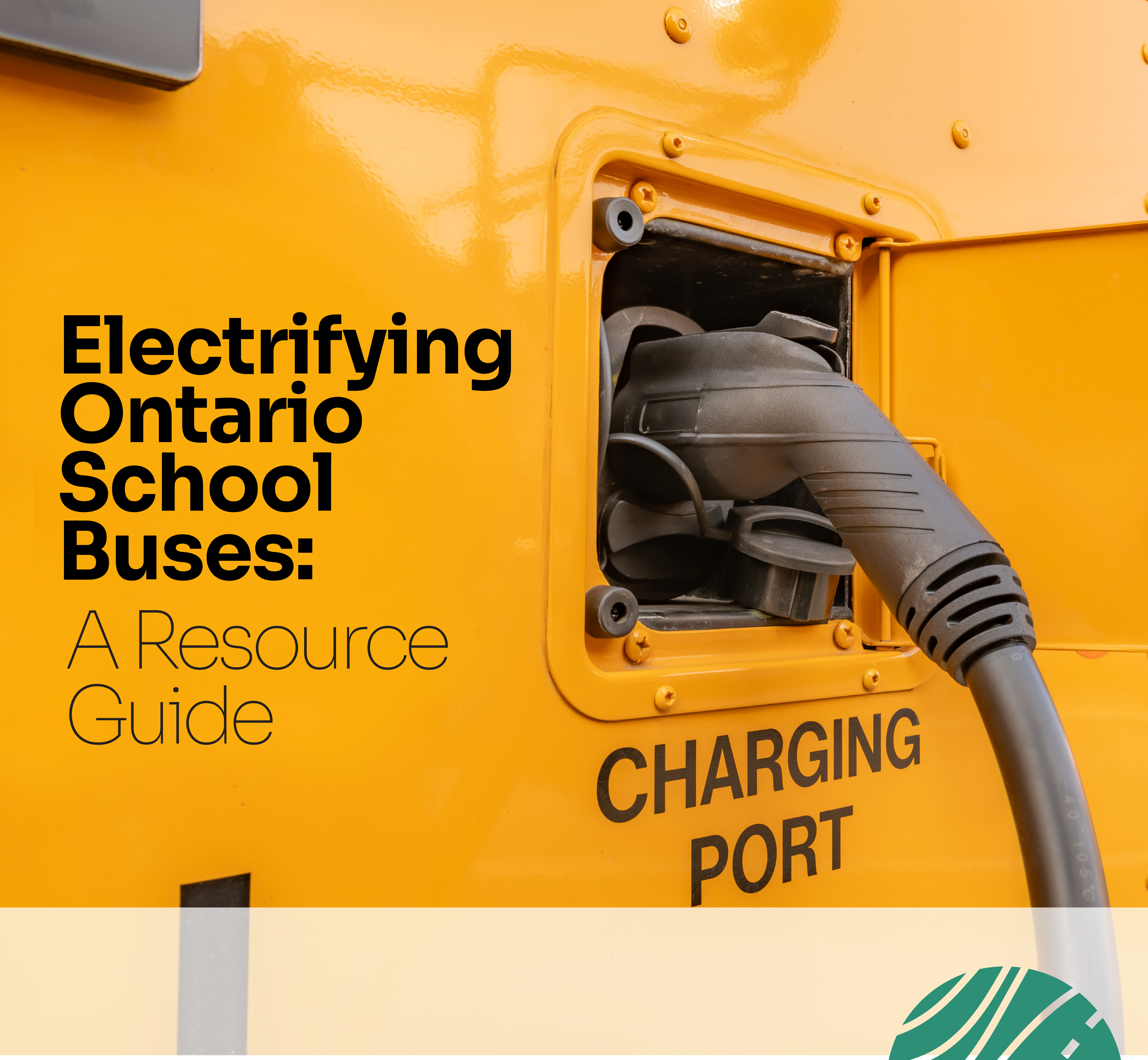
Electrifying Ontario School Buses:

A Resource Guide



Pollution Probe

Mobility Futures Lab

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About

Pollution Probe

Pollution Probe is a Canadian charitable environmental organization founded in September 1969 by University of Toronto students and professors. Over the past 5 decades, Pollution Probe has been at the forefront of progress on a range of environmental issues. Progress on many of these issues took decades of hard work to achieve. We pursue environmental gains by working productively with governments, industry and the public, with a steadfast commitment to Clean Air, Clean Water, and a Healthy Planet. We engage people as thinkers to nurture and act on areas of consensus. Our niche in the environmental movement lies in our systems approach, which embraces three principal drivers for progress: Technology and Innovation; Rulemaking; Behavioural Change.

Pollution Probe is one of Canada's leading independent transportation solution providers. Our work supports aggressive actions to address climate change and reduce air pollution while promoting job creation and economic growth. In addition to projects we actively contribute to expert transportation committees and working groups at local, regional, national and global levels. We are technology neutral and work collaboratively with a wide variety of stakeholders to develop transportation decarbonization solutions across all modes.

Mobility Futures Lab

Mobility Futures Lab is a leading sustainable transportation consulting firm that is at the forefront of innovation and research in the field of mobility. The firm's services are designed to help clients navigate the complex landscape of sustainable transportation, with a focus on proprietary software tools and data-driven solutions. Our approach is based on a deep understanding of the interconnections between transportation, energy, and the environment.

Delphi

A recognized leader in corporate sustainability and climate change, Delphi provides strategic consulting services and innovative solutions to both private and public sector organizations across North America. We have helped some of Canada's best-known companies improve the sustainability of their organizations – as well as the local and global communities in which they operate. Over the past 30 years, we have provided bold solutions through more than 2,500 projects across all major sectors of the economy. Our clients benefit from the Delphi difference: we bring a unique combination of policy expertise, strategic thinking, and technical know-how to every project.

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Introduction

There are approximately 20,000 school buses operating across Ontario, most of which are powered by diesel. Diesel exhaust has significant environmental and health impacts and contributes to climate change through greenhouse gas (GHG) emissions. Additionally, criteria air pollutants such as nitrogen oxides (NOx) and fine particulate matter (PM2.5), commonly associated with diesel, are linked to cardiovascular and respiratory illnesses at varying exposure levels. Electric school buses (ESBs) offer a solution to mitigate these effects. Because they do not emit tailpipe pollutants, they reduce health risks for children, drivers and the general public.[1] Their GHG emissions are tied to the electricity grid's emission intensity in Ontario, one of the cleanest in the world, resulting in approximately eight times lower GHG emissions per kilometer compared to diesel buses.[2] For the many kids suffering from climate anxiety, this is a welcome opportunity to be part of the solution.

Medium and heavy-duty battery electric vehicles have experienced both significant technological advancements and price reductions, largely due to advances in battery technology over the past decade. Financial incentives and emission regulations in North America have further promoted large-scale manufacturing of these vehicles, with additional cost reductions expected as adoption increases. Many school bus operators have begun planning for a gradual transition to ESBs, while others are looking to start familiarizing their staff and organizations with the technology. This guide serves as a valuable resource to support both the planning and implementation process.

Proper planning for both vehicle deployment and the necessary infrastructure, including route and charging optimization, is essential for a smooth, cost-effective transition to this new technology. In this context, the Trottier Family Foundation supported the development of this guide for Ontario school boards, transportation directors, and school bus operators to facilitate the transition to ESBs.

Glossary

AC	Alternating Current
CCS	Combined Charging System
CFR	Clean Fuel Regulation
CIB	Canada Infrastructure Bank
CMVSS	Canadian Motor Vehicle Safety Standards
DCFC	Direct current (DC) Fast Charging
ESB	Electric School Bus
EVCCP	Electric Vehicle Charging Connection Procedures
EVSE	Electric Vehicle Supply Equipment
GHG	Greenhouse Gas
kW	Kilowatt – a unit of power
kWh	Kilowatt-hour – a unit of energy
LDC	Local Distribution Company
L2	Level 2 (chargers)
OEB	Ontario Energy Board
OEM	Original Equipment Manufacturer
NEMA	National Electrical Manufacturers Association
RFI	Request for Information
RFP	Request for Proposals
RPP	Regulated Price Plan
TCO	Total Cost of Ownership
ToU	Time of Use
V2B	Vehicle-to-Building
V2G	Vehicle-to-Grid
WRI	World Resources Institute
ZETF	Zero Emission Transit Fund
ZEVIP	Zero Emission Vehicle Infrastructure Program

1 Pollution Probe (2023). An Electric School Bus Strategy for Ontario. Retrieved from: https://www.pollutionprobe.org/wp-content/uploads/2023/10/School-Bus-Report_Ontario_Oct18.pdf

2 The GHG emissions per kilometer for diesel buses were calculated using a fuel efficiency of 28.83 L/100 km and a diesel emission factor of 2,663 gCO2eq/L, while the electric bus emissions were based on a grid intensity of 120 gCO2eq/kWh and an energy consumption of 0.8 kWh/km.

