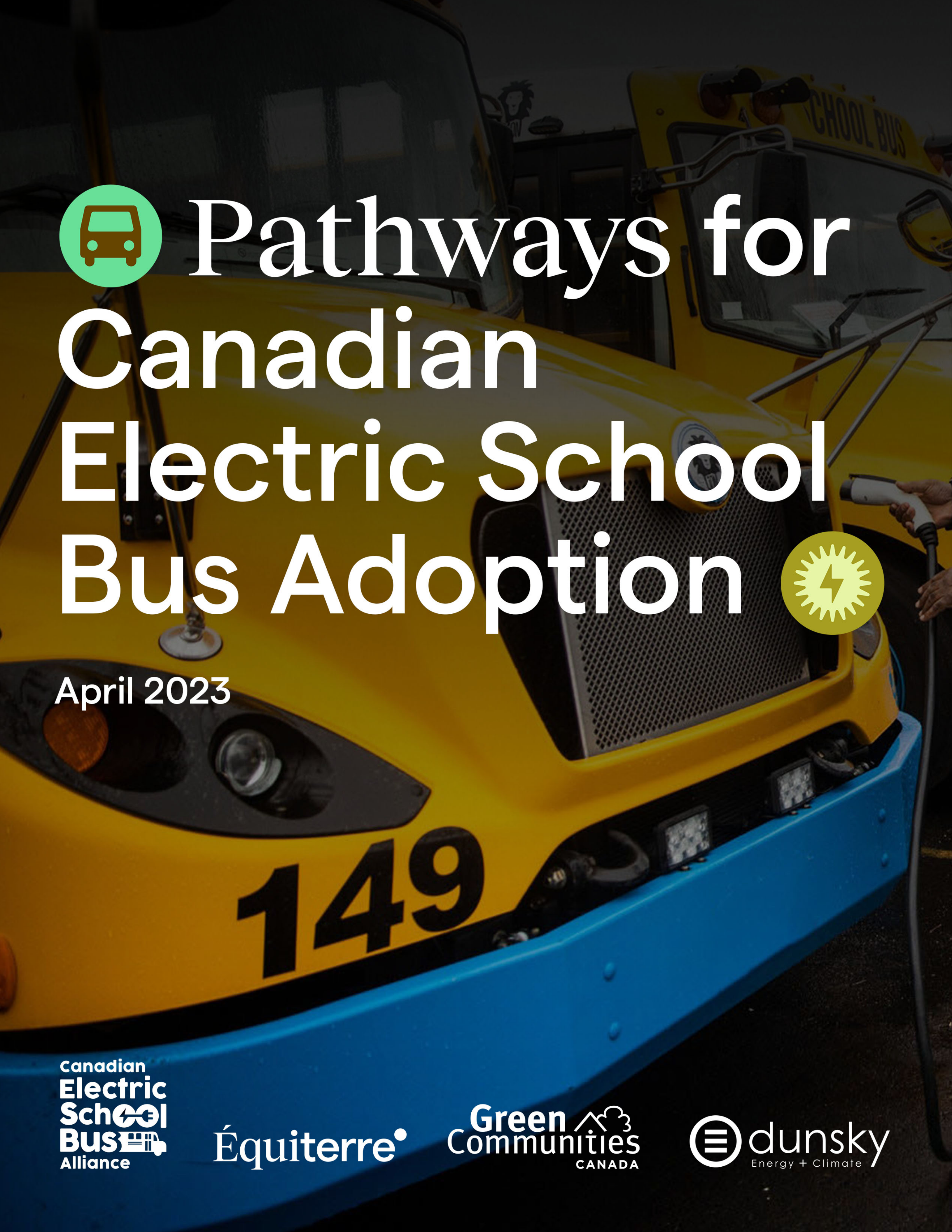


Pathways for Canadian Electric School Bus Adoption

April 2023

Canadian Electric School Bus Alliance
Équiterre
Green Communities Canada
dunsky Energy + Climate

Submitted to:

Équiterre
Sustainable Mobility Team
https://www.equiterre.org/

Prepared by:

Dunsky Energy + Climate Advisors
50 Ste-Catherine St. West, suite 420
Montreal, QC, H2X 3V4

www.dunsky.com | info@dunsky.com
+ 1 514 504 9030

About Dunsky

Dunsky supports leading governments, utilities, corporations and others across North America in their efforts to accelerate **the clean energy transition**, effectively and responsibly.

With deep expertise across the Buildings, Mobility, Industry and Energy sectors, we support our clients in two ways: through rigorous **Analysis** (of technical, economic and market opportunities) and by designing or assessing **Strategies** (plans, programs and policies) to achieve success.

Dunsky is proudly Canadian, with offices and staff in Montreal, Toronto, Vancouver, Ottawa and Halifax. Visit dunsky.com for more information.

List of Acronyms and Abbreviations

CAD	Canadian Dollars
CAGR	Compounded Annual Growth Rate
CCA	Capital Cost Allowance
CESBA	Canadian Electric School Bus Alliance
CFR	Clean Fuel Regulation
CIB	Canada Infrastructure Bank
DCFC	Direct Current Fast Charger
EPA	Environmental Protection Agency
ESB	Electric School Bus
EV	Electric Vehicle
GHG	Greenhouse Gas
GWh	Gigawatt Hours
ICE	Internal Combustion Engine
kWh	Kilowatt Hours
MHDV	Medium- and Heavy-Duty Vehicle
MFASB	Multifunction Activity School Bus
NA	North American
NRCan	Natural Resources Canada
OEM	Original Equipment Manufacturers
TCO	Total Cost of Ownership
US	United States
V2G	Vehicle-to-Grid
ZETF	Zero Emission Transit Fund
ZEV	Zero-Emission Vehicle
ZEVIP	Zero-Emission Vehicle Infrastructure Program

EXECUTIVE SUMMARY

The Government of Canada intends to work towards 35% of total medium- and heavy-duty vehicle (MHDV) sales being zero-emission vehicles (ZEVs) by 2030 and 100% by 2040, where feasible. School buses, in particular, represent a low-hanging fruit in the transition to zero-emission MHDVs: their routes are predictable and often relatively short and they typically return to a central location between shifts where they can charge, making them ideal candidates for electrification. In addition to reducing GHG emissions, electric school buses (ESBs) present notable health benefits and can significantly reduce operating costs.

Given the considerable benefits that ESBs present, the Canadian Electric School Bus Alliance (CESBA) was founded to support policy commitments at all levels of government to enable a widespread transition towards ESBs by 2040. In this study, we set out to better understand the feasibility of CESBA's goal of a fully electric Canadian school bus fleet by 2040 and whether a more ambitious target is feasible. To determine this, we answer the following questions:

- What ESB targets have other leading jurisdictions set?
- What will a transition to 100% ESBs cost?
- How many ESBs would need to be adopted annually to meet CESBAs tentative target of 100% by 2040 and a more ambitious target of 100% by 2035?
- Is there expected to be a sufficient supply of ESBs to meet either target?
- What policies or programs are needed at the federal level to support this transition?

Background

Figure ES1 provides a breakdown of the school bus populations by type across each Canadian province and territory. There are an estimated 45,000-50,000 school buses in operation across the country. The vast majority of these buses are fueled with diesel.

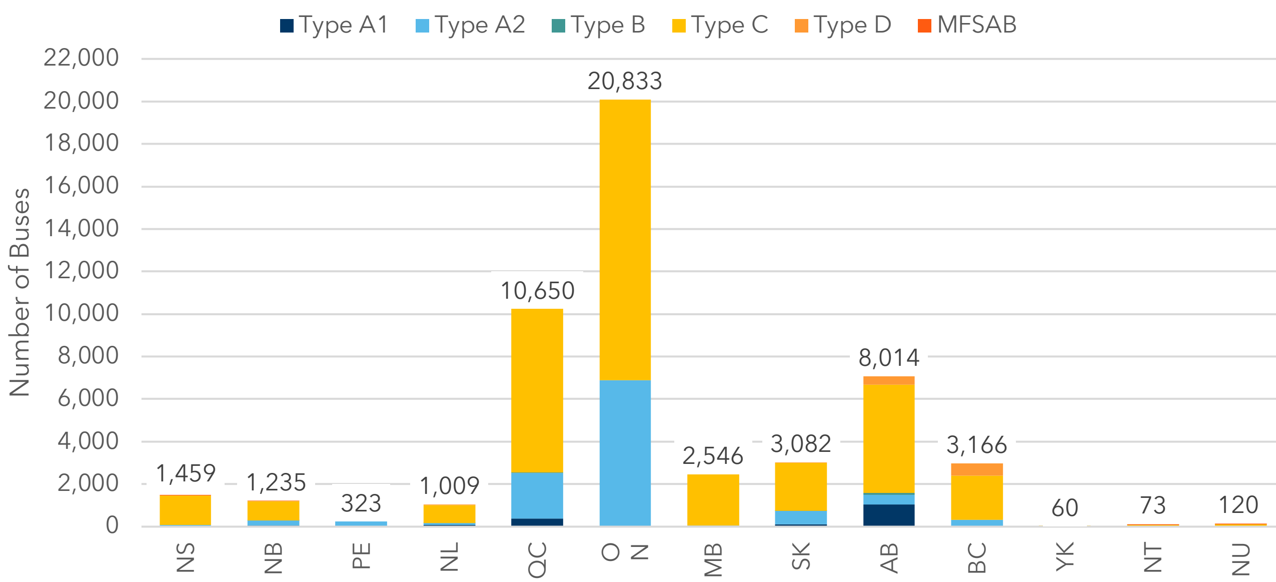


Figure ES1. Breakdown of provincial and territorial school bus fleets by type

Jurisdictions across Canada and the United States have started making commitments to electrify their school bus fleets. These have taken the shape of sales targets for electric school buses, as well as funding programs to support ESB purchases. While the Government of Canada has not yet set a target specifically for zero-emission school buses, they fall under the current target to achieve 35% of total MHDV sales being ZEVs by 2030 and 100% by 2040, where feasible. Given that this is only 100% of new sales by 2040, and not 100% of the fleet converted to electric by 2040, this target falls short of other leading jurisdictions in Canada and the US.

The Cost of Transitioning to 100% ESBs

Overview of ESB Costs

The cost of owning an ESB can be broken down into four major components: (1) upfront vehicle costs, (2) electricity costs, (3) maintenance costs and (4) the cost of charging infrastructure. One of the greatest barriers to ESB bus adoption in the near future will be its high upfront cost. ESBs can cost anywhere between 1.5 to 2.5 times an equivalent ICE bus (see Figure ES2).

