Electric Transit Buses in Manitoba
Update for Joint Task Force on Transit Electrification

Economic and Emission Profile Update Report on
Electric Transit Buses Compared to Conventional Diesel

By
Vehicle Technology & Energy Centre

Research Partnerships & Innovation
Red River College
Winnipeg, Manitoba

July 2018
(Analysis Date)

VTEC
Vehicle Technology & Energy Centre

RED RIVER COLLEGE

Table of Contents

Executive Summary

Red River College, as part of the Joint Task Force on Transit Electrification, prepared updates on both the economics and the greenhouse gas (GHG) emission profiles for electric transit buses relative to diesel bus counterparts, these compared to results from the earlier public report issued by the Joint Task Force, reflecting analysis in July 2016. In the earlier report, electric buses were identified as still somewhat more expensive on a lifetime basis than diesel buses, but with the advantage clearly moving to electric over time. It was also outlined that electric buses in Manitoba can achieve a 98% reduction in GHG emissions compared to diesel.

The economic update finds that differences in the lifetime costs between electric and diesel are now smaller, such that, based on assumptions as employed, the two can be considered effectively on par. At the same time, lifetime costs are still subject to variability and some uncertainties, such that the results are not definitive. Also, although the economics have improved, there is not yet any large cost advantage for the electric option. The emissions profile update finds that emissions for diesel and electric buses have been both dropping somewhat for various reasons, but the percentage reduction in GHG emissions in moving from diesel to electric remains identical, at around 98%.

The transition forward on electrification, as identified in the earlier report of the Joint Task Force, remains valid. At the same time, five major considerations are identified that need to be addressed for electrification to be accomplished successfully. These are:

1. **Electrical power infrastructure**. This limits the number of electric buses that can be practically implemented in the near term, and also affects capital costs.

2. **Changing ownership structure**. Moving forward, this needs to transition away from a development and demonstration orientation toward conventional purchasing procedures, with direct ownership of buses by Winnipeg Transit, under the City of Winnipeg.

3. **Technical uncertainties**. Most notable in this regard is realistic battery life, which impacts vehicle in-service availability and maintenance saving. Second is realistic annual travel, which directly impacts both economic viability and emission reductions.

4. **Federal co-funding support**. There is definite interest from the Federal government, especially for emission reductions. This is appreciated, but the detailed mechanisms of available programs are complicated, requiring substantial effort to navigate. Further, there is never a guarantee of Federal funds being available.

5. **Integration**. While electric technology obviously can compare well one-on-one, existing transit operations involve complex network systems that are built around the characteristics of diesel buses. Making the transition to electrification requires not just changes in technology, but a broad variety of changes in organization, planning, scheduling, training and other areas. These have cost implications too. Such “change management” will also require a robust and flexible implementation plan, and sufficient resources from all levels of government in order to ensure a successful transition. Members of Joint Task Force are in a position to help, in a coordinated manner, to identify and to avoid pitfalls associated with switching from one powertrain to another. Red River College in particular can assist with issues relating to training, and beyond. Further, achieving success in Winnipeg can translate to success elsewhere.

In terms of proposal preparation for the future, the equipment costs for implementation of 20 electric buses, including chargers, now appear to be in the range of $25 to $30 million. These, however, do not include any costs associated with integration. Red River College is in a good position to assist in better defining the specifics of integration and the associated costs.

Introduction

The Joint Task Force on Transit Electrification was announced in 2015 and formed in early 2016. Its purpose has been to investigate the potential of an all-electric transit system in Winnipeg, this based on the success of the on-route pilot project that has been already underway. The Joint Task Force issued a public report that outlined the status of electric transit buses. It included an evaluation of the economic business case and GHG emissions profiles, as well as outlining likely future directions.[1] The earlier report was dated July 2016, based on when the analysis was completed.

Red River College, as part of its ongoing participation in the Joint Task Force, prepared an economic update, reflecting the changing status of electric transit buses, based on more-recent discussions by the Joint Task Force, including technology improvements and a better understanding today of what is involved. Red River College has also prepared an update of the GHG emission profiles for diesel, electric and other alternative options, along with associated potential reductions.

This brief report summarizes the overall findings of these updates in terms of major implications, describes the likely steps involved in moving forward, and identifies key considerations to be addressed for electric buses to be successfully implemented. At the same time, the electric transit bus market has become extremely competitive on a global basis. As such, summary findings are provided, but details of the analysis are not directly presented so that commercially sensitive information is not inadvertently released.

Economic Update

In 2016, the Joint Task Force found that electric transit buses were still somewhat more expensive than their diesel counterparts, but with the advantage clearly moving over time toward electric. The update now shows electric bus lifetime costs are now essentially comparable to diesel, although costs are still subject to variability and some uncertainties. Based on assumptions as employed, electric transit buses range from about $50,000 less expensive than diesel to about $50,000 more expensive than diesel. Given that overall lifecycle costs for buses are roughly around $1.5 million, the differences involved are quite small. As such, the lifetime costs of diesel and electric in rough terms are today at about par.

The advantage is obviously continuing to move toward electric, but there is not yet any dramatic economic advantage. This is entirely consistent with the 2016 report in that improvements in economic viability of electric transit buses were anticipated to be ongoing and incremental, rather than revolutionary or disruptive.

Equipment costs to implement 20 electric buses, including necessary chargers, range from $25 to $30 million, but this excludes costs associated with integration. Additional key insights from the economic update are summarized in the table on page 3.

Emission Profile Update

The Joint Task Force, as part of its earlier work, developed GHG emission profiles for both electric buses and their diesel counterparts. Red River College has reevaluated GHG emissions, as well as the extent of emissions reductions possible. The latter in percentage terms has remained effectively unchanged.

It was noted in the 2016 report that emissions from a conventional diesel bus are dominated by diesel fuel consumption itself, with diesel emission fluid (DEF), associated with Tier-4 emissions controls, also contributing some emissions due to fossil carbon-based ingredients. The emissions from an electric bus include grid-mix based emissions for electricity, as consumed, calculated using a five-year grid mix consumption intensity average, as well as a small amount of diesel fuel for auxiliary heating during winter. Emissions from all diesel combustion, at the same time, are reduced somewhat due to Manitoba's biodiesel mandate, today requiring 2% of diesel-blend to be biodiesel or renewable diesel, likely higher in the future.

Key insights from economic update in 2018 on electric transit buses relative to diesel
Purchase costs for electric transit buses (including charging infrastructure) continue to be higher than for diesel counterparts, but less so today than two years ago. Continuing to reduce the purchase cost differential remains a key priority, although it is important to note that direct cost comparisons for selected individual vehicles can vary depending on differences in requirements for bus physical size, battery capacity and charging capabilities incorporated.
Optimizing electrical **charging infrastructure** is important, but primarily in reducing total charging system capital costs (i.e., not having to overbuild). Improving the load factor for charging systems reduces demand fees and thus reduces unit electricity costs, but as it turns out the economics of electric buses are not that sensitive to increases in unit electricity costs.
Currency conversion relative to the U.S. dollar remains an important concern, especially given that the Canadian dollar has softened since 2016. Just as with other vehicles, transit bus manufacturing is integrated continentally, with a variety of key components, including electric-motive components, coming from outside Canada. While transit buses are obviously assembled here in Manitoba, purchase costs do depend significantly on the relative value of the U.S. dollar. Similar impacts have been seen within Canada on light-duty electric passenger vehicles too, so this is nothing new.
The **lifespan of buses** is important in terms of economics. It is typical for a 12-year life to be assumed, as in the earlier report. Winnipeg Transit, however, usually keeps vehicles longer. Considering a longer 20-year life, including a mid-life new battery pack, improves the economic viability for electric buses. At the same time, associated risks include additional weight versus frame longevity, and the number of battery replacements actually required over a 20-year life.
Savings in **fuel costs** remain the big advantage for electric buses. Fuel costs associated with diesel buses continue to increase. This includes two new components not directly counted in the earlier analysis. First is the cost associated with an impending **carbon tax**, in response to Federal government requirements, whether implemented provincially or Federally. This aspect was discussed separately in the earlier report. For the purpose of analysis, a rate of $25 per tonne is assumed, translating to 6.6¢ per Litre of diesel-blend (including biodiesel mandate). Second is the cost to address **price volatility** with diesel. Diesel was once an economically advantageous fuel for heavy applications with low price-variability, but that has no longer been the case for some time. Although the City of Winnipeg, as a volume-user, does receive discounts, their prices move up and down too with changing market conditions. Further, it is now not uncommon for diesel fuel budgets to be exceeded. Recent research completed by the University of Manitoba shows the cost to address diesel price volatility, based on historical data for Winnipeg, translates to about 5.3¢ per Litre of diesel-blend.[2]
Just as important as diesel fuel costs is the annual **travel distance** for the electric buses. As outlined in the earlier report, it is important for annual travel to as high as can be practically possible, while still meeting transit operational and scheduling requirements. A reasonable travel distance has been employed, but how far electric buses may be able to realistically achieve in practice needs to be proven out.
Some savings in **maintenance** costs are also included but not large, and thus not a significant factor for economic viability. A major concern with such savings is that they depend critically on battery life (i.e., if batteries do no last adequately, then costs will be different). As discussed later, there has been as yet simply too little on-road experience to confirm realistic battery life, and thus also what sort of maintenance saving level may be realistic.
Costs for additional **roadway-wear** due to heavier electric vehicles are also included for completeness, but this component cost is relatively small. It is not a significant factor affecting economic viability.[2]

