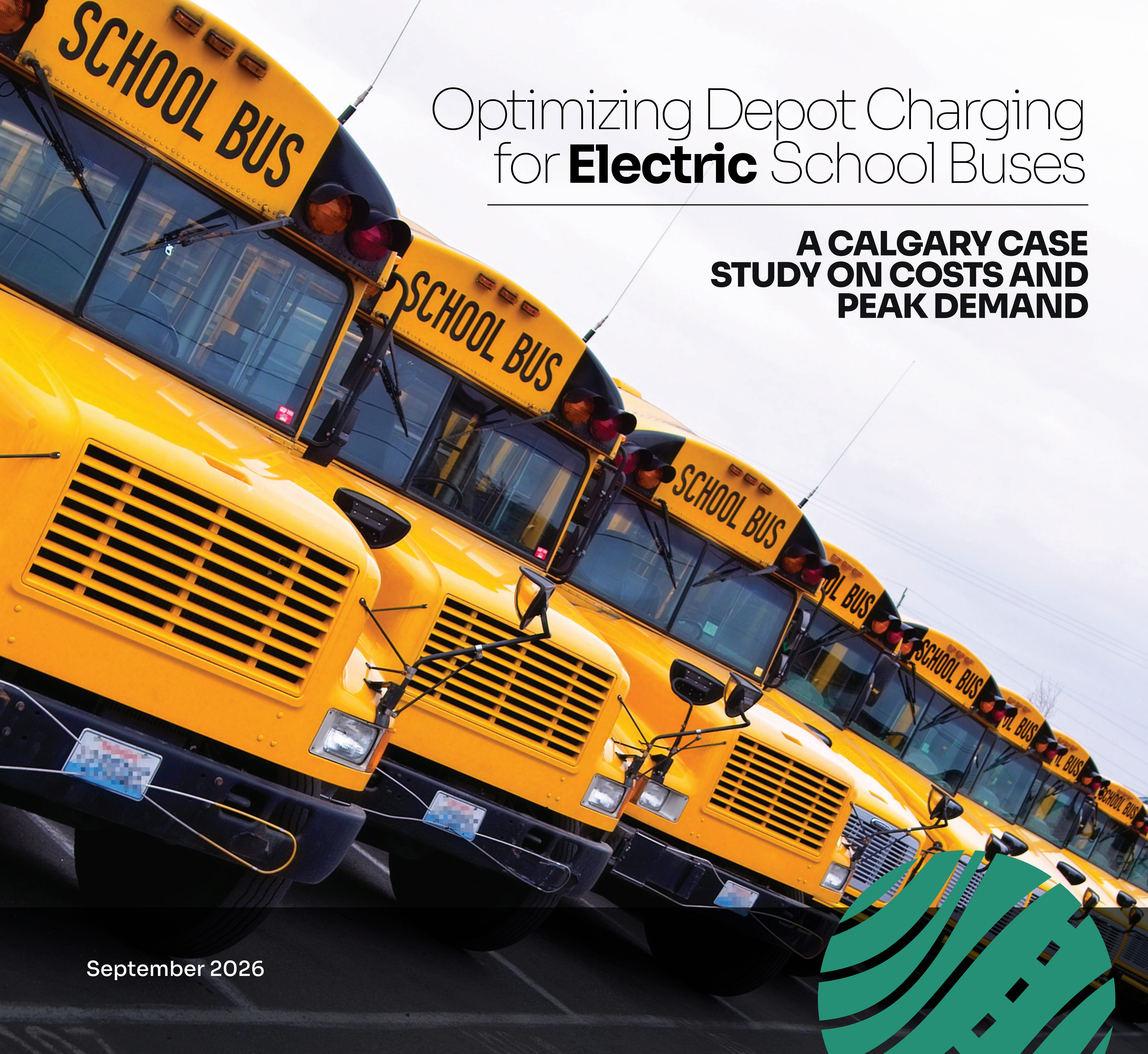
Optimizing Depot Charging for **Electric** School Buses

A CALGARY CASE STUDY ON COSTS AND PEAK DEMAND



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Pollution Probe

Pollution Probe

Pollution Probe is a Canadian charitable environmental organization that is a leading agent of change at the intersection of communities, health and environment. Since 1969, we have been defining environmental problems through research, promoting understanding through education and pressing for practical solutions through advocacy. Pollution Probe has a proven track record of working in successful partnership with industry and government to develop practical solutions for shared environmental challenges.