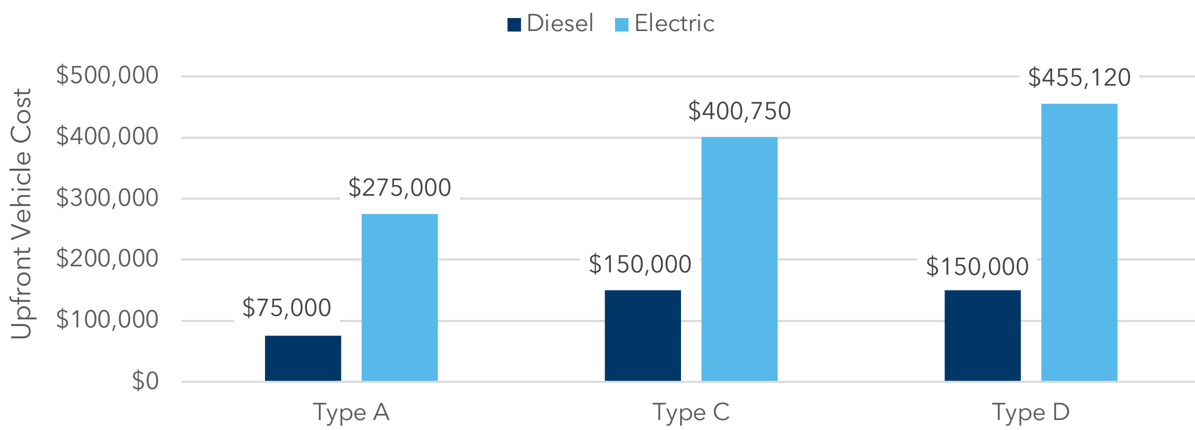


Figure ES2. Diesel and electric upfront school bus cost

On the other hand, we calculate that it will cost on average 80% less to power and at least 50% less to maintain an ESB versus a diesel bus.

Given the nature of school bus operations – the fact that they tend to return to a central facility between shifts where they have a significant amount of downtime – ESBs are well-suited to charging at their "home base" using a Level 2 charger. We estimate that the cost to procure and install a Level 2 charger is $10,000 per charger, excluding the cost of any electrical upgrades that are required to support the additional load.

Potential Revenue Sources

In addition to the operational cost savings offered by ESBs, there is also the possibility that ESB operators may leverage the Clean Fuel Regulation (CFR) coming into effect nationwide in 2023, as well as utility-led vehicle-to-grid (V2G) programs to generate revenue. At an assumed credit rate of $300, one bus could generate over $5,000 in credit revenue per year under the CFR and on the order of $1,200-$4,000 through V2G programs should they be established.

Federal Sources of Funding

There are two primary sources of non-repayable funding at the federal level: the Zero Emission Transit Fund (ZETF) and the Zero-Emission Vehicle Infrastructure Program (ZEVIP). In addition to these sources of non-repayable funding, the Canada Infrastructure Bank offers direct loans through the Zero-Emission Buses Initiative, and tax credits are available through the accelerated capital cost allowance program. Provincial sources of funding are also available in select provinces and territories.

Comparing the Total Cost of Ownership (TCO) of Electric and Diesel Buses

While ESBs offer significant operational cost savings over their diesel counterparts, their high upfront costs may act as a significant barrier to adoption. Without adequate funding, each of the major types of ESBs is currently expected to have a higher TCO than an equivalent diesel bus (see Figure ES3).

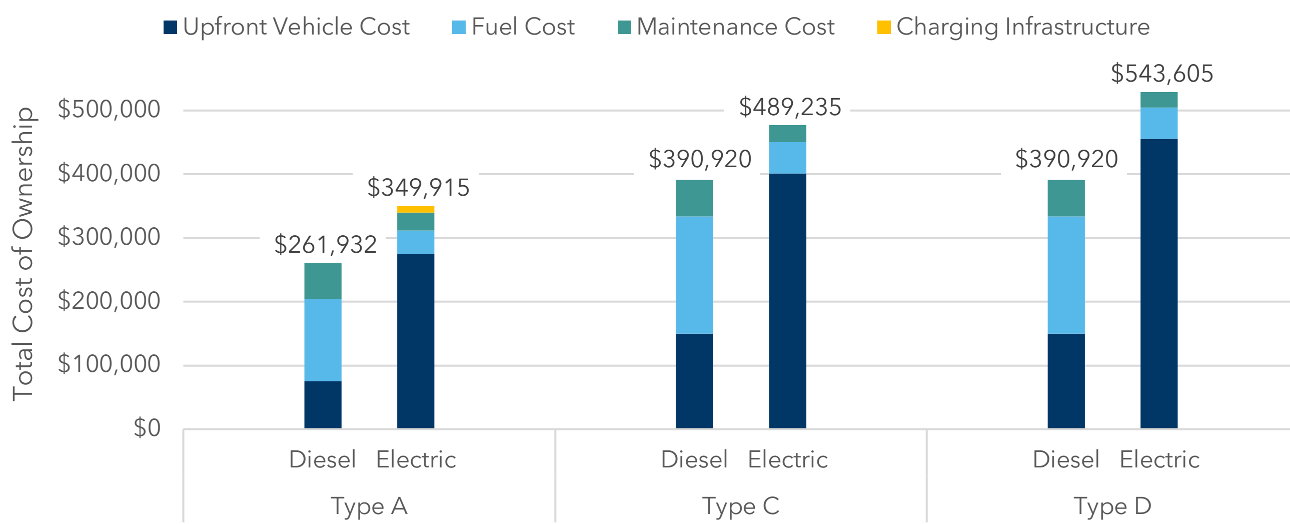


Figure ES3. Total cost of ownership comparison of diesel and electric school buses by type

Federal programs can significantly reduce the upfront cost of an ESB. If ZETF, ZEVIP and the CIB loan are all leveraged, fleets can end up paying less than an equivalent diesel bus to cover the upfront capital costs of ESBs (see Figure ES4).

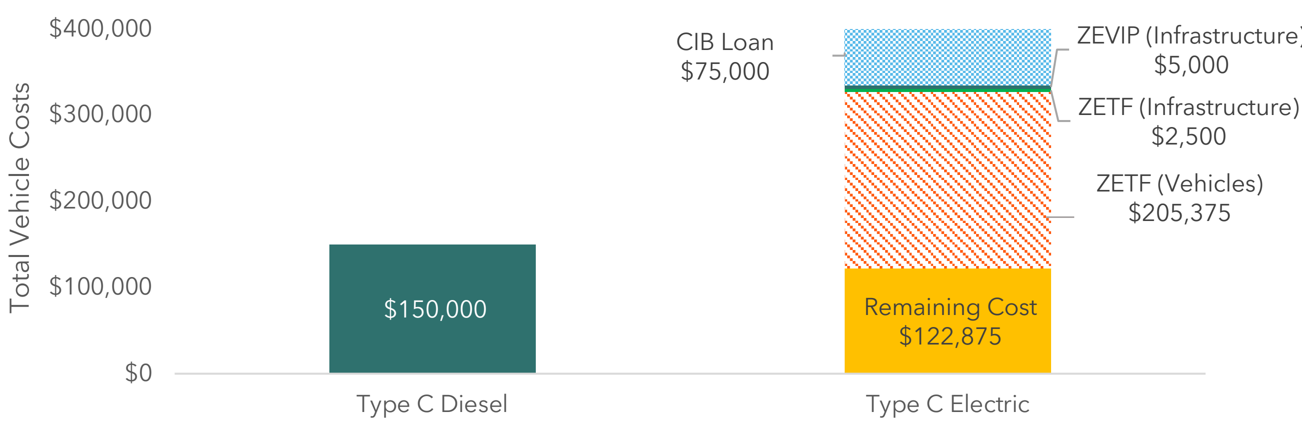


Figure ES4. Type C upfront diesel and electric school bus costs with maximum federal funding

Similarly, by participating in the CFR and V2G programs as they become available, school bus operators can further reduce the payback period of ESBs (see Table ES1). For Type C school buses, which represent 71% of school buses in Canada, by leveraging maximum amounts of federal funding as well as revenue from the CFR and V2G, an operator could reduce the payback period of an ESB from 19.3 years to 2.7 years.

Table ES1. Payback period of ESBs under different funding and revenue-generating scenarios

	Type A	Type C	Type D
No funding or additional revenue	20.7 years	19.3 years	23.3 years
Federal funding (ZETF + ZEVIP)	7.0 years	4.4 years	6.4 years
Federal funding + CFR revenue	5.3 years	3.2 years	4.6 years
Federal funding + V2G revenue	5.4 years	3.6 years	4.6 years

Charting a Pathway to 100% ESBs

School Bus Fleet Turnover Rates

We calculated the number of school buses that would need to be converted to electric each year to reach CESBA's supposed objective of 100% ESBs on the road by 2040 and to determine what it would take to reach a more ambitious target of 100% by 2035. This took into account the existing age distribution of the fleet and a typical retirement threshold of 12 years.

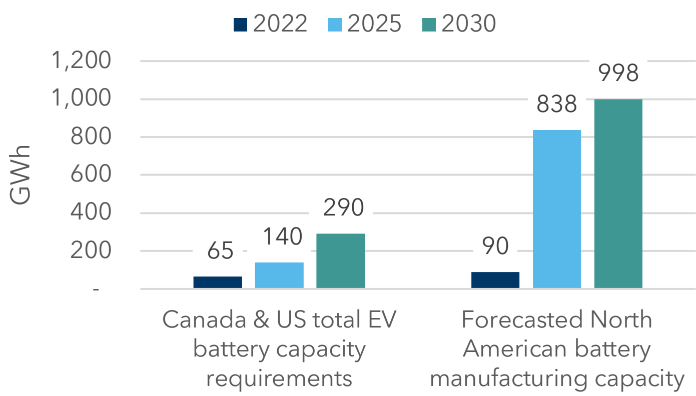
1. **100% ESBs by 2040:** over 2,850 buses would need to be converted to electric annually, on average, between 2023 and 2040. This reflects 51-85% of school bus retirements each year.
2. **100% by 2035:** 100% of school buses that have reached their retirement age of 12 years would need to be replaced with an electric model starting in 2023. Given the current age distribution of Canada's school bus fleet, the greatest number of ESB replacements over the 2023-2035 period would occur over 2023-2024 (approximately 5,600 per year).

ESB Supply Forecasts

To better understand whether there is expected to be a sufficient supply of ESBs to meet either a 100% by 2035 or 2040 target, we have examined forecasts for battery production capacity as a proxy for how the electric vehicle (EV) ecosystem is expected to evolve over time.

The annual GWh needed per year to electrify all ESBs is 0.5 GWh to reach full school electrification by 2040, or 0.5-0.9 GWh to reach an earlier target of 2035. The local GWh capacity needed to meet the projected sales of all EVs in 2025 and 2030 is estimated at 140 GWh and 290 GWh respectively. Not only is this well within the range of forecasted battery manufacturing capacity in North America, but it highlights that ESBs are marginal (≤1%) to total EV production and anticipated battery production capacity (see Figure ES5).

While these targets and announcements suggest that future ESB manufacturing capacity will not act as a long-term barrier to reaching full electrification, ultimately supply chain constraints have led to limited manufacturing capacity in recent years.



