Guide TRANSPORTEUR+

Electric from school to home

A technical guide to the electrification of quebec school buses for a successful transition

propulsion Québec

Published in June 2022.
Updated in November 2023.

About this report

Propulsion Québec commissioned the consulting firm WSP Canada to prepare this guide for school bus operators, entitled Transporteur +. The purpose of this guide is to provide easy and direct access to resources in order to clarify the steps, issues, conditions and facilitating measures for a successful transition to electrification.

Acknowledgements

Propulsion Québec would like to thank The Transition Accelerator and the WSP Canada team for their critical contributions, as well as all the experts involved in the development of this guide.

This guide was made possible thanks to the financial support of the:

FONDATION FAMILIALE TROTTIER FAMILY FOUNDATION

GREATER MONTRÉAL CLIMATE FUND

FONDS de solidarité FTQ

Table of contents

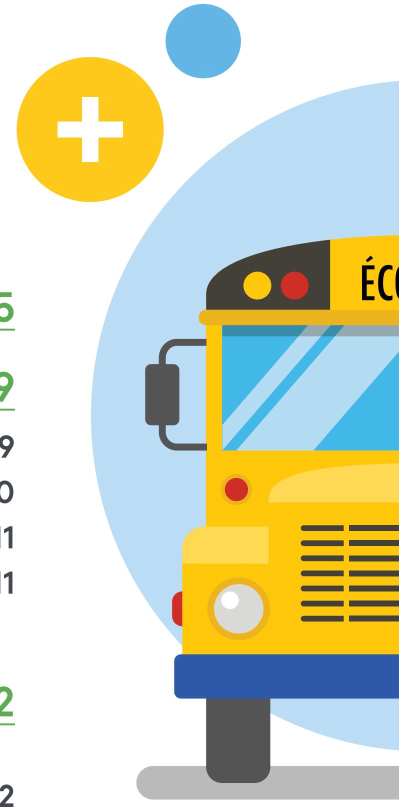

Table of contents

Executive summary

Electric buses provide an important solution for transforming student transportation into a more sustainable, efficient and resilient alternative over the long term. While this technology has many similarities to standard diesel buses, it is important to understand what makes it unique in order to better prepare for its arrival.

This technical guide provides a review of electric bus technologies and their charging systems, future prospects, and key steps to consider for successful deployment. Its aim is to demystify the scope of the work to expect for the transition, identify the operational constraints of the technology and the solutions that currently exist to address them, and propose tangible means for school bus operators to tackle this technological shift by 2025. We are seeing more and more funding and grant opportunities. This is the right time to start the transition process.

This guide is intended primarily for small and medium-sized operators (up to 50 buses) that do not necessarily have the human resources to compile the information contained in this guide, and that are in the early stages of their transition.

Key information about electric buses and infrastructure

Electric buses are powered by electricity and must be charged regularly—usually once a day—to remain operational. Most school bus routes can be completed with a single long charge at night when the bus is parked, as a bus can run for 150 km to 250 km on such a charge. An auxiliary diesel heater is installed to ensure the vehicles' range even in winter, when temperatures are low.

Mechanics who perform light and regular vehicle maintenance, such as changing small connectors, do not require specialized training but must be equipped with new insulated tools to ensure their safety. Heavier maintenance, such as battery replacement, must now be done by the manufacturers.

For the majority of school bus fleets in Quebec, electric buses will require Level 2 charging with up to 19.2 kW of electricity for between 7 and 10 hours, depending on battery capacity. One charging station per vehicle is recommended, with the option of adding extra charging stations as needed. These stations will have to be maintained throughout their life cycle.

Most buildings do not have enough electrical capacity to distribute the required power to the chargers beyond three Level 2 terminals. This means their current distribution system has to be reconfigured or a new independent power supply has to be added to supply electricity to the chargers. This second solution involves a modular container or platform in which transformers and switching devices are installed. The guide includes a section dedicated to reviewing the impact of electrification on buildings. See section 2.4 for more details.

Using electric buses makes it possible to collect real-time data on vehicles and their infrastructure. This data can help reduce the need for maintenance and extend the average life of components, as well as optimize the allocation of routes to vehicles based on battery degradation. In addition, the charging management software that integrates with the infrastructure makes it possible to minimize the simultaneous use of all chargers at night, which reduces peak electricity demand and thus the electricity bill.

Step one: planning

A successful transition depends on properly planning your electrification project. During the planning stage, you must start by putting your short-, medium- and long-term vision on paper in order to clearly identify your needs. How many buses need to be replaced every year? What are my daily service requirements? What will my future electrical needs be? These questions help establish the framework for the transition plan.

It is important to understand the expenses associated with this transition and to plan, inasmuch as possible, what modifications will be required in the shops, how charging stations will be arranged in the field, and how many stations the fleet will need each year. Several financing models can be considered to help pay for the transition, making the most of currently available grants and low-interest borrowing options. Grant applications must be made in this initial phase.

Specialists are available to help you through the transition. They can advise and support you by offering you one-off assistance or turnkey services, including design, permit applications, Hydro-Québec connection applications, infrastructure acquisition and construction monitoring. These activities can be included in a contract as an after-sales service provided directly by bus suppliers or through external firms.

It is at this initial stage that discussions should be initiated with Hydro-Québec, if necessary, to review the current garage connection and plan its upgrade. The planning phase can take up to a year to prevent risks to future facilities.

Step two: selecting your bus, charger and software suppliers

When it comes to transitioning to electric buses, you need to consider the entire system: the vehicle, its charging infrastructure, and the operating and planning software. This guide lists the kinds of questions that should be asked when selecting bus or service providers. Key issues around battery capacity and life, availability of specialized labour for heavy repairs, and lead times are on the list of questions.

Similarly, when selecting charging stations, you have to ensure that systems are interoperable and that specialized technicians are available for repairs. When designing the electrical system, care must be taken to ensure that it can be repaired promptly in the event of electrical equipment failure or malfunction. Electric buses cannot operate without chargers.

Finally, with regard to software, it is necessary to inquire about monthly licensing costs, which are ongoing costs, as well as the availability of supplier data. Different features may be available to optimize charging and deploy buses with the technical specifications best suited to their routes.

Step three: implementing the pilot project and phase-in

By this stage, the financial structure should be in place. Running a pilot project gives the teams the opportunity to test and push the boundaries of the technology to understand its constraints, implement new organizational processes while training employees, and adapt its transition strategy to local conditions (distances, weather, types of roads, etc.). Six to ten months after a pilot project, a post-mortem analysis should be conducted to correct any potential problems before the next electric buses are introduced. Pilot projects must run for at least one year to provide data on all seasonal variations.

Step four: adapting buildings and infrastructure

At this stage, infrastructure adjustments need to be made to reflect the long-term adoption strategy. The building's current power supply capacity must be assessed, and the space required for the installation of charging stations for each vehicle must be checked. Thought should also be given to the process for filling any diesel buses, as these will have to operate at the same time as electric buses. In some cases, maintenance shops will need to be redesigned to make them safe and dedicate specialized spaces for the new vehicles. It is important to have engineers who specialize in infrastructure reconfiguration validate plans and specifications before the construction phase. Section 4.4 of this guide provides general information on space configurations, which will vary greatly from operator to operator.

To ensure that the electric buses do not remain idle during construction, it is important to plan the timeline so that the infrastructure is ready to accommodate the buses before they are delivered. This step takes roughly 6 to 18 months, depending on the complexity of the work to be done.

Step five: testing

The infrastructure has been installed and the electric buses have been delivered: all that's left to do is to test them on the usual routes. As of yet, there are no standard tests for checking bus performance. Therefore, it is recommended that drivers be given as many opportunities as possible to get used to the new buses and their charging systems. This is also where teams will be able to learn about charging management software and real-time data visualization.

Conclusion

This guide presents a review of the five steps required to transition to electric vehicles, the constraints to be taken into account and a general timeline. Usually beyond three buses, the transition becomes more complicated as it will involve a new power supply system and specialized equipment for distribution. However, there are technical solutions tailored to the needs of companies.

For a successful transition, it is recommended that you take your time during the planning stage, develop your financial plan with as much detail as possible, and discuss a long-term vision to optimize costs. Experts are available to help you with this process, either through after-sales service when purchasing vehicles or through external firms.

Why this guide?

1

1.1 Current context

According to a recent survey, nearly 535,000 students take a school bus every morning and afternoon in Quebec, representing nearly 60% of enrolled students.[1] When it comes to electrifying school buses, this figure provides a pretty good indication of the magnitude of the impact this transition will have on our society and the number of Quebec families that will benefit from it.

We have come a long way since the deployment of the first electric school bus prototype in 2014 in Quebec.[2] Today, several manufacturers offer a full range of electric school buses, and Quebec has a growing ecosystem of companies offering turnkey and after-sales services to school bus operators. In January 2021, 130 electric buses were in service on Quebec roads,[3] part of a total fleet of 10,000 buses.

In its Plan for a Green Economy, the Government of Quebec set a goal of converting 65% of school buses to zero emissions by 2030, focusing on electrification. Several financing programs were introduced to support the gradual adoption of the various technologies involved. If they are to achieve the government's objectives, Quebec's school bus operators will have to act in unison.

This transition presents a tremendous opportunity for Quebec's school bus operators to run zero-emission vehicles and pave the way toward more environmentally friendly technologies.

However, it is important to recognize that electric buses are very different vehicles than those that school bus operators have been using for decades. Planning not only for vehicle deployment, but also for infrastructure and route optimization, are critical to a seamless transition to this new technology, which promises so many benefits. This transition may seem daunting at first glance because it requires a different organizational model, but this guide helps demystify, one by one, each of the elements involved in this transition.

> We believe that the key to the success of electrification projects lies in understanding the challenges and clear planning. The purpose of this guide is to present all the steps necessary to facilitate and optimize the electrical transition.