1 Understanding Electric School Buses

1.1. Performance

ESBs rely on a battery electric powertrain to generate the power needed for vehicle movement. A battery management system ensures the battery operates efficiently, maintains optimal temperature, and prevents degradation. Regenerative braking allows the vehicle to recapture energy during stop-and-go conditions, typical in school bus operations. Drivers have noted that ESBs offer a smoother, quieter ride compared to diesel buses, with instant torque and simplified controls making for an improved driving experience. Additionally, the added weight of the battery improves traction, which can be particularly beneficial in winter conditions.

ESBs are recharged using plug-in chargers. These vary in power output, which determines the time required to fully recharge an ESB. Electric school buses typically rely on AC Level 2 chargers for overnight charging, which are cost-effective and use standard power levels. For faster charging during the day, such as mid-route or in emergencies—DC fast chargers (DCFC) deliver significantly more power, though they come with higher costs. Compatibility between the charger and the ESB's charging port is essential. The standard for ESBs in North America is the SAE J1772 Combined Charging System Combo 1 (CCS1).

The battery chemistry of ESBs involves trade-offs in cost and range.[3] Larger batteries provide greater range, but at significantly higher costs. Fleet operators should analyze their range requirements to avoid purchasing oversized batteries. Current models have stated single charge ranges of 160 to 280 kilometers, which is sufficient to reliably cover most routes in service. Actual range of ESBs can vary from these stated ranges, however, due

3 US department of Energy (2019). Medium and Heavy Duty Vehicle Electrification. An Assessment of Technology and Knowledge Gaps. Retrieved from: https://info.ornl.gov/sites/publications/Files/Pub136575.pdf

to factors including outside temperature, weather conditions and road grade. Several demonstration studies have explored the range of ESBs in different environments. A Calgary study found that range can decrease by up to 40% in harsh weather, particularly when the heating system draws power exclusively from the battery.[4] However, using auxiliary diesel heaters in extreme weather, as is common practice with diesel buses, mitigates this issue by preventing significant battery drain. Other demonstrations of ESBs with auxiliary diesel heaters have reported range reductions of only up to 15% in winter.[5]

Interviews with Ontario fleets that participated in a 2016 pilot program by the Ontario government where each operator received a single bus, revealed that winter weather did not necessarily pose any major barriers to range. Some participating fleets, such as Langs Bus Lines, have since committed to larger deployments, supported by federal incentives.[6]

Ongoing improvements in battery management systems are expected to enhance vehicle efficiency beyond the first-generation models from most Original Equipment Manufacturers (OEMs). These demonstrations also highlighted the important role of regenerative braking in extending range. For fleet operators and school boards considering the transition to ESBs, these findings highlight important operational factors. While ESBs offer clear advantages in terms of driver experience, reduced emissions, and lower operating costs, charging logistics and range performance must be carefully planned. Cold weather impacts on range can be mitigated with auxiliary heating strategies and efficient route planning. The choice between Level 2 and Level 3 charging will depend on depot infrastructure and scheduling needs. With ongoing advancements in battery technology and charging infrastructure, ESBs are becoming an increasingly viable and reliable option for student transportation.

1.2. Model Availability

Electric models are available for Type A, C and D buses. This section focuses on Type A and C – the two bus types operating in Ontario. Table 1 below lists the ESB models (Type A and C) available for sale. These buses typically have battery capacities between 88 and 288 kWh and can travel between 160 and 280 km on a single charge, with Type C buses generally having longer ranges than Type A buses.

All ESB models in **Table 1** are manufactured in North America, and all models use the CCS1 charging standard. Note that some models can only be charged via DCFC.[7] In some cases, additional fees may be required to equip certain models with L2 charging[8].

4 Pollution Probe (2024). Electric School Bus Operational Assessment: A Calgary Demonstration Case Study. Retrieved from: https://www.pollutionprobe.org/electric-school-bus-operational-assessment-a-calgary-demonstration-case-study/

5 WRI (2024). All About Operating Electric School Buses in Cold Weather. Retrieved from: https://electricschoolbusinitiative.org/all-about-operating-electric-school-buses-cold-weather

6 Canada (2024). Zero to 200 – Federal government and Langs Bus Lines race ahead on fleet electrification. Retrieved from: https://www.canada.ca/en/housing-infrastructure-communities/news/2024/06/zero-to-200--federal-government-and-langs-bus-lines-race-ahead-on-fleet-electrification.html

7 Propulsion Quebec (2022) Electric from school to home. Retrieved from https://propulsionquebec.com/wp-content/uploads/2023/11/TransporteurPlus-GuideComplet-EN.pdf

8 Virginia Clean Cities (2021). Electric School Bus Projects – Charging Stations. Retrieved from https://vacleancities.org/electric-school-bus-projects-charging-stations-and-your-facilities/

Table 1: ESB Models (Types A and C) available in Canada. [9]

Manufacturer	Model	Passenger capacity	Range (km)	Battery size (kWh)	Charging time (hours)	
					With L2 charger at a maximum power of 19.2 kW	With DCFC above 50 kW
Type A						
Motiv	EPIC E-450	20	168	127	8	2 to 3
GreenPower Motor Company	Nano BEAST	24	225	118	6	2 to 3
Blue Bird	Micro Bird G5 Electric	30	161	88	7	2
BYD	Achiever Type A	30	169	156	8	2
Type C						
Blue Bird	Vision Electric	77	193	155	8	2.5 to 3
Blue Bird	Vision Electric – Extended Range	77	241	196	N/A	3 to 4
Lion Electric	LionC	77	200	168	6.5 - 11	2.5 to 4
IC Bus	eCE	78	217	210	8	3
BYD	Creator Type C	78	280	288	14 - 15	3
Thomas Built	Saf-T-Liner C2 Jouley	81	241	246	N/A	3.5

L2: Level 2 charging. DCFC: Direct current fast charging

As an alternative to purchasing new ESB models, fleet operators can also consider repowering existing internal combustion engine school buses. Repowered buses use the same charging infrastructure as newly manufactured buses. They typically have lower upfront costs than buying new ESBs and may overcome delays due to supply chain challenges for chassis and body components . This is an emerging alternative to purchasing new ESB models and fleet operators should note that not all buses may be suitable for repowering. Companies offering such services (e.g. Unique Electric Solutions) tend to focus on buses from a specific OEM produced within specific model years. There is also a preference for repowering newer buses that tend to require less mechanical and cosmetic improvements.

1.3. Electric School Bus Economics

1.3.1. Capital Costs

Type C electric school buses are the most common in Ontario and have a purchase price of approximately $300,000[12] more than their diesel counterparts. Beyond the capital cost of the vehicles, fleets must also account for the charging infrastructure,

9 ESB specifications collected from the following sources: Pollution Probe (2023). An Electric School Bus Strategy for Ontario; Clean Energy Canada (2024). Canadian ZEMHDV Model Availability Catalogue; WRI (2024). Electric School Bus U.S. Market Study and Buyer's Guide; ASTSBC (2024). RFSO TRA 24-01 Standing Offer Information.

10 Ly & Werthmann (2024). 8 Things to Know about Electric School Bus Repowers. Retrieved from https://www.wri.org/insights/repowering-electric-school-buses

11 Unique Electric Solutions. Retrieved from https://www.uesmfg.com/

12 As of writing, ESBs generally cost around $360,000 for Type A and $475,000 for Type C buses.

which can vary significantly depending on the charging speed. The cost per unit can range from CAD $6,000 to $10,000 for a Level 2 charger, and from CAD $19,000 to $60,000 for a Level 3 charger. Additional costs may be incurred if grid upgrades are required to accommodate the power requirements of EV charging. Charging infrastructure options and associated costs are further addressed in Section 4.

1.3.2. Operational Costs

Typically, these higher capital costs are at least partially offset by lower operational costs for charging and maintenance over the vehicle's lifetime. Because electric vehicles have fewer components than diesel ICEs, the maintenance costs tend to be around 60% lower over the lifetime of the vehicle.[13] This is addressed further in Section 6.1.3.