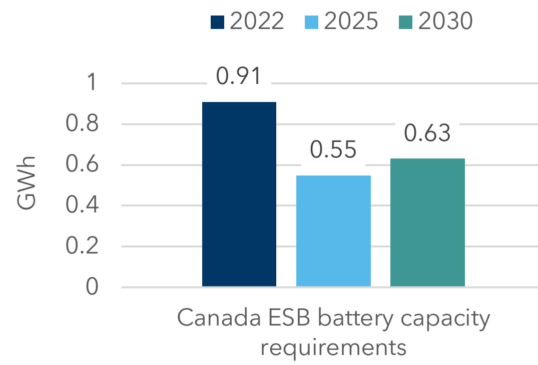


Figure ES5. Left: Forecasted EV battery capacity requirements in Canada and the US vs North American (NA) battery manufacturing capacity; Right: Annual battery capacity needed to reach 100% ESBs in Canada by 2035

Capital Required to Support 100% ESB Adoption

While supply chain constraints may act as a barrier to ESB adoption in the near-term, capital may act as a longer-term barrier. There is a significant amount of capital required in the near term to support a Canada-wide transition to 100% ESBs. This includes capital to cover the upfront purchase of ESBs, as well as the purchase and installation of charging infrastructure. Under a 100% by 2040 target, over $1.25 billion would be required from all stakeholders in 2023, whether from bus operators or other stakeholders (e.g., government). This is expected to decrease over time alongside declining ESB costs to approximately $1.01 billion by 2040 (see Figure 10). The total capital required over the 2023-2040 period is equivalent to approximately 2.5 times the annual capital requirements for diesel buses.

TRADE-OFFS OF 2035 AND 2040 TARGETS

The sooner Canada's school bus fleet is converted to electric, the sooner Canadians will be able to reap the benefits, including GHG emissions reductions, air quality improvements and operational cost savings. Achieving a more ambitious target of 100% ESBs by 2035 would have positive implications on our carbon budgets and GHG emissions reduction goals as a tonne of carbon reduced today will have a greater impact on climate change mitigation than one reduced in the future. Moreover, the sooner our school bus fleets are fully electric, the sooner communities will benefit from improved air quality, and school bus operators will be able to reduce their operating costs and benefit from a quieter, more comfortable drive.

However, achieving 100% by 2035 also presents challenges. Most importantly, we lack the supply and manufacturing capacity to convert the necessary number of vehicles to ESBs in the near term. This means that either vehicle retirement ages will need to be extended beyond their typical 12-year lifespan (like what Quebec has done), or alternatively, more diesel buses will need to be purchased in the near term and retired early to be replaced with an ESB. Furthermore, transitioning the fleet to ESBs sooner will require more capital. As the cost of ESBs declines with decreasing battery costs and with increasing economies of scale, less capital will be required year-over-year to support the transition.

Recommendations: The Federal Government Should Consider Increased Support for ESBs

The findings of this analysis demonstrate that, particularly in the near term, the business case for ESBs is weak without substantial government support. To reap the invaluable benefits these buses can offer – on climate, local air quality, and from an operational cost savings perspective – action needs to be taken at the federal level to support school bus operators across the country to make the switch. The following recommendations have been identified as key to supporting ESB adoption:

1. Set Canada-wide ESB sales targets.

Federal funding for ESBs can be complemented by nationwide sales targets that will ensure there is sufficient ESB supply for school bus operators across the country to make the switch.

2. Extend existing federal funding programs for ESBs.

Given that ESBs are not expected to reach price parity with diesel buses between now and 2040, the federal government should consider continuing to help make ESBs more affordable by allocating additional funds to the ZETF program after it expires in 2025. Similarly, funding through ZEVIP should be extended past the 2027 end year.

3. Ensure federal funding for ESBs and charging infrastructure is sufficient and easily accessible.

Given that the upfront cost of ESBs represents the largest incremental cost for fleet operators (barring any major on-site electrical upgrades), the federal government should consider offering point-of-sale rebates on ESB purchases to provide more certainty to fleet operators as they build their budgets.

4. Work with provinces to explore the possibility of temporarily extending the retirement age of diesel school buses to support the near-term adoption of ESBs.

By temporarily extending the lifespan of diesel buses, it would be possible to smooth out the spike of ESB replacements that would be needed in 2024-2025 to meet a 100% by 2035 target.

5. Lead or fund education and awareness campaigns that promote the benefits of ESBs.

These campaigns are key to ensuring that school bus operators understand the multitude of benefits that ESBs present, as well as the various financial supports that are available to them across the country.

Table of Contents

List of Acronyms and Abbreviations i

EXECUTIVE SUMMARY ii

Table of Contents 8

1. Introduction 9

2. Background 11

2.1 Canada's School Bus Fleet 11

2.2 ESB Targets and Support in Leading Jurisdictions 13

3. The Cost of Transitioning to 100% ESBs 15

3.1 Overview of ESB Costs 15

3.2 Potential Revenue Sources 16

3.3 Federal Sources of Funding 17

3.4 Comparing the Total Cost of Ownership (TCO) of Electric and Diesel Buses 19

4. Charting a Pathway to 100% ESBs 21

4.1 School Bus Fleet Turnover Rates 21

100% by 2040 21

100% by 2035 21

4.2 ESB Supply Forecasts 22

4.3 Capital Required to Support 100% ESB Adoption 24

5. Recommendations: The Federal Government Should Increase Support for ESBs .. 26

Appendix A 28

Assumptions Used in Calculations 28

Appendix B 30

Fuel and Electricity Price Forecasts 30

Appendix C 32

Regional Carbon Intensities of Grid Electricity 32

Appendix D 33

Types of School Buses in Canada 33

1. Introduction

The Government of Canada's *2030 Emissions Reduction Plan* outlines a suite of actions the federal government intends to take to meet its target of reducing greenhouse gas (GHG) emissions by 40 to 45% below 2005 levels by 2030 and to be net-zero by 2040. As a part of this plan, the Government of Canada intends to work towards 35% of total medium- and heavy-duty vehicle (MHDV) sales being zero-emission vehicles (ZEVs) by 2030 and 100% by 2040, where feasible.[1] This transition will encompass the diverse array of vehicles that make-up the MHDV sector, ranging from long haul tractor trailers to buses. **School buses, in particular, represent a low-hanging fruit in the transition to zero-emission MHDVs**: their routes are predictable and often relatively short and they typically return to a central location between shifts where they can charge, making them ideal candidates for electrification.

The **GHG emissions reductions** achieved by transitioning from a diesel internal combustion engine (ICE) bus to an electric school bus (ESB) can be significant. This is because GHG emissions associated with operating an electric school bus (ESB) come almost exclusively from upstream electricity production. The opportunities for emissions reductions are greatest in regions where the carbon intensity of electricity production is low and where renewable and carbon-free sources like hydro and wind are responsible for the vast majority of electricity generation. Provinces that currently have a high carbon intensity of electricity production but have plans to decarbonize their grids will see GHG emissions savings increase over time.

In addition to being an important climate solution, ESBs also present notable **health benefits** to both operators and the populations they serve. ESBs do not produce any tailpipe emissions, so they do not contribute to the same adverse health effects as their diesel ICE counterparts. Traffic-related air pollution from sources like diesel exhaust has been linked to asthma, impeding the development of children's lungs, and in some cases, premature death.[2,3,4,5] School bus passengers are particularly susceptible to the harmful effects of diesel exhaust as levels of air pollution are typically higher inside the bus than they are outside. A Natural Resources Defense Council and Coalition for Clean Air report

---

[1] Environment and Climate Change Canada, *2030 Emissions Reduction Plan* (2022), 57. https://publications.gc.ca/collections/collection_2022/eccc/En4-460-2022-eng.pdf

[2] Government of Canada, *Health Impacts of Air Pollution in Canada: Estimates of morbidity and premature mortality outcomes – 2021 Report* (2021). https://www.canada.ca/en/health-canada/services/publications/healthy-living/2021-health-effects-indoor-air-pollution.html#a4

[3] Sandi Ha, Hui Hu, Dikea Roussos-Ross, Kan Haidong, Jeffrey Roth, Xiaohui Xu*, The effects of air pollution on adverse birth outcomes, Environmental Research*, 134:198-204 (2014). https://doi.org/10.1016/j.envres.2014.08.002

[4] Mudway et al., *Impact of London's low emission zone on air quality and children's respiratory health: a sequential annual cross-sectional study*. Lancet Public Health (2019), 4(1):e28-e40. https://doi.org/10.1016/s2468-2667(18)30202-0

[5] Pollution Probe, The Delphi Group and Canadian Partnership for Children's Health and Environment, *Opportunities for Accelerating School Bus Electrification in Ontario*, May 2022. https://www.pollutionprobe.org/wp-content/uploads/2022/05/White-Paper-Opportunities-for-accelerating-school-bus-electrification-in-Ontario.pdf

found that diesel exhaust levels on school buses were 23 to 46 times higher than what the US Environmental Protection Agency (EPA) and US federal guidelines consider a significant cancer risk.[6] Recent analysis from Dunsky Energy + Climate Advisors estimates that a single ESB could result in $11,800 in total health cost savings over its 12-year lifetime.[7] In addition to reducing adverse health impacts and associated healthcare costs, ESBs also reduce the levels of noise pollution within communities thanks to their quiet engines. Noise pollution from heavy-duty vehicles has been shown to result in hearing loss in drivers which can be mitigated through the use of ESBs.[8]

Finally, ESBs can have significantly **reduced operating expenses** in comparison to their diesel ICE counterparts. Low electricity costs and the high efficiency of electrical engines mean that it costs significantly less to power an ESB than it does to refuel a diesel school bus. Due to the simplicity of the electrical engine and significantly fewer moving parts, maintenance costs are considerably lower for ESBs. Statistics from the Public School Bus Commission (PBC) in PEI, which has deployed 82 ESBs to-date, show that the cost of running ESBs is 75% lower than the cost to operate diesel buses.[9]

Given the considerable benefits that ESBs present, the **Canadian Electric School Bus Alliance (CESBA)** was founded to support policy commitments at all levels of government to enable a widespread transition towards ESBs by 2040. In this study, we set out to better understand the feasibility of CESBA's goal of a fully electric Canadian school bus fleet by 2040 and whether a more ambitious target is feasible. To determine this, we answer the following questions:

- What ESB targets have other leading jurisdictions set?
- What will a transition to 100% ESBs cost?
- How many ESBs would need to be adopted annually to meet CESBAs tentative target of 100% by 2040 and a more ambitious target of 100% by 2035?
- Is there expected to be a sufficient supply of ESBs to meet either target?
- What policies or programs are needed at the federal level to support this transition?

[6] National Resources Defense Council (2001). "Tests Reveal High Levels of Toxics Inside Diesel School Buses." https://www.nrdc.org/media/2001/010212
[7] The Pembina Institute, *Electric School Buses* (2022), 4. https://www.pembina.org/reports/electric-school-bus-adoption-in-bc-rev.pdf
[8] Siamak Pourabdian et al., *Prevalence hearing loss of truck and bus drivers in a cross-sectional study of 65533 subjects* (2019). https://pubmed.ncbi.nlm.nih.gov/31861971/
[9] Rafe Wright, "P.E.I. electric school buses showing promise in reducing carbon emissions, fuel prices," January 11, 2023. https://www.saltwire.com/atlantic-canada/news/pei-electric-school-buses-showing-promise-in-reducing-carbon-emissions-fuel-prices-100812877/

2. Background

2.1 Canada's School Bus Fleet

School buses are responsible for safely transporting students to and from school and school-related activities every day of the week. There are an estimated **45,000-50,000 school buses** in operation across the country.[10,11] The vast majority of these buses are fueled with **diesel**.