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

Mobility Futures Lab

Mobility Futures Lab

Mobility Futures Lab is a sustainable mobility research and advisory firm working at the intersection of transportation and energy. The organization develops data-driven transportation solutions through applied research, operational analytics, and proprietary software, including Amper, its smart charging management platform. Working with governments, non-profits, academia, and industry, it delivers projects spanning fleet operations, charging infrastructure planning, transportation policy, and market analysis.

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With 50+ years of combined experience working with non-profits, think tanks, 25+ utilities and government agencies across Canada, the RFS Energy team draws from unique experience rooted in on-the-ground program implementation to support clients and bring innovation to life.

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Southland Transportation

Founded in 1971, Southland Transportation is a leader in student transportation throughout Canada and a trailblazer in forward-thinking transportation solutions. Operating over 3500 routes daily, Southland understands the GHG impact of the transportation industry and is actively reducing emissions in the communities we serve. With Canada's largest alternative fuel fleet and a growing zero emissions fleet, Southland is creating a sustainable future for the students we deliver Safely Home each day.

Acknowledgements

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The project team extends its gratitude to Southland Transportation Ltd. for their valuable contributions, providing the required data and administrative support to the project.

Land Acknowledgement

With a focus on mobility in what is now known as Alberta – subject to Treaties 6, 7 and 8 – this project is inherently land-based. The project team recognizes the true history of these lands and the injustices that First Nations, Métis, and Inuit peoples continue to experience through colonial systems and structures. We acknowledge these lands as the traditional and ancestral territory of many peoples – the Blackfoot Confederacy–Kainai, Piikani, and Siksika – the Cree, Dene, Saulteaux, Nakota Sioux, Stoney Nakoda, the Tsuu T'ina Nation, and the Métis People of Alberta.

We encourage readers to learn about the Indigenous history of where they live and work and the Truth and Reconciliation Committee of Canada's Calls to Action. We invite you to reflect on your own relationship with the lands you occupy and what meaningful actions you can take toward reconciliation.

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List of Acronyms

AC	Alternating Current
BESS	Battery Energy Storage System
CAD	Canadian Dollars
DC	Direct Current
DCFC	Direct Current Fast Charger
ENMAX	Calgary-based electric utility (ENMAX Power Corporation)
kW	Kilowatt (unit of power)
kWh	Kilowatt-hour (unit of energy)
MFL	Mobility Futures Lab
MHDV	Medium- and Heavy-Duty Vehicle
PV	Photovoltaic (solar power)
TOU	Time-of-Use (electricity pricing structure)
V2G	Vehicle-to-Grid
ZETF	Zero Emission Transit Fund

Executive Summary

Electrification Context

This case study examines the electrification potential and charging infrastructure options for a 35-bus school depot in Calgary, Alberta. Analysis of route lengths, dwell times, and depot access found that 22 buses (63%) could be electrified under current operations without changes to schedules or routes, using 170 kWh usable capacity batteries. These buses have sufficient daily energy margins and dwell time to recharge using lower-power, lower-cost Level 2 chargers.

Electricity Pricing and Depot Capacity

Electricity costs for electric school bus charging are driven by two distinct factors: total energy consumption and peak power demand. Energy charges reflect how much electricity is used over time, similar to fuel consumption in a diesel fleet. Demand charges, however, are based on the highest level of power drawn at any moment during the billing period. At depots where multiple buses charge simultaneously, peak demand, not total energy use, often becomes the dominant cost driver.

As a result, the number of chargers, their power ratings, and whether charging sessions overlap can significantly affect both operating costs and required grid upgrades. Without coordination, even fleets using relatively low-power Level 2 chargers can trigger high demand charges. Managing when buses charge is therefore as important as determining how much energy they need.