The GHG emissions, as calculated in 2016, are summarized in the first table on page 5 on a "per 100 kilometer" travel basis. It is important to also note that the emissions, as calculated, correspond to National Inventory Report (NIR) requirements, with all emissions generated within the province being counted. Such an approach, however, does not reflect either a combustion-only or a full-cycle evaluation. More details of calculations for GHG emissions are also included in an appendix of the 2017 final report by Red River College on the initial prototype electric bus development and demonstration.[3]

Updates of GHG emission profiles for diesel, electric and other relevant alternative bus options are also compared in the first table on page 5. GHG emissions for diesel and electric buses are reduced somewhat from the earlier report, but the percentage reduction in this case remain virtually identical in practical terms.

Reduced emissions for the diesel bus reflect anticipated movement to higher renewable content in diesel fuel. As part of its Climate and Green Plan, Manitoba indicated as an option that the mandate level could be increased fully to 5% biodiesel or renewable diesel. At the same time, the Federal government is in the process of considering new regulations covering a clean fuel standard, which is a form of low-carbon fuel standard or LCFS. In either case, increased renewable content in diesel is coming.

Reduced emissions for the electric bus reflect improved energy consumption, reduced electrical grid-mix emissions for Manitoba Hydro, again using a five-year consumption intensity average, and elevated renewable content in the small amount of diesel fuel used for auxiliary heating.

The extent of resulting GHG emissions reductions depends, obviously, on travel distance (i.e., the more travel, the greater the reduction). For a reasonable range of annual travel distances the corresponding per-bus emission reductions for electric operation are presented in the second table on page 5. As in the case of economic viability, this emphasizes the importance of achieving annual travel distances for electric buses as high as practically possible.

Future Transition

The original report of the Joint Task Force identified that the logical progression for electrification of transit within Winnipeg would involve not a few-buses-at-a-time, but rather a sequential process of major step-changes. The first step would involve implementation of in the range of 12 to 20 electric buses (i.e., 2% to 3% of fleet), a sufficient deployment to assess the technology at essentially large-scale, allowing performance, costs and future design directions to be confirmed.

The second step would involve implementation of a much larger number of buses, in the range of 120 to 200 (i.e., 20% to 30% of fleet). The electric bus fleet numbers as part of this step are much larger than has been contemplated so far anywhere in North America. This step is to be undertaken with the intent again to confirm performance, costs and design directions, taking into account lessons learned from the first step. The third and final step would involve fleet-wide or nearly fleet-wide implementation (i.e., 600 or more electric buses).

Ongoing discussions by the Joint Task Force suggest that the original approach is still generally valid, but with five major considerations identified that need to be addressed in order to achieve a successful transition. These are:

- Electric power infrastructure;
- Changing ownership structure;
- Technical uncertainties;
- Federal co-funding support; and
- Integration.

Each of these considerations is discussed in more detail in the third table beginning on page 5.

Greenhouse gas emission profiles of different bus types for Winnipeg			
Year of calculation	GHG emissions (kg per 100 km travel)		Percentage reduction
	Diesel bus	Electric bus	
2016 (original)	165	3.0	98%
2018 (update)	160	2.7	98%
	Diesel bus	CNG bus	
2018 (update)	160	156	3%
	Diesel bus	Diesel hybrid bus	
2018 (update)	160	119	26%

Annual greenhouse gas emission reductions with electric operation by travel distance	
Annual travel distance (km)	Annual emission reduction (per bus)
35,000 (low-range travel distance)	55 tonnes/year
50,000 (Winnipeg Transit average)	79 tonnes/year
70,000 (high-range travel distance)	110 tonnes/year