There are several different configurations of school buses that are in operation across Canada, including Types A to D and Multifunction School Activity Buses (MFSABs) (see Figure 1). For a technical breakdown of each type, see Table 7 in Appendix DAppendix .

Type A1/A2

Photo Credit: Michela Simoncini, Flickr

Type B

Photo Credit: Ina â™¥ New York â™¥ New York â™¥, Wikipedia

Type C

Type D

Photo Credit: Tiomax80, Flickr

MFSAB

Figure 1. Types of school buses in Canada

---

[10] Statistics Canada, *Table 23-10-0086-0: Canadian passenger bus and urban transit industries, equipment operated, by industry and type of vehicle*. https://doi.org/10.25318/2310008601-eng

[11] Task Force on School Bus Safety, *Strengthening school bus safety in Canada* (2020), 4. https://comt.ca/Reports/School%20Bus%20Safety%202020.pdf

The make-up of the school bus fleet varies from one province or territory to another. Figure 2 provides a breakdown of the school bus populations by type across each Canadian province and territory. The most common type of school bus in Canada is **Type C, accounting for 71% of registered school buses**. Type B buses, meanwhile, are very rare.

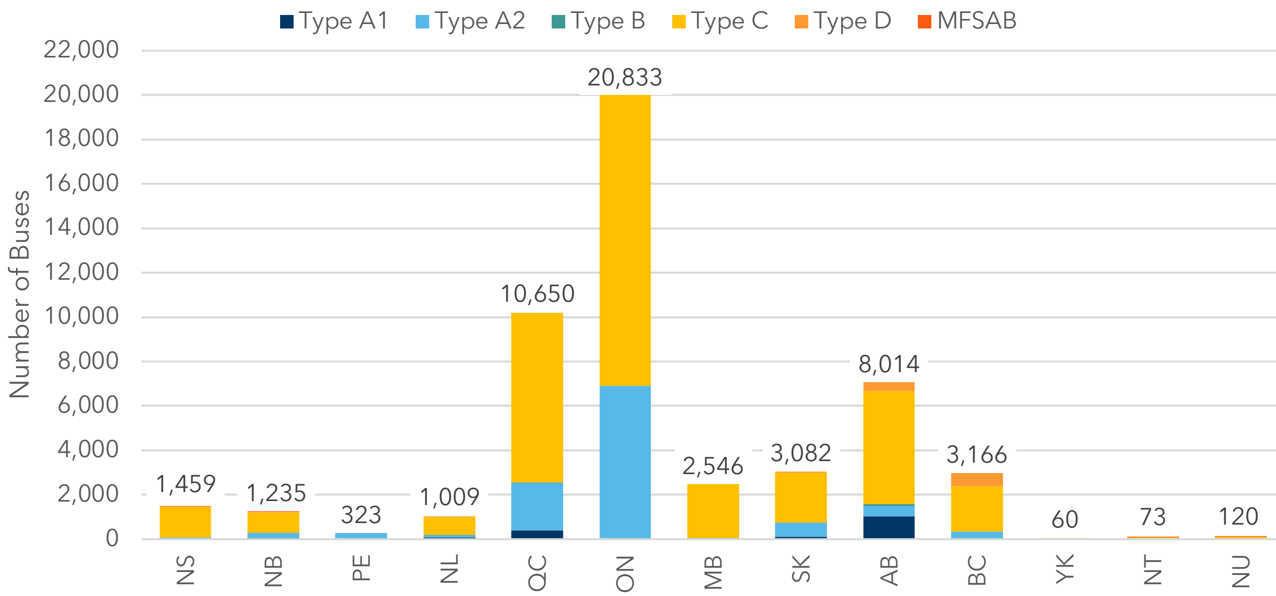


Figure 2. Breakdown of provincial and territorial school bus fleets by type (Data Source: Task Force on School Bus Safety in Canada[12])

Canada's school bus fleet is relatively new, with 45% of the fleet being less than five years old (see Figure 3). There is, however, a considerable share of the fleet that is over 10 years old (22%). Across most provinces in Canada, school buses must be retired when they reach the age of **12 years**. One exception is in Quebec, where the province has recently extended the retirement age to 14 years for operators that are waiting on the delivery of an ESB.[13]

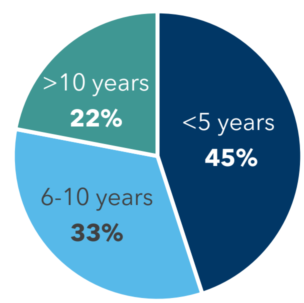


Figure 3. Age breakdown of Canada's school bus fleet

A **small number of ESBs** have been deployed to date in Canada. While data on the exact number is limited, this includes 82 in P.E.I.,[14] 766 in Quebec (as of April 2023)[15], 52 in B.C. (as of January 2022)[16] and 20 in Ontario.[17]

---

[12] *Strengthening school bus safety in Canada*, 11.
[13] *Règlement sur le transport des élèves: Loi sur l'instruction publique*, Chapitre I-13.3, r.12, a. 453 et 454. https://www.legisquebec.gouv.qc.ca/fr/document/rc/I-13.3,%20r.%2012%20/
[14] Shane Ross, "P.E.I. adding more electric school buses, placing charging stations at drivers' homes," *CBC News*, June 10, 2022. https://www.cbc.ca/news/canada/prince-edward-island/pei-electric-school-buses-1.6484478
[15] Data provided by the Quebec Ministère des Transports et de la Mobilité durable
[16] The Pembina Institute, *Electric School Buses* (2022), 1-2. https://www.pembina.org/reports/electric-school-bus-adoption-in-bc-rev.pdf
[17] Ecology Ottawa, "Electric School Buses." https://www.ecologyottawa.ca/yellowbus

2.2 ESB Targets and Support in Leading Jurisdictions

Jurisdictions across Canada and the United States have started making commitments to electrify their school bus fleets. These have taken the shape of sales targets for electric school buses, as well as funding programs to support ESB purchases. A sample of leading state and provincial policies and funding programs is outlined in Table 1.

Table 1. A sample of leading jurisdictional ESB targets and funding programs

Jurisdiction	ESB Target	Funding Programs
British Columbia	New ZEV targets for MHDVs expected to be developed in alignment with California (all new trucks and buses to be electric by 2045).	Significant financial support exists for through both the Ministry of Education and Child Care and Clean BC; combined financial support ranges from $100,000 to over $200,000 per ESB.
Prince Edward Island	Targeting 100% electrification of the Public Schools Branch fleet by 2030.	The Government of Prince Edward Island and the Government of Canada are each contributing $6.3 million towards the purchase of ESBs in the province through the Green Infrastructure stream of the Investing in Canada infrastructure plan.[18]
Quebec	All new school bus purchases to be electric starting in April 2021. 65% of Quebec's school buses must be electric by 2030.	Provincial subsidy of $150,000 towards ESB purchases in the 2021-22 fiscal year, now reduced to $125,000 for the 2022-23 fiscal year.
California	Bill awaiting approval: 100% new school buses electric by 2035. Currently, all new trucks and buses in California must be electric by 2045.	The State has spent $1.2 billion on school bus electrification to-date. Another $1.8 billion is set to be spent between fiscal years 2023/24 and 2027/28 on ESBs and associated charging infrastructure.
Colorado	100% electric school bus fleet by 2035.	The state has allocated $65 million in funding between 2022-2034 towards the Electrifying School Buses Grant Program to support the purchase of ESBs and charging infrastructure.
Connecticut	School buses operating in environmental justice communities must be 100% electric by 2030.	A $20 million grant program has been established to support the purchase of ESBs and charging infrastructure.

[18] Provincial intake for this funding stream closed on March 31, 2023.

Maine	75% of new school bus purchases and contracts must be zero-emission by 2035.	-
Maryland	100% of new school bus purchases and contracts statewide must be electric by 2025.	The Zero-Emission Vehicle School Bus Transition Grant Program provides grants to purchase zero-emission school buses and install charging infrastructure.
New York	100% zero-emission school bus fleet by 2035. All new school bus purchases are to be zero-emission by 2027.	As part of the final 2023 budget, NY Governor and state lawmakers committed $500M to ESBs.

While the Government of Canada has not yet set a target specifically for zero-emission school buses, they fall under the current target to achieve 35% of total MHDV sales being ZEVs by 2030 and 100% by 2040, where feasible. Given that this is only 100% of *new* sales by 2040, and not 100% of the fleet *converted* to electric by 2040, this target falls short of other leading jurisdictions in Canada and the US.

Nonetheless, the Government of Canada has established several programs that can help bring down the cost of the transition to zero-emission school buses, including the Zero Emission Transit Fund, the Zero-Emission Infrastructure Program, the Zero-Emission Bus Initiative and accelerated capital cost allowance for zero-emission vehicles. These programs will be discussed in more detail in Section 3.3.

3. The Cost of Transitioning to 100% ESBs

3.1 Overview of ESB Costs

The transition to an electric school bus fleet requires major shifts in vehicle technology and infrastructure requirements, and with that comes costs. The cost of owning an ESB can be broken down into four major components: (1) upfront vehicle costs, (2) electricity costs, (3) maintenance costs and (4) the cost of charging infrastructure. In this section, we break these costs down and provide an overview of how they compare to the conventional diesel ICE baseline. Vehicle financing and insurance represent two additional categories of costs, but these will not be explored in detail in this study.

Upfront Vehicle Costs

One of the greatest barriers to ESB bus adoption in the near future will be their high upfront cost. ESBs can cost anywhere between 1.5 to 2.5 times an equivalent ICE bus (see Figure 4).

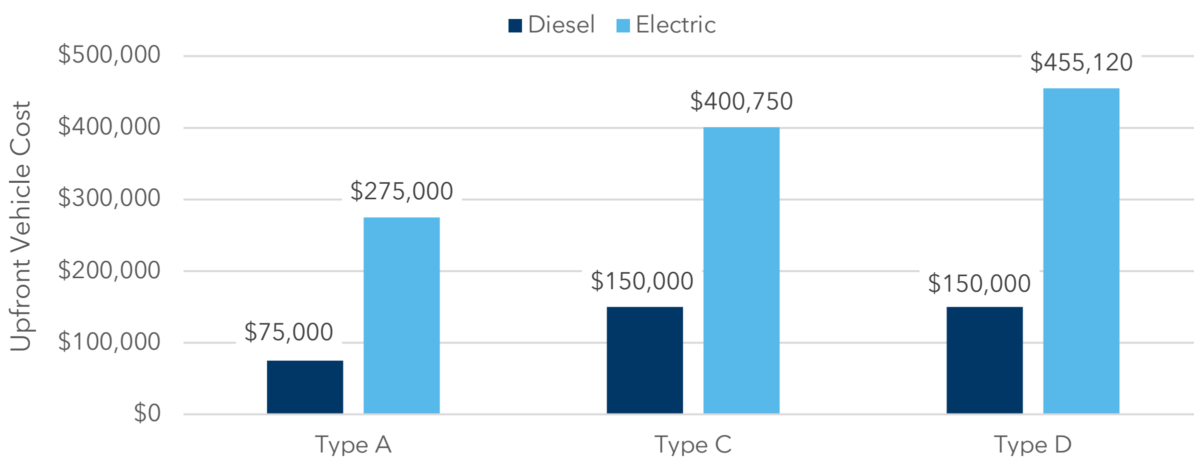


Figure 4. Diesel and electric upfront school bus cost

As ESB manufacturing capacity increases and the cost of batteries falls in line with forecasts,[19] we expect that upfront ESB costs will also decline. For example, we forecast that a Type C ESB will decline in cost from $400k in 2023 to $340k in 2030 and $310k in 2040 (see Appendix A for a breakdown of our assumptions).