Charging costs in Ontario are among the lowest in the country. Electricity rates comprise the commodity charge and the electricity delivery charge, as described below. Rate structures vary depending on the facility's peak demand over the year and are grouped into Class A, Class B and low-volume customers. Class A customers are industrial customers with very high demand. Rates for low-volume and Class B customers are described below.

Electricity Commodity Charge

The commodity charge (a per kWh charge) only covers the actual cost of the electricity consumed and does not include the costs of transporting the electricity to the customer (see below).

Low-volume customers are largely residential and small business customers. This rate structure is applicable to ESB adoption by fleets where drivers park the bus at their home rather than returning to a centralized depot. Most low-volume customers in Ontario fall under the Regulated Rate Plan (RPP) and purchase their electricity through their local LDC using time of use (ToU) rates. Set twice a year by the energy regulator, the Ontario Energy Board (OEB), these define separate rates for off-peak, mid-peak and on-peak times of day, which vary by season. There is also an optional ultra-low overnight time of use rate that is designed to accommodate overnight charging of electric vehicles. They encourage customers to shift usage to off-peak periods, where possible, to reduce grid strain and save money.[14] For drivers charging a bus at home, the timing will dictate the rate that is charged.

Class B customers that are unable to participate in the Regulated Rate Plan include mid-size commercial, institutional and industrial operations. School bus fleets with a centralized depot will typically pay under a Class B rate structure. Starting May 1, 2025, Ontario introduced the Ontario Price as the new electricity commodity charge for commercial and institutional customers, replacing the previous Hourly Ontario Energy Price. This updated rate is tied directly to the wholesale electricity market and reflects real-time supply and demand conditions. Class B customers also pay the Global Adjustment, which accounts for broader system costs such as long-term energy contracts, based on their overall consumption. Class A customers are larger consumers—defined as those with a monthly peak demand of 50 kilowatts or more—are charged the Ontario Price along with the Global Adjustment. For Class A customers their Global Adjustment charges depend on their peak demand during the five highest peak hours the previous year.[15]

Electricity Delivery Charge

Ontario's commercial and institutional electricity delivery rates vary by LDC and may vary based on the chosen rate plan, where applicable. Electricity delivery rates include costs for maintaining the grid, which include both fixed charges and

13 US Department of Energy (2024). Alternative Fuels Data Center. Flipping the Switch on Electric School Buses: Cost Factors. Retrieved from: https://afdc.energy.gov/vehicles/electric-school-buses-p8-m3

14 Ontario Energy Board (2025): Electricity rates. Retrieved from: https://www.oeb.ca/consumer-information-and-protection/electricity-rates

15 IESO (2025): Electricity Pricing Explained. Retrieved from: https://www.ieso.ca/Learn/Electricity-Pricing-Explained/Medium-and-Large-Businesses#:~:text=For%20medium%20and%20large%20businesses%20with%20a%20monthly%20peak%20demand,reductions%20in%20their%20electricity%20bills

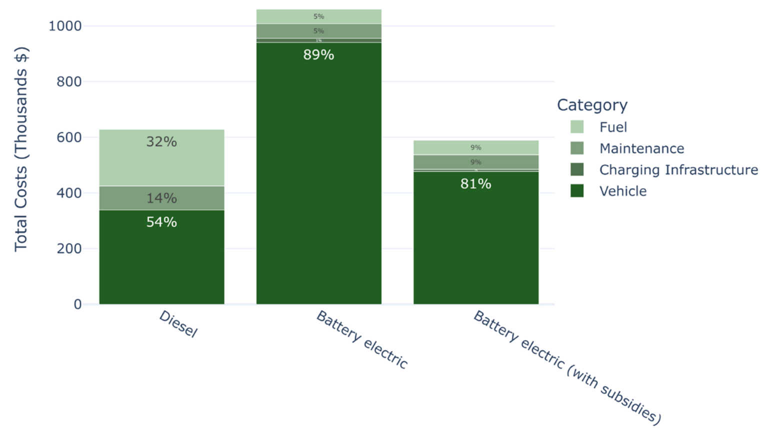
variable charges based on electricity usage. They are determined by the LDC's network and must be approved by the OEB. Low-volume and Class B customers pay either a fixed charge regardless of consumption, or a combination of fixed charges and a charge based on their overall electricity consumption, depending on the facility's peak demand. Class A customers pay an electricity delivery charge that is based on the customer's peak demand, which is the highest amount of electricity the facility requires.

1.3.3. Total Cost of Ownership

As of 2025, financial incentives remain crucial to making school bus electrification financially viable, especially for larger deployments that require grid upgrades. Section 2.2 provides additional information on incentives and grants to support the purchase of ESBs and associated charging infrastructure.

Fleets can estimate the financial impact of a deployment using the AltFleet Insight tool, developed for the Canadian Transportation Council.[16] This tool enables Canadian fleets to compare costs and emissions reductions across various powertrain technologies, including battery electric school buses, in the Canadian context. **Figure 1** illustrates an example where two Type C ESBs replace diesel buses in a one-to-one pilot deployment, without significant grid upgrades. The example shows that for this small deployment of two ESBs, the economics were favorable over a 13-year ownership period due to ZETF funding, which covered 50% of the vehicle cost ($205,000 per bus) and charging infrastructure ($6,725). The total cost without subsidies was 68% higher compared to diesel buses, but with ZETF funding, the total estimated costs over the 13-year period were 6% lower compared to diesel buses. Vehicle costs account for the largest portion of both capital and operational expenses.

Figure 1: Cost comparison for Type C bus deployment for diesel versus electric based on the AltFleet Insight tool [17]



16 Canadian Transportation Council (2024). Altfleet Insight. Retrieved from: https://altfleetinsight.mobilityfutureslab.ca/

17 A federal vehicle subsidy of $205,000 is assumed per vehicle, with the selection of three 11.5 kW single port chargers ($4725 each) and cost of $4,000 for installation/grid upgrades with a subsidy of $6,725 for the chargers and infrastructure rebate. All price values were used as default in the Alt fleet Insight tool.

2 School Bus Regulatory and Policy Environment

2.1. Provincial and Federal Regulations

Safety Codes and Standards
Codes and standards are in place to ensure the electrical and fire safety of ESBs, batteries and chargers to protect occupants, users and other road users.

School buses must comply with the federal Canadian Motor Vehicle Safety Standards (CMVSS), which include many requirements that apply to all school buses, including electric ones, focusing on passenger and pedestrian safety. Some new regulations address the unique characteristics of electric vehicles, notably that pertain to Low-Speed Acoustic Alerts. This standard for electric and hybrid vehicles requires an acoustic alerting system to emit sounds at low speeds, making these quiet vehicles audible to blind, visually impaired, and other pedestrians and cyclists.

ESB batteries must follow global safety standards from organizations such as the SAE, ISO and UL, which ensure that they are constructed and designed to protect the battery from the elements, impact and fire, among others.

Chargers must be installed according to the Ontario Electrical Safety Code (section 86)[19]. This includes standards for charger enclosures in the form of National Electrical Manufacturers Association (NEMA) ratings, which specifies how well they are built to withstand the elements when installed outdoors.

Emissions Regulations
Ontario requires heavy-duty diesel vehicles, including school buses, to undergo emissions tests when a vehicle older than seven years is registered under

19 Electrical Safety Authority (2024). Ontario Electrical Safety Code. Retrieved from https://esasafe.com/role/oesc/

Photo: gettyimages.com/ Photo Concepts

a new owner, or upon license plate sticker renewal. Being without a diesel engine, electric school buses are exempt from these emissions tests.

2.2. Funding Landscape

Two federal programs have provided incentives to offset the capital costs of ESBs and charging infrastructure: the Zero Emission Transit Fund (ZETF)[20] and the Zero Emission Vehicle Infrastructure Program (ZEVIP)[21].

It is recommended that fleet operators verify the status of the funding landscape during the planning process as it will remain subject to change as the zero-emission vehicle landscape develops and matures.

Revenue Streams Associated with ESBs

The federal Clean Fuel Regulations (CFR) aim to reduce the carbon intensity of transportation fuels by establishing a credit market[22]. By deploying ESBs, school bus operators may generate credits that can be traded in this market to provide an additional source of revenue. Credits are generated based on the GHG reductions when displacing fossil fuels by charging ESBs with electricity. This benefits Ontario substantially as it has one of the least carbon-intensive grids in Canada. These credits are sold on the credit market to other parties that need to meet their emissions reductions targets. Depending on energy consumption and CFR credit prices, an ESB running on Ontario‘s electricity grid could potentially generate credits valued at $800 to $4,500 per year[23].

