

**Office of the Auditor General**  
**Audit of Zero-Emission Buses**  
**Sprint 1 – Technology and Performance**



**February 2022**

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## Acknowledgement

The team responsible for this audit was comprised of MNP (external consultant) under the supervision of Joanne Gorenstein, Deputy Auditor General and my direction. My colleagues and I would like to thank those individuals who contributed to this project, and particularly, those from the Zero-Emission Buses project team who provided insights and comments as part of this audit.

Respectfully,

A handwritten signature in blue ink that reads "N. Gougeon".

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## Introduction

The Audit of the Zero-Emission Buses (ZEB) (or battery-electric buses) was approved to be included in the Office of the Auditor General's (OAG) 2021 Interim Audit Workplan, via Motion No. 57/6 and an accompanying amendment memo, as approved by City Council (Council) on July 7, 2021.

## Background and context

As part of the Climate Change Master Plan approved by Council in January 2020 (revised in December 2020 - [ACS2020-PIE-EDP-0043](#)) to reduce greenhouse gas (GHG) emissions by 100 per cent by 2040, the City of Ottawa (the City) has undertaken a ZEB transformation to convert its OC Transpo fleet to battery-electric buses.

While some other Canadian jurisdictions initiated their conversions to ZEBs several years ago, this has allowed the City to leverage lessons learned and experiences of other cities in testing out the technology. An options analysis was also conducted by the City which provided a detailed assessment of alternative energy systems throughout Canada, prior to making a recommendation on the technology for the City to pursue. Leveraging the experiences of cities including Montreal, Edmonton, and Toronto in their ZEB transformations, has allowed the City to initiate their battery-electric program with a base foundation and expectation of how the buses and related infrastructure would perform.

On June 23, 2021, Council approved the "Zero-Emission Buses for OC Transpo" report ([ACS2021-TSD-TS-0009](#)), which outlined the plan for the City to enter into a loan agreement with the Canada Infrastructure Bank (CIB) and to seek additional funding from Infrastructure Canada to gradually convert the bus fleet to battery-electric buses. The aim would be to phase in a total of 450 ZEBs by 2027 and to have a fully electric bus fleet by 2036. As a starting point, and following direction from the Transit Commission on June 19, 2019, staff initiated a competitive procurement process to procure four (4) battery-electric buses for a pilot project.

The following outlines some of the key completed and planned dates associated with the pilot project:

ZEB Pilot Milestone	Milestone Completed/Expected Date
Pilot bus procurement complete	January 2021
Charging infrastructure procurement complete	June 2021
City Council approval to convert bus fleet to ZEB	June 23, 2021
Garage renovations complete	September 2021
Delivery of pilot battery-electric buses complete	November 2021
Pre-inspection of battery-electric buses complete	November 2021
Pilot buses added to revenue service	December 2021-January 2022
Ongoing monitoring of pilot bus performance	Commencing December 2021
Procurement initiation for next 74 ZEBs (estimated)	July 2022

Given some of the inherent risks related to the underlying technology, securing of funding, and implementation challenges faced in other cities, the OAG announced its intention to engage early in the transformation and conduct an audit of the ZEB implementation.

The Audit of ZEB leverages an agile audit approach. This methodology provides periodic reports, performed in iterative cycles (or sprints) of audit on a continual basis with a focus on areas of greatest risk to the City. The audit aims to provide independent and objective opinions before key decisions are made and agreements and funding arrangements are signed.

## Audit objective and scope

Large-scale programs, such as the ZEB, can be broken down into four (4) key categories of risk: Technology and Performance, Financial, Program Governance and Management, and lastly Logistics and Operations. This audit sprint (Sprint 1) focused on ZEB Technology and Performance. The objective was to provide reasonable assurance that the City has assessed and considered the technology risks and operational requirements as it selected the type of technology/vendor and in developing its plan to evaluate bus performance within its pilot project.

Within the Technology and Performance risk category, the following assessment areas were reviewed:

1. Business Proposition and Feasibility
2. Technology Evaluation
3. Performance Management

The audit fieldwork was conducted between September and October 2021, and the observations highlighted within this report are based on review of evidence and documentation as of October 31, 2021.

For further details on the objective, scope audit criteria and assessment areas, please refer to **Appendix B**.