Operational Costs

While ESBs may cost more to procure, they cost significantly less to operate. The two major operating costs of school buses are fuel/electricity and maintenance costs.

Fuel/Electricity Costs

Although electricity rates will vary from one province or territory to another, the higher efficiency of EVs over ICE vehicles in combination with the fact that electricity tends to cost less than diesel means

[19] BloombergNEF, *Electric Vehicle Outlook 2022* (2022), 122. https://about.bnef.com/electric-vehicle-outlook/

significant operational savings are expected for ESBs. Using a Canada-wide average electricity rate, we calculate that it will cost on average **80% less** to power an ESB than it would to fuel an ICE school bus with diesel.[20]

Maintenance Costs

Electric engines are much simpler and have significantly fewer moving parts than ICEs, and for this reason cost significantly less to maintain. Estimates vary, but we can expect ESBs to cost at least **50% less** to maintain than diesel ICE buses.[21]

Charging Infrastructure Costs

Given the nature of school bus operations – the fact that they tend to return to a central facility between shifts where they have a significant amount of downtime – ESBs are well-suited to charging at their "home base" using a Level 2 charger.[22] The fact that there is a significant amount of downtime between shifts means that school bus operators can avoid the higher cost of direct current fast chargers (DCFC) and can get away using a Level 2 charger. Since they return to a central facility, school bus operators do not need to worry about relying on the availability of public charging stations and can instead conveniently charge at their home base. We estimate that the cost to procure and install a Level 2 charger is **$10,000 per charger**, excluding the cost of any electrical upgrades that are required to support the additional load. It is assumed that a single Level 2 charging port will be installed for each bus.

3.2 Potential Revenue Sources

In addition to the operational cost savings offered by ESBs, there is also the possibility that ESB operators may leverage the Clean Fuel Regulation coming into effect nationwide in 2023, as well as utility-led vehicle-to-grid (V2G) programs to generate revenue.

Clean Fuel Regulation Credits

Under this regulation, vehicle charging site operators such as fleet owners can receive financial credits for powering their vehicles with clean fuel. If school bus operators opt to collect these benefits, at an assumed credit rate of $300, one bus could generate over **$5,000 in credit revenue per year**, representing a significant source of revenue on top of the annual operational savings that ESBs already offer. Given that the value of credits is tied to the carbon intensity of the electricity used to supply the vehicles, school bus operators located in jurisdictions with a low carbon intensity of electricity will benefit most from these credits (see Appendix C for a breakdown of grid electricity carbon intensity by province/territory).

---

[20] Electricity and diesel price forecasts to 2040, and their sources are included in Appendix B

[21] Chris Harto, "Electric Vehicle Ownership Costs: Today's Electric Vehicles Offer Big Savings for Consumers," *Consumer Reports* (2020), 11. https://advocacy.consumerreports.org/wp-content/uploads/2020/10/EV-Ownership-Cost-Final-Report-1.pdf

[22] A number of resources are available to help school bus operators with the transition to an electric fleet, including a detailed guide from Propulsion Quebec: https://propulsionquebec.com/wp-content/uploads/2022/08/1573-TransporteurPlus-GuideComplet-ANG-VF.pdf?download=1

Vehicle to Grid (V2G)

V2G is a term used to describe the use of an electric vehicle's onboard energy storage system to provide power back to the electrical grid, sometimes also referred to as "bi-directional charging". The nature of school bus operations makes ESBs well-suited to V2G participation given that they have relatively low daily usage and, in some cases, do not run all summer. This low usage results in a relatively weak business case for school bus electrification, but it is possible that V2G could strengthen the business case by allowing fleet operators to generate revenue as they connect to the grid and supply utilities with additional capacity, particularly during peak periods. Ultimately, the extent to which ESB fleet operators can expect to earn revenue from V2G will depend on if these programs are offered by their local utility and the rate structures that have been set. Moreover, there are some technical specifications that ESBs or the chargers must meet to be able to participate in V2G programs.

An internal analysis was completed for this study to estimate V2G revenue potential in a sample of Canadian provinces with anticipated capacity shortfalls. The analysis suggests that a V2G-enabled ESB operating between 2023 to 2030 can provide the following system capacity values:

- Ontario: **$3,100-$3,300 per bus per year**
- Quebec: **$3,700-$4,000 per bus per year**
- New Brunswick: **$1,200-$1,500 per bus per year**

3.3 Federal Sources of Funding

There are two primary sources of non-repayable funding at the federal level: the Zero Emission Transit Fund (ZETF) and the Zero-Emission Vehicle Infrastructure Program (ZEVIP). ZETF provides funding for public transit and school bus operators towards electric bus planning projects, as well as upfront vehicle and infrastructure costs.[23] ZEVIP provides funding towards the purchase and installation of EV charging infrastructure for a wide range of EV users, including commercial and public fleets.[24]

In addition to these sources of non-repayable funding, the Canada Infrastructure Bank offers direct loans through the Zero-Emission Buses Initiative,[25] and tax credits are available through the accelerated capital cost allowance program.[26] Provincial sources of funding are also available in select provinces and territories.

Zero Emission Transit Fund (ZETF)

Infrastructure Canada is investing $2.75 billion over five years (starting in 2021) into ZETF to support the purchase of school and transit electric buses and to build the supporting infrastructure, including

---

[23] Government of Canada, "Zero Emission Transit Fund." https://www.infrastructure.gc.ca/zero-emissions-trans-zero-emissions/index-eng.html
[24] Government of Canada, "Zero Emission Vehicle Infrastructure Program." https://www.nrcan.gc.ca/energy-efficiency/transportation-alternative-fuels/zero-emission-vehicle-infrastructure-program/21876
[25] Canada Infrastructure Bank, "Zero-Emission Buses Initiative." https://cib-bic.ca/en/sectors/public-transit/
[26] Government of Canada, "Classes of Depreciable Properties." https://www.canada.ca/en/revenue-agency/services/tax/individuals/topics/about-your-tax-return/tax-return/completing-a-tax-return/deductions-credits-expenses/line-22900-other-employment-expenses/capital-cost-allowance/classes-depreciable-properties.html

charging and facility upgrades. ZETF provides financial contributions through two different funding streams dependent on the project stage:

3. Planning projects: up to **80% of the total eligible costs** in non-repayable contributions.
4. Capital projects: up to **50% of total eligible costs** in non-repayable contributions, to a maximum of $350 million. Non-repayable contributions to for-profit entities will only be considered if project benefits accrue broadly (i.e., health and environmental benefits).

The ZETF is a separate fund that builds on existing programming such as the Public Transit Infrastructure Stream of the Investing in Canada Infrastructure Program.

Zero-Emission Vehicle Infrastructure Program (ZEVIP)

ZEVIP, administered by Natural Resources Canada (NRCan), aims to address the lack of charging and refuelling stations in Canada as a key barrier to ZEV adoption. The program received a top up of $400 million in 2022 which is expected to last until March 2027. The funding is delivered through cost-sharing contribution agreements for eligible projects.

NRCan's contribution through this program is limited to **50% of total project costs** up to a maximum of $5 million per project and up to a maximum of $2 million per project for delivery organizations (i.e., third parties administering contributions on NRCan's behalf).

There is a cap on stacking the funding, whereby the total funding from all levels of government (federal, provincial/territorial, or municipal) cannot exceed 75% of the total project costs. Under certain cases, the stacking limit is 100% of total project costs – if the recipient is an Indigenous business or community, a not-for-profit organization, a provincial, territorial or municipal government, or their departments or agencies, they qualify for the increased limit.

Zero-Emission Buses Initiative

Administered by the Canada Infrastructure Bank (CIB), the Zero-Emission Buses Initiative provides innovative financing for zero-emission transit and school buses. Under this program, school bus operators can apply for loans to cover the higher upfront capital costs of zero-emission buses and their associated infrastructure. The repayment of these loans comes from the savings generated by the lower operating cost of zero-emission buses and organizations are charged a below-market interest rate. The CIB committed $1.5 billion in investments in zero-emission buses in its 2020 three-year growth plan.

Accelerated Capital Cost Allowance

Zero-emission school buses are eligible under class 55 for an enhanced first-year capital cost allowance, which allows profitable companies to write off a higher percentage of their zero-emission vehicle purchase in their first year. Vehicles purchased after March 18th, 2019, and before 2024 can write off 100% of their purchase in their first year. Vehicles purchased after 2023 and before 2026 can write off 75% of vehicles, while those purchased after 2025 and before 2028 can write off 55%. The structure of the depreciation schedule means that benefits are greatest for near-term purchases and will decline over time. Vehicles that were purchased with federal purchase incentives are not eligible, nor are governmental or non-profit organizations.

3.4 Comparing the Total Cost of Ownership (TCO) of Electric and Diesel Buses

While ESBs offer significant operational cost savings over their diesel counterparts, their high upfront costs may act as a significant barrier to adoption. Without adequate funding, each of the major types of ESBs is currently expected to have a higher total cost of ownership (TCO) than an equivalent diesel ICE bus (see Figure 5).

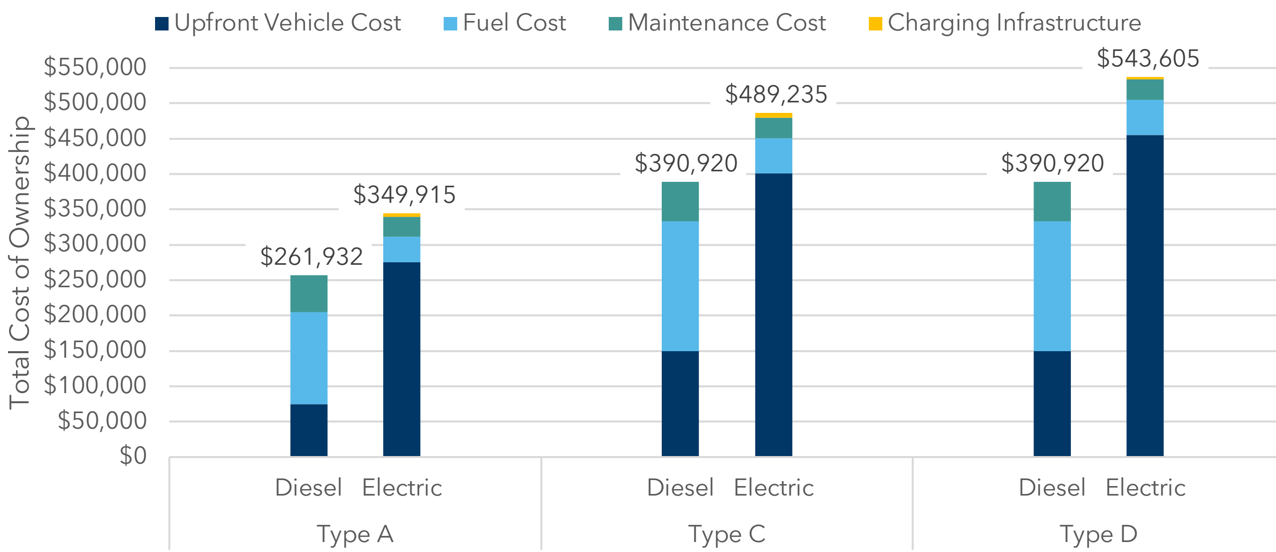


Figure 5. Total cost of ownership comparison of diesel and electric school buses by type

As diesel prices rise into the future and ESBs come down in cost, these cost differences are expected to change. Figure 6 provides an overview of how we expect the TCO of diesel and electric school buses to change between now and 2040. By 2040, we expect Type C school buses to reach cost parity with diesel buses, while Type A and Type D buses are expected to be within 15%. A breakdown of our assumptions in this analysis can be found in Appendix A.

