SCHEDULE F – PROJECT COMPLETION REPORT TEMPLATE

VERY IMPORTANT:

Timing: You need to email a report, to your GMF project officer (contact info is in Schedule C), on the dates indicated in Schedule C or whenever FCM asks for such a report.

Copyright: Before you submit a report to FCM, make sure you hold the copyright for the report. If you're hiring a consultant to prepare the report, please make sure to get the copyright (see FCM's copyright tips document), or else FCM will not be able to disburse the Grant Amount.

Accessibility for people with disabilities: Please do not change the format, font, layout, etc. of this report. This template has been specially designed, following FCM's Accessibility Guidelines, in order to be accessible to people with disabilities.

Confidentiality: If your report contains any Confidential Information that you would prefer not be made available to the public (e.g. through a case study or other materials produced by FCM that relate to your Project), please submit two versions of the report:

1. **Complete report including Confidential Information:** Please clearly label this report with the word "**Confidential**" or similar wording and FCM will treat it as confidential.

2. **Abridged report excluding Confidential Information:** This report may be posted on the FCM website and otherwise made available to interested third parties, to help FCM meet its knowledge sharing objectives.

Please contact your project officer to receive an electronic copy of the Completion Report Template.

Upon completion of the project, a copy of the Final Deliverable must be submitted along with this Completion Report.

FCM will post your report on the Green Municipal Fund™ (GMF) website. This is because one of FCM's mandates is to help municipal governments share their knowledge and expertise regarding municipal environmental projects, plans and studies.

How to complete the Completion Report

The purpose of the Completion Report is to share the story of your community's experience in undertaking your project with others seeking to address similar issues in their own communities.

Please write the report in plain language that can be understood by people who are not specialists on the subject. A Completion Report is typically in the range of 5–10 pages, but may be longer or shorter, depending on the complexity of the project.

GMF grant recipients must enclose **final** copies of the Completion Report and the Final Deliverable with their final Request for Contribution. The reports, including all attachments and appendices, must be submitted in PDF format with searchable text functionality. Reports that are not clearly identifiable as final reports, such as those displaying headers, footers, titles or watermarks containing terms like "draft" or "for internal use only," will not be accepted by GMF. Additionally, reports must be dated. If you have questions about completing this report, please consult GMF staff.

GMF number	17796
Name of lead applicant (municipality or other partner)	Burlington Transit
Name, title, full address, phone, fax and e-mail address of lead technical contact for this study	Canadian Urban Transit Research & Innovation Consortium Parvathy Pillai 18 King Street E, Suite 1400 Toronto, ON M5C 1C4 parvatly.pillai@cutric-crituc.org
Date of the report	31/08/2022

1. Introduction

The Canadian Urban Transit Research & Innovation Consortium completed a feasibility study for Burlington Transit which started in April 2021 and was completed in August 2022.

To support Burlington's efforts in reducing its carbon footprint, the Canadian Urban Transit Research & Innovation Consortium (CUTRIC) completed a project which simulated the operations of fuel cell electric buses (FCEBs) on Burlington Transit blocks and routes using some of the results from a previously completed similar study on battery electric buses (BEBs). The focus of this feasibility study was to analyze techno-economic and life-cycle emissions associated with transitioning Burlington Transit's fleet to FCEBs across all existing routes and blocks.

2. The Feasibility Study

a. Background and process

Burlington Transit is a community-focused transit agency that strives to transition its fleet to zero-carbon solutions leveraging the merits of technology and innovation. As part of planned efforts to transition the entire fleet to zero-emission technologies, with the approval of the City of Burlington, Burlington Transit commissioned CUTRIC to conduct a predictive analytics study to model the performance of zero-emission buses in 2020 and a followup study in 2021. CUTRIC completed the predictive modelling analysis for Burlington Transit in three stages - in 2020, a full-fleet block-based feasibility analysis was conducted to evaluate the performance of battery electric buses (BEBs), a follow up study in 2021 to simulate the performance of fuel cell electric buses (FCEBs) which was augmented with the environmental analysis and preliminary schedule analysis. CUTRIC has successfully completed all project deliverables and submitted them to the client.