Charging Strategies Evaluated

Two depot-based infrastructure strategies were modeled for the 22 electrifiable buses:

- **Non-Optimized Depot Charging** – Buses begin charging as soon as they are parked, regardless of time of day. This results in overlapping charging sessions, high evening demand spikes, and greater grid upgrade costs.
- **Optimized Depot Charging** – All buses charge at the depot, but charging is coordinated using smart scheduling software. Sessions are staggered and shifted to off-peak hours, reducing peak demand, lowering electricity costs, and minimizing infrastructure requirements.

Operational Insights

Smart charging at the depot substantially reduces both electricity demand and costs. By staggering charging sessions, peak demand fell from 336 kW (21 buses charging simultaneously) to 176 kW (11 buses charging simultaneously), cutting monthly demand charges by about $2,600 (≈$31,000 annually) and lowering grid upgrade requirements by $35,000. At the same time, shifting charging into off-peak hours reduced monthly energy charges by about $860 (≈$10,000 annually). Together, these reductions lowered the total monthly electricity bill by 38%.

While optimization requires charging management software, reliable internet connectivity, and staff training to ensure vehicles are plugged into the correct chargers, these added costs are modest compared with the financial savings.

Cost Findings

Over a 12-year service life, the Optimized Depot scenario costs about $1.01 M, compared with $1.52 M under the Non-Optimized scenario, a difference of more than $500,000 (≈34%). The savings are driven mainly by avoided demand charges and reduced energy costs, alongside lower grid upgrade expenditures. Even after accounting for charging management software costs (~$50k–80k over 12 years), the optimized case remains clearly the lower-cost option.

For context, a comparable diesel fleet would consume $1.8–2.5 M in fuel over 12 years, roughly twice the cost of the Optimized Depot Charging scenario. Electrification thus delivers substantial fuel savings when deployed efficiently, though the higher upfront purchase price of electric school buses remains a barrier. These vehicle costs are expected to decline over time as production scales and technology improves.

Conclusion

This analysis shows that the key to scaling charging infrastructure cost-effectively at a depot lies in right-sizing the system and optimizing how it is used. Through careful route selection, smart scheduling, and strategic deployment of chargers, fleets can reduce both upfront infrastructure costs and ongoing electricity expenses. Depot-based charging also provides a foundation for future upgrades such as battery energy storage, solar PV, or vehicle-to-grid (V2G), which will become increasingly important as fleets scale. By taking this approach, operators can build a charging system that is financially sustainable, adaptable to growth, and supportive of reliable, zero-emission school transportation.

1 Introduction

The electrification of medium- and heavy-duty vehicles (MHDVs) is accelerating, and school buses are among the fastest-growing applications. Their more predictable daily routes and consistent schedules make them well-suited for battery-electric technology. However, one of the largest barriers to widespread adoption remains the high cost of deploying charging infrastructure and managing ongoing electricity expenses. Fleets must carefully plan their charging strategy, particularly for electric school buses that will charge at the depot.[1]

This analysis focuses exclusively on depot-based charging and does not consider overnight charging at drivers' homes or other off-site locations. While home-based charging can be viable in some school bus operations, it typically relies on residential electricity tariffs that do not include demand charges, with costs and constraints instead arising from residential electrical upgrades, utility coordination, driver participation, and program administration.

Installing depot charging infrastructure involves multiple considerations, including space constraints and, more critically, the available power capacity at the site. In many cases, depots require costly and time-consuming grid upgrades to support high-power charging. Additionally, charging stations come in various power levels with different costs, and the way buses are scheduled to charge, both in terms of timing and load distribution, can significantly affect a fleet's monthly electricity costs.

To minimize costs and optimize operations, fleets need to account for key factors when designing charging infrastructure. Networked or "smart" chargers offer internet connectivity that enables remote monitoring, scheduling, and optimization of charging sessions. Unlike basic chargers that deliver a fixed output immediately upon plug-in, networked chargers can schedule power delivery in line with fleet needs and utility cost structures. As this report will show, leveraging charging management software is critical to reducing electricity costs, as it balances charging schedules and helps avoid costly demand peaks.[2]

This report uses a Calgary-based school bus fleet as a case study, made possible through a partnership with Southland Transportation, which provided access to operational data and fleet insights. The analysis centers on a 35-bus depot and highlights how smart charging strategies can significantly reduce both operating costs and infrastructure requirements. Mobility Futures Lab (MFL) led the technical analysis, leading scenario design and cost modeling using proprietary software tools.

This report delivers practical guidance for fleet operators, policymakers, and stakeholders on planning, optimizing, and scaling charging infrastructure for electric school buses.

1 Callstart (2021). Taking commercial fleet electrification to scale: financing barriers and solutions. Retrieved from: https://calstartconnect.org/nas/calstartconnect.org/files_upload/3/Taking-Commercial-Fleet-Electrification-to-Scale-White-Paper.pdf

2 US DOE (2025). Flipping the Switch on Electric School Buses: Infrastructure Planning and Solutions. Retrieved from: https://afdc.energy.gov/vehicles/electric-school-buses-p5-m2

2 School Bus Fleet Profile and Electrification Potential

The fleet evaluated in this study currently consists entirely of diesel-powered school buses. Operational telematics data from these vehicles are used to assess route characteristics, dwell times, and energy requirements in order to evaluate their suitability for potential future electrification, under various scenarios.

The school bus industry operates under unique conditions that directly impact electrification planning. While routes are generally perceived as stable and repetitive, real-world operations reveal more variability. Route variations can occur due to:

- **Daily Fluctuations:** Student absences, substitute driver assignments, or road detours.
- **Seasonal Adjustments:** Winter conditions, early dismissals, or exam schedules.
- **Extracurricular and Special Events:** Field trips, sporting events, or after-school programs that extend daily energy use.

These factors make it critical for fleet operators to design charging infrastructure that can accommodate flexible and occasionally unpredictable energy needs. Charging strategies must account for buses that may return to the depot later than expected or require more energy than standard route projections suggest.

2.1 Operational Characteristics

This case study focuses on a fleet of 35 school buses operating from a central depot in Calgary, Alberta. Like most school bus fleets, vehicles typically perform two daily runs: one in the morning to drop students off at school, and one in the afternoon to bring them home. Between these runs, buses are either parked at the depot or remain off-site, depending on operational needs and driver preference.

In this case study, actual patterns vary across the fleet. Some buses return to the depot mid-day, allowing for potential mid-day charging opportunities, while others remain parked elsewhere until the afternoon run.

Figure 1 illustrates how often buses in the 35-vehicle fleet return to the depot mid-day:

- 26% of vehicles (9 buses) consistently return to the depot mid-day, providing a predictable window for charging.
- 40% of vehicles (14 buses) never return mid-day, remaining off-site between runs.
- 34% of vehicles (12 buses) show variable behavior, returning on some days but not others.

These findings highlight that mid-day charging opportunities are uneven across the fleet. Buses that consistently return to the depot can be prioritized for mid-day charging, while those that never or only occasionally return must be scheduled to complete their daily routes on a single overnight charge.

In addition to mid-day depot access, the total time each vehicle is parked per day, its dwell time, plays a key role in determining charging strategy. Buses with longer dwell windows, whether overnight or with mid-day gaps, can use slower, lower-cost chargers by spreading charging over more hours.

Figure 2 shows the cumulative distribution of daily vehicle dwell times. This curve represents the proportion of buses parked at the depot for up to a given number of hours per day—that is, the total time each vehicle is available for charging. Most buses in the fleet have long dwell times, with over 90% parked between 11.5 and 14 hours per day. These windows include both overnight parking and mid-day returns, creating multiple opportunities for charging.

This tight distribution, clustered around 12 hours, suggests that many vehicles are well-suited to overnight or combined overnight/mid-day charging. Whether this is sufficient, however, depends on daily energy needs and charger power levels. Longer dwell windows enable greater reliance on lower-cost chargers, while higher-use vehicles may still require faster charging to maintain operational readiness.

Figure 1: Mid-Day Return Frequency of Vehicles.

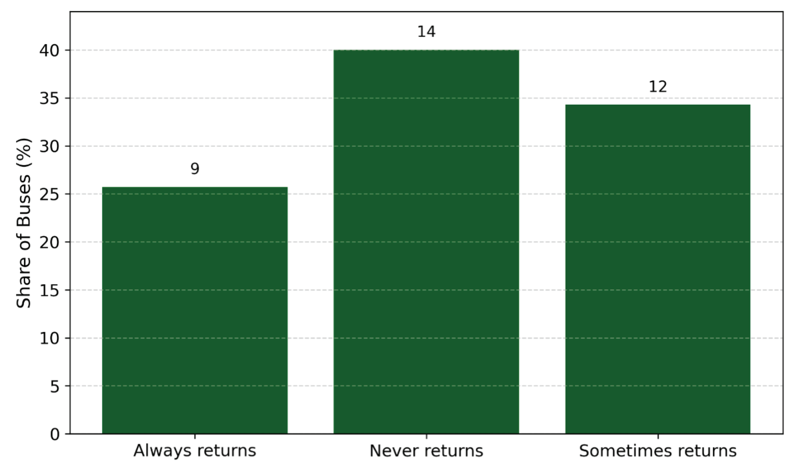
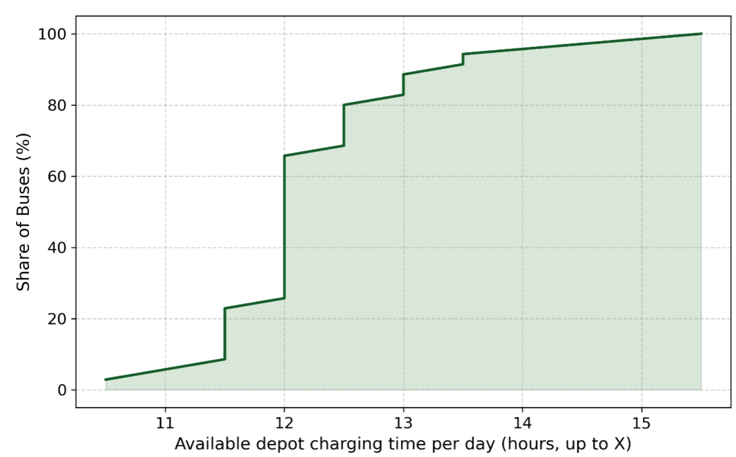


Figure 2: Share of Buses by Available Depot Charging Time (Up to Each Hour)



2.2 Energy Use and Electrification Potential

To estimate the electrification potential of the evaluated fleet, each bus's route and dwell time were analyzed alongside simulated energy consumption data. The analysis assumes a 170-kWh usable battery capacity per electric school bus, reflecting the upper range of battery sizes currently available in the market, and accounts for worst-case conditions, including winter performance reductions specific to Calgary's cold climate.[3]

Each vehicle was categorized as follows:

Electrifiable – The vehicle's daily duty cycle can be supported by either a single overnight charge or a consistent mid-day top-up at the depot.

Non-Electrifiable – The vehicle's daily duty cycle cannot be met under current routing and depot access conditions within the assumed battery capacity, without operational changes or the use of a larger battery.

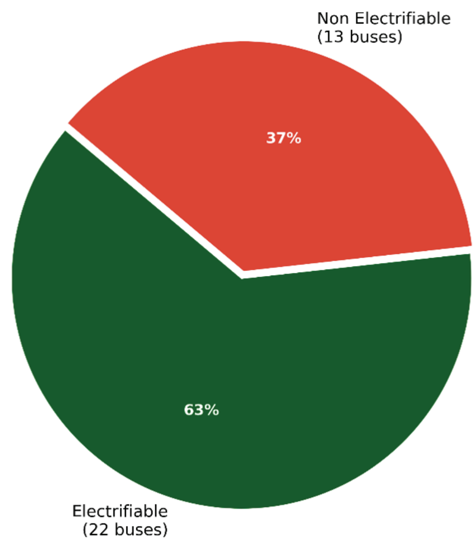
3 Pollution Probe (2024). Electric School Bus Operational Assessment: A Calgary Demonstration Case Study. Retrieved from: https://www.pollutionprobe.org/electric-school-bus-operational-assessment-a-calgary-demonstration-case-study/

In other words, even if a vehicle can complete its routes on most days of the year, it is considered non-electrifiable if it exceeds the energy capacity of a 170-kWh battery on a single extreme-weather day, under current operating conditions.

As shown in **Figure 3**, 63% of vehicles (22 buses) are considered electrifiable under current routing and charging conditions. The remaining 37% (13 buses) are classified as non-electrifiable due to one or more of the following factors:

- Daily duty cycles that exceed available range under extreme weather
- No mid-day return to the depot
- Insufficient stop time to support meaningful mid-day charging

Figure 3: Electrification Potential of Fleet Vehicles



These results underscore the importance of evaluating not only energy needs, but also route design and depot access patterns when planning for full fleet electrification. It is important to note that this analysis reflects current operations without modifying or removing existing responsibilities, such as extracurricular trips or event shuttles. This conservative approach helps illustrate how much of the fleet could realistically be electrified today, without requiring operational restructuring.

The portion of the fleet that is electrifiable is used to inform the infrastructure planning scenarios explored in the following sections, where we assess how depot-based charging models impact total cost, grid requirements, and electricity consumption.

3 Charging Infrastructure Considerations

Transitioning to an electric school bus fleet requires careful infrastructure planning. The number of buses to be electrified, their daily energy needs, and the available site power capacity all influence what types of chargers are needed and how charging should be managed. This section outlines the key technical factors that shape infrastructure deployment, electricity costs, and operational feasibility.

3.1 Charger Types and Power Levels

Charging infrastructure for electric school buses typically falls into two categories: Level 2 alternating current (AC) chargers and Level 3 direct current fast chargers (DCFC). While DCFC units enable rapid turnaround, they involve substantially higher equipment and installation costs and may require major utility upgrades to accommodate their greater power draw.

The appropriate charger type depends on several key factors:

- **Daily energy demand** – Based on route length, terrain, climate, and duty cycle.
- **Available dwell time** – Longer parked time allows for the use of lower-power, lower-cost chargers.

Table 1 summarizes commonly used charger types, their power ratings, estimated installed costs (including hardware, permitting, and site work), and the time required to fully charge the usable 170-kWh capacity of a battery.

Installed costs vary significantly depending on site-specific conditions such as electrical layout, trenching requirements, and permitting complexity. In multi-charger deployments, economies of scale can reduce per-unit costs, particularly for shared tasks such as conduit runs and service upgrades.

Table 1: Charger Types, Power Levels, and Installed Costs [4].

Charger Type	Power Level (kW)	Estimated Installed Cost ($ CAD) [5]	Full Charge Time (170 kWh)[6]	Typical Use Case
Level 2 AC (Standard)	8 kW	$2,000 – $6,000	~21 hours	Low-usage buses with long dwell periods
Level 2 AC (High-Power)	19.2 kW	$6,000 – $12,000	~9 hours	Overnight depot charging
DC Fast Charger	22 kW	$25,000 – $40,000	~7.7 hours	Mid-day top-up at depot
DC Fast Charger	50 kW	$60,000 – $120,000	~3.4 hours	High-utilization vehicles with limited dwell time

4 TRC Companies (2019). Electric Vehicle Charging Guidebook For Medium- and Heavy- Duty Commercial Fleets. Retrieved from: https://www.trccompanies.com/insights/electric-vehicle-charging-guidebook-for-medium-and-heavy-duty-commercial-fleets/

5 Estimated installed cost includes charger hardware, electrical installation, permitting, and site-specific upgrades.

6 Charging times assume a usable battery capacity of 170 kWh and chargers operating at their full rated output. In practice, charging rates may be lower depending on the amp service available and site-specific electrical constraints.

The costs shown in **Table 1** include typical installation expenses but exclude major grid upgrades such as transformer replacements or new service connections. Where sufficient electrical capacity already exists, a limited number of Level 2 chargers can be deployed at relatively low cost. By contrast, large-scale or high-power charging installations generally require utility coordination and potentially expensive grid upgrades, particularly in the case of DC fast charging.

In addition to installation, operators must account for ongoing maintenance. Like any infrastructure, charging stations require regular upkeep, with maintenance costs typically estimated at approximately two percent of station capital costs annually.

3.2 Electricity Pricing and Depot Capacity

Charging electric school buses involves more than simply plugging them in. Total charging costs and feasibility depend on both the available power capacity at the depot and the structure of electricity pricing.

3.2.1 Cost Drivers

Electricity bills typically include two major components for fleet operators[7]:

Energy Use (kWh) – The total electricity consumed over a billing cycle—similar to the number of litres of diesel a conventional bus fleet would use.

Peak Power Demand (kW) – The highest power draw recorded during the billing period. This represents the "width of the hose"—the more buses charging at once, the more electricity is needed instantly, which drives up demand charges.[8]

These demand charges can significantly increase monthly electricity bills, especially when high-power DC fast chargers are used without smart charging strategies.

3.2.2 Electricity Pricing in Calgary

In Alberta's deregulated electricity market, fleet operators can choose among several energy retailers, each offering different rates and contract structures for the energy portion of the bill. However, distribution and demand charges are fixed by the local utility (ENMAX in Calgary) and apply regardless of the energy retailer chosen.

This case study assumes a depot located in Calgary operating under the ENMAX D310 tariff, which applies to large commercial customers receiving secondary voltage service.[9]

Key features of the D310 tariff include:

- Time-of-Use (TOU) Energy Pricing (energy-only rates):
  - Peak (Weekdays 5–9 PM): ~11.23 ¢/kWh
  - Mid-peak (Weekdays 7–9 AM, 11 AM–5 PM, 9–11 PM): ~8.58 ¢/kWh
  - Off-peak (All other hours, including weekends): ~5.29 ¢/kWh
- Demand charge: $16.3/kW

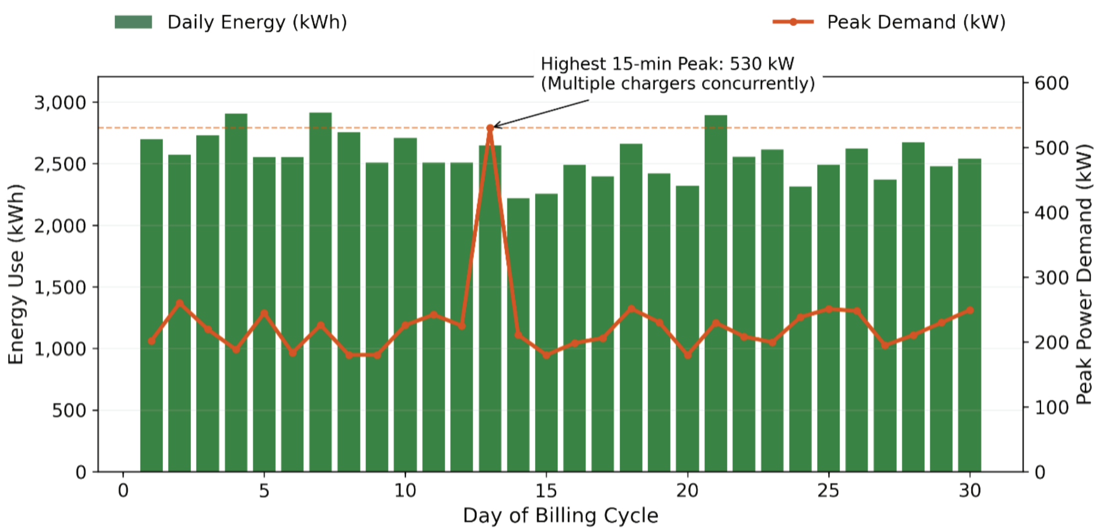
Figure 4 presents an illustrative example of these cost drivers for a 20-bus depot. Based on realistic operating assumptions (not actual study data), daily energy use (green bars) averages ~2,600 kWh/day (≈78,000 kWh/month), producing ~$5,460 in energy charges at a blended 7 ¢/kWh. Peak demand (orange line) stays around 220–260 kW except for one day when multiple DC fast chargers run simultaneously, hitting 530 kW. Because demand charges are set at ~$16.3 per kW of the highest recorded demand in the billing period, that one event increases the demand portion of the bill from roughly $4,050 to about $8,586 — effectively doubling the monthly demand cost.