In addition to incentives and grants, vehicle-to-grid (V2G) programs could be another revenue source for ESB operators. V2G uses the bi-directional charging capabilities of ESBs to offer grid support services like energy storage and load balancing. More details are provided in Section 4.3.

20 Housing, Infrastructure and Communities Canada (2025) https://housing-infrastructure.canada.ca/zero-emissions-trans-zero-emissions/index-eng.html

21 Natural Resources Canada (2025) https://natural-resources.canada.ca/energy-efficiency/transportation-energy-efficiency/zero-emission-vehicle-infrastructure-program

22 Environment and Climate Change Canada (2023). Clean Fuel Regulations. https://www.canada.ca/en/environment-climate-change/services/managing-pollution/energy-production/fuel-regulations/clean-fuel-regulations.html

23 If you would like to see the calculations, please contact us.

3 Planning the Transition

3.1. Establishing a Roadmap

Transitioning to ESBs typically involves several key steps, as outlined in **Figure 2**. Planning for the first few ESBs to be deployed could take up to two years, and transitioning an entire fleet to ESBs could require several additional years depending on fleet size and transition speed. The transition timeframe and required steps greatly depend on elements including bus ownership status, availability of local expertise, financing and funding, facility upgrade needs, local grid capacity and the availability of buses and chargers.

Establishing a roadmap orients the project team and other stakeholders throughout the process of planning for and deploying ESBs. The vision and principles set out in the roadmap will also shape many of the decisions down the line.

Figure 2: ESB Transition Planning. Adapted from the World Resources Institute's Electric School Bus Initiative [24]

		FOR MORE DETAILS
Set Foundations (3–6 months)	▪ Set visions and goals ▪ Set up project team ▪ Research market, funding and financing ▪ Engage communities and stakeholders	2.2 Funding Landscape 1.2 Model Availability
Plan and Procure (1–2 years)	▪ Plan fleet operations and charging infrastructure needs ▪ Engage utilities, assess facilities ▪ Procure buses and chargers	3.2 Assessing Fleet Needs 4 Charging Infrastructure Requirements 5 Procurement Process
Implement, Train and Deploy (ongoing)	▪ Install chargers, upgrade facilities ▪ Test equipment ▪ Train drivers, mechanics etc. ▪ Deploy buses, monitor performance, scaling strategy	6.1 Implementation 6.2 Training 6.3 Deployment 7 Data Management, Monitoring and Scaling

24 Wang et al. (2024). Electric school bus US market study: A resource for school districts pursuing fleet electrification. Retrieved from https://doi.org/10.46830/wriib.21.00135.v3

A roadmap should set out a vision for electrifying school buses; and should include context, criteria and conditions for the project. It should establish the factors for success and mitigation of potential risks; and identify stakeholders and their roles, as well as the key steps that are required for successful ESB deployment. The roadmap should further set out measurable targets with associated timelines

The roadmap can be a helpful tool to engage stakeholders and the community, and to gather feedback. As such, it should be a flexible document, adjusted as required to reflect actual data and stakeholder input.

Before establishing a roadmap, a dedicated project team should be established, which may include:

1. **Fleet Manager:** Drives the project forward and manages the electrification process
2. **Facility Manager:** Assists in identifying charger locations and coordinating facility and grid infrastructure upgrades
3. **Electrical Contractor:** Provides technical assistance with interconnection requirements, electrical upgrades, and their associated costs
4. **Procurement Manager:** Coordinates external funding applications and procures ESBs and chargers
5. **Drivers, Operators and maintenance staff:** Understand techniques to operate and maintain ESBs safely and efficiently, and provide insight into how ESBs might impact day-to-day operations

Together, the project team should set goals for the project, which could be to reduce greenhouse gas and air pollutant emissions, reduce fuel or maintenance costs, and/or pilot ESB technology. This should be followed by a learning phase where the team gains an understanding of ESB technology and current market conditions, including any available funding and financing options. With this knowledge, the team can then develop a draft version of the roadmap. The draft roadmap can then be used in stakeholder engagement to gather input and collaboratively refine the roadmap.

To assist with the process of establishing a roadmap, the World Resources Institute (WRI) has developed a template roadmap for school bus electrification[25], which outlines the key steps required and helps with project management by visualizing concurrent and sequential timelines. This helps to minimize overall project duration by allowing managers to identify task dependencies and opportunities for tasks to be completed in parallel, which reduces unnecessary waiting time.

Once a roadmap has been created, the project team can then embark on the subsequent stages in the fleet electrification process.

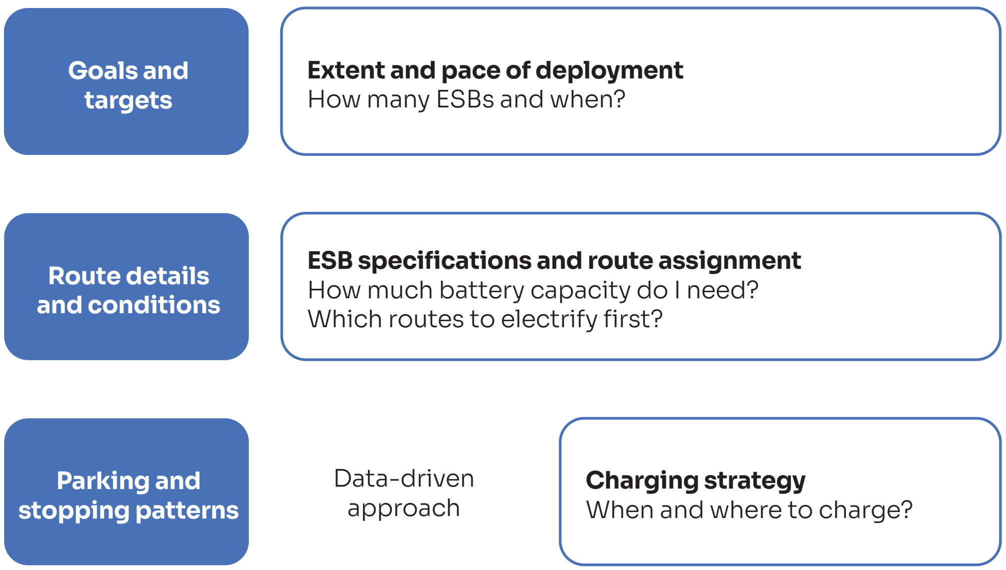
25 WRI (2022). School Bus Electrification Template Roadmap. Retrieved from https://electricschoolbusinitiative.org/school-bus-electrification-template-roadmap

3.2. Assessing Fleet Needs

A comprehensive assessment of your fleet's ESB requirements is essential for developing strategic plans that optimize the benefits of electrification while controlling costs. These needs are shaped by your organization's electrification goals and performance targets, as well as operational factors such as route characteristics, environmental conditions, and daily parking and stopping patterns.

To ensure accuracy and effectiveness, a data-driven approach is recommended—leveraging real-world operational data from your existing fleet. Engaging experienced engineering consultants for expert guidance in operational planning and infrastructure design can further enhance the assessment process.

Figure 3: Assess your fleet's ESB needs with a data-driven approach based on existing operational conditions. Professional engineering firms can help in needs assessment and operations planning.



A thorough assessment of your fleet's ESB requirements is foundational to a successful transition. The following categories of information should be collected to inform deployment strategies and infrastructure planning:

- **Goals and Targets** Clearly define the overarching objectives of your fleet electrification initiative. As outlined in Section 3.1 on establishing a roadmap, these goals should be translated into specific ESB deployment needs, guiding the scale, timeline, and sequencing of implementation. For instance, a target to reduce school bus fleet greenhouse gas emissions by 50% by 2030 may translate into a defined number of ESBs operating on strategically selected routes to maximize emissions reductions.

- **Route Details** Analyze daily travel distances for each route, including both typical and extended operations such as long-distance field trips. This data will help determine the minimum range requirements for ESB replacements and identify routes that align with current ESB capabilities.

- **Route Conditions** Environmental and operational factors—such as temperature extremes and terrain—can significantly impact ESB performance. In colder climates, auxiliary diesel heaters may be necessary to maintain range. [26] Additionally, route topography (e.g., hilly vs. flat) and traffic patterns influence energy consumption and regenerative braking potential, as discussed in Section 1.1 on ESB performance.