Major considerations to be addressed in order for transition to electric to be successful	
Consideration	Description and implications
Electric power infrastructure	The Joint Task Force has confirmed electrical power infrastructure is critical to consider regarding the number of electric buses that can be realistically implemented in the near future. There appears to be adequate electricity supply already available in locations where it could be required in order to support implementing around 20 electric buses, this of course being subject to final detailed confirmation. As part of its Climate and Green Plan, the Government of Manitoba already suggested the possibility for a much larger number of buses, as many as 100 electric buses by 2022.[4] The Joint Task Force has confirmed that implementing a large number of electric buses (i.e. 100 or more), must consider necessary electricity supply system upgrades for preferred locations. This applies whether looking at centralized or distributed charging options, and includes not just cost and timing issues but also the possibilities that environmental licensing and public hearing processes may be needed, depending on line-size as outlined in Manitoba's *Classes of Development Regulation* (Regulation 164/88).
Changing ownership structure	As part of the electric bus development and demonstration activities so far, Winnipeg Transit has been a major partner, but has not actually been the owner of any of the buses. The original prototype electric bus as well as the core of the rapid-charging system at its airport site have been under the control of the original research consortium funding partners, while the four second-generation electric buses and other equipment used to support the on-route pilot project co-funded by Sustainable Development Technology Canada, are under the control of New Flyer. A critical consideration is that for any further electrification, the City of Winnipeg, through Winnipeg Transit, would need to be the owner of any new electric buses, and to procure them using conventional purchasing procedures. This leads directly to the need for an electric bus specification to be prepared, similar to what is done for diesel, and for standard quotation and ordering procedures to be employed, again similar to what is done for diesel. These procedures, however, do take time. Also, given that all buses are custom-built to specification, there is also a future delivery timeframe that needs to be considered, roughly six to twelve months.

Technical uncertainties	In discussions by the Joint Task Force it is clear that some technical aspects remain less resolved than would be desired, imposing uncertainties. Two are relatively important in terms of impacts on economics and emission reductions: First is **battery life**. This impacts both in-service availability and maintenance savings. Given electric buses involve relatively new technology, there is much less experience with them than with conventional diesel buses. Commercial warrantees are certainly provided, but identifying and addressing battery problems takes time and effort. This directly impacts the extent of maintenance savings. As important background, while Winnipeg has been a leading location on electric buses, all of the batteries employed so far have been early commercial versions. They helped prove the technology can work, but these batteries are no longer commercially supported. Second is anticipated annual **travel distance**. As described earlier, this has a major effect on both economic viability and emissions reductions. Reasonable values are assumed as part of the update, but exactly what can be achieved on a regular basis in practice remains unconfirmed.
Federal co-funding support	The Joint Task Force has confirmed that securing co-funding from the Federal government can be complex. Federal funding availability is highly positive, and the Federal government has certainly indicated its interest, especially where GHG emission reductions can be achieved. At issue are public misconceptions that appear to exist, and are even outlined in the media, suggesting Federal funds are readily available and accessible. In reality, the detailed rules associated with Federal funding programs are complicated. Significant effort is required to navigate these funding programs, and the acquisition of funding can be never assured. The **Low Carbon Economy Leadership Fund** (LCELF) is a useful example for illustration. This fund has been identified by many, including within the media, as a logical choice to help finance electric buses.[5] It involves funding intended for projects within individual provinces and territories that have signed onto the Pan-Canadian Framework, with Manitoba's allocation being about $67 million. However, even if a project is a provincial priority, it may not necessarily be eligible. Indeed this is precisely the case for electric buses with the LCELF, where detailed rules permit only three narrowly defined types of projects: energy-efficiency for buildings; energy efficiency, fuel switching, and process changes for industries; and enhanced carbon storage in forests and agricultural land.[6] As such, electric buses are not eligible.
Integration	The last important consideration needing to be addressed is integration, which also directly impacts the costs. Transit, in general, represents an important urban utility service that depends on meeting schedules. As part of the original report, the Joint Task Force recognized that transit involves highly complex network operations that have been built up based primarily on the characteristics of diesel buses. This means electric buses, especially at large-scale beyond a few test units, need to be successfully integrated into transit systems that were designed around the technical features of diesel buses. Scheduling and provision of redundancy represent immediately recognizable aspects, and were identified in the earlier report as contributing potential costs, but issues relating to integration ripple throughout transit operations, including organization, planning, training and other areas. As such, integration can be most broadly described as a form of "change