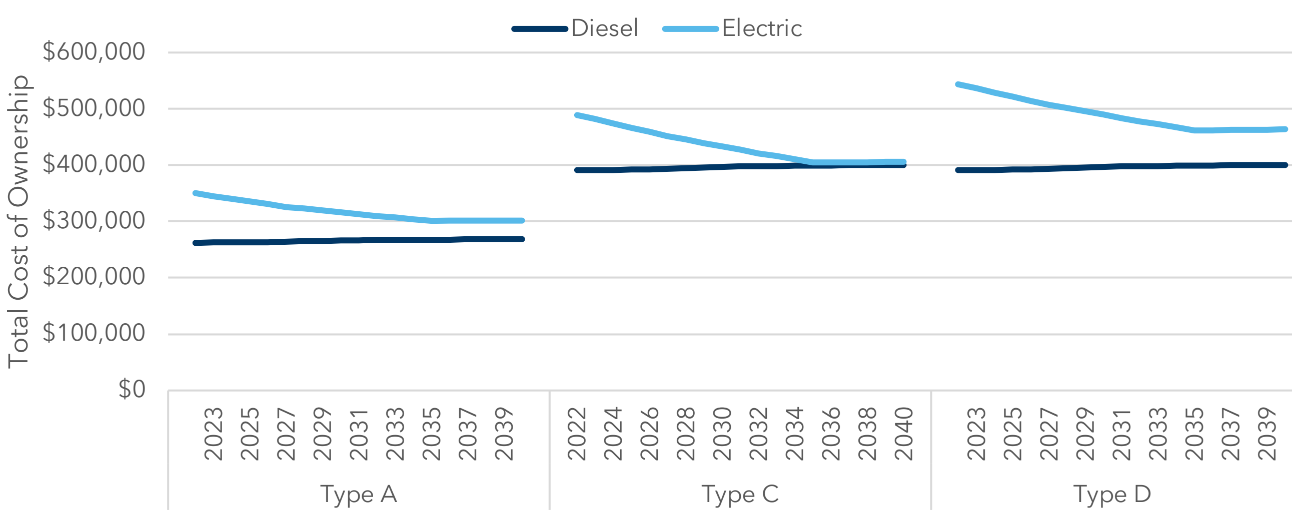


Figure 6. Diesel and electric school bus forecasted TCO by purchase year and type (2023 CAD)

Federal programs can significantly reduce the upfront cost of an ESB. Fleets across Canada can apply to both ZETF and ZEVIP, and if successful with both applications, can receive contributions up to 75% of the cost to procure and install a Level 2 charger, and up to 50% of upfront vehicle costs. Similarly, fleets can access loans to cover the cost of zero-emission buses and their infrastructure through the CIB. If all three of these programs are leveraged, fleets can end up paying less than an equivalent diesel bus to cover the upfront capital costs of ESBs (see Figure 7 for an example using Type C buses). Non-repayable contributions through ZEVIP and ZETF can also reduce the payback period so that it falls within the 12-year lifespan of a typical bus (see Table 2).

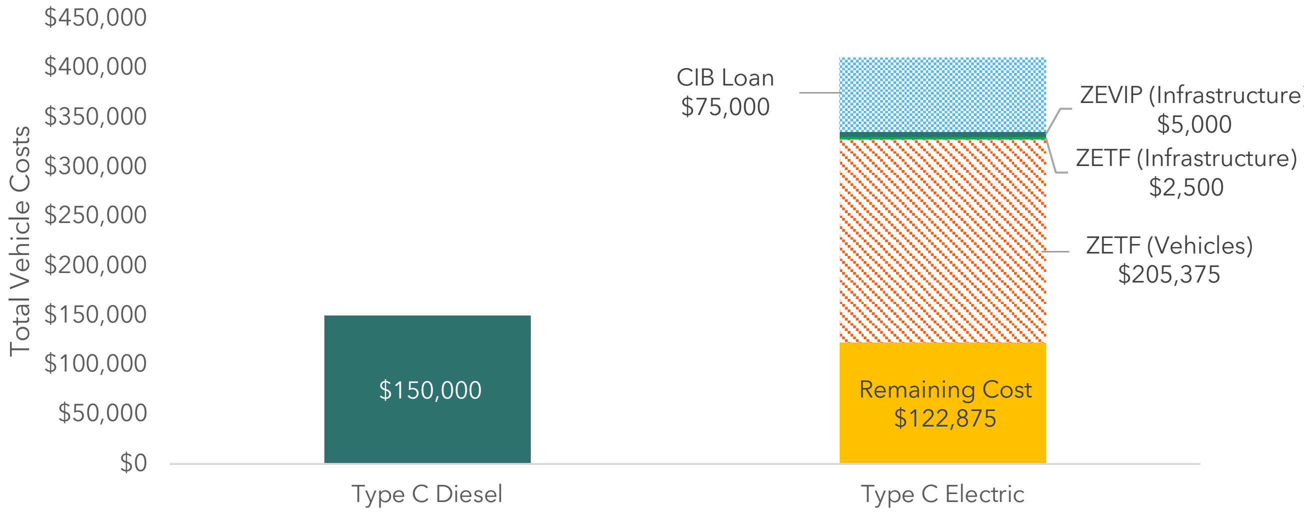


Figure 7. Type C upfront diesel and electric school bus costs with maximum federal funding

Similarly, by participating in the CFR and V2G programs as they become available, school bus operators can further reduce the payback period of ESBs (see Table 2).[27] For Type C school buses, which represent 71% of school buses in Canada, by leveraging maximum amounts of federal funding as well as revenue from the CFR and V2G, an operator could reduce the payback period of an ESB from 19.3 years to 2.7 years.

Table 2. Payback period of ESBs under different funding and revenue-generating scenarios

	Type A	Type C	Type D
No funding or additional revenue	20.7 years	19.3 years	23.3 years
CFR revenue	15.6 years	13.9 years	16.8 years
V2G revenue[28]	17.8 years	17.3 years	20.6 years
Federal funding (ZETF + ZEVIP)	7.0 years	4.4 years	6.4 years
Federal funding + CFR revenue	5.3 years	3.2 years	4.6 years
Federal funding + V2G revenue	5.4 years	3.6 years	4.6 years
Federal funding + CFR + V2G revenue	4.3 years	2.7 years	4.0 years

[27] Note that payback periods reflect the purchase of a Direct Current Fast Charger (DCFC) for $35,000 across all scenarios as this will in many cases be critical to enabling participation in future V2G programs
[28] Assuming an average revenue of $3,000 per bus per year

4. Charting a Pathway to 100% ESBs

4.1 School Bus Fleet Turnover Rates

We calculated the number of school buses that would need to be converted to electric each year to reach CESBA's supposed objective of 100% ESBs on the road by 2040 and to determine what it would take to reach a more ambitious target of 100% by 2035. This took into account the existing age distribution of the fleet and a typical retirement threshold of 12 years.

100% by 2040

Under a *100% by 2040* target, over **2,850 buses** would need to be converted to electric annually, on average, between 2023 and 2040. This reflects a uniform rate of annual ESB replacements over this period. Under this target, however, there is flexibility for the ESB replacement rate to change year-over-year. In particular, this could reflect a ramp-up period with lower levels of ESB replacements in the near-term to better reflect near-term supply chain constraints. This would increase to higher rates over time as ESB supply increases.

Table 3 provides a breakdown of the percentage of new annual school bus purchases that would be electric under a *100% by 2040* target with a uniform rate of annual ESB adoption. The table provides a breakdown of the number of vehicles in Canada's school bus fleet that are up for retirement each year, and the number and share (%) of those vehicles that would need to be converted to electric in order to hit an average 2,857 ESB replacements each year. In years where there are fewer vehicle retirements and replacements, the share of the fleet that needs to be converted to electric is higher, reaching a maximum of 85%.

Table 3. Share of annual school bus replacements that would be electric under a *100% by 2040* target

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Annual School Bus Retirements	5,578	5,578	3,370	3,370	3,370	3,370	3,370	3,890	3,890	3,890	3,890	3,890	3,890	5,578	5,578	3,370	3,370	3,370
ESB Replacements	2,857	2,857	2,857	2,857	2,857	2,857	2,857	2,857	2,857	2,857	2,857	2,857	2,857	2,857	2,857	2,857	2,857	2,857
ESB Share of Annual Replacements	**51%**	**51%**	**85%**	**85%**	**85%**	**85%**	**85%**	**74%**	**74%**	**74%**	**74%**	**74%**	**74%**	**51%**	**51%**	**85%**	**85%**	**85%**

100% by 2035

To achieve a more ambitious target of *100% by 2035*, every school bus that has reached its retirement age of 12 years would need to be replaced with an electric model starting in 2023. Otherwise, under most regulations diesel school buses purchased in 2023 would not need to be replaced again until 2036, at which point the target would be missed. It is possible that diesel school buses purchased in the interim period (i.e., between 2023 and 2035) could be retired early, but this would only delay populations from reaping the air quality and climate benefits of ESBs and could end up costing fleet operators more overall.