1 https://legacy.equiterre.org/sites/fichiers/ase_-_analyse_du_sondage_css_-_vf_4_0.pdf

2 https://www.ivisolutions.ca/en/realisations/development-of-an-electric-school-bus/

3 https://www.transports.gouv.qc.ca/fr/aide-finan/electrification/programme-electrification-transport-scolaire/Pages/programme-electrification-transport-scolaire.aspx

1.2 Benefits of school bus electrification for operators

Electrifying transportation is a prevalent theme in the effort to reduce greenhouse gas (GHG) emissions. This is especially true in Quebec, which has a source of electricity with very little GHG emissions: hydroelectricity.

According to Quebec's Ministère des Transports, an electric school bus can reduce GHG emissions by 23 tonnes of CO_2 annually,[4] equivalent to 5 cars consuming 2,000 L of gasoline per year.[5]

GHG is not the only negative result of diesel bus emissions. Fine particles emitted by older buses have been shown to have a negative impact on the health of people in their vicinity, such as increased asthma and cardiovascular problems.[6] Electric buses produce no particles and also have the advantage of being almost silent, which has a direct positive impact on drivers, students and the residential areas they drive through.

And there are other noteworthy societal benefits to consider. The perceptions of the public, parents, and especially students, who are becoming increasingly interested in environmental issues, are important to school bus operators. According to a recent survey conducted by Équiterre, 65% of school boards have a positive or very positive perception of the electrification of school buses. By electrifying this branch of transportation, other transportation sectors can be encouraged to transition through lessons learned from across the ecosystem.

The noise reduction associated with electric buses is due to the fact that they have far fewer moving parts, which means less vibration. Once they have gotten used to the new vehicles, some drivers have reported improved working conditions thanks to the decreased noise and vibrations, which have also led to students being calmer on the bus.

Finally, another important benefit is that lessons learned from the electrification of school buses will facilitate electrical transition in other areas of transportation, leading to further positive effects reducing GHGs

4 https://www.transports.gouv.qc.ca/fr/ministere/acces-information-renseignements-personnels/documents-reglement-diffusion/demande-acces/Documents/2020/03/DA-2019-2020-00543-prsdaseq-programme-aide.pdf

5 https://www.rncan.gc.ca/sites/www.nrcan.gc.ca/files/oee/pdf/transportation/fuel-efficient-technologies/autosmart_factsheet_6_f.pdf

6 https://ici.radio-canada.ca/nouvelle/1877984/equiterre-bus-scolaire-electrique-reduction-energie-fossile-environnement

1.3 Users of this guide

This guide is intended for any school bus operator wishing to understand the steps required to electrify its fleet of vehicles as well as the options available to meet the technical and financial challenges involved in adopting these vehicles. In this guide, operators with a vehicle fleet of **1 to 10 buses or 11 to 50 buses** will find additional and more detailed information to help guide future decisions and facilitate electrification in their central garages. The charging solutions required when a bus is parked at the driver's residence, also known as rural charging, are not detailed in this guide. This guide was based on an impartial analysis, aiming to support all operators, and does not recommend any specific vehicle and/or service suppliers.

1.4 Participants and acknowledgements

This guide was developed with the invaluable assistance of the Bus Carriers Federation (BCF), in particular its CEO Luc Lafrance, and its electrification committee. We would like to thank Caroline Vallée, President and CEO of Autobus Vausco in Lac-Mégantic; Ugo Barrette, Director of Maintenance Services at Autobus Maheux; and Stéphane Boisvert, President of Autobus Séguin for their contributions and for sharing their experiences with the electrification of their school bus fleet.

The assistance of the Quebec ecosystem was also key in the development of this guide. We would like to thank the teams at Cléo, Girardin Electric, Lion Electric Co., Girardin and Hilo for conveying the major market opportunities and for their detailed explanations of their services to school bus operators to guide them through the steps discussed in this guide.

Finally, the review of financing options currently available to operators would not have been possible without the collaboration of the Canada Infrastructure Bank (CIB), the Fonds de solidarité FTQ and the Greater Montreal Climate Fund.

Electric buses: vehicles closely connected to their infrastructure

2

2.1 The importance and interdependence of each component in an electrification project

IN A NUTSHELL *An electric vehicle cannot be treated as an independent system, because its operation depends on its ability to charge. Equal consideration should be given to installing charging stations, reconfiguring infrastructure and using specialized software as is given to purchasing the vehicles themselves.*

The most important paradigm shift when it comes to electric school buses is that you not only have to consider the vehicle, but also integrating all the associated infrastructure for charging, repairing and managing it. Figure 1 depicts the interdependence of these three elements, which must be planned in parallel to ensure a successful electrification project.

Vehicles must be able to satisfy the range, safety and power requirements to cover the school bus routes under all conditions, i.e., summer and winter and with different route variations.

Buildings and parking lots must also be ready to accommodate these potentially heavier vehicles that require specific attention due to their high-power electrical systems.

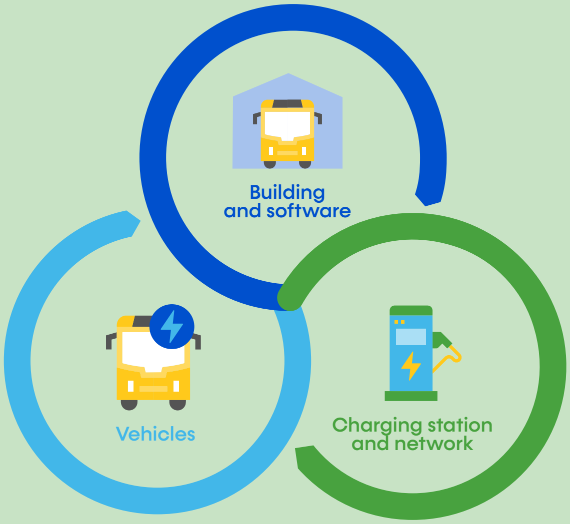

FIGURE 1 • Successful deployment of an electric bus calls for the acquisition of suitable vehicles, the proper conversion of buildings and an electrical charging installation that meets operational requirements

Finally, the charging stations must be capable of charging buses while taking into account the limits on the amount of time the buses are parked overnight and the limits on power supply to the property. This means that chargers cannot be too fast, due to the constraints of the power supply to the building, or too slow, to ensure that batteries are fully charged and buses can complete their routes the following day. Finally, the deployment of smart charging management software will enable operators to instantly access the charge status of each bus, be alerted in case of problems and, above all, manage peak electricity demand to minimize electricity costs (see section 3.4.3 for more details on this topic).

The following sections define the key concepts related to these three categories.

2.2 Characteristics of electric buses

IN A NUTSHELL *Electric school buses use an electric powertrain, which uses electricity stored in batteries for propulsion. Some of the energy can be recovered during braking. The range of the vehicle depends on several external factors, such as temperature, number of passengers, driver, use of electric heating, etc.*

2.2.1 Powertrain components

An electric bus is a bus that operates using electricity stored on board the vehicle. It is powered by an electric motor, which is itself powered by batteries. The battery is an electrochemical component that discharges when the bus is in operation and recharges when the bus is connected to the charger.

Today, most batteries are made of lithium, which acts as an energy vector during charging and discharging. These batteries are readily available and popular on the market thanks to their stability, energy density and durability. Batteries are constantly evolving and becoming denser every year, meaning that more energy can be stored for the same weight (Wh/kg). Today's lithium batteries have a density of up to 150 Wh/kg. Chemistries making it possible to achieve higher performance levels are likely to emerge in the coming years, such as solid batteries, which promise a density up to three times greater than currently exists.

It should be understood that the energy storage capacity of a battery is expressed in kWh or Wh/kg. The energy consumption of an electric vehicle is expressed in kWh/km, the equivalent of L/100 km for diesel buses.

Electric buses

To understand how an electric bus works, it is useful to review the different components that make up the powertrain. Firstly, the electric motor not only operates the automatic transmission system but also acts as a generator during regenerative braking. Regenerative braking is activated when the driver stops accelerating and can be optimized with anticipatory driving.

The batteries are assembled into modules that feature thermal management systems to maintain ideal temperatures, as well as a multitude of sensors that provide information to the battery management system. In addition, several converters are required as not all components operate at the same power level. A global vehicle control system can coordinate the vehicle response according to the driver's choices. These elements are represented in Figure 2.

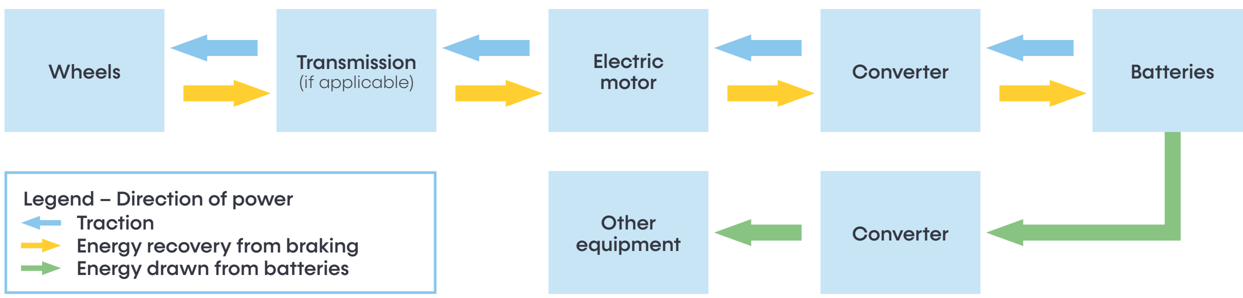

FIGURE 2 • Electric bus powertrain component diagram

Battery range is strongly influenced by route length, driving style and external conditions such as temperature, number of stops and number of passengers. School bus manufacturers today claim ranges between 120 and 250 km depending on the size of the battery and the bus model, corresponding to energy consumption between 0.8 and 0.9 kWh/km[7] under regular conditions.

7 https://legacy.equiterre.org/sites/fichiers/fiche_autonomie_en.pdf

2.2.2 Electric school buses in winter

IN A NUTSHELL *In Quebec, electric school buses are now equipped with diesel heating to ensure adequate range even in winter. The consumption of auxiliary heating nevertheless allows for a significant decrease in diesel consumption in winter.*

Tok Transportation in Alaska[8] reported consumption of 2.1 kWh/km at -40°C on a particularly cold winter day. Such temperatures also occur in Quebec but arerather rare in most municipalities.

To maximize battery life in winter, some electric school buses are now equipped with auxiliary diesel heaters. This is important because it affects operating costs and the percentage of emission reduction. Although currently available data is scarce, auxiliary bus heaters use between 1.5 and 3 litres of diesel per hour of operation. Moreover, the exhaust of these booster heaters does not have the same degree of particle filtration that is found on diesel buses, so they emit more fine particles.

While there is no denying this reality, emission reductions on electric buses are high even in winter. Assuming an average distance of 150 km and a consumption of 25 L/100 km, a diesel bus will consume 37.5 L/day. In five hours of service, an electric bus will consume a maximum of 7.5 L to 15 L per day, a minimum reduction of 60% during the winter months. Other 100% electric heating technologies are under development, such as heat pumps, which are more efficient than resistance heaters. In addition, increasing battery capacity year after year could solve problems related to their range when using electric heating, and therefore allow for complete electrification.

The vast majority of school buses in Quebec are parked outside overnight. When temperatures drop in winter, it is important to ensure buses have access to a charging station to maintain a minimum system temperature when not running. In addition, it is possible to start heating at a set or software-optimized time while the bus remains connected to the charger to avoid using battery power. It takes more power to warm up the vehicle than to keep it at a desired temperature.

8 https://electrek.co/2021/11/19/heres-how-alaskas-only-electric-school-bus-is-performing-in-temps-as-low-as-40f/

2.2.3 Battery maintenance and degradation

IN A NUTSHELL *General maintenance is the same for an electric bus. What changes is the specific maintenance of the powertrain and electrical connectors. For safety reasons, heavy maintenance cannot be done in-house and must instead be done by the manufacturer.*

Most of the general preventive and corrective maintenance elements of electric vehicles related to the chassis and vehicle shell will remain the same as for diesel buses. The big difference is under the hood and concerns the new components such as batteries and the high voltage system, including the converters and inverters.

Generally speaking, an electric vehicle requires significantly fewer maintenance steps than an internal combustion vehicle. The need to change and fill specialized liquids is almost eliminated because operations are more electrical than mechanical, which considerably reduces the number of moving parts. All maintenance related to the combustion engine is eliminated. Brake wear can also be reduced thanks to regenerative braking, thereby increasing the brakes' service life by 20%.

2.2.3.1 Specialized maintenance

Some electric bus models require frequent battery balancing, which involves handling high voltage equipment and specialized training. Furthermore, battery degradation means that batteries must be replaced during the life of the vehicle. There is little operational data currently available about degradation, but we estimate a 1.5–2% loss of total battery capacity per year of operation. Thus, if a battery has a total accessible capacity of 200 kWh in the first year, the capacity will be 196 kWh in the second year.

The modes of use that most exacerbate battery degradation are overcharging and prolonged use of the battery requiring it to discharge with less than 20% stored energy, both of which can be avoided with sustained management of specialized software. At the end of their life, batteries can be recycled or reused for other second-life applications. School bus manufacturers now offer specialized contracts to take back batteries for recycling.

The tools required to maintain electric vehicles are different, as laptops are needed to solve technical problems, as is specialized testing and diagnostic equipment and protective equipment to work around high voltage equipment.

In the event of breakdowns during operation, electric vehicles should be towed on a platform truck to limit damage to the powertrain.

The extensive data collected from electric bus fleets will make it possible to adopt predictive maintenance management processes. This type of maintenance consists of using preventive and corrective maintenance data to predict the service life of each component and to predict maintenance needs in order to maximize the service life of the equipment. This can apply to both vehicles and their infrastructure.

2.2.4 Driving

IN A NUTSHELL *With practice, drivers can quickly adapt to the new driving style.*

An electric bus responds differently to driver commands than a standard diesel model. Acceleration is almost instantaneous with these vehicles, as electric motors react quickly and produce high torque. In addition, regenerative braking, the intensity of which can usually be adjusted according to preference, can produce a jerky deceleration, which may require adjustments in the early stages. Although there is a period of acclimation for driving electric buses, specialized training and regular practice allow for rapid adaptation, quickly followed by smooth driving.

2.2.5 Real-time data collection

IN A NUTSHELL *Electric vehicles offer the ability to collect real-time data to learn about vehicle fuel efficiency and optimize operations.*

One of the new features of electric buses, which contain many sensors and can communicate with their infrastructure, is the collection of real-time performance data, also known as telemetry.

This makes it possible to gather a wealth of information to help facilitate operational management. For example, it is possible to determine:

- the exact location of a vehicle at any time
- the battery charge level
- problems encountered
- the vehicle's energy consumption
- the life of vehicle components to predict maintenance needs

This data can be used to guide operational choices, measure the impact of external temperatures on bus efficiency, and guide future bus purchases to ensure that the models acquired better meet local operational challenges.

2.2.6 Acquisition and operating costs

IN A NUTSHELL *Vehicle acquisition and operating costs are difficult to estimate as they depend on factors such as battery size, fleet peak demand, etc. This section provides a brief review of known price ranges.*

It is difficult to give a set cost per bus because it depends on after-sales service options, the total battery capacity, the bus model and the specified warranty clauses for the main components of the vehicles, especially for the lifetime of the batteries.

Two studies, one conducted by Équiterre and Dunsky in 2019[9] and the other conducted by Raymond Chabot in 2021,[10] agree on a range of purchase prices between $305,000 and $310,000 for a Type C electric school bus with a range of 150 km, which is 2.3 to 2.8 times the cost of an equivalent diesel bus. A recent market study conducted by one of the school bus operators surveyed indicates that this cost can go as high as $370,000. Several grants are available on the market to reduce this cost gap. They are presented in section 4.3. However, the cost of purchasing a vehicle with a range of 200 km is higher and can be as high as $350,000. This difference is not covered by the grant.

In terms of operating costs, the higher the cost of gas, the greater the savings. A study sponsored by the BCF shows that the total cost of electricity and heating for an electric bus is $3,700 per year, compared to $6,900 per year per diesel bus[11,12]. This cost varies based on mileage, peak electrical demand and other external factors, and should therefore be treated as a guideline only. Each school bus operator must therefore conduct its own cost analysis.

During interviews conducted to develop this guide, one of the comments made was that the building insurance premium could be more expensive if the electric vehicles are parked inside the garage in the maintenance area for a long period of time, as this increases the fire risk premium. This should be taken into consideration in the total cost analysis.

9 https://legacy.equiterre.org/sites/fichiers/rapport_autobus_1.pdf

10 https://www.federationautobus.com/uploads/documents/files/EnvoisFTA2022/Com_.Rapport%20-%20Analyse%20de%20l'impact%20de%20l'%C3%A9lectrification%20mai.pdf

11 https://www.federationautobus.com/uploads/documents/files/EnvoisFTA2022/Com_.Rapport%20-%20Analyse%20de%20l'impact%20de%20l'%C3%A9lectrification%20mai.pdf

12 This analysis does not take into account peak demand cost ($/kW) or monthly electricity charges. In addition, this analysis assumes fuel costs of $1/L, whereas it was almost $2/L at the time of writing this report.

2.3 Review of commercially available charging station models and software

2.3.1 Review of different charging options

IN A NUTSHELL *Two main charging options are available to school bus operators: Level 2 charging ("slow") and Level 3 charging ("fast"). The main features of both options are set out in this section.*

It is important to understand what charging station options are available on the market and how each option best meets the fleet's operational needs. Charging options are categorized based on the charger output and current type.

For up to 19.5 kW running on 240 V, you need a Level 2 charger using alternating current (AC). An example of this type of charger is shown in Figure 3. For chargers supplying greater than 19.5 kW and up to 50 kW, you need Level 3 fast chargers running on direct current (DC).

FIGURE 3 • Lion Electric buses charging at Level 2 charging stations, photo added with permission from Lion Electric

Electric buses

Level 2 connectors connecting the bus to the chargers are now standardized under the Society of Automotive Engineers' SAE J1772 standard. Therefore, all Level 2 charger models that meet this standard must be able to work with any electric bus model. These models are considered interoperable. This type of charger can be mounted directly on a pedestal or wall. These terminals require minimal maintenance. Care must be taken to ensure that the cable connecting the vehicle and the charger does not drag on the ground to minimize wear and tear on the cable. In cold weather, the cable may become very rigid and difficult to handle, which may cause the connector to break more quickly.

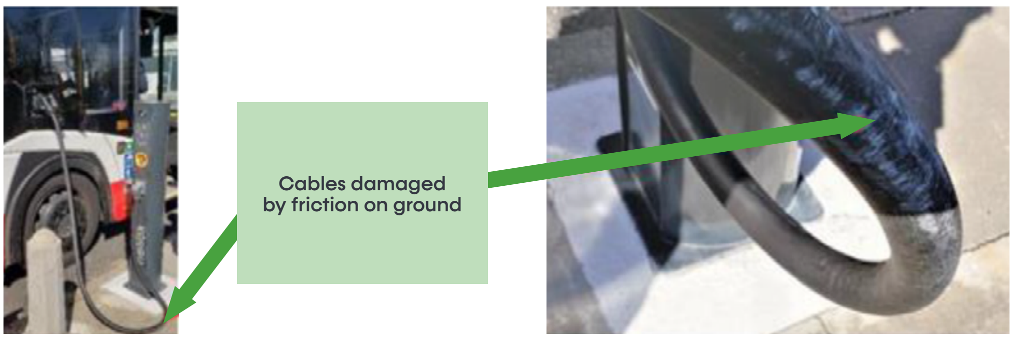

Photo taken by WSP at an urban electric bus project.

