Cost Benefit Analysis (CBA) for Repowered Existing Diesel School Bus Converted under *Electric School Bus Conversion* Project

August 2025

Authors:

Robert V. Parsons, Ph.D., M.B.A., Sessional Instructor †
Mario Petit, B.B.A. *
Maitha Alshamsi, B.Eng. *
Geoffrey Hurd, B.Comm. *
(* MBA Students in Course IDM 7090 G05, Winter 2025)
† Email contact: robert.parsons@umanitoba.ca

Additional Advisory Assistance:

Narendra Malalgoda, Ph.D., Assistant Professor and Associate Director
University of Manitoba Transport Institute
Barry Prentice, Ph.D., Professor and Director
University of Manitoba Transport Institute

CBA Prepared for: Red River College Polytechnic (RRCP), Winnipeg, Canada
CBA document supporting completion of project funded by the Manitoba Conservation and Climate Fund, Canadian Shield Foundation, Seven Oaks School Division (in-kind provision of suitable bus for conversion), and with collaboration and technical support from Noble Northern.
CBA and results released through the auspices of University of Manitoba Transport Institute (UMTI), I.H. Asper School of Business, University of Manitoba, Winnipeg, Manitoba, Canada

University of Manitoba

TRANSPORT INSTITUTE

Summary

In 2023, Red River College Polytechnic (RRCP) began a successful collaborative project to convert an already-used conventional Type-C diesel school bus to electric, and to demonstrate operational suitability to meet necessary capabilities required for the school bus application. Funds to support the project were secured from the Manitoba Conservation and Climate Fund and Canadian Shield Foundation, along with in-kind provision of a suitable bus for conversion by Seven Oaks School Division, and technical support from Noble Northern. This project is unique in that it represents the first, and so-far only, electrified school bus vehicle in the Province of Manitoba, and even appears to be the first to involve re-powering within Canada, although the approach has already been employed in the United States, with some international firms able to offer this service. The re-powered vehicle with completed conversion is illustrated in Figure 1.

Figure 1. Re-Powered Electric School Bus at Official Roll-Out Announcement
(May 27, 2025, Photograph by R. Parsons)

This report presents a cost-benefit analysis (CBA) comparing electrification options for Type-C school buses, and focuses on how to make a cost-efficient and affordable transition from traditional diesel-powered school buses to electric alternatives, specifically: **factory-built electric school buses**; versus **re-powered school buses**. This report assumes a glider frame lifespan of approximately 20 years is possible, and uses a conventional diesel school bus as the baseline. A power train lifespan of 10 years is further assumed in all cases, involving necessary major engine replacement for diesel, necessary major battery-pack replacement for factory-built electric, or option of re-powering diesel. The re-powered option assumes electric operation for remaining

lifespan, assuming consistently a power-train lifespan of 10 years. A variety of performance and cost parameters are also assumed, which are outlined in more detail within the report.
The main conclusion of the analysis is that re-powering of existing diesel school buses to electric represents a highly promising incremental approach to address greenhouse gases (GHG), as well as other smog pollutants associated with diesel vehicles, notably nitrogen oxides (NOx) and particulate matter (PM). Lifecycle financial costs, whether determined based on **power train lifespan** (Figure 2), or full **glider frame lifespan** (Figure 3), confirm the re-powering approach has strong merit, as a means for school boards and other education-transport entities to cost-efficiently implement an important step towards achieving zero-emission transportation.

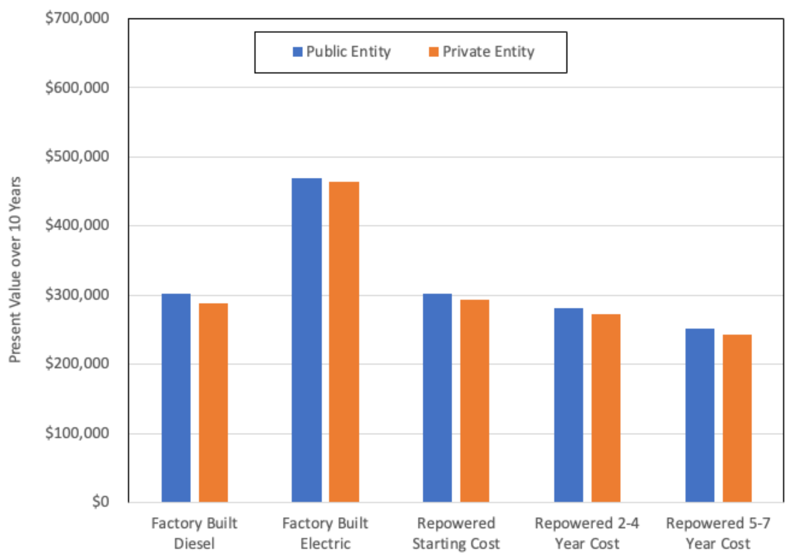

Figure 2. Present Value Costs over 10-year Power Train Lifespan

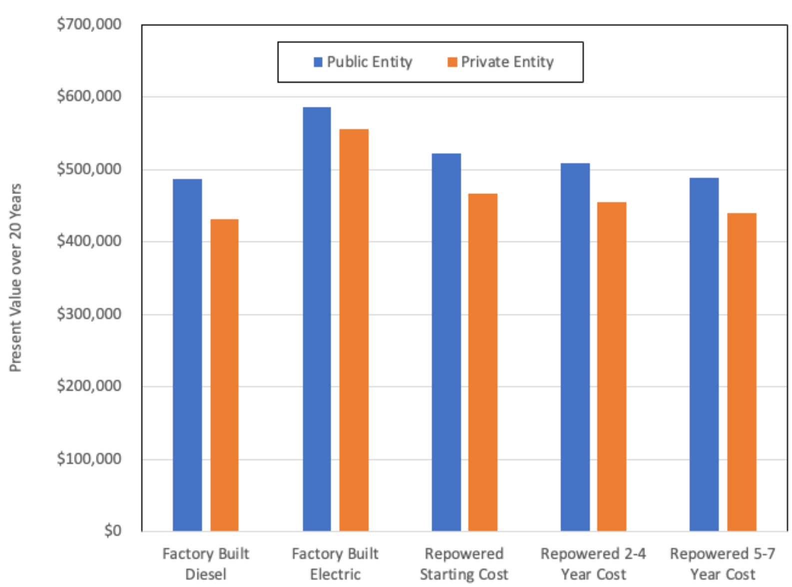

Figure 3. Present Value Costs over 20-year Glider Frame Lifespan

Considering the power train lifespan, present value costs for re-powered school buses are either very similar or lower than conventional diesel, and much lower than factory-built electric. Considering the full glider frame lifespan, present value costs are only slightly higher overall than conventional diesel, and again much lower than factory-built electric.

The re-powered option is especially attractive at the point when school boards or other education transport entities may be facing major engine replacements for existing individual diesel school buses. At the same time, the re-powering approach contrasts starkly with the option of factory-built electric school buses. These remain excessively expensive and thus effectively impractical for education-related transportation into the foreseeable future, particularly within Manitoba. Reasons explaining this situation for new vehicles are outlined.

The use of diesel-powered auxiliary heaters is necessary for all electric school buses within Manitoba, given climatic conditions. This applies whether factory-build or re-powered. A key finding from a health perspective regarding the potential exposure of children to diesel exhaust fumes, is that such heaters result in effectively negligible associated health externality costs. These heaters are thus not a concern.

Analyses suggest that a modest per-vehicle incentive of $20,000 per re-powered school bus, on completion of the conversion, would be suitable. This value is fully in-line with other incentives offered within Manitoba, and shows a modest cost per tonne reduction. Such an incentive would ensure lifespan cost differences compared to conventional diesel are completely or mostly covered, and ensure risks and uncertainty are addressed for school boards or other entities. Electrical-power delivery infrastructure for re-powered buses is relatively low cost too, with expensive high-power charging not required, and ample abilities for opportunity charging.

Sensitivity analyses suggest for the re-powered option that reducing conversion cost is the most important priority, most likely achievable both through increasing conversion-volumes (i.e., getting better pricing on conversion components), and greater experience (i.e., better stream-lining and standardizing conversion procedures). Sensitivity analyses further suggest travel distance and diesel fuel price or consumption as important variables, with re-powered bus viability improved when either or both increases. At the same time viability is relatively insensitive at all to changes in the price of electricity.

This report provides valuable insights for school boards, fleet operators, and policymakers considering the adoption of electric school buses, balancing economic feasibility with environmental goals. A series of recommendations are provided, including a simplified incentive of upwards of $20,000 per converted bus, as well as needs for further information and experience to confirm suitability, and trend tracking, especially regarding tariffs on batteries.

Table of Contents

List of Figures, Exhibits and Tables

1.0 Introduction

School buses represent an important class of medium-duty (MD) vehicles targeted within Canada and more globally for transition to zero-emissions operation, primarily via electrification. Such a transition is highly relevant given school buses in Canada, and in particular Manitoba, are still predominantly diesel powered. Benefits of conversion include reductions of both greenhouse gas (GHG) emissions and conventional smog pollutants (criteria air contaminants or CAC), including nitrogen oxides (NOx) and particulate matter (PM), the latter both especially important given these vehicles largely carry children.

At the same time, school buses also represent a class of vehicles for which the life of the glider itself tends to be longer than conventional engines. This characteristic, different from light duty cars and trucks, means that already-used conventional school buses, primarily diesel, are potentially amenable to being repowered to electric for an extended further operating period. Costs are more modest than new all-electric bus versions, thus more affordable, while benefits appear still appreciable. Further, while still just an interim measure, this approach is doable for achieving tangible results within the 2030 timeframe, noting Canada overall still lags significantly on progress with medium -and heavy-duty zero-emission vehicles.

Red River College Polytechnic (RRCP) as part of its *Electric School Bus Conversion* project, successfully converted an already used Type-C diesel school bus to electric. Under Gross Vehicle Weight Ratings, these units are designated as Class 6 vehicles (U.S DOE n.d.). A key objective of the project has been to create a standard “kit” that could be provided to individual school boards, school bus systems operators or conversion contractors to permit selection and conversion of used-school buses to electric in a straightforward and lower-cost manner.

This report considers costs and economic feasibility, environmental and societal (health factors), including monetization of externalities and savings, and preparation of a standardized cost-benefit analysis (CBA). The CBA compares three options:

- Conventional factory-built diesel school bus, used as the baseline for evaluation;
- Factory-build electric school bus from an established manufacturer; and
- Re-powered school bus converted from diesel operation, which is assumed to occur around mid-life (i.e., 10 years) in the lifespan of the bus glider frame.

Consideration of externalities focuses on two key areas:

- Reductions of GHG emissions achieved by moving to one of the electric options; and
- Reductions of NOx and PM emissions achieved by moving to one of the electric options.

A series of sensitivity analyses are included, as well as addressing four major identified uncertainties: (a) relative health impacts of using diesel-powered auxiliary heater; (b) selection of an optimal time in lifespan to convert; (c) applicable regulations relevant to the student transportation application; and (d) tariff implications.

2.0 Opportunities and Constraints Transitioning to Electric School Buses

In a recent report, the prominent consultant Dunsky Energy + Climate Advisors (Dunsky 2023) provided a summary of the rationale for considering school buses as "low-hanging fruit" opportunities to transition to zero-emissions, in particular to electric-based operation. Specific factors noted include:

- Highly predictable and relatively short routes that are effectively replicated twice daily (i.e., travel to schools in morning and return home in afternoon).
- Vehicles typically returning to a central location between shifts and at the end of the day meaning that a consistent charging site can be employed, with opportunity charging too.
- Conventional school buses typically diesel-powered, which represents a high emissions intensity fuel, with potential for significant unit greenhouse gas (GHG) emission reductions.
- Associated reductions in air pollutants (criteria air contaminants or CAC), including particulate matter (PM) and nitrogen oxides (NOx).
- Health benefits from pollutant reductions becoming particularly important given school buses deliberately carry children.
- Ample available charging times means that cost-efficient Level 2 infrastructure (i.e., upwards of 19.2 kW) is adequate, meaning rapid, high-power charging infrastructure is not required.
- Significant operating cost savings, both in terms of fuel and maintenance, are possible.

Within Manitoba there are currently in the range of 2,500 to 3,000 school buses, with these overwhelmingly Type-C (Dunsky 2023). For some time, there have been passionate encouragements to pursue electric school buses in Manitoba (e.g., Cicek 2018), however, so far there have been no such vehicles introduced here, until this current project. A national advocacy organization, the Canadian Electric School Bus Alliance, was formed in 2022 with the aim of securing government policy commitments to enable all school bus fleets within Canada to be transitioned from diesel to electric by 2040 (CESBA n.d. a). This organization provides an extensive library of resources discussing and supporting the transition (CESBA n.d. b).

Yet, there are major constraints limiting the implementation of electric school buses, most notably the prohibitively high prices for new, factory-built electric school buses that have not begun to decline as anticipated and as needed. For Type-C school buses, new unit prices are documented to be much higher than for conventional diesel in multiple objective third-party reports and academic sources:

- World Resources Institute's Electric School Bus Initiative (Levinson *et al*. 2023) showed a purchase price ratio for Type-C electric of 3.4-times higher, outlining additional cost data.

- Marpillero-Colomina (2022), in *The Conversation* academic forum, promoted electric school buses, but noted prices can range from 2.7- to 3.6-times higher than conventional diesel.

- Dunsky Energy + Climate Advisors work sponsored by Pembina Institute regarding British Columbia (Kasteel 2022), suggested new Type-C electric buses range from 2.3- to 3.0-times higher, from data on administered standing offers from the Association of School Transportation Services of British Columbia (ASTSBC).

As also directly outlined later by Dunsky (2023), purchase prices for new electric school buses are still overly high such that despite significant annual operating-cost savings, these vehicles are still not economically viable on a total cost of ownership (TCO) basis without significant financial assistance or incentives. Thus, despite public pressure and encouragement to electrify, the ability to cost-efficiently implement electric school buses remains questionable.

While this is not a desirable situation, the fact that prices for new electric school buses have still remained high does make sense. These are specialized vehicles made by specialist manufacturers, involving much lower production volumes than light duty vehicles. For illustration, by 2023 the total number of school buses in Canada was only upwards of 50,000 (Dunsky 2023), compared to upwards of 24 million light duty vehicles (Statistics Canada 2024). Manufactures do not have adequate resources to simply write-off costs, and must fully amortize overhead expenses associated with research, design, development and manufacturing of electric school buses across a relatively smaller number of units.

The nature of how incentives have been provided in Canada for electric school buses, especially at the federal level, is also a critical part of the problem. Rather than providing simplified individual incentives on a vehicle-by-vehicle basis, school buses have been clustered by the federal government under the much larger, but more complex, Zero Emission Transit Fund (ZETF). The latter program was announced in 2021, providing $2.75 billion in funding over five years, with the announcement itself specifically noting in terms of eligibility "public transit and school buses and associated infrastructure" (HICC 2021). A specific goal noted was to implement about 5,000 additional zero-emission buses across Canada, including both transit and school buses.

The program design, however, was inherently targeted toward larger projects, with no specified incentive levels stated, and award based on individualized evaluation, effectively "one-off." An important contrast was the Incentives for Medium- and Heavy-Duty Zero-Emission Vehicles (iMHZEV) Program, announced in 2022, providing $550 million in funding over four years, involving specified per-vehicle incentives intended to be worth up to 50% of the price difference between electric and traditional vehicles (Transport Canada 2022a). Virtually identical Type-C vehicles are included as "shuttles", with a stipulated incentive of approximately $100,000 (Transport Canada 2022b), however, not applicable for vehicles in school bus applications. This issue for school buses is consistent with an earlier concern for transit systems within smaller cities, whereby a simplified per-bus incentive would be preferred (Melo and Parsons 2019).

Kasteel (2022) noted that many school districts have remained hesitant to take on debt from federal loans, and found the ZETF application process to be overly burdensome, thus impractical for smaller-scale projects. Concerns regarding school bus funding via the ZETF continued, with both excessive delays and convoluted application requirements being noted (McGregor 2024). Ultimately, Lion Electric, which had been the marquee Canadian firm in the electric school bus manufacturing space, had to file for bankruptcy protection, specifically blaming a lack of timely federal incentive supports (Mathieu Dion 2024). Many economic-related problems thus remain for this industry.

3.0 RRCP *Electric School Bus Conversion* Project as Implemented

The project to re-power an already existing school bus began in the summer of 2023 (RRCP 2023). The college secured funding from the provincial Conservation and Climate Fund (CCF), now termed Climate Action Fund (Government of Manitoba 2023). The Canadian Shield Foundation provided additional funding as well, with Seven Oaks School Division making available an eleven-year-old Type-C school bus for conversion as an in-kind contribution.

Prior to beginning conversion, staff from RRCP and Seven Oaks School Division together reviewed a number of candidate buses for conversion. The importance of this crucial step could be easily overlooked, with review as undertaken focussed primarily on the condition and suitability of glider bodies for continued operations. For such conversion, not necessarily every unit may be appropriate to consider.

Automotive students at RRCP undertook the process of removing the diesel engine and associated drive train components prior to further conversion steps. RRCP partnered with manufacturer Noble Northern for the actual conversion itself (Noble Northern 2023a), with additional information available from their site, including a process flow diagram for the conversion (Noble Northern 2023b).

RRCP confirmed that the nominal capacity of the battery pack, as implemented on the bus, was 105 kWh, with stated usable capacity of about 97 kWh. This pack size is somewhat smaller than those cited for a number of factory-built electric school buses, i.e., averaging around 210 kWh based on four manufacturers (Lion Electric 2025, Thomas Build Buses 2021, IC Bus 2023, and Blue Bird 2025). The pack nevertheless is adequate for initial testing, and still capable of achieving a single-charge travel distance of close to 100 km.

The converted bus incorporates a Level 2 charge-port for AC power, following the J1772 standard (SAE 2024), with an on-board charger (OBC) unit to convert AC to DC for the actual charging of batteries, this capable of accommodating upwards of 19.2 kW. Level 2 chargers all involve AC electricity at around 220 V, and given interoperability, the charging rate can be limited by either the OBC unit itself, or the amperage level of the circuit at point of connection. Natural Resources Canada (NRCan 2025) considers Level 2 to involve charging rates ranging from 3.3 kW up to 19.2 kW. Further, based on their intent for incentives to cover roughly 50% of total project costs, their incentive level of $5,000 per connector translates to an approximate charging station cost of about $10,000 as suitable for the bus.

The bus as implemented can thus accommodate to the upper limit of Level 2 capability, but with charging time dependent on the amperage level at the point of connection. As such, there is flexibility for opportunity-charging. The approximate time to fully charge the bus from empty could require as little as 5.5 hours if at 19.2 kW, which is most desirable for vehicle home base. It is also possible to use a standard 3.3 kW circuit, with roughly 15 A delivered, meaning full charge in upwards of 32 hours or a reasonably common 6.6 kW circuit, with roughly 30 A delivered, translating to 16 hours. While obviously slower, the latter plug-ins can still contribute energy if needed. For testing RRCP will employ a variety of Level 2 charging points as available. The bus incorporates no Level 3, or Direct-Current Fast Charge (DCFC) capabilities, which are essentially unnecessary for this type of vehicle.

Costs associated with the first re-power conversion were tabulated by RRCP. Given that gaining further experience and increasing volumes would reduce costs, estimates were undertaken on anticipated cost levels within the next 2- to 4-year period, and the further 5- to 7- year period, with no taxes included, as outlined in Table 1. Respective cost reductions are 11% and 26%.

Table 1. Current and Anticipated Re-powering Conversion Costs Over Time

Category	**Current Cost**	**2 to 4 Year Cost**	**5 to 7 Year Cost**
Battery pack	$ 90,000	$ 70,000	$ 55,000
Motor	$ 32,000	$ 32,000	$ 28,000
Power distribution unit (PDU)	$ 12,000	$ 12,000	$ 11,000
High-voltage charger (OCB)	$ 9,000	$ 9,000	$ 8,000
12-volt battery	$ 2,000	$ 2,000	$ 2,000
Auxiliary heater	$ 5,000	$ 5,000	$ 5,000
Miscellaneous equipment	$ 13,000	$ 13,000	$ 11,000
Labour	$ 39,000	$ 35,000	$ 30,000
Total	$ 202,000	$ 180,000	$ 150,000
Reduction from Initial Cost	0%	11%	26%

The most significant cost reduction anticipated is for the battery pack itself (down 38%), reflecting higher volumes, improved battery efficiencies and greater experience. Additional electrical component costs anticipated to decline all reflect higher volumes, including miscellaneous equipment (down 15%), motor (down 13%), OBC (down 11%), and PDU (down 8%). Labour is anticipated to decline based on greater experience (down 23%). Items not anticipated to reduce include the 12-volt battery and auxiliary heater, which are already well-established commodities.

The following graphic from Noble Northern (Exhibit 1) summarizes:

- Photograph of the converted bus, prior to final colour-scheme implementation;
- Diagram illustrating the conversion process steps (also at Nobel Northern 2023b); and
- More detailed summary of components included in the conversion package,

Exhibit 1: Graphic Summarizing Conversion by Noble Northern

Specifications & Equipment

- Battery: CATL; (3x) C-Pack; 606Vdc Nominal; 173Ah; 105kWh rated, 97kWh usable
- Motor: DANA TM4; Sumo MD-HV3300-6P-L-158; MP-340_240-49, 3,000rpm; 959NM continuous; 3,000NM peak; 132kW continuous; 235kW intermittent
- MCU: DANA TM4; CO200 Inverter; INV-HP2HV-16, 6-phase; 300-800Vdc operating; 600Adc continuous; 890Adc peak
- OBC: CSI Branded; eOBC20.0hv; 20kW max output; 85-265Vac, 1ph input
- PDU: CSI Branded; ePDU-004; built-in pre-charge resistor; (2x) 5.5kW inverter, 2.5kW dc-dc converter
- BTMS: CSI Branded; eBTMS8.0HV; 18.0kW dc heating capacity; 8.0kW cooling capacity, integral pump
- Cabin Heater: ProHeat X30 diesel fired heater, 4.4~9.1 kW thermal (15,000~31,000 Btu)

Brief explanations of relevant terms as noted are summarized in Table 2 for clarify.

Table 2. Explanations of Terms Provided in Specifications Information

Term	Explanation
CATL	Contemporary Amperex Technology Co. Limited, Chinese-based international battery manufacturer headquartered in Ningde, Fujian province. One of the largest battery manufacturers in the world, especially for motive traction-battery applications. Well known to employ batteries incorporating Lithium Iron Phosphate (LFP) chemistry, although employ other chemistries as well (https://www.catl.com/en/).
MCU	Motor Control Unit, also termed Power Electronics Controller, for conversion of DC current from battery to AC for electric motor, and continuous to ensure adequate torque, speed and power provided to the drive train.
OBC	On-Board Charger, for conversion of AC to DC for charging of battery (noted earlier)
PDU	Power Distribution Unit, for distribution of high-voltage power from traction battery, both traction and auxiliary, and conversion to necessary DC voltage levels.
BTMS	Battery Thermal Management System, for ensuring battery pack remains within optimal temperature operating range.

Lastly, although the vehicle incorporates an electrically-operated thermal management system for the battery itself to ensure it is maintained within optimal temperature conditions, a diesel-based auxiliary heater was included to provide heat for the cabin. The use of diesel-based heating is well understood to be important for electric buses, both school buses and transit buses, this to preserve charge for motive operation (Hoemsen 2017). Diesel consumption for the re-powered school bus heating system is thus important to understand and estimate.

The re-powered bus incorporates a ProHeat X30 diesel-based heater, commonly used on buses. At maximum heat, the fuel consumption is listed as 1.17 Litres per hour (Marine Canada Acquisition 2021). Actual consumption will depend on temperature conditions, but a simplified assumption can be made: heat utilization for annual operation effectively follows a triangular shape, building linearly as ambient temperatures decline, and then reducing linearly as ambient temperatures increase, with average annual heat requirement thus effectively half maximum over relevant operating hours. Based on this method, calculated fuel consumption was estimated as about 490 Litres annually as follows (*equation 1*):

$$\text{Heater Fuel} = 840 \text{ hours per year} \times 1.17 \text{ Litres per hour maximum}/2 = 490 \text{ Litres diesel} \qquad (1)$$

The re-powered school bus is now undergoing a series of preliminary trials to confirm performance characteristics as well as adequacy of operability and reliability. This primarily involves its use of the bus as an internal RRCP shuttle vehicle between difference campuses within Winnipeg. Any necessary further modifications will also be identified in order to better streamline the desired conversion kit.

4.0 Methods for Comparison in Cost Benefit Analysis

This report considers costs and economic feasibility, environmental, and societal (health) factors to prepare a CBA, following the basic methodology outlined by the Treasury Board of Canada (2007). The baseline in this case is a new conventional diesel school bus, with **two electric options** considered:

- First is the factory-build electric school bus from an established manufacturer; and
- Second is the re-powered school bus converted from diesel operation, which is assumed to occur around year 10 of the life of the glider frame.

These options are **analyzed in two ways** to fully understand implications:

- First considers the **power train lifespan** only, which for both the diesel school bus and the factory-build electric school bus are assumed as approximately 10 years up to the time when either a new engine or a new battery pack are likely required, and for the re-powered school bus operation is also assumed as approximately 10 years, which in this case represents up to the end of the effective bus glider frame lifespan; and

- Second considers **glider frame lifespan**, which for the baseline and options involve:
    - Conventional diesel school bus operating for 10 years, with then a major engine replacement, followed by further 10 years of operating on diesel to end of glider lifespan;
    - Factory-build electric school bus operating for 10 years, with then a major battery pack replacement, followed by further 10 years of operating on electricity to end of glider lifespan; and
    - Re-powered school bus starting as a conventional diesel school bus operating for 10 years, with then re-powering conversion to electric, followed by further 10 years of operating on electricity to end of glider lifespan.

For each of these cases, the effective total cost of operation (TCO) is tabulated for the baseline and each option including:

- Vehicle purchase costs for diesel baseline and factory-built electric option;
- Vehicle conversion cost for the re-powered option, including anticipated declining costs for conversion kits as outlined above;
- Vehicle charging infrastructure costs for electric options;
- Vehicle annual energy costs, whether diesel fuel or electricity;
- Vehicle annual maintenance costs, whether for diesel or electric;
- Vehicle disposal cost or recoverable value, when considering power train lifespan;
- Major engine changeout cost for diesel baseline, when considering glider frame lifespan;
- Major battery pack changeout cost for factory-build electric option, considering glider frame lifespan;
- End of life vehicle and battery pack disposal costs.

In terms of evaluating GHG impacts, the use of an estimated externality cost, such as the social cost of carbon (SCC), is not considered in this case. Instead, emissions performance for the electric options are evaluated compared to the baseline diesel for each of the two lifespans (i.e., for **power train** and for **glider frame**) to determine net reductions in emissions. The net present value (NPV) economic costs (or reductions) for the two electric options are also determined, compared to baseline diesel. This approach permits more-useful comparisons, including direct calculations of:

- Necessary incentive levels, if required, on a per-school bus basis, for the electric options to be able to match the economic TCO for the diesel baseline; and
- Effective “cost per tonne reduction” for each of the electric options based on both analysis lifespans.

The "cost per tonne reduction" is a metric employed by the Working Group on Specific Mitigation Opportunities (2016). It is defined as the costs attributable to the measure divided by the total emission reductions achieved, with that earlier report also outlining relevant benchmark costs for comparison.

For NOx and PM pollutant emissions, relevant emission factors were employed, as up to date as possible. For both pollutants estimates of potential health damages were based on methods outlined by Parsons *et al*. (2017), the latter outlining externality costs associated with transition of transit buses from diesel to electric. This earlier analysis suggested that while both mortality- and morbidity- based costs can be determined, the former dominate overwhelming, and were solely used. As such costs were estimated based on a statistical value of life (SVL) of $6.5 million, and ratioed from previously estimated overall emissions and associated premature mortalities for Manitoba from Health Canada (2016), as follows:

- For NOx, 14 premature deaths associated with total annual emissions of 14.15 million kg; and
- For PM2.5, 15 premature deaths associated with total annual emissions of 697,000 kg.

The calculation equations for NOx (*equation 2*) and PM2.5 (*equation 3*) costs are as follows:

$$\text{NOx cost} = \text{annual kg NOx} \times \$6.5 \text{ million SVL} \times 14 \text{ premature deaths} \div 14.15 \text{ million kg NOx} \quad (2)$$
$$\text{PM2.5 cost} = \text{annual kg PM2.5} \times \$6.5 \text{ million SVL} \times 15 \text{ premature death} \div 697{,}000 \text{ kg PM2.5} \quad (3)$$

Estimated costs were further compared with the higher costs associated with electric vehicles. Heath-related savings estimates are somewhat of a problem area, with advocates often known in some cases to unrealistically overestimate health-related savings (Parsons *et al*. 2017). Part of the reason for reduced externalities involve implementation of ultra-low sulphur diesel fuels in the mid-2000s and Tier 4 emissions control requirements for both NOx and PM in the early 2010s.

Sensitivity analyses were undertaken, specifically examining results for necessary incentive values for the 20-year glider frame lifespan, with five major factors considered:

- Change in cost of money associated with private versus public operators;
- Change in re-powered bus cost of conversion anticipated;
- Change in annual travel distance
- Change in diesel consumption/price of diesel fuel; and
- Change in electricity consumption/price of electricity.

Lastly, four important uncertainties were specifically addressed relevant to the project:

- Relative health impacts of using a diesel-powered auxiliary heater;
- Selection of an optimal time in lifespan to convert;

- Operational considerations;
- Applicable regulations relevant to the student transportation application; and tariff implications.

5.0 Parameters Employed in Cost Benefit Analysis

Values related to three aspects are summarized in the following sections dealing, with performance factors, cost factors, and NOx and PM pollutant emissions and costs.

5**.1 Performance-Related Parameters**

Performance parameters employed for the CBA are summarized in Table 3, as follows.

Table 3. Performance Parameters Employed in Cost Benefit Analysis

Parameter	**Value**	**Explanation**
Vehicle glider lifespan	20 years	Maximum possible life
Power train lifespan	10 years	Engine or battery pack life
Charging station lifespan	20 years	Expected life for Level 2
Annual travel	22,500 km annually	Levinson *et al*. (2023) and others
Diesel fuel consumption rate	36 Litres per 100 km	Levinson *et al*. (2023) and others
Annual diesel consumption	8,100 Litres annually	Calculated
Diesel emission fluid (DEF)	162 Litres annually	Assumed as 2% of diesel
Annual diesel fuel emissions	21.86 tonnes annually	2.7 kg CO2e per Litre
Annual DEF emissions	0.08 tonnes annually	0.5 kg CO2e per Litre (Parsons *et al*. 2020)
Electricity consumption rate	105 kWh per 100 km	Levison *et al*. (2023) and others
Annual electricity consumption	23,625 kWh annually	Calculated
Annual electricity emissions	0.06 tonnes annually	2.5 g CO2e per kWh (ECCC 2025, Table A13-8)
Diesel auxiliary heater	490 Litres annually	See above
Annual heater emissions	1.33 tonnes annually	2.7 kg CO2e per Litre
Annual emission reductions	20.6 tonnes annually	21.86 + 0.08 – 0.06 – 1.33

The estimated annual emissions reduction for operation of an electric school bus in Manitoba, whether factory-built or repowered translates to approximately 20.6 tonnes. This value is based on calculations as noted and very close to a value of 20.5 tonnes annually presented earlier by RRCP (2023).

5.2 Cost-Related Parameters

Cost parameters employed for the cost benefit analysis are summarized in Table 4, as follows.

Table 4. Cost Parameters Employed in Cost Benefit Analysis		
Purchase-Related Costs	**Value**	**Explanation**
Diesel bus purchase cost	$150,000	Dunsky (2023) and others
Electric school bus	$400,000	Dunsky (2023) and others
Charging station	$10,000	NRCan (2025) see above
Additional One-Time Costs/Values	**Value**	**Explanation**
Major engine replacement/rebuild	$40,000	Rough value
Major battery pack replacement	$70,000	Consistent with re-powering
Diesel bus salvage at 10 years	$40,000	Rough value
Electric bus salvage at 10 years	$20,000	ESBI (2023) for battery pack
Disposal of any bus at 20 years	$5,000	Smith (2024)
Disposal of battery pack(s)	$5,000	Parsons *et al*. (2020)
Annual Operating Oriented Costs	**Value**	**Explanation**
Electricity rate	$0.0775 per kWh	Hydro Quebec (2024)
Rough diesel fuel pump-price	$1.40 per Litre	Rough contemporary price
Price variability equivalence	$0.08 per Litre	Parsons *et al*. (2017)
Added DEF fluid cost	$0.02 per Litre	Add 2% of fuel use
Total diesel fuel cost	$1.50 per Litre	Calculated
Diesel bus maintenance – years 1-5	$0.33 per km	Levinson *et al*. (2003)
Diesel bus maintenance – years +5	$0.59 per km	Levinson *et al*. (2003)
Electric bus maintenance – years 1-5	$0.20 per km	Levinson *et al*. (2003)
Electric bus maintenance – years +5	$0.36 per km	Levinson *et al*. (2003)

5.3. Nitrogen Oxides and Particulate Matter Generation and Externality Costs

NOx and PM emission factors for operations of diesel engines and auxiliary heaters, as employed in analysis are summarized in Table 5.

Table 5. NOx and PM Emission Factors Employed in CBA		
Parameter	**Value**	**Source**
Diesel engine NOx	0.6067 g per km	Burnham (2021)
Diesel engine PM	0.00621 g per km	Burnham (2021)
Diesel auxiliary heater NOx	1.377 g per Litre fuel	Hollquist and Solberg (2025) mean value from testing (5)
Diesel auxiliary heater PM	0.013702 g per Litre fuel	Hollquist and Solberg (2025) mean value from testing (5)

Annual emissions and costs are summarized in Table 6 based on 22,500 km or 490 Litre fuel.

Table 6. NOx and PM Annual Emissions and Associated Externality Costs		
Parameter	**Annual Quantity**	**Annual Cost**
Diesel engine NOx	13.65 kg annually	$87.80 annually
Diesel engine PM	0.14 kg annually	$19.60 annually
Diesel auxiliary heater NOx	0.675 kg annually	$4.34 annually
Diesel auxiliary heater PM	0.0067 kg annually	$0.94 annually

Given component costs as outlined for NOx and PM emissions, the annual externality costs for the diesel engine are $107.40 while annual externality costs for the diesel auxiliary heater as employed for the electric options are $5.28. Given that these costs are applied annually, overall total costs in both cases require further financial analysis based on the respective lifespans.

The annual impacts of pollutants from diesel auxiliary heaters are much smaller on annual basis than from the operating diesel engine, less than 5%. In both cases, engine or heater, the costs associated with NOx are the largest and most important, while those for PM are consistently less than 20% of annual costs in both cases.

6.0 Cost Benefit Analysis Results

The results of the CBA are presented for each of the two lifespan scenarios considered: **power train lifespan**, directly comparing re-powered vehicles to new diesel or electric; and **glider frame lifespan**, comparing re-powered with diesel and electric in terms of how they fit together over the full use of the vehicle frame. GHG implications are presented in conjunction with each of these cases, while NOx and PM2.5 implications are provided separately

6.1 Evaluation based on Power Train Lifespan

Present value (PV) costs for the various options in this case, including public and private entities (given differing costs of money), are presented in Table 7. This analysis covers a ten-year period, with new factory-build diesel and electric options sold at the end of the time, given they still have remaining useful life, while the re-powered vehicle reaches the end of its effective frame lifespan and can be used no longer. Differing conversion costs are also included for the re-powered vehicle illustrating expected effects of increasing experience and higher volumes.

Table 7. Present Value Costs over 10-year Lifespan of Power Train		
Option	**Public Entity**	**Private Entity**
Factory-Built Diesel	$301,665	$288,903
Factory-Built Electric	$468,934	$463,724
Re-powered (Starting Cost)	$302,836	$294,003
Re-powered (2-4 Year Cost)	$280,836	$272,003
Re-powered (5-7 Year Cost)	$250,836	$242,003

As illustrated, the highest PV cost is for the factory-build electric, while the lowest is for either the factory-build diesel or the re-powered bus depending on the decline in conversion costs achieved for the latter. Differences in PV costs compared to the baseline diesel option are presented in Table 8, which de facto represent incentive levels necessary in order to match the TCO for a conventional diesel school bus.

Table 8. PV Cost Differences (Incentive Levels) for Options Compared to Baseline Diesel

Option	Public Entity	Private Entity
Factory-Built Diesel	n/a	n/a
Factory-Built Electric	$167,269	$174,821
Re-powered (Starting Cost)	$1,171	$5,100
Repowered (2-4 Year Cost)	($20,829)	($16,900)
Repowered (5-7 Year Cost)	($50,829)	($46,900)

These results are illuminating. Over the ten-year power train lifespan, the factory-built electric bus shows a much higher overall cost. This makes sense and shows that in order to work financially for school bus users, incentives need to be in the range of $165,000 to $175,000 per vehicle, much higher than levels implied under the ZETF or listed for comparable non-school vehicles listed under the iMHZEV program. It is thus no wonder school boards and pupil transport organizations have shown diminished interest in electric school buses.

At the same time, the re-powered school bus shows very positive results. Even for the relatively high starting costs considered for conversion, the cost difference is small, less than 2%, while based on expected declines in conversions cost, the re-powered indeed shows a lower TCO. The advantage here is being able to utilize the still usable glider frame. It is also possible to estimate an effective "break-even" conversion cost such that PV values match the diesel baseline with no incentive needed. This translates to the range of about $195,000 to $200,000.

This evaluation only considers the 10-year power train life but reflects and supports near-term decisions by school bus users, illustrating that a cost-efficient approach does exist to begin making consequential emission reductions. On an interim basis, a modest incentive would be useful to help kick-start conversions, and ensure any additional risks (perceived or real) are covered. As discussed later a suitable incentive level of around $20,000 would be desirable.

For any relatively-immediate decision relating to power train choice, such an incentive would ensure the re-powering option to be completely viable, even for still relatively high conversion costs. The incentive would address risks and stimulate immediate practical actions within Manitoba to reduce emissions, but also not be an onerous burden for government.

In terms of GHG, cumulative 10-year emissions are as follows:

- Base-line diesel school bus option involves approximately 219 tonnes CO2e; while
- Factory-electric and re-powered electric options involve approximately 13 tonnes CO2e.

The net reduction over 10-years for all of the electric options is thus about 206 tonnes, which combined with net PV costs translate to "cost per tonne reduction" values as follows:

- Factory built electric school bus shows $800 to $850 per tonne CO2e, which is unrealistically high, especially when comparted to typical cost ranges of $100 to $250 per tonne noted for a variety of transportation-related measures (Specific Mitigation Opportunities Working Group 2016);
- Re-powered electric school bus shows at most about $25 per tonne CO2e, which is low, and as conversion costs reduce below breakeven levels actually show a net benefit rather than cost. Such results, which do not consider any government incentives, strongly support the use of re-powering for school buses.
- If an incentive of $20,000 were to be provided, the cost per tonne reduction for the government incentive would translate to less than $100 per tonne CO2e. For comparison a crudely estimated cost per tonne reduction of somewhat over $150 per tonne CO2e projected for the highly successful Efficient Trucking Program (ETP) in 2023 (Piche 2023). These values are all practical and within realistic ranges based on earlier emissions costing (Working Group on Specific Mitigation Opportunities 2016).

6.2 Evaluation based on Glider Frame Lifespan

Results from the above analysis based on the power train lifespan are very positive, but, importantly, re-powered school buses must also be considered in the context of the full glider frame lifespan. Present value (PV) costs for the various options in this case, including public and private entities (given differing costs of money), are presented in Table 9. This analysis covers a 20-year period, representing the overall full potential lifespan possible. For the baseline factory-built diesel bus, this covers 20-years of diesel operation, including a major engine change-out at year 10. For the factory-built electric bus option, this covers 20-year of electric operation, including a major battery pack replacement at year 10. The re-powered is most complicated. The bus starts as diesel and is operated as such for 10 years, followed by conversion to electric and operation for the final 10 years using electricity. Differing conversion costs are also included for the re-powered vehicle illustrating expected effects of increasing experience and higher volumes.

Table 9. Present Value Costs over 20-year Lifespan of Glider Frame

Option	Public Entity	Private Entity
Factory-Built Diesel	$486,037	$431,240
Factory-Built Electric	$585,379	$555,355
Re-powered (Starting Cost)	$522,427	$466,835
Re-powered (2-4 Year Cost)	$508,260	$455,115
Re-powered (5-7 Year Cost)	$488,942	$439,133

Again, as illustrated, the highest PV cost is for the factory-built electric, while the lowest is the factory-built diesel, with the re-powered bus costs intermediate between the two. Differences in PV costs compared to the baseline diesel option are presented in Table 10, which de facto represent incentive levels necessary in order to match the TCO for a conventional diesel school bus. Importantly, although re-powered bus costs are always slightly higher than diesel, if costs can be reduced to the level anticipated within 5-7 years, i.e., $150,000, the different between TCO with that for the conventional diesel bus is no more than about 2%. The prospect of a re-powered bus having reduced emissions but still costing almost the same as a diesel bus is highly positive.

Table 10. PV Cost Differences (Incentive Levels) for Options Compared to Baseline Diesel

Option	**Public Entity**	**Private Entity**
Factory-Built Diesel	n/a	n/a
Factory-Built Electric	$99,342	$124,114
Re-powered (Starting Cost)	$36,390	$35,595
Repowered (2-4 Year Cost)	$22,224	$23,875
Repowered (5-7 Year Cost)	$2,906	$7,893

These results show similar patterns as in the case of the power train lifespan, but with some differences. The 20-year cost of the factory-built electric bus is sufficiently high that in order to work financially for school bus users, incentives need to be in the range of $100,000 to $125,000 per vehicle. These are lower than in the case of the power train lifespan, and close to the levels available from existing incentive programs. This suggests that, financially, factory-built electric school buses potentially could be workable, however, only over very long periods and not guaranteed. This situation continues to emphasis the concern of excessive costs still associated with factory-bult electric school buses. For these vehicles to be viable, it is imperative for purchase costs to come down significantly.

At the same time, the re-powered school bus continues to show positive results. The differences in costs are higher than when considering the power train lifespan, but are not excessive. It is possible to estimate an effective “break-even” conversion cost such that PV values match the diesel baseline with no incentive needed. This translates to the range of about $135,000 to $145,000. It is likely over-optimistic to anticipate that this low conversion cost could be achieved, meaning that some sort of incentive would be required to ensure re-powered vehicles can fully match the TCO of conventional diesel over a longer glider frame lifespan. Yet incentive levels needed are not excessive. As noted in the last section, an incentive level of around $20,000 at the time of conversion is suggested.

Such an incentive would significantly cover incremental cost differences when considering glider frame lifespan, translating to a break-even conversion cost in the range of $155,000 to $165,000, which is well within that anticipated to be achieved within the 5- to 7-year timeframe. A simplified $20,000 incentive for each re-powered bus would help to fully achieve economic viability compared to diesel, both assisting to address financial risks and encouraging conversions.

In terms of GHG, cumulative 20-year emissions are as follows:

- Base-line diesel school bus option involves approximately 438 tonnes CO2e; while
- Factory-electric electric option involves approximately 26 tonnes CO2e; and
- Re-powered option, involving diesel followed by electric, involves approximately 232 tonnes CO2e.

The net reduction over 20-years for the factory-built electric option is about 412 tonnes, while for the re-powered bus is about 206 tonnes. Combined with net PV costs these translate to “cost per tonne reduction” values, as follows:

- Factory built electric school bus shows $240 to $300 per tonne CO2e, which is not unrealistic, but still high comparted to typical cost ranges of $100 to $250 per tonne noted for a variety of transportation-related measures (Working Group on Specific Mitigation Opportunities 2016);
- Re-powered electric school bus shows in the range of $15 to $180 per tonne CO2e, which is moderate to low, depending on the extent that conversion costs can be reduced. Such results again strongly support the use of re-powering for school buses.
- Consistent with the analysis based on power train lifespan, the reduction cost for a suggested $20,000 incentive at conversion time translates to less than $100 per tonne CO2e.

6.3 Costs for Diesel NOx and PM Emissions

Total PV costs associated with NOx and PM emissions for the **power train lifespan** are summarized in Table 11, and for the **glider frame lifespan** are summarized in Table 12.

Table 11. Present Value Costs for NOx and PM Emissions for 10-year Lifespan of Power Train		
Option	**Public Entity**	**Private Entity**
Factory-Built Diesel	$838	$772
Factory-Built Electric	$41	$38
Re-Powered Electric	$41	$38
Factory-Built Electric Savings	$797	$734
Re-Powered Electric Savings	$797	$734

Table 12. Present Value Costs for NOx and PM Emissions for 20-year Lifespan of Glider Frame		
Option	**Public Entity**	**Private Entity**
Factory-Built Diesel	$1,397	$1,183
Factory-Built Electric	$69	$58
Re-Powered Electric	$811	$738
Factory-Built Electric Savings	$1,328	$1,125
Re-Powered Electric Savings	$586	$445

The results show externality costs for combined NOx and PM emissions are very small for a single bus, whether based on power train lifespan or glider frame lifespan. In particular, the higher PV costs associated with electric buses for the 20-year glider frame lifespan, whether factory-build or re-powered, are all much higher than the above externality costs, meaning that inclusion of NOx and PM emissions does not entail any significant alteration in viability. Improvements in NOx and PM are affected, however, overall, these are much less important, in particular compared to GHG reductions.

6.4 Sensitivity Analyses

In terms examining sensitivity, five factors are considered examining necessary incentive levels required the 20-year glider frame lifespan case, with results summarized in Table 13, in their relative order of impact.

Table 13. Sensitivity of Factors Affecting Necessary Incentive for Glider Frame Lifespan

Factor	Change in Needed Incentive per +1% Change in Parameter	
	Re-Powered Electric Bus	Factory-Built Electric Bus
Cost of Money	+4.8% change	+12.5% change
Re-Powering Cost	+3.3% change	n/a
Annual Travel Distance	-3.1% change	-1.6% change
Diesel Consumption/Price	-2.4% change	-1.3% change
Electricity Consumption/Price	+0.4% change	+0.2% change

This analysis shows the relative order of importance, with capital related factors being most crucial to address. The cost of money is largely determined by the overall organization involved, with less flexibility. Next most important, for the re-powered bus, achieving incremental reductions in conversion costs is the highest priority. For all but one parameter, the re-powered bus is more sensitive to changes than the factory-built electric bus. That exception is changes in the cost of money, which makes sense and emphasizes again the excessively high cost of factory-built electric buses. Increases in two parameters, travel distance and diesel price, positively affect the necessary incentives (i.e., lower incentive needed to breakeven), while increases in all the others negatively affect the necessary incentives (i.e., higher incentive needed to breakeven).

7.0 Important Uncertainties to Address

Four important factors were considered further to clarify uncertainties, addressed in the following sections.

7.1 Relative Health Impacts of Using Diesel-Powered Auxiliary Heater

The move towards electric school buses is widely promoted as a “zero-emission” transition, and a critical step towards reducing both GHG and smog pollutants, especially NOx and PM. An important operational detail, however, is that electric school buses incorporate diesel-fueled auxiliary heaters. This matter is often overlooked, and leads to a somewhat skewed perception of the true nature of the vehicles, particularly in regions that experience low temperatures (Anttila *et al*., 2024). At the same time, there is broad recognition and a clear rationale for using auxiliary heating systems to provide cabin heat. Cold temperatures significantly affect the performance of battery electric vehicles if and when electrical battery capacity is consumed for heat provision.

As outlined by the U.S. Department of Energy (Walsh *et al*. 2024), at roughly -18 °C, battery electric vehicles can lose around 50% of driving range, this given expected higher energy demand to maintain cabin and battery temperatures, as well as reduced efficiency of battery chemistry in colder conditions. As a result, auxiliary heaters are commonly installed to meet the heating demand while preserving battery capacity. As noted earlier (Hoemsen 2017), this has already been a well-established requirement locally regarding transit buses.

Various sources (Anttila *et al*. 2024, Humphries *et al*. 2024, Sutton *et al*. 2021). highlight this glaring lack of acknowledgment in electric buses, citing operational and regulatory gaps as the culprit. Consumption and emission data are often highly inconsistent, given performance can vary based on external temperature, heater type, vehicle size and daily operational hours. From a regulatory standpoint, currently there are no regulations in North America that govern the use of fuel-fired heaters in electric buses. Nevertheless, it is highlighted that emissions from diesel auxiliary heaters are low compared to diesel powered engines.

This situation is evident in results from this current work regarding school buses. Overall reductions in diesel-related emissions associated with auxiliary heaters for factory-built and re-powered electric options versus diesel engines are summarized in Table 14 (i.e., results from Table 3 and Table 6).

Table 14. Diesel-Related Emissions Reductions Over Power Train Lifespans

Option	**GHG Emissions***	**NOx Emissions**	**PM2.5 Emissions**
Diesel Bus Engine	21.94 tonnes annually	13.65 kg annually	0.14 kg annually
Diesel Auxiliary Heater	1.33 tonnes annually	0.675 kg annually	0.0067 kg annually
Reduction	93.9% reduction	95.1% reduction	95.2% reduction

*Note this comparison excludes grid-related emissions for electric operation, which reduce net emission savings to about 20.6 tonnes annually

As seen, reductions of GHG emissions are close to 94%, while reductions of both NOx and PM emissions are more than 95%. While emissions are not completely eliminated, the differences are dramatic.

7.2 Optimal Timing for Conversion within Overall Lifespan

The ultimate overall lifespan for school buses varies by region, usage, and environmental factors, with most buses operating in the range of 2 to 6 hours per day. A typical current practice often cited for diesel school buses for buses to be retired or more typically sold at auction after 10 to 12 years (DOT 2016). This primarily reflects using the bus only while maintenance costs for the initial user remain reasonably low, i.e., prior to major repairs or critical drive component replacements. Major component replacement, such as engines depends on engine hours and km driven, can occur as early as around 7 years.
Buses, can and indeed are used for longer periods than 10 to 12 years. Rather than being scrapped outright, buses will typically go on to a second use by an alternative user. As buses age, however, maintenance costs increase.

For the purposes of this analysis, an overall glider frame lifespan of 20 years is selected, with a power train lifespan of 10 years, reflecting when either a major engine replacement or major battery pack replacement is required. As such, 10 years reflects the selection point for conversions. While reasonable as starting point assumptions, actual timing for re-powering will require further validation through actual experience.

7.3 Regulations Appliable to Student Transportation Applications

The regulation of school buses involves a number fairly unique. While most vehicles are governed by transportation-related legislation and regulations, school buses are also subject to specific requirements often falling under education-related legislation and regulations.

To explore this further, three Canadian jurisdictions were reviewed, Manitoba, Ontario and British Columbian to identify potential barriers to converting an existing diesel school bus to electric operation, including Acts identified for each province in Table 15.

Table 15. Relevant Legislation Reviewed for Potential Barriers to School Bus Repowering

Jurisdiction	**Relevant Legislation**	**Access Portal**
Manitoba	Public Schools Act	https://web2.gov.mb.ca/laws/statutes/ccsm/p250.php
Manitoba	Highway Traffic Act	https://web2.gov.mb.ca/laws/statutes/ccsm/h060.php
Ontario	Highway Traffic Act	https://www.ontario.ca/laws/statute/90h08
British Columbia	Motor Vehicle Act	https://www.bclaws.gov.bc.ca/civix/document/id/complete/statreg/96318_00

British Columbia	Passenger Transportation Act	https://www.bclaws.gov.bc.ca/civix/document/id/complete/statreg/04039_01

Detailed highlights of relevant Manitoba regulations are presented in Appendix A.

A common theme among all regulations within Canada is that school buses must meet the Canadian Standards Association's D250 Standard with all referring specifically to this standard. The most current version is CSA: D250- 2022 (CSA 2022), with synoptic description provided by Schirn (2022). A key point requiring further exploration is found in the Manitoba regulations, which state that a school bus may not be altered or modified without the approval of the Minister of Education (see Appendix A). The term modification, however, is not defined in the regulations.

The regulations in Manitoba and British Columbia include a restriction that a school bus can only be used for the purpose of transporting pupils to and from school. This limits how the demonstration model can be tested as it cannot be used to transport pupils without all of the required pupil safety equipment installed; however, installation of such equipment and registration as a school bus limits use to transportation of pupils only unless the pupil safety equipment and distinctive school bus markings are covered while being used for another purpose.

Another key point requiring further exploration is found in examples of school bus conversions in the US. In some states, re-powering an older vehicle means that the bus must meet current standards which may impose additional costs or make the conversion impractical. An example is the installation of seatbelts which are now required in some states (Worthmann 2024). Further exploration with the regulators to confirm which version of the standards would apply to a re-powered school bus is required to confirm that a re-powered school bus would meet the relevant standards and still be eligible for registration.

7.4 Tariff Implications

Trade disruptions and tariffs are modern realities that are directly relevant for the re-powering project, in particular given that batteries from the Chinese manufacturer CATL are involved. In October 2024, the Government of Canada implemented tariffs on specific products from China, suggesting Canadian workers, industries and critical supply chains are "are threatened by unfair competition from Chinese producers, who benefit from China's intentional, state-directed policy of overcapacity and oversupply, as well as its lack of rigorous labour and environmental standards." The suite of tariffs included (Finance Canada 2024a):

- 100% surtax on all Chinese-made EVs, effective October 1, 2024;
- 25% surtax on imports of steel and aluminum products from China, effective October 22, 2024; and

- Potential surtaxes on critical manufacturing sector products, particularly batteries and battery parts, semiconductors, solar panels, and critical minerals, which the government consulted on from September 10, 2024, to October 10, 2024.

The latter is most relevant to the re-powering project. Possible surtaxes ae mentioned, but nothing certain yet. Relevant consultations and results were outlined in more detail by Finance Canada (2024b). Under Annex 1, the consultation document notes under "Batteries and Battery Parts":

Tariff Item 8507.60.10 "Lithium-ion ---For use as the primary source of electrical power for electrically-powered vehicles of subheading 8703.80 or 8703.90."

From available information, it appears that possible surtaxes could be applied at some time to the batteries from CATL as used for the re-powering, but as yet nothing specific. In the China Surtax Order implemented in 2024 (Government of Canada 2024), the above tariff item (i.e., 8507.60.10) is not noted. It is crucial to track over time what may be happening regarding Chinese batteries that are not integral parts of Chinese-manufactured vehicles.

8.0 Conclusions

Main conclusions of this cost benefit analysis are as follows:

- Re-powering of existing diesel school buses to electric represents a highly promising approach for addressing GHG emissions and other smog pollutants (CAC like NOx and PM).

- Lifecycle financial costs, whether determined based on power train lifespan or full glider frame lifespan, confirm the repowering approach has strong merit, as a means for school boards and other education-transport entities to cost-efficiently implement an important step towards achieving zero-emission transportation.

- The re-powered option is especially attractive at the point when school boards or other education transport entities face major engine replacements likely being needed for existing individual diesel school buses.

- Repowering approach contrasts starkly with the option of factory-built electric school buses, which remain excessively expensive and thus effectively impractical for education-related transportation into the foreseeable future, in particular within Manitoba.

- Electrical-power delivery infrastructure for re-powered buses is relatively low cost, with expensive Level 3 charging not required, with ample abilities for opportunity charging at various points during the day.

- Analyses suggest that a modest per-vehicle incentive of $20,000 per re-powered school bus, on completion of the conversion, would be suitable. Such an incentive would ensure lifespan cost differences compared to conventional diesel are completely or mostly covered, and ensure risks and uncertainty are addressed for school boards or other entities.

- Such a $20,000 incentive-level is in-line with other incentives offered for light-duty vehicles, and would not be onerous for government, with resulting incentive-cost per tonne reduction less than $100 per tonne CO2e.

- Sensitivity analyses suggest for the re-powered option that reducing conversion cost is the most important priority, most likely achievable both through increasing conversion-volumes (i.e., getting better pricing on conversion components), and greater experience (i.e., better stream-lining and standardizing conversion procedures)

- Sensitivity analyses further suggest travel distance and diesel fuel price or consumption as important variables, with re-powered bus viability improved for increases in either or both, while at the same time viability is relatively insensitive at all to changes in the price of electricity.

- Analysis as undertaken suggests re-powering should be undertaken at approximately the 10-year point in the overall lifespan of a bus glider frame, the latter assumed to be upwards of 20-years. Further investigation and greater practical experience are required to confirm this selection.

- The presence of an auxiliary diesel heater is a practical reality of electric school buses, whether factory built or re-powered, which may appear at odds with the "green" image implied by electric operation. Analyses suggest the costs of health-related externality damages are very small for auxiliary heaters, and confirm, compared to a diesel engine, that GHG emissions are reduced by almost 94%, and NOx and PM emissions are reduced by more than 95%.

- Regulation of school buses, within Manitoba and in other provinces, is relatively more complex than for vehicles not associated with pupil transportation. Across all provinces, a critical requirement is to ensure compliance with the Canadian Standards Association standard CSA: D250- 2022, or most current version into the future.

- Given that Chinese-based batteries from CATL are used as part of the Noble Northern conversion package, the prospect of tariffs needs to monitored. It appears so far that no tariffs are in place, but these components have been noted for possible tariff consideration.

9.0 Recommendations

Major recommendations emerging from this cost benefit analysis are as follows:

- RRCP should ensure that sufficient testing of the demonstration vehicle be completed in order to provide key information to validate performance, including:
    - Electricity consumption, in particular over varying ambient temperature conditions,
    - Practical travel distances achievable,
    - Recharging performance covering a range of potential Level 2 plug-in locations, including the practicality of opportunity charging at relevant sites,
    - Tracking reliability and maintenance issues as may occur over the demonstration period to ensure these are understood, and
    - Potentially shadowing exercises with Seven Oaks School Division whereby the demonstration vehicle follows actual school buses on route (but without students) in order to mimic actual use patterns.

- RRCP should communicate with school boards and other education transportation entities regarding the results and future prospects for re-powered conversion, both to raise awareness and potentially to identify prospective organizations for future conversions.

- Relevant package of information materials, including likely Q&A, should be prepared for distribution to school boards and other education transport entities, notably including discussion of auxiliary heaters.

- RRCP should continue discussions with Manitoba Public Insurance (MPI) and Manitoba Education regarding all the necessary rules and requirements for the school bus application, in particular order to identify any not yet addressed limitations.

- RRCP should work with Noble Northern to monitor likely progress conversion costs, and potential proactive means to reduce conversion costs.

- RRCP together with Noble Northern should monitor the ongoing situation regarding tariffs on Chinese-based batteries.

- RRCP should communicate more broadly the results of this successful project to academic, industry and educational sectors, which is so far the first of its kind in Canada.

References

Anttila, J., R. Pettinen and Y. Todorov. 2024. Conventional cabin heating in electric buses – the scale of pollution. Paper associated with 8th E-Mobility Power System Integration Symposium (EMOB 2024), October 28, 2024. *IET Conference Proceedings* 2024(15): 75–82. DOI: https://doi.org/10.1049/icp.2024.3736

Blue Bird. 2025. *Vision ELECTRIC: Technical Specifications*. https://www.blue-bird.com/wp-content/uploads/2025/03/Vision-Electric-Spec-Sheet_3_17_25.pdf

Burnham, A. 2021. *MOVES3 vehicle operation emission factors*. Argonne National Laboratory (ANL) (October 2021), Argonne, United States. (Downloadable PDF file from ARN).

Canadian Electric School Bus Alliance (CESBA). n.d. a. About the Alliance. https://eschoolbusalliance.ca/about-the-alliance/

Canadian Electric School Bus Alliance (CESBA). n.d. b. Resource library. https://eschoolbusalliance.ca/resource-library/

Canadian Standards Association. 2022. Standard CSA D250:22 School buses https://www.csagroup.org/store/product/CSA%20D250:22/?srsltid=AfmBOopwHltzJaZE8CL_AiAsC_5RyjDVU1TVeJ3BbHoisSHq6rvrAX5I

Cicek, N. 2018. Moving school buses into the 21st century. Winnipeg Free Press (Posted: 4:00 AM CDT Friday, Jun. 22, 2018). https://www.winnipegfreepress.com/opinion/analysis/2018/06/22/moving-school-buses-into-the-21st-century

Dunsky Energy + Climate Advisors (Dunsky). 2023. *Pathways for Canadian Electric School Bus Adoption*. Equiterre, Montreal, Canada. https://cms.equiterre.org/uploads/CESBA_STUDY_Pathways-for-electrification_May-2023-ENGpdf.pdf

Electric School Bus Initiative (ESBI). 2023. How electric school bus fleet owners can ensure that their used vehicle batteries avoid the landfill – and reap economic and environmental benefits (Posted: October 24, 2023). https://electricschoolbusinitiative.org/how-electric-school-bus-fleet-owners-can-ensure-their-used-vehicle-batteries-avoid-landfill-and

Environment and Climate Change Canada (ECCC). 2025. *National Inventory Report 1990–2023: Greenhouse Gas Sources and Sinks in Canada. Canada's Submission to the United Nations Framework Convention on Climate Change*, Part 3. Government of Canada, Gatineau, Canada. https://publications.gc.ca/collections/collection_2025/eccc/En81-4-2023-3-eng.pdf

Finance Canada. 2024a. Canada announces tariff remission process for Canadian businesses importing certain Chinese goods. News release: Ottawa, October 18, 2024, Government of Canada. https://www.canada.ca/en/department-finance/news/2024/10/canada-announces-tariff-remission-process-for-canadian-businesses-importing-certain-chinese-goods.html

Finance Canada. 2024b. Consultations on potential surtaxes in response to unfair Chinese trade practices in critical manufacturing sectors. Government of Canada, Ottawa, Canada. https://www.canada.ca/en/department-finance/programs/consultations/2024/consultations-on-potential-surtaxes-in-response-to-unfair-chinese-trade-practices-in-critical-manufacturing-sectors/consultations-potential-surtaxes-response-unfair-chinese-trade-practices-critical-manufacturing-sectors.html

Government of Canada. 2024. China Surtax Order (2024): SOR/2024-187 https://gazette.gc.ca/rp-pr/p2/2024/2024-10-09/html/sor-dors187-eng.html

Government of Manitoba. 2023. News release: Manitoba Government Invests $1.5 Million in Projects to Reduce Carbon Emissions, Create Green Jobs (July 28, 2023). https://news.gov.mb.ca/news/print,index.html?archive=&item=60101

Hallquist, A. and H. Salberg. 2025. Emissions from fuel-operated heaters in battery-electric buses. *Atmospheric Environment: X* 26: 100332. DOI: https://doi.org/10.1016/j.aeaoa.2025.100332

Hoemsen, R. 2017. Zero Emission Electric Transit Bus in Manitoba: Prototype Electric Transit Bus Development and Demonstration Final Report. Electric Vehicle and Technology Centre (EVTEC), Red River College, Winnipeg, Canada. https://www.rrc.ca/vtec/wp-content/uploads/sites/78/2019/05/Prototype-Electric-Bus-Development-and-Demonstration-Final-report-1pxb35m.pdf

Housing, Infrastructure and Communities Canada (HICC). 2021. Government of Canada targets zero emission bus transportation with launch of new fund: $2.75 billion available for infrastructure projects through the Zero Emission Transit Fund. News release: Ottawa, August 10, 2021, Government of Canada. https://www.canada.ca/en/housing-infrastructure-communities/news/2021/08/government-of-canada-targets-zero-emission-bus-transportation-with-launch-of-new-fund.html

Humphries, K., H. Rashid and F. Araji. 2024. Diesel Fuel-Fired Heater Emissions from a Battery Electric Transit Bus in Real-World Conditions. SAE Technical Paper 2024-01-5011. https://doi.org/10.4271/2024-01-5011.

IC Bus. 2023. *Electric CE Series School Bus* https://www.icbus.com/-/media/Project/Navistar/ICBus/ICBus/Why-ICBus/Zero-Emissions/IC_BUS_eCE_SpecSheet_2023_FINAL.pdf

Kasteel, C. (Dunsky Energy). 2022. *Electric School Buses: The benefits to British Columbians and options for accelerating the transition*. Pembina Institute, Vancouver, Canada. https://www.pembina.org/reports/electric-school-bus-adoption-in-bc-rev.pdf

Levinson, M., P. Burgoyne-Allen, A. Huntington and N. Hutchinson. 2023. *Recommended Total Cost of Ownership Parameters for Electric School Buses: Summary of Methods and Data, Technical Note*. World Resources Institute, Washington, D.C., U.S.A. https://files.wri.org/d8/s3fs-public/2023-02/recommended-total-cost-ownership-esb-summary-methods-data.pdf?VersionId=dFh.syMjwVcYF9cBpomUkK5_hepMvyIB

Lion Electric. 2025. LION's all-electric type C school bus. https://thelionelectric.com/lionc/

Marine Canada Acquisition Inc. 2021. ProHeat X30 Specifications. Document: SL9133D.

Marpillero-Colomina, A. (The New School). 2022. Electric school buses are taking students back to school – bringing cleaner air and lower maintenance costs to school districts across the country. *The Conversation* (Published: August 17, 2022 8.39am EDT). https://theconversation.com/amp/electric-school-buses-are-taking-students-back-to-school-bringing-cleaner-air-and-lower-maintenance-costs-to-school-districts-across-the-country-185659

Mathieu Dion, M. (Bloomberg News). 2024. Lion Electric expects bankruptcy filing amid EV pushback: The Quebec government has invested $177 million in Lion so far, and the federal government, $30 million. *Financial Post* (Posted: December 17, 2024). https://financialpost.com/commodities/energy/electric-vehicles/lion-electric-bankruptcy-ev

McGregor, J. 2024. Why doesn't Canada have more electric school buses? 3 years in, the federal zero emission transit fund hasn't done much to electrify school fleets. *CBC News* (posted: September 6, 2024, 3:00 AM CDT). https://www.cbc.ca/news/politics/green-school-bus-funding-delays-1.7314006

Melo, F. and R. Parsons. 2019. Simplified rebates would get more electric buses on Canadian roads: We've fallen behind in adopting electric buses, but predictable and streamlined funding would help transit agencies make the jump. *Policy Options* (Posted: August 22, 2019). https://policyoptions.irpp.org/magazines/august-2019/simplified-rebates-would-get-more-electric-buses-on-canadian-roads/

Natural Resources Canada. 2025. Zero Emission Vehicle Infrastructure Program funding for owners and operators of charging and refuelling infrastructure. Government of Canada. https://natural-resources.canada.ca/energy-efficiency/transportation-energy-efficiency/zero-emission-vehicle-infrastusture/zero-emission-vehicle-infrastructure-program-0

Noble Northern. 2023a. EV School Bus Repower Solution. https://noblenorthern.com/ev-school-bus-repower

Noble Northern. 2023. EV School Bus: Repowered Process. https://img1.wsimg.com/blobby/go/dad90ac4-c142-4add-b57b-37f09b352d86/RRC.pdf

Parsons, R.V., M.J. Kizuik, T.G. Miles, S.C. Prud'homme, J.S. Sodomsky and M. Wang. 2020. Preliminary Cost Benefit Analysis (CBA) of Zero-Emission Transit Bus Options for the City of Winnipeg. I.H. Asper School of Business, University of Manitoba, Winnipeg, Canada (Version 3.0, June 2020). https://umanitoba.ca/asper/sites/asper/files/2022-12/CBA%20for%20Zero%20Emission%20Bus%20Options%20June%202020%20V3.pdf

Piche, G. 2023. Reducing emissions for the long haul: Renewed government funding to help trucking industry trim carbon footprint. *Winnipeg Free Press* (Posted: 2:00 AM CDT Friday, May. 26, 2023). https://www.winnipegfreepress.com/business/2023/05/26/reducing-emissions-for-the-long-haul

Red River College Polytechnic (RRCP). 2023. News: RRC Polytech leading conversion of diesel school buses to EV technology (August 15, 2023). https://www.rrc.ca/marcom/2023/08/15/rrc-polytech-leading-conversion-of-diesel-school-buses-to-ev-technology/

Schirn, A. 2022. CSA D250-2022: School Buses Standard. American National Standards Institute (Posted: September 7, 2022). https://blog.ansi.org/ansi/csa-d250-2022-school-buses-standard/

Society of Automotive Engineers (SAE). 2024. SAE Electric Vehicle and Plug in Hybrid Electric Vehicle Conductive Charge Coupler: J1772 202401. https://www.sae.org/standards/content/j1772_202401/

Smith, S. 2024. How much is a bus worth in scrap? Schmidt's Auto Recycling, Kitchener, Canada (Posted: December 26, 2024). https://schmidtsautorecycling.ca/how-much-is-a-bus-worth-in-scrap/

Statistics Canada. 2024. Table 23-10-0308-01, Vehicle registrations, by type of vehicle and fuel type. DOI: https://doi.org/10.25318/2310030801-eng

Sutton, K., K. Jokinen and F. Silver. 2021. *Fuel-Fired Heaters: Emissions, Fuel Utilization, and Regulations in Battery Electric Transit Buses*, White Paper. CALSTART, Pasadena, United States. https://calstart.org/wp-content/uploads/2022/01/FFH-White-Paper_Final.pdf

Thomas Built Buses. 2021. *Introducing the SAF-T-LINER C2 Jouley Electric bus*. https://thomasbuiltbuses.com/content/uploads/2021/09/brochure-c2_jouley_and_proterra-fall-2021.pdf

Transport Canada. 2022a. Minister of Transport announces new Incentives for Medium- and Heavy-Duty Zero-Emission Vehicles Program. News release: London, July 11, 2022, Government of Canada. https://www.canada.ca/en/transport-canada/news/2022/07/minister-of-transport-announces-new-incentives-for-medium--and-heavy-duty-zero-emission-vehicles-program.html

Transport Canada. 2022b. Medium and heavy-duty zero-emission vehicles: Eligible Vehicles. Government of Canada. https://tc.canada.ca/en/road-transportation/innovative-technologies/zero-emission-vehicles/medium-heavy-duty-zero-emission-vehicles/eligible-vehicles

Treasury Board Secretariat. 2007. *Canadian Cost-Benefit Analysis Guide - Regulatory Proposals*. Government of Canada, Ottawa, Canada. https://www.tbs-sct.canada.ca/rtrap-parfa/analys/analys-eng.pdf

U.S. Department of Energy (U.S. DOE). n.d. *Types of Vehicles by Weight Class*. https://afdc.energy.gov/data/10381

U.S. Department of Transportation (DOT), Volpe Center. 2016. Bus Lifecycle Cost Model for Federal Land Management Agencies: User's Guide. Government of United States, Washington, D.C., United States. Access portal: https://rosap.ntl.bts.gov/view/dot/9548#:~:text=John%20A.-,Volpe%20National%20Transportation%20Systems%20Center%20(U.S.),full%20lifecycle%20of%20the%20vehicle.

Walsh, P., R. Isaac, R. Vijayagopal, A. Rousseau, J. Seo and N. Kim. 2024. *Impact of Cold Ambient Temperature and Extreme Conditions on Electric Vehicles*. U.S. Department of Energy, Washington, D.C., United States. https://www.energy.gov/sites/default/files/2024-10/Impact_of_Cold_Ambient_Temperature_on_BEV_Performance_v15_TechEditFinal_12Sep2024__0.pdf

Working Group on Specific Mitigation Opportunities. 2016. *Final Report*. Environment and Climate Change Canada. (Report prepared under Pan-Canadian Framework. Ottawa, Canada). https://www.canada.ca/content/dam/eccc/migration/cc/content/6/4/7/64778dd5-e2d9-4930-be59-d6db7db5cbc0/wg_report_specific_mitigation_opportunities_en_v04.pdf

Worthmann, E. 2024. All about electric school bus repowers. Electric School Bus Initiative (Posted: May 15, 2024). https://electricschoolbusinitiative.org/all-about-electric-school-bus-repowers

Appendix A
Selected Aspects of Regulations Relevant to School Bus Re-Powering in Manitoba

School Buses Regulation, 465/88R, of The Public Schools Act, CCSM c P250
https://web2.gov.mb.ca/laws/regs/current/_pdf-regs.php?reg=465/88%20R

Alteration or modification prohibited
Section 3: "…no person shall alter or modify…any school bus vehicle or equipment thereof unless that specific alteration or modification has been approved by the minister…."

Standards and specifications
Section 4: "Each school bus registered under The Highway Traffic Act in the name of a school board, and each school bus that is under contract with a school board, shall conform to standards and specification as follows:
a) Canadian Standards Association—Standards for School Buses
i) "Each school bus and all school bus equipment shall be maintained in accordance with the original manufacturer's recommended procedures as set out in published repair and maintenance manuals…."

Section 6(1): "A person who is under contract with a school board and who is registered as owner of a school bus under The Highway Traffic Act shall,
a) "…file with the school board a copy of the subsisting inspection certificate for the school bus that is required by the Periodic Mandatory Vehicle Inspection Regulation, Manitoba Regulation 76/94…."

Use of a school bus for other purposes and authorized uses
Section 10: "A vehicle that is registered as a school bus and for other purposes under The Highway Traffic Act, shall not be used for those other purposes during any period in which the vehicle is used as a school bus, and unless all marks showing or indicating that it is a school bus are concealed, no person shall operate a school bus for purposes other than those set out in section 11."

Section 11: "Notwithstanding section 10, a school board may authorize the use of a school bus
a) To transport pupils for the purpose of participating in or attending extracurricular activities;
b) To transport trustees, administrative officers and teachers employed by the school division or district while carrying out their regular duties or attending professional development sessions; and
c) As may be required for the purpose of repairing or servicing it."

The Highway Traffic Act, CCSM c H60
https://web2.gov.mb.ca/laws/statutes/ccsm/h060.php

Uses

Section 137(4): "A person must not operate a school bus for a purpose other than transporting pupils to or from school unless any markings identifying the bus as a school bus are covered."

Section 202: "No person who acquires or has possession of a used school bus which is no longer used for the purpose of a school bus shall drive it upon a highway, or cause, authorize or permit it to be driven upon a highway, unless
(a) all signs or words which identify the motor vehicle as a school bus have been removed from the vehicle;
(b) any warning lamps and warning systems required for school buses under the regulations have been removed from the vehicle; and
(c) the front and rear of the bus have been repainted with a colour other than chrome yellow."

Regulations

Section 319(5): "The Lieutenant Governor in Council may make regulations
(a) designating classes or types of motor vehicle that may be used as a school bus;
(b) prescribing standards for school buses and their equipment;
(c) requiring school buses to be equipped with warning lamps, warning systems and safety devices, and respecting the use of such lamps and devices and the standards to which they must conform."