Integration (continued)	management." Also, while clearly identified in Winnipeg, the importance of integration has not yet been well recognized elsewhere, with some detrimental impacts resulting. In the recent past, there has been a spate of bad news in the media about electric buses, primarily from California but also including locations in Canada. More than anything these stories speak to a lack of sufficient attention to integration. The full extent of concerns with integration remains nebulous. As such, a next important action would involve, firstly, defining in more detail the component activities needed to successfully integrate electric buses, and, secondly, determining costs for these activities so that a more fulsome understanding of implementation can be obtained. Red River College is in a good position to assist in better defining the specifics of integration and the associated costs. Further, integrating electric buses will require an implementation plan that is robust and flexible. It will not just happen on its own. The nature of different technical solutions that may be required is also not yet fully understood. If the switch to electric buses is simply left to happenstance, adoption will be erratic and subject to pitfalls and uncertainty. Many trial-and-error related problems could be avoided by using a "change management" approach. The Joint Task Force member organizations are in a position to act in a coordinated manner to help identify and to avoid pitfalls. Red River College, in particular, is in a position to provide academic support in key areas such as training, and even beyond to help coordinate integration-related efforts. Lastly, in order to ensure success with integration, sufficient resources need to be allocated by all levels of government. Achieving success in Winnipeg can help lead to success elsewhere in Manitoba, and even more broadly. This is an important opportunity.

Vehicle Technology & Energy Centre (VTEC) Description

This report was prepared through the VTEC initiative at Red River College. VTEC is responsible for applied research and innovation projects concerning ground transportation electric and hybrid vehicles that utilize renewable fuels. VTEC is a federally funded program that aims to increase research capacity at the College in the areas of vehicle technology, particularly vehicle performance and development. VTEC supports electric vehicle (EV) innovation amongst firms in Manitoba's transportation sector; enhances electric vehicle education at the College and in the region; and increases public awareness and understanding of electric vehicle technology in general.

Contacts

Ray Hoemsen, P.Eng., Executive Director
Research Partnerships & Innovation
Red River College
204.632.2523
rhoemsen@rrc.ca

Jose Delos Reyes, Research Manager
Vehicle Technology & Energy Centre
Red River College
204.631.3301
jdelosreyes@rrc.ca

References

1. Manitoba Government and City of Winnipeg Joint Task Force on Transit Electrification. 2016. The Future is Ahead of You: Summary Report.
[Government of Manitoba site]
http://www.gov.mb.ca/jec/energy/pubs/transit_electrification_taskforce_2016.pdf
[Or City of Winnipeg site]
http://winnipegtransit.com/assets/2162/Transit_Electrification_Taskforce_2016.FINAL.PDF

2. Parsons, R.V., E.G. Kwan, N.L. Wood, M. Hall, A.A. Akerstream, J.E. Sinnock, T.N.N. Nguyen, I.D. Frank, J.E. Kopp, K. Shah and N.P.A. Nguyen. 2017. Cost Benefit Analysis of Externality Factors for Battery Electric Transit Buses. Report from Sustainability Economics (Course IDM 7090 G05), MBA Program, I.H. Asper School of Business, University of Manitoba, Winnipeg, Canada. http://blogs.rrc.ca/ar/wp-content/uploads/2013/11/UofM-AsperMBA-2017-EBus-Externalities-CBA.pdf

3. Research Partnerships & Innovation. 2017. Zero Emission Electric Transit Bus in Manitoba: Prototype Electric Transit Bus Development and Demonstration Final Report. Red River College, Winnipeg, Canada. http://blogs.rrc.ca/ar/wp-content/uploads/2013/11/Prototype-Electric-Bus-Development-and-Demonstration-Final-report.pdf [Refer to Appendix for GHG emissions calculations]

4. Manitoba Sustainable Development. 2017. A Made-in-Manitoba Climate and Green Plan. Government of Manitoba, Winnipeg, Canada.
https://www.gov.mb.ca/asset_library/en/climatechange/climategreenplandiscussionpaper.pdf [Refer to page 55 of plan for mention of 100 electric buses by 2022 timeframe]

5. Kives, B. 2018. Province's push for electric buses to help cut greenhouse gases ignores the area of greatest need. CBC News, Analysis (July 15, 2018 7:45 AM).
https://www.google.ca/amp/s/www.cbc.ca/amp/1.4738428

6. Environment and Climate Change Canada. 2018. Low Carbon Economy Leadership Fund: Backgrounder. https://www.canada.ca/en/environment-climate-change/news/2018/07/low-carbon-economy-leadership-fund.html