FIGURE 4 • Worn cables at a Level 3 charging station, photo taken by WSP for an urban electric bus project

Level 3 charging models, on the other hand, have a standardized type of connection called Combined Charging System (CCS) and must be installed with sufficient spacing for safety and ease of maintenance. This type of terminal requires more maintenance. Such maintenance involves air filter changes, frequent checks to ensure that the cooling system is working properly, and cable protection to limit friction on the ground (see Figure 4).

It should be noted that some electric bus models are only compatible with Level 2 or 3 charging, while others are compatible with both types of charging. This criterion should be part of the technical specification review when selecting vehicles, as indicated in section 5.2.

2.3.2 Choice of options tailored to needs

IN A NUTSHELL *Most school bus operators in Quebec will only require Level 2 charging for their operations, as they will be able to charge overnight. The two charging options are compared in this section.*

The total charge time for a bus is highly dependent on the capacity of the installed battery. For a 150 kWh battery with a range of approximately 150 km, the charging time with a Level 2 charger will be approximately 7 to 8 hours. In a recent survey of Quebec school bus operators, over 83% of respondents indicated daily routes of less than 150 km as well as a complete overnight stop, which would allow electric buses to be charged after their evening trips.[13] In addition, the vast majority of respondents indicated that school buses run an average of 5 hours per day over two daily routes: morning and evening. Thus, Level 2 chargers could satisfy the energy needs of the vast majority of school bus routes in Quebec.

However, there are exceptions to the types of operations indicated above, as some school buses travel more than 200 km per day with little overnight charging time. Similarly, some of these buses are sometimes parked at the driver's home before being redeployed the next day. In these cases, specific planning and modes of operation will have to be assessed. These will be discussed further in section 4.1. In some specific cases, a mid-day fast charge with a Level 3 charger could be considered for redundancy, i.e., for emergency needs. Similarly, Level 3 chargers may in some cases be more economically viable, as they can charge multiple buses a day, compared to Level 2 chargers, each of which needs to be dedicated to one bus.

The table below compares the two preferred charging options for electric school buses. Each school bus operator will have a different electrification strategy depending on their needs. Most small and medium operators will likely only require Level 2 charging stations. Others will need a blended strategy with both levels of charging to maintain their service.

13 https://legacy.equiterre.org/sites/fichiers/ase_-_analyse_du_sondage_transporteurs_-_vf_v4.pdf

TABLE 1 Comparison of different charging solutions

Characteristic	Level 2	Level 3
Power conversion	Alternating current	Direct current
Power	Up to 19.5 kW at 240 V	Up to 50 kW and above
Connection type	J1772	CCS – Type 1
Dimensions for the largest manufacturer (inches)	13.7 x 19 x H:95.5	46.3 x 17.4 x H:88.2
Average life	10 years	10 years[14]
Usage	Long charging (7 to 8 hours), ideal when the bus is parked in the same place overnight	2- to 3-hour fast charging, ideal for situations where the bus has little available charging time or for long trips (>150 km)
Equipment acquisition costs	Between $5,000 and $7,000 depending on the complexity of the equipment (warranties, communications, etc.)	Between $12,000 and $35,000 depending on the complexity of the equipment
Annual maintenance cost	Up to $500/charger[15]	Up to $3,000/charger
Charging management software cost (estimate)	Up to $100/charger	Up to $500/charger
Cost of installation	Varies depending on location in relation to Hydro-Québec transformers, power supply capacity, electrical distribution and number of chargers that must operate simultaneously.	

It should be noted that the cost of acquiring the equipment is only part of the total cost. In fact, it is necessary to provide for an additional connection to the power grid, an upgrade of the electrical distribution system, and sometimes even conversion of the maintenance shop to bring the fire safety measures up to code and to lift the heavier vehicles, depending on the current power supply and capacity at the site. These costs should never be minimized or generalized, as they are highly dependent on the existing infrastructure and could be a significant part of the total cost. It is important to do a detailed cost analysis. These steps are outlined in section 5.1.

14 Estimated

15 https://afdc.energy.gov/fuels/electricity_infrastructure_maintenance_and_operation.html

2.4 Impact of electrification on buildings

2.4.1 Power supply and distribution

IN A NUTSHELL *To acquire more than three electric vehicles, it will generally be necessary to review the building's power supply and design a new electrical distribution system to power the chargers.*

When it comes to electrifying school bus fleets, all of the infrastructure necessary for running the vehicles must be considered, from the Hydro-Québec connection to charging stations and reconverting maintenance shops.

If the building's power supply is insufficient, a new dedicated power supply must be added through a second independent meter. Typically, a second power supply is required for a fleet of more than 3 electric buses, as each charger requires approximately 100 amps.

To supply several chargers at once while minimizing the loss of space in the existing garage, several suppliers offer a container system, as shown in Figure 5. These containers house the necessary transformers and switching devices to supply the required power to the chargers.

FIGURE 5 • Installation by Cléo of a container for Autobus Séguin bus capable of supplying up to twelve 260 kW charging stations

As shown in this photo, a container capable of powering up to 12 charging stations takes between one and two bus parking spaces. When considering this type of solution, it is important to ensure that the location chosen for the container takes into account the wiring distance requirements between the container and the chargers, which is an additional constraint. These containers are practical because they reduce the required number of building modifications and concentrate all electrical equipment in one place. The installation of these systems sometimes requires a municipal permit to comply with local municipal planning by-laws.

Another solution developed by Girardin Energy is a modular electrical receptacle that includes a measuring and distribution cabinet, switchgear and transformer. This system can be used for different fleet sizes.

2.4.2 Building conversion

IN A NUTSHELL *Building modifications must comply with applicable building codes and fire standards. It is recommended that specialized engineers be called in to identify site modification requirements and to draft plans. The space layout should also be reviewed to ensure that it is compatible with simultaneous use of electric and diesel technology.*

Each school bus operator runs its fleet of vehicles from its own sites and buildings. Each site has different characteristics. Some small operators have their maintenance done at a garage that specializes in that kind of work. Others have it done on-site in a garage or shop that will need to be modified to meet the new requirements.

To determine the impact of electrification on buildings, it is useful to look at what has been done for urban bus garages that already operate electric buses. Safety is the most important consideration, especially when several electric buses are maintained side by side. Although the risk of a battery fire is low, this type of fire is nonetheless more difficult to contain. Therefore, it is important to put in place the necessary measures to protect the building's equipment in the event of a fire. There are several solutions.

The Régie du bâtiment du Québec's building code does not yet provide specialized standards in this regard. Thus, we have to rely on U.S. building codes, such as NFPA 855, for stationary battery installations that include smoke and high heat detection systems and fire extinguishers capable of extinguishing nearby battery fires in addition to a jet fire suppression system. In the event of an accident, firefighters must use specialized equipment and must therefore be warned of the risk of battery fire.

Further modifications to the shop, albeit more limited in scope, will likely be needed. The charger electrical distribution system will generally be independent of the building's main electrical distribution system. However, it might be worth considering adding a Level 2 charger in the maintenance area to facilitate vehicle testing.

Space distribution will also need to be re-evaluated with respect to fuel distribution as any flammable product must be kept at a minimum safe distance from the chargers, which can impact current operations and how the non-electric buses refuel.

Currently, electric buses are heavier than diesel buses, so it is necessary to check their impact on the concrete floor slabs and on the jacks used to lift the buses. In the long term, the floor slab may have to be modified to minimize its deterioration.

There should also be a dedicated space for the use of specialized tools for electric bus repairs. All these elements will vary from one building to the next, but they must be considered in the overall implementation of a transition project to ensure that every part of the infrastructure is ready to accommodate the new technology and that both technologies (diesel and electric) can be operated simultaneously.

2.4.3 Charging management software

IN A NUTSHELL *Charging management software is recommended for three or more vehicles as it helps minimize peak demand by controlling each charger. This saves on the electricity bill.*

Charging management software helps control automatic and real-time charging of the electric vehicle fleet, and minimizes the number of vehicles charging at any given time to reduce electricity costs.

In Quebec, there are two components to the electricity bill: the first is the amount of energy used, i.e., the number of kWh consumed over a one-month period, and the second is based on peak demand ($/kW). For users requiring more than 50 kW of power, which is the case if more than three Level 2 chargers are used simultaneously, the second component is added to the monthly electricity rate.

Peak fixed electricity costs can be reduced by planning the best charging times using specialized software. For example, if it takes 8 hours to charge the buses but they are parked in the lot for 12 hours, the additional four hours can be used to distribute the load and minimize peak power demand. This example is illustrated in Figure 6. A charging management software will monitor this automatically. It can easily communicate with a cloud-based platform to view the state of charge of each bus at any time and activate an alert in case of malfunction. It is important that this software be compatible with the charging stations of all selected manufacturers.

This type of software is not mandatory for smaller-scale operations, i.e., less than five buses, but must be considered to facilitate operations and minimize costs on a larger scale. That being said, software can help smaller operations stagger nighttime bus heating to optimize energy efficiency and reduce costs.

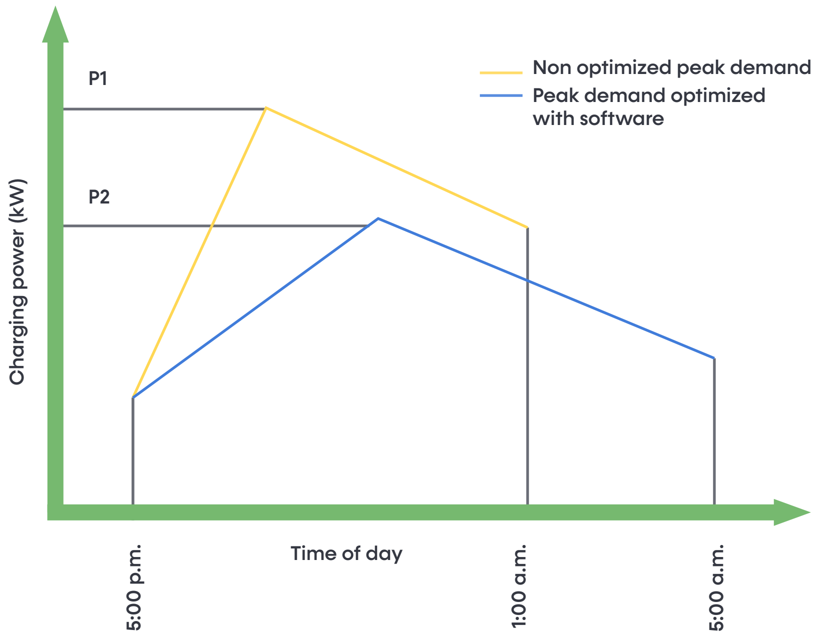

FIGURE 6 • Illustration of the reduction in peak demand with charging management software. Peak demand P1 is higher than P2 and therefore electricity costs will be higher.

Services and financing offered to facilitate transitions

3

The purpose of this section is to present the ecosystem of available services in Quebec and the different choices available to school bus operators to transition their fleet.

3.1 Manufacturers and builders

IN A NUTSHELL *The availability of electric school buses is on the rise in North America, but only two manufacturers are currently eligible for Quebec grants. Several manufacturers of Level 2 charging stations are available and eligible for grants. A non-exhaustive list is presented in this section.*

There are several manufacturers or resellers of electric school buses in Canada. In Quebec, a few models from two local manufacturers are eligible for grants under the Quebec government's Programme d'électrification du transport scolaire.

Depending on the manufacturer and type of school bus, the battery charge will range from 78 kWh to 210 kWh and can require a Level 2 or 3 charging station. The list below identifies school bus manufacturers in Canada, as well as those eligible for financial assistance from the Quebec government.

TABLE 2 List of manufacturers and models of electric school buses in North America and their access to financial assistance in Quebec

Manufacturer	Models	Financial assistance
Girardin Blue Bird Drummondville, QC	Micro Bird G5E Vision C TX4 D	Yes
GreenPower Motor Company Vancouver, BC	BEAST	No
IC Bus Illinois, USA	CE Series	No
Lion Electric Co. Saint-Jérôme, QC	LionA LionC LionD	Yes
Thomas Built Buses North Carolina, USA	C2 Jouley	No

Note: This list was updated on May 1, 2022. Other manufacturers could always apply for financial assistance for their electric vehicles under the program.

With regard to charging terminals, the market is large and consists of several major players, including those listed in the table below*:

ABB	AddENERGIE Solutions de recharge I Smart Charging Solutions	chargepoint
elmec Semplicemente affidabili	PROTERRA	SIEMENS

* This list is not exhaustive

Charging stations use software to optimally manage the amount of power needed and required charging times. This software is provided by suppliers of vehicles, charging stations, or charging systems. Such a system lets electric bus fleet operators monitor charging remotely, receive alerts about charging problems, collect charging data to optimize vehicle charging cycles, and avoid more costly peaks of power usage. Note that telecommunications and cybersecurity must be considered when planning charging station deployment to ensure a stable communication link between chargers and the charging management system. These systems enable customers to quickly take action to avoid delays and service breakdowns.

3.2 After-sales and support services

IN A NUTSHELL *Support and after-sales services have expanded over the past few years to provide school bus operators with assistance at every stage of the process. From planning to grant and permit applications, selection of specialized electricians and installation of electrical equipment, school bus operators can choose turnkey or "à la carte" services.*

3.2.1 After-sales services

To facilitate the transition to electric buses, most manufacturers offer support services for electric bus charging infrastructure. These services may include choosing charging stations from a selection of charging stations compatible with their vehicles. It may also include planning and installing the entire charging infrastructure. By using these services, operators gain a solution that will ensure compatibility between buses and the charging infrastructure, thereby reducing the technological risks associated with the electrification transition. These services also include applying for a municipal building permit and negotiations with the various stakeholders.

Once buses are delivered, most manufacturers also offer various services to enable their customers to take advantage of the new technological features of electric vehicles. Whether through training drivers and electromechanics, teams at affiliated service centres or telemetry systems, operators will be able to benefit from these services to ensure vehicle maintenance. For additional details on these elements, go to section 4.5.

For example, Girardin Energy offers 3D visualization and electrical design services to better understand the proposed concepts (see Figure 7).

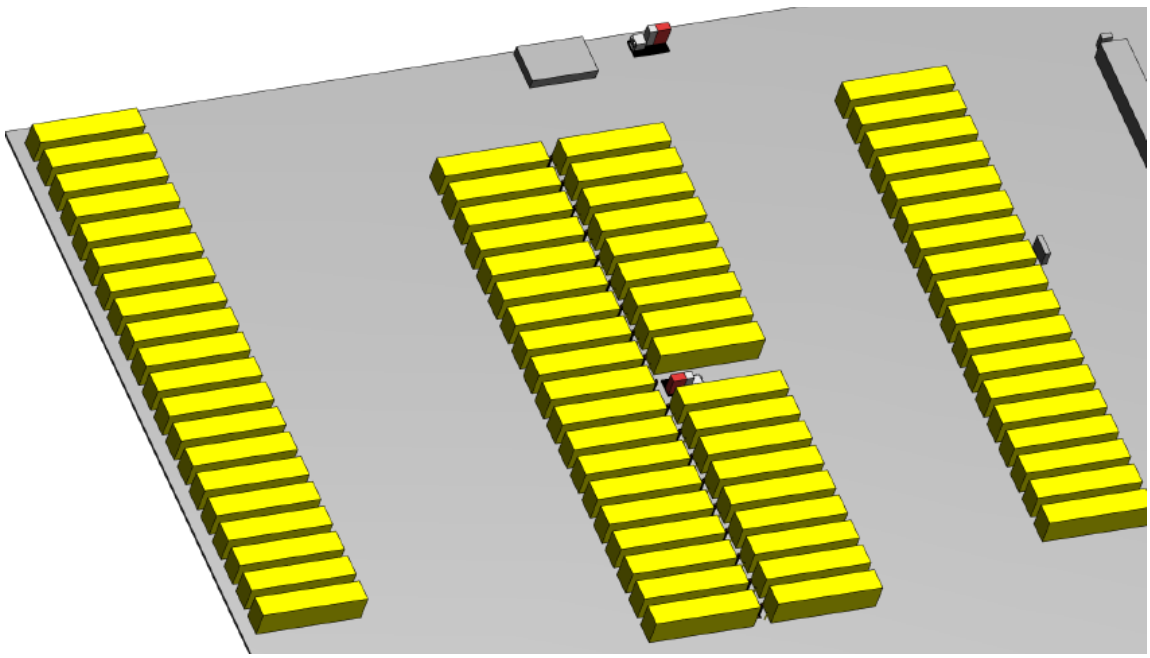

FIGURE 7 • 3D visualization of the charging system in a parking lot, image courtesy of Girardin Energy

3.2.2 Other support services

School bus operators can also hire specialized firms such as Cléo or engineering firms to support infrastructure reconfiguration and electrical installation independently of the bus supplier. Such an approach is agnostic in terms of the type of vehicle being purchased and may be preferable if the operator is considering purchasing several different electric vehicle models.

It is highly recommended to use a firm that can implement plans and specifications validated by engineers to ensure that physical standards and constraints are met, rather than going directly to a specialized electrician. The electrician can then follow the approved plans and specifications. 75% of this service is currently funded by the Government of Quebec.

3.3 Financing options

IN A NUTSHELL *There are government grants that can cover almost a third of the cost of electric buses and 75% of the costs of installing charging stations and the studies required to install them. The Canada Infrastructure Bank, in partnership with the BCF, offers financing at a very low interest rate, to be paid back only if cost savings are realized through the introduction of electric buses. A review of each financing option and its advantages and disadvantages is provided in this section.*

There are now several advantageous options available to Quebec school bus operators to finance a transition to electric vehicles. It is important to distinguish between two options offered by the provincial and federal government: grants and low-interest loans.

3.3.1 Grants

A grant is financial assistance from a government entity that does not need to be repaid. Grants may be provided to help with the adoption of new technology, and generally have time constraints and maximum amounts. Quebec's school transportation electrification program provides school bus operators with two types of grants, one for vehicles and the other for charging stations. The goal is to help electrify 14% of Quebec school buses by March 2024.

You can apply for a provincial grant that will cover $125,000 per bus until March 31, 2023, and $150,000 thereafter until 2024 or $175,000 for buses with a battery capacity of 155 kWh or more.[16] Two bus manufacturers are eligible for this grant, Girardin Blue Bird and Lion Electric. The grant is paid directly to the supplier, so the school bus operator does not need to advance the total amount and only needs to pay the difference.

For charging stations, the grant is 75% of acquisition and installation costs up to a maximum of $50,000 per electric school bus. To obtain this grant, the operator must submit a report prepared by an expert in consultation with a qualified electrician and a licensed professional engineer.

Another way to finance studies, plans and specifications for integrating new technologies is the Fonds Écoleader fund. The Fonds Écoleader supports tangible measures such as preparing diagnostics and studies, developing action plans and carrying out support procedures. The Fonds Écoleader provides grants to cover 75% of the cost of studies and action plans up to $60,000.

16 https://www.transports.gouv.qc.ca/fr/aide-finan/electrification/programme-electrification-transport-scolaire/Pages/programme-electrification-transport-scolaire.aspx

3.3.2 Loans

A low-interest loan is another way to finance the capital portion of the transition. This option, offered by the Canada Infrastructure Bank (CIB), allows the school bus operator to share the risk, as loan repayment is only required if the electric buses reduce the operator's maintenance and fuel costs.