- **Parking and Stopping Patterns** Most school buses operate on a morning and afternoon schedule, with mid-day downtime. Understanding where buses are parked during these intervals and overnight is critical for identifying charging opportunities and planning infrastructure. While chargers are typically installed at depots, additional installations may be required at schools or drivers' residences if buses are regularly parked there.

Informing Deployment and Charging Strategies

This data will support key decisions regarding route selection and ESB deployment. Use route-specific travel distances and conditions to identify which routes are best suited for electrification. There are publicly available tools to support the analysis, for example, the U.S. Joint Offices of Energy and Transportation offer an ESB Route Analysis Tool to estimate energy usage and charger power requirements.[27] When selecting routes, consider the operating range and battery capacity of available ESB models.

To mitigate risk and optimize performance, a phased deployment approach is recommended—starting with shorter, less demanding routes that offer more downtime, then gradually expanding to longer and more complex routes. Based on your goals and phasing strategy, determine the number of ESBs required over the transition period.

Develop an initial charging strategy informed by parking patterns. Identify locations—such as depots, schools, or homes—where buses are parked during the day and overnight and assess proximity to existing electrical infrastructure and load capacity. For shorter routes, ESBs may complete daily operations without recharging. However, longer routes may necessitate mid-day charging, ideally using DCFC. In jurisdictions where buses are parked at drivers' homes overnight, Level 2 (L2) chargers may need to be installed at those residences.

More details on developing a cost-effective charging strategy are available in section 4.3.

26 Pollution Probe (2024). Electric School Bus Operational Assessment: A Calgary Demonstration Case Study. Retrieved from: https://www.pollutionprobe.org/electric-school-bus-operational-assessment-a-calgary-demonstration-case-study/

27 U.S. Joint Office of Energy and Transportation (2024). Electric School Bus Route Analysis Tool. Retrieved from https://driveelectric.gov/school-districts

4 Charging Infrastructure Requirements

4.1. Charging Infrastructure Options and Costs

Charging stations are typically categorized as Level 1, 2, or 3, offering progressively faster charging speeds. The applicability of Level 1 charging, which involves plugging a vehicle into a standard electrical outlet, is limited to light duty vehicles. School bus fleet operators can use Level 2 or Level 3 chargers. Before purchasing and installing chargers however, fleet operators should verify their compatibility with the specific bus model, including charging standards, networking capabilities, and software integration, to ensure seamless operation. These concepts are outlined below.

Level 2 AC charging, at an average power of 11 kW, takes approximately 11.3 hours to charge an average (155 kWh) ESB battery to 80% of its capacity. The cost of Level 2 chargers typically ranges from CAD $6,000 to $10,000 per unit, depending on features and installation requirements.

Level 3 DC fast chargers typically employ power levels of 22 kW and 50 kW. At 22 kW, it takes approximately 5.6 hours to charge a vehicle to 80% capacity, while at 50 kW, the charging time is reduced to around 2.4 hours. Level 3 chargers are more expensive, with costs for the 22 kW chargers ranging from CAD $19,000 to $30,000, and for 50 kW chargers ranging from CAD $39,000 to $60,000, depending on features and installation requirements. These costs do not include additional expenses for necessary grid infrastructure upgrades.[28]

Figure 4: Comparison of Charging Station Levels: Cost Range vs. Charging Time (80% Battery Charge) for a typical 155 kWh ESB.

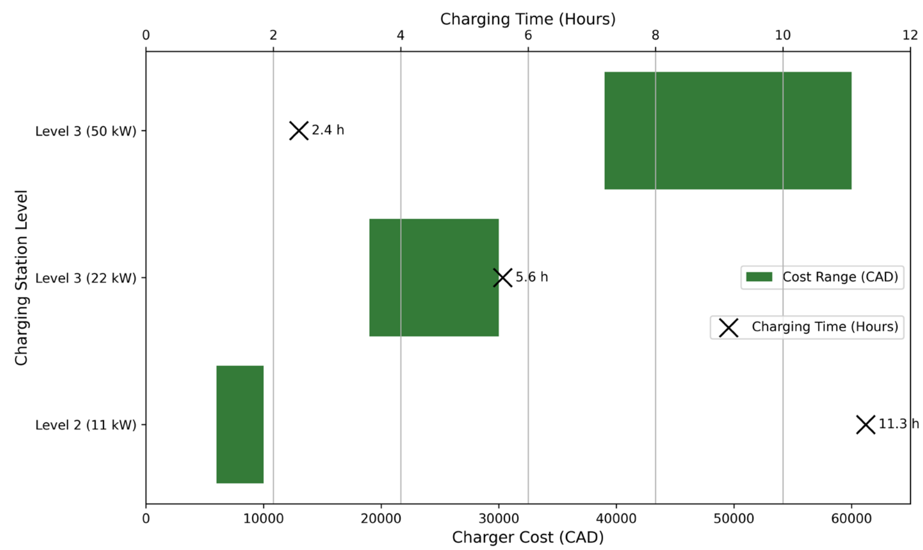


Figure 4 illustrates charging station power, charging speed to achieve an 80% charge, and their associated capital costs in Canadian dollars. Specifically, it shows Level 2 (11 kW) and Level 3 (22 kW and 50 kW) charging options. The green bars represent the cost range for each charging station, while the black crosses represent the time required to charge a vehicle to 80% of its 155-kWh battery capacity at each power level. As the power level increases, the charging time decreases significantly, but the charger costs rise, reflecting the trade-offs between charging speed and infrastructure investment.

When selecting charger options, the rule of thumb is to charge vehicles at the lowest feasible power level to minimize both the cost of the chargers and the need for grid upgrades at the yard. The higher the power output of the chargers, the greater the likelihood that grid upgrades will be required to support the simultaneous power draw from multiple chargers at the site. For this reason, some OEMs have introduced chargers with dual cords, which can either split the available power between cords or charge vehicles sequentially using a preset timing system.

28 Cost estimates from project experience and US department of Energy (2024). Alternative Fuels Data Center. Charging Depot Costs. Retrieved from: https://afdc.energy.gov/guides/electric-school-bus

4.2. Designing Charging Infrastructure Cost-effectively

The design of charging infrastructure will impact both capital and operational costs. Capital costs include:

- The cost of chargers, which vary by power level as outlined in Section 4.1;
- The cost of onsite electrical system upgrades, such as service panel upgrades and disconnect switch installations, as identified by the consulting electrician on the project; and
- The cost of utility upgrades required, as outlined in Section 4.3.

Operational costs are influenced by factors such as the fleet's facility size and the demand charge. The demand charge is based on the highest power demand (kW) recorded during the billing cycle, which is affected by the number of chargers operating simultaneously and their power output. As a result, the design must carefully balance multiple elements to maximize cost effectiveness. This is achieved using the following approaches.

Facility Assessment
Conducting a thorough facility assessment is essential for fleet operators to understand their specific needs before installing charging equipment. Charging infrastructure upgrades may require modification to depots, yards, and facilities, so this evaluation should begin with existing facility layout, and available power capacity. Based on the target number of ESBs and their charging requirements, the assessment should determine the additional electrical capacity requirements, as well as the physical space and layout needed for charging infrastructure. It should also address installation considerations such as trenching, requirements for upgrading electrical infrastructure, distance from the substation, and any obstacles that could impact installation.

Site constraints and the cost of upgrading infrastructure often determine the scale of an initial deployment. For smaller deployments, operators may use existing electrical capacity to minimize time and costs. When multiple depots are involved, operators should evaluate the trade-offs of electrifying different locations, considering infrastructure costs and community impacts.

Early engagement with LDCs is essential, as they can offer insights into available grid capacity and programs. This is further addressed in Section 4.3.

Charger Power Levels:
Level 2 chargers that can still meet the needs of school buses with long downtimes may allow for cost savings by reducing the requirement for upgrades to electrical capacity. While most ESB models are compatible with level 2 charging, this is not true for all of them.

All ESBs currently on the market are compatible with Level 3 charging, however each model has a maximum power intake limit that caps the amount of power it can receive, so this must be accounted for when selecting chargers.[29]

Spreading Charging Locations:
Depending on the fleet's operations, it may be beneficial to spread vehicle charging across multiple locations, such as schools or drivers' home locations, rather than solely at a central depot. This is particularly important for fleets with a large number of "parkouts," where drivers take the bus to their home rather than returning to a centralized depot. In such cases, fleets can explore alternatives, like installing portable chargers at drivers' homes, thereby avoiding significant grid upgrade costs at their depots.