b. Objectives of the feasibility study

The study's objective was to predictively simulate the performance of potential zero-emission buses (FCEBs) and to establish the technological feasibility of an energy transition involving those. It also included an assessment of the expected operational and asset-based capital expenditure and the amount of GHG emission reductions. The study investigated fuel cell electric bus (FCEB) technologies, drawing conclusions about the level of difficulty for electrification based on the predicted energy and fuel consumption for the system. Additionally, the environmental analysis comprised of a life cycle assessment of greenhouse gas (GHG) emissions and compares the potential reduction in global warming caused by switching from diesel buses to ZEBs, taking 40-foot and 60-foot vehicles

into account separately. Following the environmental analysis, a preliminary schedule analysis is performed to determine the availability of downtime/recovery time in the existing schedule and to compare it to charging requirements for BEBs and refuelling requirements for FCEBs.

c. Methodology

CUTRIC utilized the RoutE.i™ 3.0 simulation tool to assist BT in reducing the complexities involved in fleet electrification planning. RoutE.i™ 3.0 is a highly sophisticated simulation tool that can model various types of zero-emission buses (ZEBs) operating under the specific physical conditions that they would encounter after deployment. Road topography, typical passenger load during service, and the frequency of starting and stopping dictated by traffic impediments are among these conditions. The simulation results allow for the assessment of detailed energy consumption outcomes, as well as the estimation of GHG emission reductions and expected operational costs. Predictive performance modelling is a calculation process that simulates ZEB's energy consumption in real-world operational conditions.

Another element of the study is the life cycle assessment of emissions (LCA). The LCA analysis captures the environmental impacts that could be introduced by switching from a diesel-powered fleet to a fleet of BEBs and FCEBs from its beginning to the end of life. Infrastructure Canada has developed a guidance module (GHG+ PLUS) to assist in clearly defining the activities to be included in the LCA analysis. The activities included (but are not limited to) in the guidance module are emissions emanated due to infrastructure construction, fuel production, bus transportation, bus operations, and maintenance and repair of equipment. CUTRIC has used its in house tool and reported the environmental analysis outcomes in the GHG+ PLUS module format. Furthermore, a preliminary schedule analysis of Burlington Transit's current service, assessing how downtime/recovery time availability compares to BEB charging requirements and FCEB fueling requirements is estimated and reported.

d. **Public consultations**: None

3. Feasibility Study Findings

Environmental findings

CUTRIC calculated the yearly aggregated emission values over the project's 12-year duration. The total annual carbon dioxide equivalent emissions from the project are estimated to be 109,747 tonnes (i.e., 74 per cent and 23 per cent emission savings are realized by transitioning the full fleet to FCEBs fuelled with green and grey hydrogen, respectively). Similarly, the potential emission savings from converting the entire fleet to BEBs are approximately 79%.