The CIB's $400 million funding program for zero-emission school buses is available to all members of the BCF. An operator enrolled in this program can draw CIB financing for 5 years, after which it must repay the loan over a period of up to 10 years, depending on the expected life of the bus. The funding is determined on the expected cost savings generated by the introduction of electric buses based on a percentage set by the CIB and the BCF. For example, if a diesel busis expected to cost $1,000 per year to operate and an electric bus costs only $600, that's an expected $400 in savings per year. The operator repays the loan to the BCF based on the lowest fixed percentage of the $400, and real savings. The loan annual interest rate is 1% and the BCF charges an administrative fee currently estimated at 0.05% of the loan amount per quarter. Loan repayment must begin a year after the electric buses become operational.

3.3.3 Other financing

In addition to public financing, there are also private funds that operators can access. 7Gen partners with institutional investors to support electrification projects.

There is another way to structure electrification projects. The electrical infrastructure needed to charge vehicles can be leased instead of purchased, thereby limiting the capital investment in the project. Companies like Cléo and 7Gen provide electrical equipment planning, installation and maintenance services at a fixed cost per month. This option makes it possible to structure a project using an OPEX rather than CAPEX model.

Services and financing

The table below summarizes the options discussed in this section, as well as the benefits and risks to consider for each.

TABLE 3 Alternative grant, financing and structuring options for school bus electrification projects in Quebec

	Provincial government	CIB	Écoleader	Cléo	7Gen
Type of financing	Grant	Low-interest loan	Grant	Charging equipment rental or sell	Charging equipment rental and investor partnerships
Key Features	• Available until 2024 • Bus grant paid directly to the manufacturer • Subsidizes 75% of eligible costs for charging infrastructure • Requires that the manufacturer deliver within 12 months after the grant is paid	• Available until 2026 • Financing application through the BCF • 1% loan repaid over 8 to 10 years • Loan repaid only on savings achieved	• Applies to studies and hiring experts • Has an inventory of all ecological financing available in Quebec	• Installs and maintains charging equipment and all electrical distribution equipment for a monthly fee • Cléo also provides technical expertise and handles financing applications	• Manages the installation and maintenance of charging infrastructure and vehicles with a single monthly invoice • Expertise to provide additional private financing as required
Vehicles	Financing available	Financing available			Financing available
Charging infrastructure	Financing available			Financing available	Financing available
Studies and expertise	Financing available		Financing available	Financing available	Financing available

	Provincial government	CIB	Écoleader	Cléo	7Gen
Benefits	• Easily accessible • Detailed grant criteria and very clear application process on the site • Grant covers all expenses related to electrification (vehicles + infrastructure)	• Lower interest rates than private banks • Visibility on financing until 2026 and gradual repayment over 8 to 10 years • If no savings are achieved with electric conversion, the operator does not need to repay the loan.	• Grant to support more detailed planning studies up to $60,000	• Allows you to plan your operating budget by adding monthly management fees • Limits the operator's risk for infra-structure • Technical support included in the calculation	• Allows you to plan your operating budget by adding monthly management fees • Support to find alternative sources of financing if needed
Other considerations when preparing the budget	• Availability of the grant unclear after 2024 • The total amount of the grant decreases each year. • Acquisition and installation costs for Level 3 terminals are potentially more than $50,000 depending on the site	• Loan excludes charging infrastructure	• Limited information available online about the terms of the grant	• Consider the financial advantages and disadvan-tages of renting your equipment or buying it and maintaining it yourself	• No known deployment for school bus transportation in Quebec to date

3.4 Other services under development

IN A NUTSHELL *The services presented in this section are under development and are not yet offered within the Quebec ecosystem, but they need to be demystified to help operators understand their benefits.*

As transportation electrification progresses, complementary services are developing in Quebec. This section includes a list of services under development or that may emerge in the future, and their benefits for school bus operators.

3.4.1 Optimizing school bus transportation and the use of buses

Collecting real-time data through the telemetry of electric buses and chargers enables school bus operators to build up a large database they can use to their advantage. Automatic learning software (also known as machine learning) is being created to extract trends and optimize operations. For example, it may be more beneficial in the long term to deploy bus X on route Y because its battery capacity matches the energy requirements of the route. This type of optimization may be re-evaluated depending on the season, the number of students to be transported, the type of trip, etc. To make this type of performance analysis possible, operators need to plan data collection measures when acquiring their buses. Those measures will be offered by manufacturers, software suppliers and other specialized companies.

3.4.2 Factory inspection of level 3 chargers

In facilities where Level 3 chargers are required, some service providers offer to help customers by performing equipment inspections and tests in the factory prior to delivery and installation. Level 3 chargers are usually assembled in limited quantities, based on orders, while Level 2 chargers are more common consumer products. Level 3 chargers are more complex due to their operational requirements and greater power. These quality control activities, carried out in collaboration with experienced inspectors, help detect defects before equipment leaves the factory, thus speeding up adjustments and reducing installation and commissioning time at the customer's premises. This type of activity should be considered as early as the project planning phase and included in the charging equipment purchase contract.

3.4.3 Factory inspection of electric buses

As electric buses are a new technology for most customers, some service providers offer to help them by performing inspections and running tests on electric buses in the factory prior to delivery. As with Level 3 chargers, these quality control activities, carried out in collaboration with experienced inspectors, ensure that the delivered vehicle complies with the contract before the electric buses leave the factory, thus speeding up adoption by the customer's teams operating the vehicles.

3.4.4 Bulk purchase of electric buses

Bulk purchases of electric buses could be considered, specifically for operators that do not have the same technical and procurement resources as larger operators. This approach is already being used for urban electric buses.[17] This type of arrangement gives customers a better bargaining position based on their numbers, and to negotiate more advantageous arrangements for such things as warranties and pricing.

3.4.5 Watch for: Hilo smart charging solution

Hilo, a subsidiary of Hydro-Québec, enables its customers to benefit from services that help them reduce their electricity consumption. Existing services offered by Hilo enable their residential customers to receive compensation for participating in proposed challenges during peak periods. This could be a financial incentive for school bus operators once a smart charging solution is available to all Hilo customers. Similarly, this solution could be installed on the premises of drivers who have to park the bus at their home.

Residential customers[18]

In November 2021, Hilo launched a pilot project for a smart charging management solution that is currently under development. Once the solution is available to all customers, school bus operators, including those with buses to be charged at the driver's residence, will be able to contact Hilo directly to determine the financial benefits (decrease in total electricity costs) associated with this new solution. To benefit from these services, operators will need to ensure compatibility between the charging equipment they plan to install and the Hilo solution

Business customers[19]

Hilo's smart charging solution is currently under development and little information is available at this point. School bus operators can contact Hilo directly to discuss the benefits of these new services and to let Hilo know of their interest.

17 Ref. https://www.lapresse.ca/affaires/2022-04-12/autobus-urbains-electriques/une-grosse-commande-financee-par-quebec.php

18 Ref. http://news.hydroquebec.com/en/press-releases/1756/hilo-introduces-a-smart-charging-solution-for-electric-vehicles/

19 Ref https://www.hiloenergie.com/en-ca/business/

3.4.6 Watch for: vehicle-to-grid energy exchange (V2G)

Vehicle-to-Grid or V2G is a feature that allows a charger and bus to return power to the grid. On an electric bus, the stored energy could be used to redistribute power during peak demand times and recharge during off-peak times.

Several pilot projects testing the feasibility of this solution are underway in the United States, where the electrification rate model varies by time of day in many states.

Nonetheless, using electric vehicles to supply the electricity grid presents many challenges and is not currently possible in Quebec. This technology could benefit school bus operators in the long term if financial benefits were offered in exchange. However, owners of electric vehicles will also need to consider the impact of increased use of the battery over its lifetime.

4 Key steps for converting your fleet to electric power

This section lists and describes key steps in preparing for the transition to electrification.

4.1 Planning

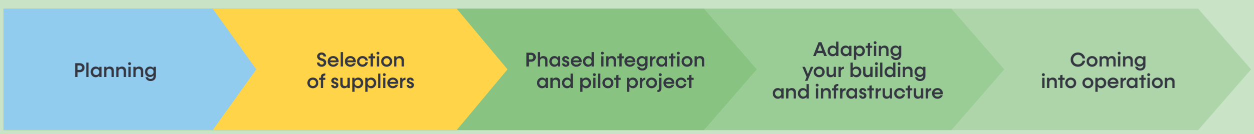

FIGURE 8 • The main stages of an electrification project

Whether electric or diesel, a school bus is an operator's largest asset. Before choosing a vehicle, it is important to identify the service requirements. Before embarking on the purchase of an electric vehicle, it is important to clearly define the tasks that the electric vehicle will need to perform, including:

- number of kilometres driven per day
- number of exits from the garage (morning, noon, evening) and downtime at the garage/parking site
- use for long trips (e.g.: class trips)
- route variables (city, country, suburban, paved road, gravel)
- bus route geography (flat terrain, slope, hills, etc.)
- ability of the electrical system and grid to handle the new charge

This will help select the best bus models and charging strategy to meet those requirements. To be properly prepared, it is important to know the operating costs of the diesel bus that will be replaced. This step will help operators better understand the future costs of acquiring an electric bus.

Key steps

The planning stage is where the project's financial structure and the various financing methods are identified. The different cost categories to plan for are as follows:

- Operating costs (OPEX): electricity ($/kWh, $/kW, administrative), light and heavy maintenance (labour + parts), fuel for auxiliary heating, infrastructure maintenance , licensing fees for software and access to real-time data, training, insurance, towing contingency, etc.
- Capital costs (CAPEX): acquisition of vehicles and warranties and repair contracts, acquisition of charging infrastructures, connection with Hydro-Québec, building reconfiguration, installation of a new distribution system, updating tools for maintenance and computers, battery replacement, etc.

It is during this stage that the work and conversion of existing infrastructures must be reviewed and the plans and specifications for the electrical installation must be developed.

Professional services such as those described in section 3.2 are recommended to help throughout the planning process.

4.1.1 Planning for the implementation of pilot projects

It is recommended that operators of more than ten school buses proceed in stages, starting with the purchase of a single electric bus. This will enable the operator to gradually acclimate to the electric bus and facilitate the integration of additional electric buses.

To maximize the benefits of a pilot project, its planning should involve identifying and using the same requirements as those identified to deploy a full fleet of electric buses and their associated charging equipment. In this way, the pilot project will help validate as many hypotheses as possible. Once the pilot project is underway, it will be essential to implement the findings of a post-mortem analysis to correct the full fleet deployment strategy as required.

4.1.2 Planning for phased implementation

In a phased integration, requirements must be identified from the outset for all deployment phases. This will help meet those requirements through informed choices.

Implementing the conclusions and recommendations of the post-mortem analysis of the first deployment phase will ensure the success of the subsequent phases.

4.2 Selecting suppliers

Once the type of bus, charging strategy and building conversion have been determined and the acquisition plan has been set up, other elements will have to be checked before making the purchase. It should be remembered that as a buyer, an operator has the right to request technical answers from its suppliers so it can make an informed decision.

The questions below can be used as a guide when conducting research to understand the contract terms and conditions and dissect the solutions offered by bus and equipment suppliers and service providers.

4.2.1 Questions for bus suppliers

- **What is the battery warranty and what are the conditions of the warranty?**

  Lithium batteries can be guaranteed for up to 12 years, but this comes at an additional cost. It is important to understand the warranty conditions. Some suppliers may require the battery charge level to never go below a certain percentage, for example 10%. This entails operational constraints the operator must comply with at all times.

- **What is the life cycle of the batteries and how are they recycled?**

  A definition of battery life needs to be agreed upon to ensure that batteries are replaced if they have degraded to 20% to 30% of initial capacity, as this has an additional impact on operations. It is important to agree on how quickly batteries will be changed when they reach the end of their life cycle to minimize the impact on operations. It is also important to understand the measures taken by suppliers to recycle batteries once they reach the end of their useful life.

- **What are the conditions for heavy maintenance and spare parts availability?**
  Which repair centre and dealer are closest?

  As an operator, it is possible to negotiate the terms of the maintenance contract. It is important to know the average and maximum wait times when a problem is reported that requires a technician on site. It is also possible to negotiate conditions for spare parts availability to ensure that the supplier keeps the necessary spare parts on hand at all times.

- **What is the general warranty period for manufacturing issues?**

  This question addresses the warranty period and the conditions for return if a bus is defective.

- **What is the delivery lead time?**

  It is important to determine the bus delivery lead times prior to purchase. Once the grant is provided, the supplier has 12 months to deliver the bus to the operator. Any financial risk associated with lead times is assumed by the supplier, because they receive the grant directly. The operator only pays the amount outstanding after the grant is paid. It should be noted that according to data collected, current lead times for electric buses may exceed 12 months.

- **What kind of training is included?**

  It is important to understand what kind of training will be offered when the bus is delivered, including whether this training includes safety equipment maintenance.

- **What is the procedure for notifying first responders and firefighters?**

  The bus manufacturer must provide a technical emergency plan to address the fire hazards.

4.2.2 Questions for electrical equipment and service providers

- **What is the delivery and installation time for charging equipment?**

  Bus and infrastructure deliveries must be coordinated.

- **If purchasing charging management software: is this system compatible with all manufacturers' charging stations?**

  It is likely that over the long term, the transition will involve electric charging stations from various providers. This means ensuring that the software is interoperable with all models.

- **How does the support process work?**

  It is important to know all the details of the proposed services. Does the service provider take care of or help with grant applications? Planning? The bidding process for selecting the best charging option? etc.

- **How will you plan for electrical redundancy?**

  In the event of a power failure or malfunction of the electrical equipment, the following day's operations will be severely affected. Ensure turnkey charging solution providers consider the problem and propose one or more solutions to correct for power failures and commit to fixing them quickly. For larger facilities, it may also be possible to install a generator on site.

- **What is the annual management fee for the software if the number of electric buses in the fleet changes?**

  Software usually involves additional operating fees (OPEX).

- **Is the software compatible with the computers at the site (operating system, version, etc.)?**

  If not, additional equipment will be required.

4.3 Pilot project and phased integration

The implementation of a pilot project and the gradual integration of electric vehicles reduces the operational risks associated with the transition by giving operators the opportunity to identify and correct issues without any impact on their services. This approach enables them to become familiar with new technologies associated with electric vehicles, charging systems and the various after-sales services available. It also makes it possible to identify the operational best practices to adopt based on local characteristics (distances, weather conditions, types of roads, etc.). Following a pilot project or the first phase of a phased integration, a post-mortem analysis is recommended to identify areas for improvement when integrating future electric buses. This analysis should take place 6 to 10 months after the electric buses are commissioned and should include a winter use period to validate all system components under extreme use conditions, as well as recommendations for future deployments.

For school bus operators with a fleet of more than ten vehicles, a pilot project replacing 10% to 15% of their fleet with electric buses will enable them to achieve the above-mentioned objectives.

For school bus operators with a fleet of ten vehicles or less, it is recommended that the vehicles be gradually integrated in phases, starting with one or two electric buses and their charging equipment in the first phase.

4.4 Adapting buildings and infrastructure to accommodate electric school buses

As mentioned in section 3.4, modifications to the building or site may be required to charge and maintain electric buses. Unless you have the appropriate resources internally, it is recommended that you use an external specialized service such as those described in section 4.2 to validate plans and specifications, find a project manager, and monitor electrical equipment installation and infrastructure rebuilding work.

In addition to the charging stations, electrical redundancy and resiliency features should also be considered to ensure continued operations in the event of a power failure.

Adaptations to the building and site will vary significantly for each operator as they depend on a number of variables: the conditions of the existing building, capacity of the power supply, location where the maintenance will be done (on-site or off-site), available space, distance from the hydro pole, etc. Figure 9 shows the general rules that apply for fleets of different vehicle sizes. It should be noted that a new power supply may be required in some cases with as few as three new buses, given that building electrical panels generally have little spare amperage.

Key steps

1 to 3 electric buses	4 to 7 electric buses	7 to 15 electric buses	16+ electric buses
• Level 2 chargers only (1 charger per bus) • Using existing power supply • No reconversion of the maintenance area required • No charging management software required, but can be considered to manage the start of cascaded heating	• Gradual integration of buses • Level 2 chargers only • Space reconfiguration to accommodate electrical equipment • New power supply • Charging management software may be desirable to reduce electricity costs	• Level 2 and 3 chargers for potential redundancy • Pilot project recommended • Charging management software required	• Level 2 and 3 chargers potentially depending on the circuits • Pilot project recommended • Charging management software required

FIGURE 9 • Examples of general rules on the extent of changes to be anticipated in relation to fleet size

4.5 Start of operations

Once the vehicles and charging solution have been selected, their deliveries must be synchronized so the buses can be used as quickly as possible. To this end, it is recommended that the charging stations be fully installed several months before the electric buses arrive.

When the buses are delivered, a series of tests will be required to ensure proper operation. It is important to plan several weeks of adaptation, especially for the first order of electric buses. Buses will have already been tested by the manufacturer when they leave the factory but will not yet have been tested at the operator's facilities.

For an initial acquisition, familiarize yourself with this new technology by:

- setting up and testing the data collection system
- incorporating procedures for preventive and corrective maintenance, both in day-to-day operations and for tools and the garage
- ensuring that mechanics, drivers and other staff are properly trained to maintain and operate the equipment, including the vehicles, charging stations, and data collection and processing systems.

No standardized tests currently exist, but it is recommended to drive the usual routes several times before bringing passengers on board the buses. If in doubt, it is important to promptly contact the manufacturer's representative.

4.6 Overall timeline

The following table summarizes the main stages of implementation, including an overall estimated duration for each stage. This chart should be used as a guideline as it will vary based on the supply chain lead times, specificities and size of each project. In addition, some of the steps will not be necessary for smaller fleets.

Key steps

TABLE 4 Example of an electrification project timeline (details vary for each project)

	6 months	1 year	1.5 years	2 years	2.5 years	3 years	3.5 years	4+ years
Planning								
Current asset profile								
Initial vision to replace the first 3 diesel buses (duration, estimated budget)								
Review of different financing, purchase and lease options								
Selection of a partner to assist with the planning (consultant or specialized firm)								
Detailed fleet development plan for replacing the entire fleet								
Calculations of energy and battery size requirements for each route								
Cost analysis and financing requests								
Planning for infrastructure changes in the shop								
Planning for Hydro-Québec connection								
Selecting the bus and charger supplier(s)								
Pilot project								
Building adaptation and construction								
Construction plans and specifications								
Municipal building permits								
Work monitoring and charging station installation								
Gradual commissioning of buses								
Vehicle testing								
Staff training								
Data analysis								
Communications with firefighters and first responders to develop an emergency plan								

Tips and resources for a successful energy transition

5

FIGURE 10 • Autobus Vausco's Electric Buses

5.1 Testimonials and lessons learned from past deployments

5.1.1 Planning is the watchword

Every day, Vausco Transport Scolaire carries 1,500 students over 22 routes throughout the Lac-Mégantic region. With a fleet of nearly 23 school buses, the Vausco team operates and maintains its fleet of vehicles in-house. To minimize their environmental impact, the company introduced a series of measures, including providing eco-driving training, and quickly took a stand on electrifying its fleet of vehicles by reserving one of the electric bus prototypes available on the Quebec market.

To begin its long-term fleet transition project, the company hired Nixo Experts-Conseils to guide it through the early planning stages of electrical infrastructure and building modifications. The consulting firm helped Vausco determine its priorities for a phased transition to achieve the goal of commissioning 6 electric buses over the coming years.

Several electric charging and power supply solutions were considered in this process, resulting in the choice of the best option for minimizing costs and facilitating access to financing, including access to Fonds Écoleader funds.

Since 2020, the company has been operating an electric bus that recharges with a Level 2 charging station, which ran in both summer and winter. An auxiliary diesel heater was installed and is mainly used in winter to maintain battery range. When the bus was delivered, the company received general training to familiarize employees with the vehicle. No specialized maintenance training was provided. This has been problematic as the bus's high voltage system requires special attention to ensure the safety of maintenance personnel. All heavy maintenance on the bus is now done directly by the bus manufacturer's technicians.

Another observation is that most of the maintenance processes on the body, wheels, and the interior cabin remain unchanged. However, as the company was a pioneer and was working with a prototype, there were some issues with the batteries. One of the modules was frequently overheating, which prevented the bus from starting. This required a dedicated technician, who travelled to the site several times, causing the vehicle to remain idle while the breakdown was resolved. However, this issue has since been resolved. Each new model provides more information about this technology and ways to improve manufacturers' models.

Advice from Caroline Vallée, President and CEO of Groupe Vausco, on the success of their electrification projects:

"It is very important to take the time to assess all possible options and not be afraid to seek a second opinion. Thanks to the guidance we received from a consulting firm, we were able to reassess our initial plan, select our industrial electricians to install the charging infrastructure, and assess offers from different manufacturers without rushing. This let us implement an optimized solution that meets our needs."

5.1.2 Determining costs ahead of time

Autobus Maheux provides school bus services to transport thousands of students every day in several towns and villages in the beautiful Abitibi-Témiscamingue region. The company offers a wide range of transportation services in Abitibi-Témiscamingue, with a fleet of more than 200 vehicles, particularly in intercity, charter, urban, mining and school transportation. In addition, Autobus Maheux also operates on the North Shore in the Fermont area, a few kilometres from the border with Labrador, with a fleet of more than 20 school buses.

FIGURE 11 • Autobus Maheux's updated building electrical room to power the charging infrastructure

Autobus Maheux is a fleet electrification pioneer, having purchased its first two vehicles in 2016 and 2017. At the time of delivery, the manufacturer provided a brief training to familiarize the team with the new vehicles. The team faced some technical challenges during the deployment of these first-generation buses, especially during winter operation, particularly with the diesel heating not running continuously. There were also issues with the Level 2 charging system, and the charging stations had to be changed several times in accordance with the manufacturer's recommendations, as the charger technology was also constantly evolving. On several occasions, the buses ended up out of commission because of various problems.

These trials enabled the manufacturers to adapt their products to facilitate future integrations. Since then, the technology has matured significantly, but there are still reliability challenges in certain areas, such as issues with uninterrupted charging.

Tips and resources

The past few years have seen higher operating costs than initially projected on several levels, including maintenance, electricity consumption, diesel consumption for heating, and connection infrastructure.

Building on its experience, the company deployed three additional Lion Electric school buses in Fermont in winter 2021 to test them under extreme conditions, as winter temperatures can reach around -50°C. During the entire period, there was not a single service interruption due to the cold, even though the vehicles ran a great deal. These three vehicles performed well and had no difficulty maintaining a comfortable cabin temperature in winter. There were connection problems in cold weather because of the rigidity of the cables, a communication issue between the bus and the charging station, and a significant reduction in the vehicle's range, but only at very low temperatures. These buses will be transferred to Abitibi, where the Maheux team is preparing the necessary changes to accommodate 10 more electric school buses ordered in April 2021, for which government grants were received.

To prepare the infrastructure, the team followed the advice of the Lion Electric team and installed a container system. Such an infrastructure required a special municipal permit. It was necessary to assess the connection capacity with Hydro-Québec and determine the type of overhead or underground connection, which required an inspection of the site to check for the presence of gas lines and other lines.

The need for a greater power supply may require Hydro-Québec to add hydro poles, as in some cases the distance between poles has to be reduced for higher voltages. This happened with the Rouyn-Noranda installation, forcing Maheux to convince two nearby neighbours to agree to have hydro poles installed in their private yards. Work is moving ahead in anticipation of the electric buses' arrival, and the company is confident that it will successfully complete the project by the start of the school year in September 2022.

Advice from Ugo Barrette, Director of Maintenance Services at Autobus Maheux, on the successful implementation of electrification projects:

"Try to find ways to anticipate costs as early as possible. There are several new cost categories that are not intuitive, such as maintenance for charging stations, which need to be factored into budget planning, and having more charging stations than buses. A number of new questions were raised. Should we have a mega generator in case of a major outage? How do we ensure that we do not have a surcharge on our electricity bill due to a peak in the winter? What kind of training is required? Do we need new tools? Do not hesitate to discuss these questions with the BCF, which will advise operators on these matters. We also needed to determine the proper battery size and make sure that the vehicle we chose was right for our operations.

It is important that all project stakeholders work in parallel to avoid surprises like we experienced during infrastructure conversion projects. Here are a few examples: exemption to be able to place a container in our yard, requesting authorization from neighbours to install hydro poles on their land, overloading the Hydro-Québec network with outdated, poorly functioning wiring, complaints from neighbours about the noise of bus fans when charging in hot weather, unexpected installation issues that increased project costs, etc."

5.1.3 Having a long-term vision

Autobus Séguin offers a student transportation service with more than 345 regular and adapted vehicles serving seven school service centres and several private colleges in the greater Montreal area. With orders for 115 electric buses, including 70 LionC and 45 LionA buses, the company is one of the most ambitious school bus operators in Quebec in terms of school bus electrification. The company aims to electrify 75% of its fleet by 2030 and is developing the means to do so.

Autobus Séguin has already tested several electric buses and has found that the vehicle maintains a range of at least 145 km, even in winter. After covering the scheduled routes, the bus usually returns to the garage with almost 50% of its charge remaining. There have never been any issues related to the routes.

The company called on Cléo for assistance with the integration of the charging and electrical distribution infrastructure. Cléo designed a container to supply up to 22 charging stations. There are currently 12 charging stations in use. The others will be installed when the new electric vehicles are in the garage. The agreement between Autobus Séguin and Cléo provides for two additional charging stations to easily replace the existing stations in case they break.

Autobus Séguin's maintenance team consists of several mechanics, some of whom are qualified to perform maintenance on the electrical components of the buses. They say most of the problems encountered with electric buses are caused by small electronic components that need to be replaced with adapted equipment. To accommodate electric buses, Autobus Séguin had to make changes in the shop area by purchasing specific insulated tools for electric buses. Once the manufacturer received confirmation that this equipment had been purchased and received, it shared the necessary maintenance documents with the company.

To manage vehicle charging and operations, the group uses Cléo's smart platform as part of its pilot project with Autobus Séguin. The platform predicts the energy needs of vehicles and ensures reliable charging so that they can carry out their circuits at the lowest electricity cost.

Tips and resources

Advice from Stéphane Boisvert, President of Autobus Séguin, on successful electrification projects:

"The starting point for a good transition to electric starts with good strategic planning of the deployment plan, including the choice of vehicle and the selection of infrastructure needed in the future. A medium- to long-term vision for electrification is essential, as this will influence your infrastructure choices and deployment. Then, you can address the vehicle operations component and its challenges, hence the importance of selecting the right consultants, and there are more and more of them out there."

5.2 Project support resources

One of the important messages in this guide is that school bus operators are not alone in dealing with the major shift to electrification. Many experts are available to advise, guide and support them, taking into account the constraints faced by individual operators. In addition, manufacturers are developing a range of technical support services for each stage of implementation. It is now possible to seek opinions from several different specialists, which was very difficult until recently.

Similarly, there are more and more financing and grant opportunities to help electrification projects achieve a return on investment and thereby support the industry's development.

The lessons learned from members of the BCF's Electrification Committee that were compiled during the drafting of this guide reflect the willingness of association members to share the results of their projects, to identify the solutions put in place and to seek advice from the rest of the industry.

As a result, more and more resources are mobilizing to help operators with their energy transition and help streamline the energy transition throughout the province of Quebec.

Conclusions

With the availability of clean, inexpensive and reliable electricity, the electrification of school bus transportation presents many opportunities for Quebec's school bus operators. With this technology, operators can join the collective effort to reduce GHGs while maintaining the same level of service for students.

This guide highlights the key characteristics of electric buses compared to diesel buses.

> **When it comes to electrification, the same level of consideration must be given to the vehicles as to the charging infrastructure, operation management software, and conversion of buildings and maintenance shops. All three of these elements must be planned in a synchronized manner to ensure that electric buses can meet the needs of users.**

In assessing the different charging options available on the market, it appears that Level 2 charging during overnight parking will likely be the predominant strategy for transition projects, as it can meet the needs of most operators. Level 3 charging may satisfy the need for faster and more frequent charging, depending on the routes and required vehicle range, and for more redundancy, but this option remains expensive.

The after-sales and support services available in Quebec were also reviewed. The electrification market in Quebec is booming, leading to innovations that aim to reduce costs, increase efficiency and reduce emissions. Significant effort has been put into researching and developing batteries and battery recycling. Operators will be able to rely on these innovations to facilitate the integration of school buses over time. However, these innovations can only be useful and commercialized on a large scale if they are tested and phased in. Operators are therefore encouraged to be bold and show that they can meet the challenges of these new technologies with the help of a wide range of financing options. Quebec can position itself as a world leader in school bus electrification.

The purpose of this guide was also to outline the main steps for successful conversion to electric vehicles, including planning, pre-purchase questions, phased integration, building conversion and bus commissioning. These major steps can be used as guidelines and are key to understanding the extent of change and effort required for the transition.

Remember: you're not alone. All school bus operators in Quebec, big and small, have the opportunity to set an example across the province, in the regions, for families and future generations. Propulsion Québec's goal is to help the ecosystem shine and accelerate the energy transition for school bus operators. We hope this guide proves useful and will help you plan the next steps in your electrification journey.

Guide
TRANSPORTEUR+

propulsion Québec

Published in June 2022