Depot-Based Software Based Charging Demand Management:
For vehicles that operate from a central depot, optimizing charging infrastructure is key to reducing operational costs at scale.[30] Networked charging systems

29 World Resource Institute (2024). Electric School Bus U.S. Buyer's Guide. Retrieved from: https://electricschoolbusinitiative.org/electric-school-bus-market-study-and-electric-school-bus-us-buyers-guide

30 Center for Transportation and the Environment (2023). Blueprint Report Provides Guidance on Reducing Costs of Electric School Bus Charging. Retrieved from: https://cte.tv/post/blueprint-report-provides-guidance-on-reducing-costs-of-electric-school-bus-charging

allow chargers to communicate with the vehicle through fleet management software, enabling real-time monitoring, load balancing, and optimized charging schedules. By dynamically adjusting power distribution, networked charging helps fleets avoid excessive demand charges and ensures efficient energy use. This allows fleet operators to limit demand spikes and shift charging to off-peak hours, which can significantly lower operating expenses while avoiding costly grid upgrades.

As the number of buses at a depot scale, the ratio of chargers to buses can decrease from one to one as buses can potentially share chargers. For example, instead of plugging in all buses simultaneously upon returning to the depot, an optimized charging schedule can stagger charging times based on vehicle energy needs and electricity rates. Buses with shorter routes and lower energy requirements can be charged earlier in the evening, while those with higher energy demands are charged overnight when electricity rates or the overall demand charge are lower. Continuous monitoring allows for real-time adjustments, further enhancing the efficiency of the charging process.[31]

Energy Storage and Renewable Energy: Charging infrastructure should be designed with future scalability in mind, particularly when fleet expansion is anticipated. Planning for utility upgrades and collaborating with utilities to assess the current grid capacity is essential to avoid costly retrofits in the future.

Integrating energy storage can help reduce peak demand, thus reducing electricity costs (see section 4.1). In addition, by storing energy during lower-price hours—when electricity rates are lower—these systems can supply power to charge vehicles during peak times, reducing peak demand and reducing costs. Energy storage also adds resilience by ensuring that charging can continue during grid outages or fluctuations, thereby improving operational reliability.

On-site sources like solar power can be paired with energy storage to create a more self-sufficient charging setup. Solar panels can generate power during the day, which is then stored in batteries for use when charging. This combination of renewable energy and battery storage can significantly lower both operational costs and the fleet's overall carbon footprint by reducing reliance on grid electricity, especially during high-demand periods. For larger fleets, investing in on-site renewable energy—such as solar power—becomes more viable due to the ability to offset higher electricity consumption and manage demand charges more effectively. The feasibility of integrating renewable energy depends on factors such as the fleet's overall energy demand, the rate structure for large electricity consumers, and the capital costs of solar and storage infrastructure.

Vehicle to Everything

Fleet operators can also explore the potential of vehicle-to-grid (V2G) and vehicle-to-building (V2B) technologies. V2G allows electric vehicles to discharge stored energy back into the grid, helping reduce utility costs through reducing peak demand and supporting grid stability during peak demand periods. V2B enables electric vehicles to provide backup power to buildings, enhancing energy resilience. Fleet operators can benefit from partnering with local utilities to test these technologies through pilot projects, which can demonstrate real-world benefits.

Beyond operational advantages, participating in V2G programs may offer financial incentives or revenue opportunities for fleet operators. Utilities and grid operators may compensate fleets for supplying energy during peak demand, similar to demand response programs. By strategically discharging stored energy when electricity prices are high and recharging when rates are lower, fleets can offset energy costs and generate additional income.

31 World Resource Institute (2024). Electric school bus US market study. A resource for school districts and other school bus operators for pursuing fleet electrification. Retrieved from: https://electricschoolbusinitiative.org/sites/default/files/2024-08/Electric%20School%20Bus%20U.S.%20Market%20Study%20%28August%202024%29.pdf

However, V2G and V2B use may increase battery wear due to more frequent charge and discharge cycles.[33] Fleet operators should consult with manufacturers to understand the potential impact on battery health and warranties. As these technologies evolve, ongoing pilot programs and research will offer valuable insights into their effects on battery life and overall fleet operations, helping operators make informed decisions about integrating V2G and V2B into their electrification strategies.

4.3. Role of Electrical Utilities

The Ontario Energy Board recently introduced a set of Electric Vehicle Charging Connection Procedures (EVCCP), which mandates utilities to adopt a standardized procedure for installing and connecting new EV charging infrastructure.[34] This is expected to streamline the installation of chargers.

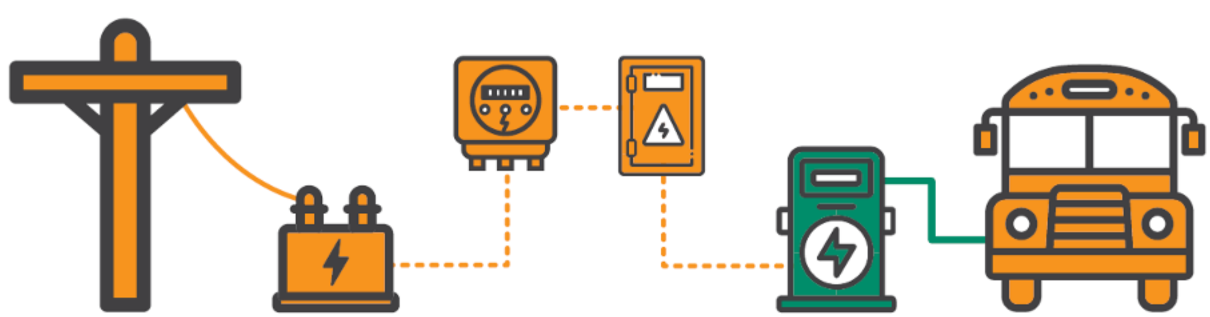
Many LDCs now have specialists on staff to assist customers in planning for fleet electrification. LDCs urge fleet operators to engage with them early in the planning stage to allow ample time for necessary electrical upgrades and to develop demand-side management strategies. This can help control potential costs, both for system expansion and for ongoing electricity and delivery costs.

Assessing Requirements for Grid Upgrades

During the planning phase, fleet operators should contact their LDC to assess whether their proposed charging infrastructure will require modification to the distribution system. The additional load may require grid upgrades ranging from a transformer replacement, which can take six months to two years, to a full substation replacement, which can take up to six years (**Figure 5**).

Typically, the cost of the new infrastructure is the responsibility of the customer requesting the new service. Based on current rules set by the OEB, if another customer takes advantage of the infrastructure upgrades within a set period of time (5 to 10 years), some reimbursement may be granted.[35]

Figure 5: Grid infrastructure involved in EV Charging[36]



33 Kumar, P., Channi, H. K., Kumar, R., Rajiv, A., Kumari, B., Singh, G., Singh, S., Dyab, I. F., & Lozanović, J. (2025). A comprehensive review of vehicle-to-grid integration in electric vehicles: Powering the future. Energy Conversion and Management: X, 25, 100864. https://doi.org/10.1016/j.ecmx.2024.100864

34 The EVCCP applies to Electric Vehicle Supply Equipment (EVSE) connections including charging stations for commercial EV fleets. Ontario Energy Board (2024). Electric vehicle charging connection procedures. Retrieved from https://www.oeb.ca/sites/default/files/Electric%20Vehicle%20Charging%20Connection%20 Procedures%20%28EVCCP%29_20240216.pdf

35 OEB. "Appendix B: Methodology and Assumptions for An Economic Evaluation." 2025. https://www.oeb.ca/sites/default/files/Appendix%20B%20Aug%2014%20 2025%20Amend.pdf

36 World Resource Institute (2024). Electric Vehicle Make-Ready Programs. Retrieved from: https://electricschoolbusinitiative.org/electric-vehicle-make-ready-programs

5 Procurement Process

5.1. Key Considerations

There are various possible approaches to procuring ESBs and chargers, as outlined in the following section. Whichever model best suits your needs, it can be helpful to begin with a Request for Information (RFI) to solicit information from potential suppliers and vendors about the ESBs and services they provide. With a phased approach to fleet electrification, multiple procurements over several years are likely. Consider establishing a multi-year contract with a vendor that can meet all your anticipated needs. Depending on the procurement approach, ESBs may be procured separately from chargers, or together in a single package.

Developing and identifying procurement strategies early in the process is also helpful when preparing applications for external funding. Coordinating the procurement strategy with external funding programs will ensure eligibility and that sufficient funds are available before committing to procuring ESBs. To minimize delays between external funding approval and ESB delivery, conditional purchase orders may be placed while awaiting confirmation of external funding support.