In order to identify observations and provide recommendations related to the above assessment areas, a number of interviews were conducted with internal and external stakeholders. The purpose of these interviews was to leverage industry research and standards, as well as obtain insights on comparable municipal implementations of electric buses. These interviews included: key City staff, specific ZEB manufacturers (New Flyer Industries, Proterra), and other municipalities/transit organizations such as the Edmonton Transit Service (ETS) and the Société de transport de Montréal (STM) which have ZEB initiatives in a more advanced stage than that of the City of Ottawa. We also interviewed the Canadian Urban Transit Research & Innovation Consortium (CUTRIC), which is a non-profit organization that spearheads, designs, and launches technology projects that advance next-generation zero-carbon mobility and transportation solutions across Canada, to leverage their expertise and learnings. The City is a member of CUTRIC.

## Conclusion

Recognizing the need to transition the OC Transpo bus fleet from diesel to a zero-emission platform to support the City's GHG emission reduction target, management, at the direction of the Transit Commission, has initiated a pilot project to procure four (4) battery-electric buses to test and inform future larger scale procurements of ZEBs. The audit confirmed that a thorough technical evaluation exercise was conducted as part of the procurement for the four (4) pilot buses, where the performance requirements defined for the buses are aligned to key variables and parameters of industry research bodies (e.g., CUTRIC) and a sample of comparable municipal implementations (Toronto Transit Commission (TTC), ETS, STM).

While the City has initiated this pilot project, considering the planned timeframe to facilitate procurement for the next group of 74 ZEBs in mid-2022, management will be unable to benefit from complete insights of the pilot results to inform this next procurement given that not all performance data (one full-year cycle) will be available from the pilot by that time. Additionally, considering the short timeframe and the large increase of fleet size (4 ZEBs to 78), a key risk is whether the City will have sufficient time to adequately plan for the transition, including: new buses and associated technology, charging infrastructure, tools/systems, training, route scheduling, garage readiness and charging strategies to ensure a successful integration into the OC Transpo fleet.

At the time of drafting this audit report, the City had commenced work on establishing a ZEB performance evaluation and management framework for the pilot buses. This includes a controlled testing approach for pre-revenue service and a performance evaluation framework to track metrics for buses in ongoing revenue-service. As the framework continues to be developed, consideration should be given to formalizing the mechanisms for capturing the performance data (i.e., systems source data) and the approach for monitoring and analysis (i.e., frequency, ownership and responsibilities, and targets/thresholds).

To support the pilot Project Management Office's (PMO) continuous improvement efforts, we also highlighted opportunities to enhance specific project management mechanisms within the pilot project. Work has progressed on these project management tools and their continued development and integration into the pilot project will support the achievement of pilot objectives and support a foundation for the broader ZEB program.

# Observations and Recommendations

## Business Proposition and Feasibility

### Positive Observations:

- ✓ Options analysis of various technologies was conducted to evaluate bus alternative energy systems and to recommend a technology to replace traditional diesel for the OC Transpo bus fleet. The analysis evaluated alternatives based on vehicle, operational, environmental and infrastructure implications and leveraged an industry scan of similar implementations, supply chains and industry drivers.
- ✓ Charging infrastructure scope and costing analysis was conducted by Hydro Ottawa in collaboration with the City. It included a review of building and structural elements involved in the installation of the charging equipment, as well as energy capacity planning.

### Key Observations:

**Due to the planned timing of the next procurement (Q3 2022), the City will not have enough time to retrieve fulsome data from the pilot project and may not have sufficient time to plan the successful integration of the next 74 electric buses.**

Based on planned procurement timelines, there will be insufficient time to implement the four (4) bus pilot project across all seasons to assess results, and identify technical findings and recommendations, ultimately to provide input into the procurement of the next group of 74 electric buses in mid-2022. This includes insights from the results of buses in revenue-service, controlled engineering tests, performance against variables and climates, customer perceptions, and City staff feedback. It is worth noting that the City's plans are in line with Council direction and that there is intention to leverage lessons learned for the specifications/requirements for the next procurement to the extent possible; however, the planned timing does not allow for a complete analysis on the results.

In addition, without sufficient planning time to consider the technology (both bus and charging infrastructure), tools, training, route scheduling, garage readiness and approaches to charging the buses, there is a risk to the successful implementation of the next group of ZEBs which, if continued as planned, will increase the size of the battery-electric fleet by a factor of almost 20.



Through interviews conducted with industry stakeholders and by referencing other municipal ZEB implementations, an increase in ZEB fleet size from four (4) to 78 is a large operational task, considering that there is limited time to analyze actual performance data related to charging requirements, range, and climate performance from the initial pilot of (4) four buses. Examples of implementation activities to integrate a further 74 ZEBs into the fleet would include the establishment of the necessary charging infrastructure and retrofitting/building sufficient maintenance facilities for the electric bus fleet. It is worth noting that other municipalities expanded their ZEB fleet in smaller increments (e.g., STM went from seven (7) buses to 30, and ETS procured 40 after their initial pilot exercise).