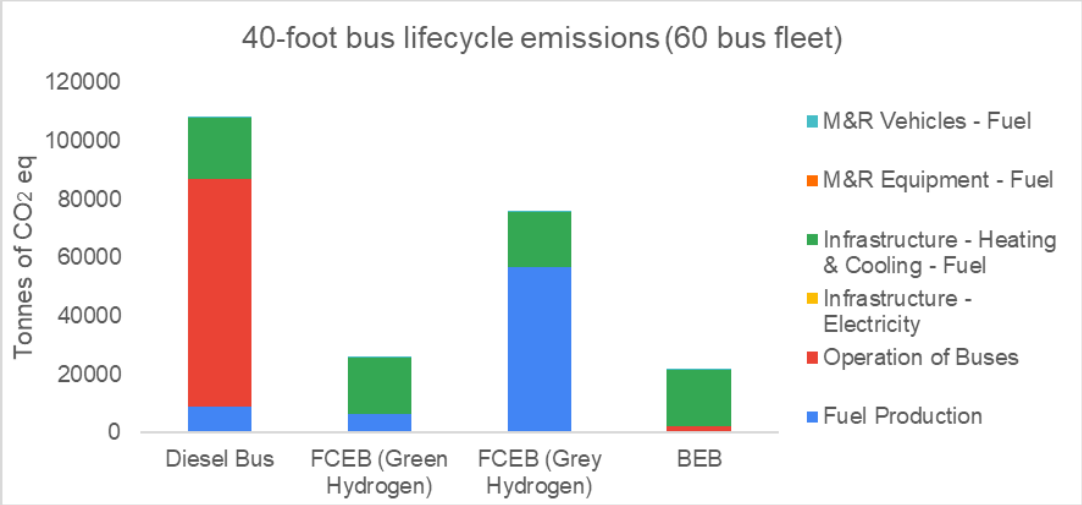

Figure 1: Comparison of 40-foot ZEB bus lifecycle emissions to diesel

Figure 1 compares diesel bus life cycle emissions to BEBs and FCEBs. While FCEB tailpipe emissions are negligible in terms of global warming, emissions from hydrogen production pathways are significant when hydrogen is sourced from steam methane reforming - grey hydrogen. When charged with Ontario grid electricity, the BEBs emit significantly fewer emissions than diesel. Additional details including the risk assessment matrix are found on pages 19 and 20 of the Burlington Transit FCM report.

In the schedule analysis, the evaluation reveals that more than 50 per cent of the blocks in Burlington Transit's current schedule do not have enough downtime at the terminals. Minor adjustments are required in the schedule, even if all blocks are serviced by BEBs experiencing opportunity charging. Refuelling a hydrogen bus usually takes less than 10 minutes. Furthermore, most vehicles would only need to be refuelled once when they returned to the depot after completing their daily service. There may be times when an FCEB requires a single mid-day refuelling episode. Therefore, the system schedule is agreeable to electrification using FCEBs.

Financial findings

CUTRIC conducted a preliminary total cost of ownership assessment and the details of the analysis are presented on Page 37 of the Burlington Transit Fleet Electrification Analysis (FCEB) Report.

Recommended Next Steps

CUTRIC is a non-profit organization experienced in handling more than 50 decarbonization projects ranging from full fleet feasibility studies to full ZEB rollout and implementation planning. Our recommendation is that Burlington Transit develops a full implementation plan for zero emission assets with a focus on comprehensive schedule optimization to determine all adjustments required for all blocks to be electrified using BEBs or FCEBs. However, the BEB solution would necessitate significant additional operational time for a few vehicles, whereas the FCEB solution would most likely necessitate minimal to no schedule changes. A financial analysis with a long enough time frame should be included. The transition to a ZEB fleet, as well as the stable state in which no diesel-powered buses operate and ZEBs are retired and replaced, should be considered.

4. Lead applicant's next steps

Burlington Transit is considering moving to a full fleet implementation planning project to bring all the lessons learned over the feasibility study to the next level and also are considering procurement options ahead.

5. Lessons learned

One of the most important aspects of feasibility studies is to involve local utilities in fleet electrification planning projects from the start. The increase in power demand caused by the transit electrification and implementation project assists local utilities in identifying and planning for capacity. Furthermore, supply chain delays must be considered because they can affect operational costs and service levels (due to increased electricity demand), as well as cause overall delays in project implementation and meeting declared emission targets.

6. Knowledge Sharing

1. The information is not publicly available as the reports are confidential.
2. The outcomes are presented in an anonymized manner to other transit agencies at knowledge sharing sessions such as conferences, committees, and other stakeholder meetings that enable the agencies to have electrification confidence by understanding the pathways others have taken.

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