Take note of timelines in the procurement, delivery, and installation process, as it is best to have chargers installed and operational before ESBs are delivered.

5.2. Procurement Models

The procurement of both vehicles and charging infrastructure requires coordination with multiple stakeholders, including fleet personnel, the transportation authority and school board(s), as well as equipment and service providers, and OEMs.

Fleet operators should strive to balance their existing relationships with established OEMs and new entrants by conducting deployments that allow them to assess the viability and performance differences across various models. Procurement decisions are not only based on which manufacturer is likely to remain in the market long-term, but also on which one can provide the necessary support during the early stages of deployment to ensure vehicle reliability. Securing multi-year deployment support from OEMs and service providers during the procurement phase is a critical consideration. Fleet operators interviewed have indicated that this support is a key factor in their procurement decisions for early EV deployments.

Direct Purchase of Vehicles and Infrastructure

Similar to procuring conventional diesel school buses, ESBs and chargers may be purchased directly through a purchase order with a dealer or manufacturer. For larger ESB orders with unique add-ons, a Request for Proposals (RFP) may be issued to gather bids from several vendors, who might also offer additional operations and maintenance assistance, or include both ESBs and chargers in a single package. The World Resources Institute has developed an RFP template[37] to assist in the process. Cooperative or bulk purchases may also be useful if several fleets also have similar ESB and/or charger requirements and give fleets better bargaining power to negotiate more favorable offers around pricing, warranties and maintenance. These procurement approaches will involve capital costs which may be managed with grants, incentives, and/or financing as described in section 2.

It is critical to request important information from potential OEMs and suppliers during the procurement process. Table 2 lists some questions and considerations for procuring ESBs and chargers, which relate to compatibility, delivery lead times, features, warranties, maintenance, repairs, training and safety.

37 WRI (2023) Request for Proposal (RFP) Template. Retrieved from https://electricschoolbusinitiative.org/request-proposal-rfp-template

Turnkey Services
As-a-service contracts or turnkey services can also help fleets mitigate uncertainties around ESB deployment. These services may cover a wide range of tasks and responsibilities, such as installing, operating and/or maintaining ESBs and chargers on your behalf, or additional services like route assessment, ESB and charging infrastructure planning and design, charge management software, utility engagement, and training.

Using a turnkey service provider may also simplify budgeting and facilitate funding applications as they typically involve multi-year agreements with set monthly payments to cover capital costs and some operational costs.

Table 2: Considerations when procuring ESBs and chargers.

	For ESB suppliers	**For charging providers**
Compatibility	What chargers and charging speeds are known to work with the ESB? Does the ESB support L2 and/or DCFC charging?	What ESBs are known to work with the charger?
Lead time	What is the delivery lead time?	What is the delivery and installation lead time?
Features	Is it capable of bi-directional charging? Is a telematics or data collection system included, or does it need to be added to the bus specifications? What Heating, Ventilation, and Air Conditioning (HVAC) options are available and what is their impact on ESB range?	If you are purchasing charge management software: Is the software compatible with chargers from all manufacturers, and with the computers you currently have on site?
Warranty, maintenance, repair, training and safety	What is the warranty period for manufacturing issues? What is the duration and conditions of the battery warranty? What are the conditions for heavy maintenance and spare parts availability? Where are the closest repair centers and dealers? What training is included? What are the safety procedures for first responders and firefighters? (See section 6.2.3 on training for first responders)	What is the warranty period and warranty conditions? Who is responsible for maintenance and repair, and is there a response time for repairs? What support is available in case of a long-term charger outage?

6 Implementation, Training and Deployment

Photo: gettyimages.com/Nikada

6.1. Implementation

6.1.1. Installation

Chargers should be installed according to the charging infrastructure plan (see Section 4.2). Conduct any required upgrades to existing building utility infrastructure. In addition to electrical work, site preparations might also be required for existing depots, garages or maintenance shops to accommodate the safe, simultaneous operation and maintenance of ESBs and diesel buses. Engaging specialized engineering services can help with identifying site modification requirements, followed by drafting, validating and implementing plans that comply with standards and constraints.

When preparing facilities for ESBs, ensure compliance with the Canadian Electrical Code's Section 86, which covers specific requirements for Electric Vehicle Supply Equipment (EVSE). The code establishes rules for the installation of equipment, such as insulated conductors and charging devices, and defines key terms related to EV charging to ensure safe and compliant installations within garages and other locations.[38]

During the transition towards ESBs, facilities should be able to accommodate the simultaneous operation of both ESBs and diesel buses. Issues to consider are the space requirements and layout, separation of flammable products (e.g. diesel fuel) and electrical chargers, and load-bearing capabilities of the shop floor and jack equipment to carry heavier ESBs. To facilitate ESB repair and testing, consider having a dedicated space for specialized ESB repair tools and a Level 2 charger.

TIPS: FUTURE PROOFING

Adopting modular and flexible designs today can avoid duplicative construction and infrastructure costs tomorrow as the ESB fleet grows and technology develops. For example:

Consider running additional conduits with 'stub-outs' and increase electrical service panel capacity to accommodate future electricity demand from a larger ESB fleet. 'Stub-outs' refer to electrical conduits that are installed but unfinished to enable future electrical connections without having to repeat costly excavation work.

Consider installing charging equipment on metal base plates instead of concrete foundations to make them more readily interchangeable. Alternatively, install removable concrete blocks that can be lifted out with a forklift. This avoids the need for costly concrete removal when replacing or upgrading charging equipment.

38 Electrical Industry News Week (2025): Guide to the Canadian Electrical Code, Part 1, 25th Edition - A Road Map: Section 86. Retrieved from: https://electricalindustry.ca/latest-articles/bill-burr-section-86/

6.1.2. Testing Equipment

Testing may begin after ESBs are delivered and chargers are installed. The testing phase may take several weeks, especially for the initial deployment. Test the ESBs on the routes identified in the planning phase, and under different weather and road conditions to learn how range is impacted. These test drives can also check that the telemetry, data collection and onboard operating systems are working. Based on the test findings, adjustments might need to be made to the initial route assignments and charging schedules. This is also an opportunity for drivers to get accustomed to operating the ESBs. Lastly, test the chargers, their interoperability with ESBs, and any charge management software included with the chargers.

6.1.3. Understanding Maintenance Requirements

With fewer moving parts, ESBs generally require less maintenance than diesel buses over the long run. ESBs do not require power steering fluid or engine oil changes, and brake wear is reduced because of regenerative braking. However, ESBs still require coolant, wiper fluid, and brake fluid (for ESBs with hydraulic brakes). Most of the general preventive and corrective maintenance tasks for the ESB chassis and vehicle body will remain the same as for diesel buses, and these tasks can be done by in-house maintenance crews.

The maintenance of electric drivetrain and high-voltage battery is typically covered by the manufacturer's warranty, while some tasks might require a separate maintenance contract. As mentioned in section 5 on procurement considerations, multi-year support from OEMs and service providers is recommended.

Regular maintenance includes battery balancing, which involves handling high-voltage equipment and specialized training.

Battery replacements may be required due to battery degradation over time. This can be minimized by maintaining battery health: notably, by avoiding overcharging and not allowing the battery state-of-charge to fall below 20%. Charge management software may mitigate some of these issues.

To keep chargers in good working order, conduct routine maintenance checks on the state of charging equipment, especially the cables and connectors which are subject to wear and tear. Follow manufacturer-recommended preventative maintenance and replacement schedules. To reduce charger downtime, it is useful to have a plan for basic troubleshooting when a charger stops working (e.g. rebooting or powering off and on the charger), before contacting your service provider for more assistance with diagnosing and repairing the problem.

6.2. Training

6.2.1. Drivers

Training may be provided by the dealer or manufacturer ahead of, or at the time of, delivery, or can be contracted by a training provider. ESB driver training typically includes:

- **Basic functions** of ESBs and how they may differ from diesel buses. Compared to diesel buses, ESBs have almost instant acceleration as electric motors react quickly and produce high torque. Regenerative braking can produce a jerky deceleration, which may require adjustments in the early stages. With specialized training and regular practice, drivers can rapidly adapt to driving ESBs smoothly.

- **Optimizing ESB range and performance**. Efficient driving practices should be promoted to maximize the use of regenerative braking for more efficiency and range. Drivers should be made aware of other ways to optimize battery range, especially during cold or inclement weather. For example, batteries can be conserved by pre-conditioning the bus (heating the cabin and battery) while plugged in, and heating the driver's seat instead of the cabin when all passengers have exited the bus.