It was observed that other municipalities have allowed sufficient time in their overall ZEB procurement plan to analyze relevant pilot project data. By doing so, these municipalities were able to substantiate key estimates and assumptions with the pilot data obtained, including ZEB range, charging requirement ratios, and performance in extreme climates in preparation for a larger scale phase of implementation.

### Recommendation 1:

The Director, Transit Operations should consider reducing the number of ZEBs planned to be procured in the next round of purchasing. While this would have costs associated with extending the lives of several diesel buses, procuring a smaller number of battery-electric buses in the short-term will allow the City to gather sufficient data from the pilot project and plan appropriately for the integration of a larger number of ZEBs into the OC Transpo fleet.

### Management Response 1:

Management agrees with the recommendation.

OC Transpo will make this recommendation part of the considerations when deciding how many electric buses to procure in the next phase, along with data compiled during the in-service testing and monitoring of the first four battery-electric buses in 2022.

Staff will also be considering supply chain risks, where delays in production may occur if order quantities are reduced or if orders are delayed. This risk is due to the increasing demand for battery-electric buses and the relative difficulty of scaling-up the manufacturing.

Staff currently expect to go to tender in Q3 2022, with closing to occur in Q4 2022, and aiming at delivery of the next batch of battery-electric buses before the end of Q4 2023.

## Technology Evaluation and Testing

### Positive Observations:

- ✓ As part of the pilot RFP and bid evaluation, the City established complete technical evaluation criteria and assessed key technical constraints and parameters that are aligned to industry standards and guidance (e.g., variables informed by research bodies such as CUTRIC, and parameters defined from other comparable case studies and related technical papers).
- ✓ A bid evaluation was conducted with supporting evidence for evaluation ratings.
- ✓ The pilot project team intends to perform controlled engineering tests of the pilot buses to evaluate performance against extreme variables.

### Key Observations:

**Formally documented plans and templates for the controlled engineering tests on the pilot buses had not been established at the time of the audit.**

While the City and pilot project stakeholders have expressed intention to perform tests and have informed the audit team of the potential testing scenarios for the pilot buses, a formal plan or template to test the buses against variables and integrate raw data from available systems is not yet in place. Based on the audit team's research of specific municipalities (TTC, STM and ETS), these initial tests should evaluate range, energy consumption, auxiliary systems (e.g., auxiliary cabin heater), bus load, and performance in various weather conditions and route topography. Without a formal controlled engineering test plan for the pilot buses, key variables may not be evaluated to provide critical input into future decision making related to fleet and charging infrastructure procurement and bus route assignment.

Through our interview conducted with CUTRIC, and by referencing other municipal ZEB implementations and their tools (e.g., ETS), controlled engineering approaches should be formally documented with a mechanism to leverage raw data and readings from the battery-electric bus systems (e.g., battery readings, ambient air temperature, state-auxiliary heater). Considering that the buses were entering into commissioning and final acceptance at the time of the audit, the audit team expected a formal plan or template to have been established.

During the development of the audit report, management informed the audit team that, as a result of discussions throughout the course of the audit, an approach had since been created for the controlled engineering testing, which is documented in a Service Bulletin. The Service Bulletin includes range confirmation (i.e., testing a loaded bus across different temperature ranges to determine the actual range of the bus against expectation) and includes testing a range of bus routes to determine the most appropriate routes/blocks to assign to the ZEBs.

## Recommendation 2:

Building on the Service Bulletin created, the Director, Transit Operations should continue to develop the approach and associated instructions for the controlled engineering tests, establish how each hypothesis will be tested (e.g., slope, incline and pitch, battery usage/charging) and how the raw data/system readings will be leveraged as part of the testing and documentation of results.

## Management Response 2:

Management agrees with the recommendation.

OC Transpo staff are learning the new technology through training and onboarding of the zero-emission buses and supporting systems. Staff will continue to develop the approach and associated controlled engineering testing documentation to include, among other things, the items identified in this recommendation by the Auditor General's Office.

This recommendation will be complete by Q1 2022.

## Performance Management Framework

### Positive Observations:

- ✓ During our interviews, management informed the audit team of the plans to leverage existing performance monitoring templates (used for the existing diesel fleet) and further enhance these templates with inputs from vendors and other cities to establish the ZEB performance management matrix. Accordingly, sample reports and metrics for bus reliability have been developed which includes mean distance between failure (MDBF) performance, defects, mileage, energy consumption, diesel heater consumption, and maintenance cost per bus.

Although this is an initial template, the metrics are aligned to research relating to monitoring bus reliability.

### **Key Observations:**

**A formal performance measurement and management framework to monitor ZEB performance against key metrics, targets, and assumptions had not been established at the time of the audit.**

While the City will be leveraging sample reports and have informed the audit team of the plans to utilize existing performance matrices, a tailored framework to evaluate the ZEB pilot project has not yet been established.

A formalized performance management strategy and data collection system would be expected to be in place that provides management with real-time performance data to monitor key performance targets such as battery capacity at an aggregate level, availability metrics and vendor performance. The performance framework would consider feedback mechanisms to assess customer and operator/maintainer experience through surveys and questionnaires tailored to the ZEB program. Key metrics related to vendor performance would also be considered.

During the development of the audit report, management informed the OAG that work has commenced in the development of a ZEB performance evaluation approach which assesses seven (7) different areas: system compatibility, accessibility, vehicle performance (including charging system performance and maintainability), vendor performance, customer experience, operator and maintainer experience and total life cycle cost. The framework is still under development and specific areas and associated criteria are still being identified.

### **Recommendation 3:**

The Director, Transit Operations should continue to formalize the performance measurement framework for the ZEB pilot project, including the establishment of the criteria to be used for each area. This would also include the mechanism to capture the performance data from source systems, define targets and metrics, and establish the method and frequency of monitoring and reporting.

## Management Response 3:

Management agrees with the recommendation.

OC Transpo staff will continue to formalize the performance measurement framework for the ZEB pilot project, identify the criteria and the mechanism to capture the performance data; and establish the method and frequency of monitoring and reporting.

This recommendation will be complete by Q1 2022.

## Pilot Project Management

### Positive Observations:

- ✓ A project charter was established for the ZEB pilot project which includes the key project deliverables, timelines, the project's major milestones and the target date of completion for each.
- ✓ Working groups have been established across seven domains each with a key focus (e.g., Bus Operations, Engineering, Materials) to discuss key deliverables/milestones, status, planned and actual completion dates, and risks associated with the milestones, which report weekly to each working group lead, the Project Manager, and Program Manager. These reports are merged into an Overall Project Status Update for the Director.

### Key Observations:

**Opportunities for improvement exist to enhance specific project management mechanisms within the pilot project that will support the achievement of pilot objectives and support a foundation for the broader ZEB program.**

Although project management was not in scope for this audit sprint, specific opportunities were identified as part of the audit which have been raised to management for timely resolution. These include the following:

- ✓ A master project schedule and project management tracker are not in place to track major milestones identified in the project charter, which would allow the tracking of key performance indicators (such as schedule and budget). These tools would provide an indicator of overall project health and performance to project executives, senior management, and Council. An integrated schedule is

necessary to monitor key milestones with a focus on project objectives and realization of benefits.

- ✓ Project risks are generally tracked by each working group and reported on in their status reports. A standalone, consolidated risk register (or listing of risks) to track and monitor priority risks and associated interdependencies with planned due dates for proposed mitigations that allows for ease of tracking/monitoring is not currently being utilized by the PMO.
- ✓ During the development of the audit report, management indicated that work had commenced in the development of the above-noted project management tools, which were being integrated into the pilot project.

#### Recommendation 4:

Based on the integrated schedule introduced for the pilot, the Director, Transit Operations and the PMO should continue to refine the schedule to consider including the necessary level of detailed activities, establishing how this schedule enables the tracking of delays and ultimately, how it can highlight impacts of delays on interdependencies.

#### Management Response 4:

Management agrees with this recommendation.

OC Transpo staff will continue to refine the program schedule, and track delays and interdependencies.

This recommendation will be complete by Q1 2022.

#### Recommendation 5:

Based on the risk register initiated, the Director, Transit Operations and the PMO should continue to update the register through weekly project updates and include key elements such as due dates for planned mitigations to allow tracking of progress against expectations. This would enable a holistic view of project risks, and the status of mitigations, by the PMO and project executives.

## Management Response 5:

Management agrees with the recommendation.

The PMO will continue to update the risk register through weekly project updates and will include key elements, such as due dates, for planned mitigations to allow tracking of progress against expectations.

This recommendation will be complete by Q1 2022.

## Appendix A - Definitions

Term	Definition
<b>Agile Audit</b>	The approach and methodology used for the audit of ZEB; designed to provide periodic reports, be performed in iterative cycles (or sprints) of audit on a continual basis with a focus on areas of greatest risk to the City.
<b>CUTRIC</b>	The Canadian Urban Transit Research & Innovation Consortium (CUTRIC) is a non-profit that spearheads, designs, and launches technology projects that advance next-generation zero-carbon mobility and transportation solutions across Canada. The City is a member of CUTRIC.
<b>ETS</b>	Edmonton Transit Service (ETS) is the public transit system that provides over 80 million rides each year to the City of Edmonton.
<b>GHG</b>	Greenhouse gas (GHG) are gases that trap heat in the atmosphere. GHG emissions are contributed by transportation including diesel buses.
<b>PMO</b>	The Project Management Office (PMO) was set up within Transit Services to oversee, lead and manage the pilot project. An overall Program Management Office is currently being established for the broader ZEB program.
<b>Revenue service</b>	The service when the buses run on actual bus routes and carry passengers. The ZEBs should enter revenue service by January 2022.
<b>STM</b>	The Société de transport de Montréal (STM) is a public transport agency that operates transit bus and rapid transit services in the City of Montreal, Quebec.
<b>TTC</b>	The Toronto Transit Commission (TTC) is the public transport agency that operates bus, subway, streetcar, and paratransit services in Toronto.
<b>ZEB</b>	Zero-Emission Buses (ZEB) are buses that adopt a zero-emission technology e.g., battery-electric buses and hydrogen fueled buses. For the City of Ottawa, the selected technology for ZEBs in the years 2021 to 2027 are battery-electric buses.



## Appendix B – About the audit

### Audit objective

The objective of this audit sprint was to provide reasonable assurance that the City has assessed and considered the technology risks and operational requirements of the City as it selected the type of technology/vendor for the pilot project and in developing its plan to evaluate bus performance as part of the pilot project.

### Audit scope

The audit sprint focused on the activities undertaken by the City to assess the various technologies and vendors to meet the City’s GHG emission reduction commitments and the plans made to date to evaluate the bus technology against the operational requirements of the City of Ottawa through its pre-planning and pilot project.

Future audit sprints will assess results of the pilot project and other aspects of the transformation. These sprints are subject to change based on a continuous assessment of risk throughout the agile audit.

### Audit criteria

Criteria listed below was assessed and validated during the audit sprint and have been developed in line with the audit objective and scope above.

-	Technology/Vendor Evaluation
1.1	Management has identified and validated the technical and business requirements, including feasibility studies for the various technologies, for ZEBs.
1.2	The RFP process to procure the pilot buses included the established technical and business requirements established by management.
1.3	Management has conducted a formal assessment of the battery-electric bus technology, including vendors and performance requirements, to support the implementation in a Canadian environment as part of selecting a vendor for its pilot project.

-	Pilot Project
2.1	A plan for the pilot project has been established to formally evaluate the bus technology for the four (4) pilot buses/associated charging infrastructure and considers electric bus risk factors, including: <ul style="list-style-type: none"> <li>✓ Battery capacity, range, and weight</li> <li>✓ Battery charge and charging requirements</li> <li>✓ Climate operability and conditions</li> </ul>
2.2	The plan for the pilot project considers how the performance of the pilot buses will be monitored and evaluated against relevant measures and indicators to allow management to assess bus performance.

## Assessment areas

Breaking down the audit criteria into more detail, the following assessment areas were reviewed within this audit sprint:

#	Assessment Area	Description
1	<b>Business Proposition and Feasibility</b>	This area reviewed the feasibility analysis and relevant research conducted by the City. This included: <ul style="list-style-type: none"> <li>✓ Business case analysis</li> <li>✓ Climate feasibility analysis</li> <li>✓ Zero-emission technology cost/benefit analysis</li> <li>✓ Implementation requirements analysis</li> <li>✓ Emission savings forecasts</li> <li>✓ Constraints and dependencies</li> </ul>
2	<b>Technology Evaluation</b>	This area reviewed the City’s evaluation of the procured ZEB technology. This included: <ul style="list-style-type: none"> <li>✓ Evaluation of technical bids and related procurement documentation</li> <li>✓ Assessment of technology/technical requirements</li> <li>✓ Incorporation of case study analysis, industry thought leadership and lessons learned from similar ZEB implementations</li> </ul>
3	<b>Performance Management</b>	This area reviewed the City’s forward-looking plans to monitor and track the performance of the procured ZEB technology. This included:

#	Assessment Area	Description
		<ul style="list-style-type: none"> <li>✓ Critical success factor analysis and monitoring</li> <li>✓ Key performance indicators and metrics</li> <li>✓ Status reporting and communications</li> <li>✓ Controlled engineering and climate performance evaluation</li> </ul>