City of Mississauga
Corporate Report

MISSISSAUGA

Date: June 7, 2021 To: Chair and Members of General Committee From: Geoff Wright, P.Eng, MBA, Commissioner of Transportation and Works	Originator's files: Meeting date: June 23, 2021

Subject
MiWay Hydrogen Fuel Cell Electric Bus Update – June 2021

Recommendation
That the report "MiWay Hydrogen Fuel Cell Electric Bus Update – June 2021" dated June 7, 2021 from the Commissioner of Transportation and Works be received for information.

Executive Summary
- The Phase 1 Feasibility Study commenced in April 2021 and is estimated to be completed in April 2022. It will deliver the lifecycle energy, emissions, and economic performance analyses of the FCEBs and fuelling infrastructure, along with a preliminary fleet electrification roadmap for MiWay based on fuel cell electric transit buses.
- As part of Phase 2, CUTRIC intends to submit a funding proposal to the Ministry of Infrastructure and NRCan by the end of June 2021, followed by a submission under the Ministry of Infrastructure's Zero Emission Bus (ZEB) Funding Program as soon as it is developed and open for applications later this year.
- This project involves participation amongst multiple stakeholders including New Flyer Industries, Ballard Power Systems, Cummins (Hydrogenics), Enbridge, Canadian Urban Transit Research & Innovation Consortium, and MiWay.
- The initial FCEB deployment project will support the achievement of innovation, energy-transition, and climate policy goals for both Infrastructure Canada and Natural Resources Canada, while creating made-in-Canada jobs spanning across the hydrogen-based transit value chain.

Background

Introduction

The purpose of this report is to provide an update to the "MiWay 2020 Hydrogen Fuel Cell Electric Bus Update" report that was presented to General Committee on October 7, 2020. Since that report, there has been progress on both Phase 1 and Phase 2 of the Pan-Canadian Hydrogen Fuel Cell Electric Bus (FCEB) Demonstration and Integration Trial.

The purpose of the initiative is to deploy innovative FCEB technology, coupled with a local green hydrogen fuel supply chain in the GTHA. Supported by an ongoing feasibility assessment, the commercialization phase of this trial will facilitate the procurement, operation, and performance assessment of 10 Hydrogen FCEBs and critical fuelling infrastructure at MiWay facilities. The project aims to demonstrate the viability of this technology as a zero-emission solution for transit decarbonization while fostering integration of green hydrogen to kick-start the hydrogen ecosystem in Mississauga and surrounding GTA.

The ongoing feasibility assessment and launch of this project involves multiple stakeholder participants including the following:

- **MiWay:** The champion transit agency that will own and operate the 10 FCEBs in the City of Mississauga.
- **New Flyer Industries:** The transit bus Original Equipment Manufacturer (OEM) that will be assembling and supplying the FCEBs. New Flyer's headquarters is based out of Winnipeg, Manitoba.
- **Ballard Power Systems:** The OEM that specializes in the development and manufacturing of hydrogen fuel cell stacks that will be used in the FCEBs.
- **Cummins (Hydrogenics):** The OEM that is assisting in the fuel production and manufacturer of the electrolyzer. Hydrogenics, recently acquired by Cummins, who are based out of Mississauga, Ontario.
- **Enbridge:** The energy delivery partner that specializes in gas transmission and distribution, who will be supplying green hydrogen to fuel the FCEBs.
- **Canadian Urban Transit Research & Innovation Consortium (CUTRIC):** the commercialization partner specializing in program management and predictive and empirical performance analysis.

Current Situation

Since the last report, there are still no dedicated hydrogen fuel cell electric buses operating in Canada. An initial deployment is therefore important and necessary for MiWay to examine the feasibility of introducing this low carbon technology into its fleet on a larger scale to meet the City's climate change targets.

This hydrogen FCEB trial would be the first of this magnitude in Canada. Being a first-mover in this technological space, MiWay has learned that there are a many reasons why hydrogen makes sense for Mississauga as an initial deployment. The benefits of this FCEB initial deployment project include:

- **Long-Term Fuelling Solution:** 10 FCEBs initial deployment is scalable to more, as deemed feasible by CUTRIC's RoutE.i modelling. Although there is a high capital cost, the service life of the fuelling infrastructure network will surpass the life of the FCEBs, which makes scalability an option in the future.
- **Scalable Green Hydrogen Delivery Model:** Fuelling station installed at MiWay's Malton garage will be designed for 3 trailer bays for future expansion, while Cummins/Enbridge will be supplying fuel with tube trailers and fuelling dispensers.
- **Outdoor Storage for FCEBs:** The operation of FCEBs outdoors will be a first for North America. A plug-in heater is required in order to moderate the temperature and manage moisture within the fuel cell stack. This is to allow buses to be able to start in sub-zero ambient temperatures.
- **ZEB Technology without BEB Range & Infrastructure Limitations:** The Malton facility does not currently meet the energy requirements to operate battery-electric buses (BEBs). Substations would need to be installed, therefore depot charging would require extensive capital infrastructure. MiWay also does not own all of the on-street infrastructure such as stations and terminals, therefore opportunity charging is limited. All of these infrastructure challenges and high capital expenditures can be mitigated with FCEBs. Secondly, range anxiety is less of a concern compared to BEBs. MiWay can service most, if not all existing routes with FCEB technology. Range has yet to be validated in Canadian climate, however testing in Orange County, California indicated that their FCEBs were able to travel 560km on a single fill. The average distance a MiWay bus travels per day is 250km.
- **Creation of Local Jobs in Ontario:** Fostering development of skills and expertise related to high-potential domestic and export sector. Mississauga will boost development of local green hydrogen production and be the trailblazer for the local hydrogen ecosystem.

Comments

Hydrogen Fuel Cell Electric Bus Phase 1

Feasibility Study

The feasibility study commenced in April 2021 and is projected to be finished in April 2022. It will deliver the lifecycle energy, emissions, and economic performance analyses of the FCEBs and fuelling infrastructure, along with a preliminary ZEB roadmap for MiWay based on fuel cell electric transit buses. The scope of work of the feasibility study includes the following:

- Conduct full fleet, block-based or vehicle-based modelling;
- Compare the total cost of ownership of FCEBs and diesel/biodiesel buses, considering the total cost of hydrogen fuel and the aggregate cost of the requisite number of FCEBs, along with fuelling infrastructure costs for MiWay;
- Analyze GHG emissions reductions by replacing diesel/biodiesel buses with FCEBs at MiWay, considering a well-to-wheel approach for all sources of fuel (steam methane reforming and electrolytic hydrogen);
- Assess current bus schedules and MiWay's fleet to optimize hydrogen fuelling times, considering MiWay's garage locations;
- Develop a ZEB roadmap using hydrogen fuel cell technology, with short term and long term recommendations on pathways toward zero-emissions. Minimize operational impacts and find the least costly solution based on energy consumption, fuel supply chains and the capital costs of infrastructure required;
- Modelling two (2) routes for two (2) models of electric low speed automated shuttles that have routes less than 3 kilometres in length (potentially on a dedicated laneway). The scope of this task is a federal funding requirement; and
- An analysis of the draft Clean Fuel Standard federal regulations and the opportunities it may create to stimulate a hydrogen economy.

As of June 2021, MiWay and CUTRIC are working through the data requests which will be used as inputs to the RoutE.i simulation model, as well as finalizing the list of assumptions and constraints related to duty cycles, operation, bus specifications and GHG emissions tables

Hydrogen Fuel Cell Electric Bus Phase 2

Funding Proposal

With ongoing efforts concentrated on an immediate launch, Phase 2 intends to facilitate the funding and/or financing for the scope, procurement and deployment of the buses in revenue service, installation of critical distribution infrastructure along the local fuel supply chain, agreement on fuel supply terms, and an empirical analysis of the economic operating performance of the buses over the first five years of their lifecycle.

Since the last report, there has been a lot of progress on Phase 2. CUTRIC has created a funding proposal that will be delivered to the Ministry of Infrastructure and NRCan by the end of June 2021. Federal funding contribution for this project will line up with the mission of Infrastructure Canada’s zero-emissions public transit funding commitments as well as Natural Resources Canada’s implementation plan for the National Hydrogen Strategy.

Infrastructure Canada has announced the immediate dedication of a portion of permanent public transit funding to support upfront capital investments for the purchase of zero-emission transit and school buses, related fuelling infrastructure components, as well as associated project planning and management efforts. MiWay, a leading transit agency in the dense urban agglomeration of the GTHA, is well positioned to harness the wide reaching environmental,

economic, and fleet operating benefits of such funding support. In line with Infrastructure Canada's vision, mission, and goals, FCEB fleet and infrastructure deployments, as well as the empirical knowledge generated as part of this trial, will set up MiWay on a long-term trajectory of zero-emission bus deployments on a larger scale as it replaces its conventional diesel bus fleet with ZEBs over the next decade.

Natural Resources Canada's key recommendations for implementation of the National Hydrogen Strategy include, but are not limited to, building of strategic partnerships, development of new policies and regulations, identification of high priority transit agencies and infrastructure needs within jurisdictions, as well as investments in marquee hydrogen pilots. Such implementation steps aim to create hubs that foster integration of green hydrogen in regional energy systems. The Markham based fuel source for this trial, and the City of Mississauga are well suited to become leading hydrogen transit hubs in the GTHA.

Fuel Cell Electric Bus Equipment

The FCEB specifications such as the bus model, fuel cell power, accessories, battery capacity, hydrogen tank size, and other components have been discussed with New Flyer and is pending approval. The next step is to understand what data is important to capture and log in order to measure the performance of the FCEBs once they are in operation.

The FCEB equipment will include (10) forty-foot heavy-duty low-floor hydrogen FCEBs. Each bus is propelled by an electric drivetrain consisting of a 160 kW traction motor. The drivetrain is powered by a 100 kWh battery, supported by an 85 kW fuel cell. The fuel cell uses compressed hydrogen stored onboard the bus as its energy source. Hydrogen is stored at a pressure of 350 bar in roof-mounted cylinders that contain (5) tanks with a total system capacity of 37.5 kg.

MiWay will own and operate the fleet of 10 FCEBs based out of the Malton campus. The lifecycle of each FCEB unit is equivalent to that of a conventional diesel bus, which is assumed to be 12 years. FCEBs will be sole-sourced from New Flyer. Ballard will supply the fuel cell module directly to New Flyer. New Flyer will provide maintenance and service support for the buses, supported by Ballard where applicable, at no additional cost to the purchase price of each bus for the first five years of the bus lifecycle. Nearing completion of this phase of the trial, MiWay will reassess preference for a turnkey subcontract versus in-house maintenance of the innovative fuel cell electric drivetrain components for the remaining lifecycle of the buses. Shown in the **Figures** below are some of the FCEB equipment.

Figure 1: New Flyer Xcelsior CHARGE H2 (Hydrogen FCEB bus)

Figure 2: Enbridge Markham Facility (North America's First Hydrogen Blending Facility & Power-to-Gas Plant). Located at 101 Honda Boulevard, Markham, Ontario.

Figure 3: Enbridge Hydrogen Storage Tanks

Figure 4: On-site Enbridge Hydrogen Production. Cabinet that houses the electrolyzer is shown on the right. Black box houses a fuel cell for low power lighting. Hydrogenics box contains dryer tank for final cleaning up of hydrogen.

Figure 5: Tube Trailer to Transport Hydrogen Fuel (Markham to and from Mississauga)

Fuel Supply Equipment & Service Process

MiWay requires a daily maximum of 300 kg of green hydrogen fuel for revenue operation of the (10) FCEBs. Until the economic feasibility of on-site green hydrogen production at MiWay's Malton campus is assessed with more FCEB deployments, the deployment will meet fuel demand at Malton, which will include installation of an on-site fuelling station to dispense hydrogen into buses. Green hydrogen will be produced at Enbridge at a centralized electrolysis facility in Markham and delivered to the Malton campus. The dedicated fuelling station at Malton will combine elements of a modular yet long-term design solution which will enable scaling of fuelling capacity with minimal incremental capital costs.

MiWay requires a bundled fuel supply agreement covering fuel production, delivery, as well as installation and maintenance of the fuelling station equipment for the 12-year lifecycle of the bus. A joint venture between Enbridge and Cummins will provide a fuel supply agreement. Until further negotiations between MiWay and Enbridge-Cummins materialize, the currently proposed fuel supply agreement framework is based on a five-year initial supply term followed by an option for a seven-year extension.

Enbridge and Cummins will supply fuel from its Markham Energy Storage Facility through newly deployed distribution infrastructure in addition to the fuelling station at MiWay's Malton campus. Gaseous green hydrogen is produced at a pressure of 30 bar at the Markham Energy Storage facility using a 2.5 megawatt (MW) electrolyzer operating with electricity from the Ontario grid.

This hydrogen will be purified to vehicle grade quality that is compliant with SAE J2719 standards. The current annual production capacity of the facility to produce economically viable green hydrogen is 219,000 kg based on a rate of 600 kg/day, seven days a week during hours of off-peak pricing of the Hourly Ontario Electricity Price (HOEP).

The purified green hydrogen will be compressed to 350 bar and filled into tube-trailers using dispensing equipment at the Markham Tube Trailer Filling Station adjacent to the Markham Energy Storage Facility. These high-pressure tube trailers with a high-capacity carbon-fibre storage tank design will deliver the hydrogen to a newly built fuelling station at MiWay's Malton campus. The Malton Fuelling Station will have a bus fuelling lane with a dispenser accompanied by two additional lanes functioning as tube trailer bays with decanting posts. A "Bump and Pump" mobile fuelling solution involving innovative compressor technology known as a hydraulic intensifier will be used to dispense the green hydrogen into the buses at 350 bar pressure.

Ownership, operation, financing and/or funding roles will be divided between MiWay and Enbridge-Cummins depending on the category and location of the fuel supply equipment/systems, as summarized in **Table 1**.

Table 1: Roles and Responsibilities – Fuel Supply Equipment and/or Process

Equipment or System Category	Location	Enbridge and Cummins	MiWay
Green Hydrogen Production	Enbridge-Cummins' Markham Energy Storage Facility	Own, Operate, Maintain	
Markham Tube Trailer Filling Station	Adjacent to Enbridge-Cummins' Markham Energy Storage Facility	Design, Fund/Finance, Procure, Install, Commission Own, Operate, Maintain	
Malton Bus Fuelling Station (Including Hydrogen Tube Trailers)	MiWay's Malton Bus Parking Facility	Design, Procure, Install, Commission Maintain	Fund/Finance, Own, Operate

Equipment or System Category	Location	Enbridge and Cummins	MiWay
Hydrogen Tube Trailer Logistics Service	Between Markham Tube Trailer Filling Station and Malton Bus Parking Facility	Plan/Design Operate, Maintain	

The strengthened foundation for a local green hydrogen supply chain through this phase will enable additional transit agencies within the local GTHA to efficiently source fuel for similar FCEB demonstrations or early-scale deployments. Scaling of green hydrogen production and distribution would further reduce operating costs of fuel cell electric transit solutions, thereby enhancing their commercial viability and operational integration at MiWay as well as other public and private fleet owners in the region.

In order for this project to be successful, the minimum viable project requirements still exist. This includes a turn-key solution option, upgrades to the maintenance facility, and MiWay must retain the ability to sole source the FCEBs and other project components such as fuel production, hydrogen transportation, hydrogen fuelling station, and maintenance support contracts.

Strategic Plan

The introduction of FCEBs would contribute to two strategic goals: **Move** (Develop Environmental Responsibility) and **Green** (Lead and Encourage Environmentally Responsible Approaches). Mississauga has been proactive in sustainability and climate change governance for over two decades. This includes joining the FCM Partners for Climate Protection program in 1999, integrating climate change and environmental considerations into the City's Strategic Plan in 2009, developing the City's Living Green Master Plan, integrating climate change considerations into its Official Plan in 2012, and becoming a signatory to the Global Covenant of Mayors for Climate and Energy (coalition of 10,000 Cities) in 2017.

Financial Impact

For **Phase 1** - the total funding available is $175,000. CUTRIC will fund $131,250 and the City will fund $43,750 (25% of the feasibility study) from existing operating funding from MiWay and the Environment Section. A corporate report to General Committee dated October 7th, 2020 was approved and recommended that City Staff participate in the Fuel Cell Electric Bus (FCEB) feasibility study. The completion of Phase 1 is on track and expected to be completed by April 2022.

For **Phase 2** – with the input of all project partners, CUTRIC (on behalf of MiWay) are developing a funding proposal that will be submitted to the Ministry of Infrastructure and NRCan, followed by a submission under the Ministry of Infrastructure's Zero Emission Bus Funding Program as soon as it is developed and open for applications later this year. The funding proposal outlines all of the multi-faceted benefits of this project, as well as current and expected capital and operating costs related to program management, empirical analysis of the operational performance of buses for the first five years of their lifecycle, facility modifications at MiWay's Malton campus, as well as deployment, operation, and maintenance of the FCEB and fuel supply equipment over the entire 12-year lifecycle of the buses. It includes current as well as committed funding, and in-kind investments by industry partners towards project launch, capital equipment, and/or operating expenditures.

Conclusion

In summary, this initial FCEB deployment project will support the achievement of innovation, energy-transition, and climate policy goals for both Infrastructure Canada and Natural Resources Canada, while creating made-in-Canada jobs spanning across the hydrogen-based transit value chain. MiWay will provide an update to General Committee on the outcome of the funding proposal submission once a decision has been made.

Geoff Wright, P.Eng, MBA, Commissioner of Transportation and Works

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