- **ESB charging**. Drivers should be trained in how to charge ESBs to prevent equipment damage. For example, the ESB should be at a suitable location relative to the charger before plugging in. Charger connection and disconnection procedures should be followed to avoid damage and frequent connector replacement. Good cable management practices should be exercised, such as returning charger connectors to their dedicated holder and ensuring they are not left on the ground.

- **Emergency procedures**, including for battery leaks, vehicle fires, or charge depletion. This includes procedures for shutting off the ESB's high-voltage electricity system in an emergency.

6.2.2. Mechanics

While the maintenance of most high-voltage electrical components is typically covered by the manufacturer's warranty, in-house mechanics should still receive training on electrical components that may not be found in regular diesel buses, such as electrical heating or cooling, power steering, voltage meters, and traction motors. Mechanics should also be aware of preventative maintenance and schedules, diagnostics and proper high-voltage shutoff procedures and routine maintenance checks for chargers, such as ensuring cables are stored securely and regular checks for equipment wear and tear. This prevents unnecessary charger damage from occurring or worsening, which reduces the chance of costly and lengthy charger repair or replacement. Enquire with your ESB vendor for any training available for maintenance crews.

6.2.3. First Responders

Training first responders on the electrical and fire safety of ESBs is important in protecting lives and property in the event of an emergency. To minimize the risk of ESB fires, only procure high-quality and rigorously tested equipment from reputable dealers and manufacturers. Engage first responders in your municipal fire and emergency department and provide them with key information such as:

- How they can identify electric buses in the fleet

- Where the manual disconnection switches are located

- Techniques to suppress battery fires

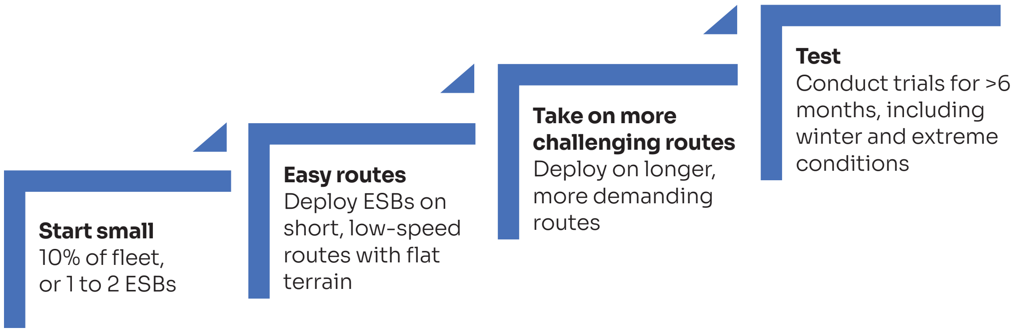
These details are provided in the emergency response guides from your ESB and charger dealers. It is important to ensure that your municipal fire departments have these guides for the specific bus models you will procure. ESB or charger dealers may also offer or recommend training specifically for first responders.

The World Resources Institute's Electric School Bus Initiative has put forward a set of ESB training standards[39] which serve as a guide for fleet operators to check if their training curriculum covers key learning objectives and outcomes and identify any knowledge or skills gaps. The training standard comprehensively covers topics around the general knowledge and awareness of ESBs, operations and safety, which are relevant to a wide range of stakeholders, such as school district staff, fleet managers, drivers, operators, maintenance crews and first responders. For example, the training standards on ESB safety include theoretical and practical knowledge of general electrical safety practices, high voltage safety tools and equipment, and de-energizing procedures for ESBs, among others.

39 WRI (2024). Electric School Bus Training Standards. Retrieved from https://electricschoolbusinitiative.org/electric-school-bus-training-standards

6.3. Deployment

Figure 6: Deploy ESBs with a phased approach to mitigate risks, gain knowledge and adopt best practices with real-world observations.



A phased deployment approach, as illustrated in Figure 6, reduces the operational risks associated with the transition by giving drivers, operators, maintenance crews and fleet managers opportunities to identify and correct any issues with minimal impact on services. It provides the opportunity to familiarize all staff with the new ESB features, charging systems and software, as well as to build working relationships with manufacturers and dealers, especially around after-sales support. Finally, a phased approach allows the project team to identify best practices based on local operating conditions (such as route distances, weather conditions, and road conditions), and apply the lessons learned for a smoother integration of additional ESB deployment.

Before ESBs are deployed on their route, standard protocols and checklists should be adapted for ESB operations. For example, inspection checklists before and after trips should be updated to include ESB-specific items. Elements of preventative and corrective maintenance should be incorporated into such procedures to prolong the lifespan of ESBs and charging equipment. Refer to user manuals provided by the manufacturers for the recommended operating and maintenance practices for your newly purchased equipment.

7 Data Management, Monitoring and Scaling

ESBs are being developed with increasingly integrated hardware and software components, enabling real-time and historical performance monitoring through telematics platforms. This integration is essential not only for tracking range, maintenance and costs but also for ensuring smooth communication between vehicles and charging infrastructure.[40] It allows fleets to optimize charging patterns, reducing electricity costs as discussed earlier.

Many OEMs are still in the early stages of developing their ESB models, with several in their first or second generation. ESB performance will improve as advancements in battery management systems and chemistries continue.[41] Variations in battery cooling systems, drivetrain configurations, and energy management strategies across OEMs can lead to differences in vehicle efficiency, range, and reliability under specific conditions such as extreme temperatures, hilly terrain, or stop-and-go traffic.

For this reason, it's important for fleets to deploy different ESB models and use telematics data to monitor their performance in local conditions—such as weather, road type, and terrain. This data is key to understanding the range capabilities and battery degradation of different vehicle models under specific conditions. It also prevents fleets from purchasing vehicles with unnecessarily large batteries and provides valuable insights into optimal charging strategies for each vehicle.

To facilitate this process, fleets should track key performance and maintenance metrics, that include Operational Performance Metrics, Cost Monitoring Metrics, Environmental Improvement Metrics and Driver Satisfaction as detailed in Table 3. These metrics provide the insights needed to adjust fleet scaling—both in terms of the number of vehicles and the required charging infrastructure.

40 Clean Cities and Communities (2022). Energy Use and Fuel Economy. Retrieved from: https://www.youtube.com/watch?v=x2wAU3420uY

41 S&P Global (2023). Batteries: Emerging chemistries create trade-offs in cost, performance. Retrieved from: https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/batteries-emerging-chemistries-create-trade-offs-in-cost-performance-75866899

Photo: gettyimages.com/courtneyk

Table 3: Deployment performance metrics

Metric Type	Description	Impact on Scaling
Operational Performance Metrics	▪ Includes Energy Efficiency (kWh/km), Battery Health, Regenerative Braking Efficiency, Charger Performance, and Downtime Due to Maintenance. ▪ These metrics assess vehicle energy use, performance under different conditions, efficiency, and uptime.	▪ Optimizes fleet size, route planning, maintenance strategies, and ensures vehicle readiness, helping fleets expand while maintaining efficiency.
Cost Monitoring Metrics	▪ Includes operational costs from fuel and maintenance, demand charges based on peak electricity usage, and charger utilization efficiency.	▪ Helps justify scaling by reducing operational costs and identifying savings opportunities in charging infrastructure.
Environmental Improvement Metrics	▪ Includes Air Quality Improvement, GHG Emissions Avoided, and Noise Levels, focusing on health and environmental benefits like pollution reduction and quieter operations.	▪ Strengthens the case for fleet expansion through demonstrated environmental benefits, helping secure funding and community support.
Driver Satisfaction	▪ Driver Satisfaction and Student Health and Performance, focusing on qualitative feedback from drivers and the health benefits for students due to lower emissions and noise.	▪ Supports operational transitions, enhances community buy-in, and contributes to smoother scaling by ensuring positive experiences for drivers and students.

Transitioning to a fully electric school bus fleet can follow different approaches, but a phased strategy often helps fleets manage risk and build internal capacity. Many operators begin with a pilot deployment, using real-world data to refine charging schedules, assess energy consumption, and plan for infrastructure expansion.

Best practices also highlight the value of comprehensive staff training to interpret and act on operational data, ensuring buses are maintained properly and that decisions, such as battery management and route planning, are optimized. While many deployments to date have involved trial and error, fleets that actively analyze real-time data and train staff accordingly are better positioned to control costs, extend vehicle lifespan, and avoid unnecessary investments as they scale up.

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Implementing Partners: