figures that underpin the recommendations of this report are based on calculations that demonstrate that the zero-emission bus conversion program is feasible because it does not add to the City funding requirement in the transit LRFP. That is, the federal loan and contributions pay for the added capital cost of the battery-electric buses and the necessary supporting infrastructure.

Several issues need resolution before the final financial commitment (“financial close”) is made. The details need to be clear of the role that the CIB will be playing to oversee the achievement of the actual savings, compared with the projected savings. The level of funding from Infrastructure Canada needs to be known.

Preliminary estimates show that the City would need 35 to 50 percent of the capital costs of the conversion program to be funded by the Infrastructure Canada funding program. And there needs to be clarity on the ability to secure pricing that limits cost inflation over the duration of the project.

As staff further discuss and negotiate with the CIB and Infrastructure Canada, they will be working to ensure that any cost inflation during the project will be shared by all funding partners.

Another risk to consider is the possibility of government policy changing over time. Converting OC Transpo's bus fleet to 100 percent battery-electric buses is expected to take 15 years, the lifecycle of the newest diesel buses in the fleet. Government policy, and funding, can shift over that time.

6. Conclusions

A well documented benefit of battery-electric buses is their contribution to improved air quality. Local emissions will be reduced in the areas where transit service is operated using zero-emission buses.

Reduced emissions are also important at bus garages, where ventilation is a major factor in keeping the air quality at safe levels for staff. A bus garage that is 100 percent electric will not need as much ventilation, reducing costs associated with operating and maintaining ventilation equipment.

A battery-electric bus is quieter than a diesel bus, reducing noise on city streets. This is also true at bus garages, where quieter buses lead to an improved work environment for employees and reduced noise levels for businesses and residents near garages.

Since battery-electric buses are so much quieter than diesel buses, concerns have been raised regarding pedestrian and cyclist safety and their ability to recognize an approaching bus. Transport Canada is currently reviewing a Canadian Motor Vehicle Safety Standard that would impose minimum noise requirements for electric vehicles.

Zero-emission buses present an opportunity for significant long-term operating cost savings. The operations and maintenance savings are expected to be significant. The expected drop in prices as the technology matures will lead to increased overall cost savings. The high up-front costs of updating bus garages and initial bus purchases will be offset by long term savings.

In order to reach the interim 2030 goals set by the City's *Climate Change Master Plan*, the full electrification of public transit by 2030 was identified as a requirement in the *Energy Evolution* roadmap, which summarizes modeling work for Ottawa's GHG emissions between now and 2050. The City is currently making significant progress on electrifying transit service through O-Train expansion across the City, and the bus fleet conversion outlined in this report will further that effort. This report illustrates that a full bus fleet conversion is possible by 2036, based on the availability of funds and the availability of suitable buses for operation in Ottawa.

RURAL IMPLICATIONS

The zero-emission buses recommended in this report would operate in both the rural and urban parts of the transit system.

CONSULTATION

N/A

COMMENTS BY THE WARD COUNCILLOR(S)

This is a City-wide report.

ADVISORY COMMITTEE(S) COMMENTS

N/A

LEGAL IMPLICATIONS

There are no legal impediments to approving the recommendations as outlined in this report.

RISK MANAGEMENT IMPLICATIONS

There are risk implications. These risks have been identified and explained in the report and are being managed by the appropriate staff.

ASSET MANAGEMENT IMPLICATIONS

The recommendations documented in this report are consistent with the City's Comprehensive Asset Management (CAM) Program objectives. The implementation of the Comprehensive Asset Management program enables the City to effectively manage existing and new infrastructure to maximize benefits, reduce risk, and provide safe and reliable levels of service to community users. This is done in a socially, culturally, environmentally, and economically conscious manner. The purchase of zero-emissions buses and supporting infrastructure aligns with the CAM guiding principle of sustainability by considering climate impacts in infrastructure decision-making.

In recent years, the City has been successful in receiving funding from other levels of government. A key criterion for these applications is having asset management programs, policies and/or plans in place. The City is and will continue to be well-positioned to leverage available funding opportunities.

FINANCIAL IMPLICATIONS

All costs will be further developed and assembled into a recommendation later in 2021 to the Transit Commission and Council for input to the 2022 capital and operating budgets. A detailed financial model will be developed that includes the negotiated terms of the agreements with Canada Infrastructure Bank, Infrastructure Canada, Hydro Ottawa Holding Inc, and detailed costs and pricing for the zero-emission buses, charging infrastructure, transition costs and program costs. The affordability model for the Long Range Financial Plan is currently being revised to reflect any changes in the financial assumptions used in 2019 that better reflect recent trends and projections. This revised affordability model will be the basis for assessing if the City will be kept whole and that the capital and operating cost pressures of the zero-emission buses is less than what is included in the Transit Long Range Financial Plan as the capital and operating costs for the diesel buses that would be replaced.

ACCESSIBILITY IMPACTS

There are no accessibility impacts associated with this report. Conversion of the Para Transpo minibus fleet from diesel to zero-emission is not in the scope of discussion in this report, as the technology is not yet available.

ENVIRONMENTAL IMPLICATIONS

The introduction of zero-emissions buses into OC Transpo's fleet will have a positive contribution to reduced GHG emissions and improved air quality in Ottawa.

TECHNOLOGY IMPLICATIONS

Technology implications and considerations are outlined in the body of the report.

TERM OF COUNCIL PRIORITIES

- Integrated Transportation: Enable effective mobility through a sustainable, accessible and connected city transportation system.
- Service Excellence Through Innovation: Deliver quality services that are innovative and continuously improve to meet the needs of individuals and communities.
- Environmental Stewardship: Grow and protect a healthy, beautiful, and vibrant city that can adapt to change.
- Thriving Workforce: Promote Service Excellence by supporting a workforce that is healthy, diverse, adaptive and engaged.

DISPOSITION

The Transportation Services Department will bring forward a plan to purchase zero-emission buses in the 2022 budget and future budgets for fleet needs, on the basis that these buses are available to meet operational requirements and that financial arrangements are affordable under the City's Long Range Financial Plan for Transit.