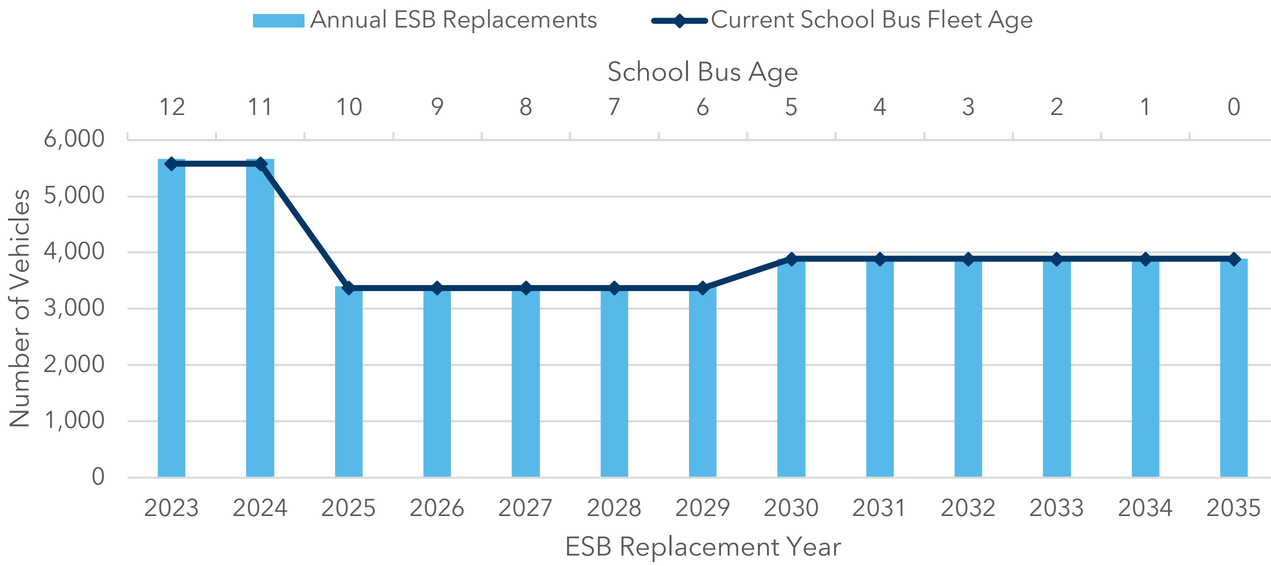


Figure 8. Annual ESB replacements under a *100% by 2035* target

Given the current age distribution of Canada's school bus fleet, the greatest number of ESB replacements over the 2023-2035 period would occur over 2023-2024 (see Figure 8). While in the long-term, we can expect battery and ESB manufacturing capacity to ramp up, there may be some challenges in meeting the near-term deployment targets outlined in Figure 8. First, mandates requiring school bus operators to switch to an electric model do not yet exist across the entire country and are only in select jurisdictions. Second, it is expected that global supply chain constraints have impacted ESB manufacturing capacity, so there may be limitations on ESB availability. Finally, the installation of charging infrastructure should precede the deployment of ESBs, and in the event that site changes or infrastructure upgrades are required, this may delay deployment.

4.2 ESB Supply Forecasts

To better understand whether there is expected to be a sufficient supply of ESBs to meet either a 100% by 2035 or 2040 target, we have examined forecasts for battery production capacity as a proxy for how the electric vehicle (EV) ecosystem is expected to evolve over time. Over the past several years, many original equipment manufacturers (OEMs) have announced plans to build EV battery manufacturing plants in North America, most of which aim to start production by 2025-2030. North America currently has a battery production capacity of about 90 gigawatt hours (GWh); this is expected to increase to more than 800 GWh by 2025, and to nearly 1,000 GWh by 2030, at a significant 41% compounded annual growth rate (CAGR).[29]

[29] David Gohlke, Yan Zhou, Xinyi Wu, and Calista Courtney, *Assessment of Light-Duty Plug-in Electric Vehicles in the United States, 2010-2021* (Argonne National Laboratory, 2022), 27. https://publications.anl.gov/anlpubs/2022/11/178584.pdf

Assuming an average battery pack capacity of 161 kilowatt hours (kWh) per school bus, the annual GWh needed per year to electrify all ESBs is **0.5 GWh** to reach full school electrification by 2040, or **0.5-0.9 GWh** to reach an earlier target of 2035.

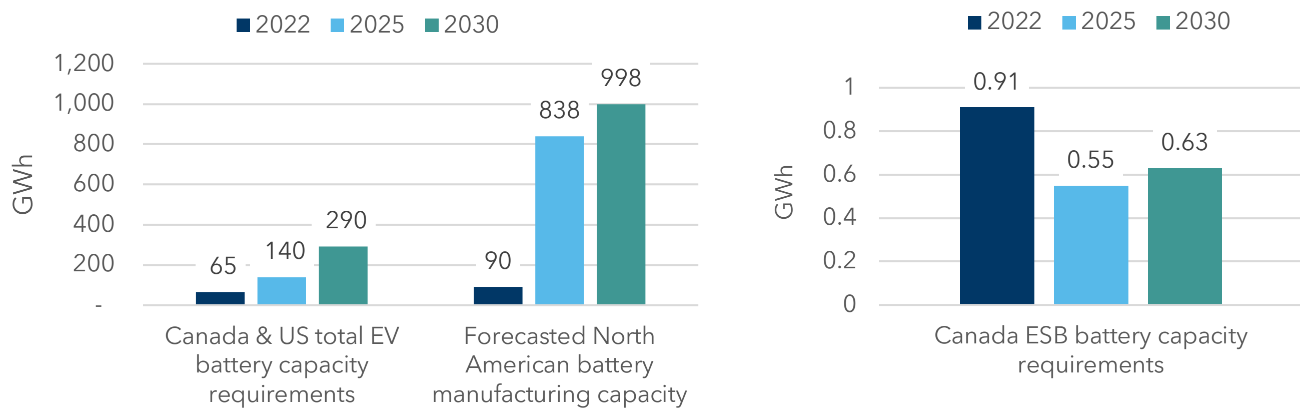


Figure 9. Left: Forecasted EV battery capacity requirements in Canada and the US vs North American (NA) battery manufacturing capacity; Right: Annual battery capacity needed to reach 100% ESBs in Canada by 2035

To put this into context, the total number of EV sales projected for Canada and the US corresponds to a battery capacity requirement of roughly 245 GWh in 2025 and 510 GWh by 2030.[30] Given over half of all EVs sold in the US have battery cells that were produced domestically,[31] and if we apply a similar assumption to the Canadian market, the local GWh capacity needed to meet the projected sales of all EVs in 2025 and 2030 is estimated at 140 GWh and 290 GWh respectively. Not only is this well within the range of forecasted battery manufacturing capacity in North America, but it highlights that **ESBs are marginal (≤1%) to total EV production** and anticipated battery production capacity (see Figure 9).

Among notable battery manufacturing announcements is the Stellantis N.V. and LG Energy Solutions Windsor, Ontario plant, which has an annual target of 45 GWh, making it the largest battery plant in North America upon its anticipated opening in 2025.[32] Meanwhile, the Lion Electric facility in Joliette, Illinois has started operations and has a planned yearly production capacity of 5 GWh in battery storage for up to 20,000 all-electric buses and trucks.[33]

While these targets and announcements suggest that future ESB manufacturing capacity will not act as a long-term barrier to reaching full electrification, supply chain constraints have led to limited manufacturing capacity in recent years. Between 2020 and 2022, Lion Electric delivered approximately

---

[30] International Energy Agency, "Global EV Data Explorer." https://www.iea.org/data-and-statistics/data-tools/global-ev-data-explorer
[31] Ibid
[32] Stellantis, "Stellantis and LG Energy Solution to Invest Over $5 Billion CAD in Joint Venture for First Large Scale Lithium-Ion Battery Production Plant in Canada." https://www.stellantis.com/en/news/press-releases/2022/march/stellantis-and-lg-energy-solution-to-invest-over-5-billion-cad-in-joint-venture-for-first-large-scale-lithium-Ion-battery-production-plant-in-canada
[33] "Lion Electric Announces the Production of its First Made in America School Bus in its Joliet Illinois Factory," November 2, 2022. https://www.newswire.ca/news-releases/lion-electric-announces-the-production-of-its-first-made-in-america-school-bus-in-its-joliet-illinois-factory-817186388.html

900 buses and trucks, among which approximately 500 were ESBs.[34] They currently have an order book of 2,408 vehicles, consisting of 323 trucks and 2,085 buses.[35] These ESB orders could, in theory, represent three-quarters of the ESB sales required in 2023 to meet a target of 100% by 2040, but it is unlikely that all of these orders were placed by Canadian school bus operators. In 2021, nearly half of Lion Electric's sales went to the US market.[36] It is possible that this share could rise as a result of a new source of significant funding – the EPA Clean School Bus Program – which has allocated $5 billion dollars in rebates over 2022 to 2026 for zero- and low-emission school buses.[37]

Girardin Blue Bird, the official school bus distributor named by Blue Bird Corporation to serve Quebec, Ontario, and the Maritime Provinces, has sold up to 510 Blue Bird and Micro Bird electric school buses by Fall 2021. Shortly before this, they obtained purchasing intentions for 1,200 electric school buses from more than 90 clients from all Quebec regions, with the majority having confirmed their orders and some being conditional on obtaining a satisfactory agreement with the government. The deliveries for these 1,200 buses were expected to start towards the end of 2021 and will continue up to March 2024.[38] The current production capacity of Lion Electric and delivery wait times for Girardin Blue Bird suggest that the current supply of ESBs may not be sufficient to meet near-term ESB sales requirements under a 100% by 2035 target.

4.3 Capital Required to Support 100% ESB Adoption

While supply chain constraints may act as a barrier to ESB adoption in the near-term, capital may act as a longer-term barrier. There is a significant amount of capital required in the near term to support a Canada-wide transition to 100% ESBs. This includes capital to cover the upfront purchase of ESBs, as well as the purchase and installation of charging infrastructure. Under a 100% by 2040 target, over **$1.25 billion** would be required from all stakeholders in 2023, whether from bus operators or other stakeholders (e.g., government). This is expected to decrease over time alongside declining ESB costs to approximately **$1.01 billion** by 2040 (see Figure 10). The total capital required over the 2023-2040 period is equivalent to approximately **2.5 times** the annual capital requirements for diesel buses.

An average of $550 million in funding is available annually through Infrastructure Canada's ZETF program. Given that the program only covers up to 50% of project costs, ZETF could theoretically provide funding for approximately 90% of ESB replacements up until 2025; however, the reality is that this funding stream is to be shared between school bus operators and transit agencies. ZEVIP, on the other hand, is expected to be able to fund all ESB infrastructure deployment costs up to a maximum

---

[34] Lion Electric, *Quarterly Financial Reports of 2020-2022*

[35] Lion Electric, *2022 Q3 Financial Results*. https://thelionelectric.com/documents/en/Lion_Electric_Q3_2022_Quarterly_Results_ENG.pdf

[36] Lion Electric, *Earnings Call Presentation Q4 2021*, 7. https://s27.q4cdn.com/902820926/files/doc_financials/2021/q4/Q4-2021-Earnings-Presentation-VERSION-FINALE.pdf

[37] United States Environmental Protection Agency, "Clean School Bus Program." https://www.epa.gov/cleanschoolbus

[38] Commercial electric bus market now opened to Girardin, accessed at: https://www.girardinbluebird.com/en/news-and-events/37-news/282-commercial-electric-bus-market-now-opened-to-girardin

of 50% per charger until the program ends in 2027 using only 13% of the program's annual funding budget.

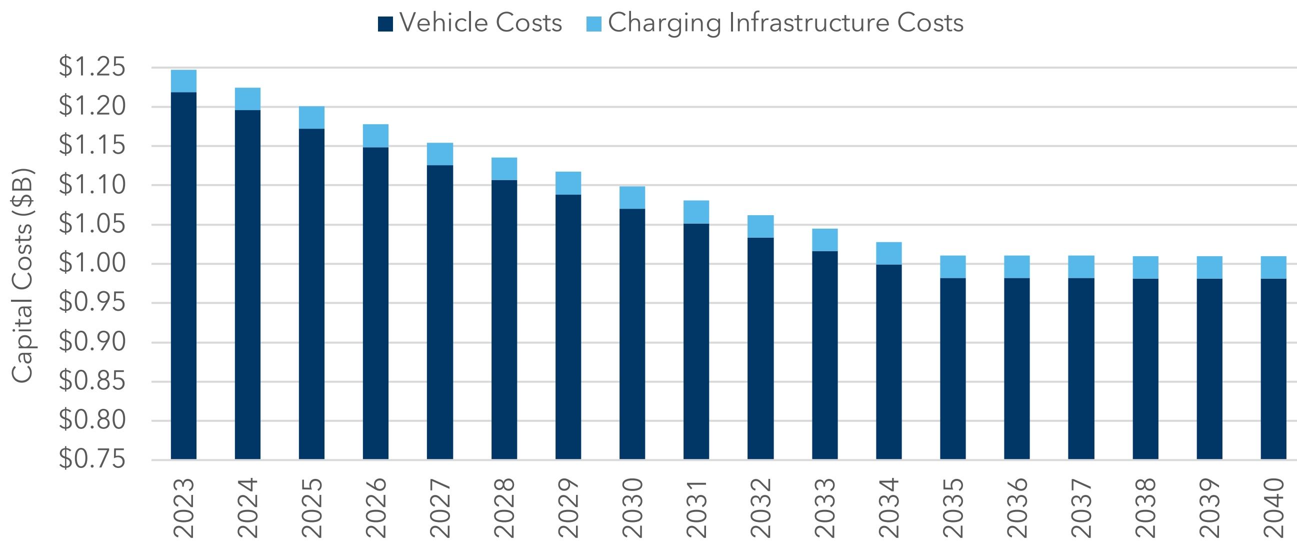


Figure 10. Annual capital required (vehicle and charging infrastructure costs) for a transition to 100% ESBs by 2040 (2023 CAD)

TRADE-OFFS OF 2035 AND 2040 TARGETS

The sooner Canada's school bus fleet is converted to electric, the sooner Canadians will be able to reap the benefits, including GHG emissions reductions, air quality improvements and operational cost savings. Achieving a more ambitious target of 100% ESBs by 2035 would have positive implications on our carbon budgets and GHG emissions reduction goals as a tonne of carbon reduced today will have a greater impact on climate change mitigation than one reduced in the future. Moreover, the sooner our school bus fleets are fully electric, the sooner communities will benefit from improved air quality, and school bus operators will be able to reduce their operating costs and benefit from a quieter, more comfortable drive.

However, achieving 100% by 2035 also presents challenges. Most importantly, we lack the supply and manufacturing capacity to convert the necessary number of vehicles to ESBs in the near term. This means that either vehicle retirement ages will need to be extended beyond their typical 12-year lifespan (like what Quebec has done), or alternatively, more diesel buses will need to be purchased in the near term and retired early to be replaced with an ESB. Furthermore, transitioning the fleet to ESBs sooner will require more capital. As the cost of ESBs declines with decreasing battery costs and with increasing economies of scale, less capital will be required year-over-year to support the transition.

5. Recommendations: The Federal Government Should Increase Support for ESBs

The findings of this analysis demonstrate that, particularly in the near term, the business case for ESBs is weak without substantial government support. ESB offer significant benefits – on climate, local air quality, and from an operational cost savings perspective. Although provinces, cities and other actors can intervene, the federal government has an opportunity to support school bus operators make the switch through different actions. The following recommendations have been identified as key federal actions to support ESB adoption:

1. **Set Canada-wide ESB sales targets.**
   Federal funding for ESBs should be complemented by nationwide sales targets that will ensure there is sufficient ESB supply for school bus operators across the country to make the switch.
2. **Extend existing federal funding programs for ESBs.**
   The $2.75B in funding available under ZETF has been allocated over fiscal years 2021/22 to 2025/26. It is unclear whether federal support will be available after this period. Given that ESBs are not expected to reach price parity with diesel buses between now and 2040, the federal government should consider continuing to help make ESBs more affordable by allocating additional funds to this program after they expire in 2025. Similarly, funding through ZEVIP should be extended past the 2027 end year.
3. **Ensure federal funding for ESBs and charging infrastructure is sufficient and easily accessible.**
   Most provinces and territories in Canada do not have funding programs to support ESB purchases and planning. That means that there are a significant number of school bus operators that will be relying on federal programs to bring down the cost of an ESB should they decide to make the switch. The current application-based structure of the ZETF program in particular makes it difficult for school bus operators to plan their vehicle replacements and identify the necessary capital outlay, as it can take several months for applications to be processed and approved. Moreover, the application processes themselves are burdensome and may act as a deterrent for some fleets. Given that the upfront cost of ESBs represents the largest incremental cost for fleet operators (barring any major on-site electrical upgrades), the federal government should consider offering point-of-sale rebates on ESB purchases to provide more certainty to fleet operators as they build their budgets. The application-based structure of ZETF's planning stream will likely need to be maintained to ensure fleet operators are getting an adequate level of targeted support as they develop their implementation strategy, though would benefit from a simpler application process and faster response time.
4. **Work with provinces to explore the possibility of temporarily extending the retirement age of diesel school buses to support the near-term adoption of ESBs.**

Modelled on Quebec's regulation, this type of policy could be implemented in provinces across Canada to support school bus operators that are facing delays in ESB procurement. By temporarily extending the lifespan of diesel buses, it would be possible to smooth out the spike of ESB replacements that would be needed in 2024-2025 to meet a 100% by 2035 target. Any implications on school bus safety would of course still need to be considered in a policy like this.

5. **Lead or fund education and awareness campaigns that promote the benefits of ESBs.**

   These campaigns are key to ensuring that school bus operators understand the multitude of benefits that ESBs present, as well as the various financial supports that are available to them across the country. The federal Zero-Emission Vehicle Awareness Initiative (ZEVAI) – Medium- and heavy-duty vehicle stream is well-suited to funding these types of campaigns.

Appendix A

Assumptions Used in Calculations

Electricity Rate

Canada's Energy Future is a yearly report that explores possible energy futures for Canadians over the long-term. The 2021 report and dataset were used to obtain end-use electricity prices across all provinces in Canada and an average $/kWh electricity price was derived based on the years 2021 to 2023. Forecasts found in the 2021 Canada's Energy Future dataset (Evolving Policies for Commercial Sector) were used to project the TCO of ESBs out until 2040.

Fuel

The price of diesel used for fuel calculations was determined by averaging the retail cost of diesel in Canada from June 2021 through November 2022. Diesel prices are highly volatile and subject to change on both a monthly and yearly basis. The price used in the calculations for this work was $1.73/L and forecasts followed the 2021 Canada's Energy Future dataset trends. Similarly, the price of crude oil in Canada utilized for trade balance calculations was averaged from June 2021 through November 2022 and was equal to $0.70/L.

Operations

School bus operations were assumed to be running 4 hours per day (2 in the morning and 2 in the evening), 5 days per week, and 4 weeks per month. These calculations do not include any additional bus usage for non-daily routes such as school trips. Although different manufacturers have different heating technology options, it was conservatively assumed that all-electric buses are currently using diesel fuel heating systems. Based on feedback from school districts, the estimated duration of heating months varied between 6-10 months of the year. An average of 8 months was used for diesel consumption to run heaters on electric school buses.

Clean Fuel Regulation (CFR)

Values used to assess monetary returns from a CFR scenario were $300 per credit, adjusted for inflation. The CFR targets carbon emission reductions from carbon content in liquid fossil fuels, primarily for those used in transportation, and it aims to spur innovation and economic growth in the low-carbon fuels sector. On June 20, 2022, the final Clean Fuel Regulations under the Canadian Environmental Protection Act, 1999 were registered, bringing a Canadian Clean Fuel Standard into law.

Upfront Vehicle Cost

ESB upfront vehicle cost forecasts have been forecasted using Dunsky's internal battery price forecast (informed by forecasts from organizations including BloombergNEF[39]) and the ICCT's forecast on

[39] BloombergNEF, *Electric Vehicle Outlook 2022* (2022), 123. https://about.bnef.com/electric-vehicle-outlook/

electric powertrain prices.[40] Keeping the non-battery cost of ESBs constant over the study period, battery and powertrain costs are projected relative to each ESB type's specifications, and the three components are added to arrive at the final ESB cost forecast.

[40] Yihao Xie, Hussein Basma and Felipe Rodriguez, *Purchase costs of zero-emission trucks in the United States to meet future Phase 3 GHG standards* (2023), 11. https://theicct.org/wp-content/uploads/2023/03/cost-zero-emission-trucks-us-phase-3-mar23.pdf

Appendix B

Fuel and Electricity Price Forecasts

Table 4. Electricity price forecast

Year	Electricity Price ($/GJ)	Electricity Price ($/kWh)
2022	36.60	0.132
2023	36.93	0.133
2024	37.27	0.134
2025	37.60	0.135
2026	37.96	0.137
2027	38.32	0.138
2028	38.68	0.139
2029	39.04	0.141
2030	39.39	0.142
2031	39.75	0.143
2032	40.11	0.144
2033	40.47	0.146
2034	40.83	0.147
2035	41.19	0.148
2036	41.56	0.150
2037	41.92	0.151
2038	42.29	0.152
2039	42.66	0.154
2040	43.03	0.155

Table 5. Diesel fuel price forecast (including taxes)

Year	Diesel Price ($/L)
2022	1.74
2023	1.74
2024	1.74
2025	1.74
2026	1.75
2027	1.77
2028	1.78
2029	1.79
2030	1.79
2031	1.74
2032	1.80
2033	1.80
2034	1.80
2035	1.81
2036	1.81
2037	1.81
2038	1.81
2039	1.81
2040	1.81

Appendix C

Regional Carbon Intensities of Grid Electricity

Table 6. Provincial/Territorial grid electricity carbon intensity (Source: Environment and Climate Change Canada[41])

Province/Territory	Carbon Intensity of Grid Electricity ($g\ CO_2e/kWh$)
Newfoundland and Labrador	25
Prince Edward Island	300
Nova Scotia	680
New Brunswick	300
Quebec	1.9
Ontario	28
Manitoba	1.2
Saskatchewan	620
Alberta	640
British Columbia	7.8
Yukon	110
Northwest Territories	180
Nunavut	800

[41] Environment and Climate Change Canada, "Emission Factors and Reference Values," https://www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work/output-based-pricing-system/federal-greenhouse-gas-offset-system/emission-factors-reference-values.html#toc14

Appendix D

Types of School Buses in Canada

Table 7. Detailed breakdown of school bus types in Canada

School Bus Type	Passenger Capacity	Chassis Type	Other Notes
Type A	10-16	Cutaway van chassis	• Two subcategories: Type A1 (lighter) and Type A2 (heavier) • Engine located in front of windshield
Type B	10-30	Stripped chassis	• Engine located partially behind windshield
Type C	Up to 76	Chassis with hood and front fender assembly	• What most would consider a traditional school bus • Engine located in front of windshield
Type D	Up to 74	Stripped chassis	• Bus flat at front • Engine located behind windshield
MFSAB	Variable	Variable	• "Multifunction school activity bus" that is used to transport children on trips and not between home and school

“NO DISCLAIMERS” POLICY

This report was prepared by Dunsky Energy + Climate Advisors, an independent firm focused on the clean energy transition and committed to quality, integrity and unbiased analysis and counsel. Our findings and recommendations are based on the best information available at the time the work was conducted as well as our experts' professional judgment. **Dunsky is proud to stand by our work.**