7 NACFE (2019). Amping up: Charging Infrastructure for Electric trucks. Retrieved from: https://nacfe.org/research/emerging-technologies/electric-trucks/charging-infrastructure/

8 Peak power demand is calculated using the facility's non-coincident peak (i.e., the maximum demand of the site itself) rather than the utility's system-wide peak.

9 ENMAX (2025). Tarrifs. Retrieved from : https://assets.enmax.com/api/public/content/7ed7e419f7ce4c79a5965239533f58bd?v=d05447a6

Figure 4. Daily Energy Use and Peak Demand (Illustrative 20-Bus Depot)



3.3 Cost Management Strategies

The type of charger selected and the local tariff structure establish the baseline for costs, but fleet operators have several levers they can pull to reduce both upfront and ongoing expenses. These levers fall into three categories: operational strategies, utility coordination, and financial support.

3.3.1 Smart Charging and Load Management

One of the most effective tools is smart charging. By connecting depot chargers to a management platform, operators can control when and how vehicles are charged.[10] Instead of all buses plugging in simultaneously and driving up peak demand, charging sessions can be staggered throughout the night. This reduces the maximum power drawn from the grid, lowers demand charges, and often avoids the need for costly service upgrades. Smart charging systems can also shift energy use into off-peak periods when electricity rates are lower, while still ensuring that every vehicle is ready for its next route.

Implementing smart charging, however, requires more than just enabling a software feature. Chargers must be networked reliably to the internet, either through wired or cellular connections, so the system can adjust schedules in real time. Depot staff play a role too: buses need to be parked and plugged into the correct chargers each day to follow the optimized schedule. Charging management platforms are usually subscription-based, adding a modest recurring cost, and depots need designated staff to monitor dashboards, troubleshoot offline chargers, and adjust settings when operating conditions change. In other words, smart charging is not just a technical upgrade but an operational system that integrates hardware, software, and staff roles.

For many fleets, this operational layer can be delivered as a turnkey service, where a third party connects to charger and vehicle telematics, configures the smart-charging logic, and monitors performance to ensure schedules are followed and optimized over time.

10 TRC Companies (2019). Electric Vehicle Charging Guidebook For Medium- and Heavy- Duty Commercial Fleets. Retrieved from: https://www.trccompanies.com/insights/electric-vehicle-charging-guidebook-for-medium-and-heavy-duty-commercial-fleets

3.3.2 Utility Engagement and On-Site Solutions

Equally important is early and proactive engagement with the local utility. Depot capacity constraints can dictate not just the number and type of chargers that can be installed, but also the pace of fleet electrification. Since major grid upgrades may take years to complete, involving the utility at the outset reduces the risk of project delays. Some fleets may also consider on-site generation or storage, such as solar photovoltaic systems paired with batteries. These systems can reduce dependence on the grid, help shave peak demand, and improve resilience, particularly if they are integrated with smart charging controls.[11]

3.3.3 Funding and Incentives

Finally, financial support programs can offset much of the upfront cost burden. In Canada, the Zero Emission Transit Fund (ZETF) covers vehicles, charging infrastructure, installation, and related grid upgrades.[12] For many fleets, this funding has been a decisive factor in moving projects forward. However, the program has now concluded. Future deployments may need to rely on provincial funding opportunities, private financing, utility programs, or internal capital budgets, making long-term financial planning even more critical.

11 California Energy Commission (2023). Blueprint for Medium- and Heavy-Duty Zero Emission Vehicle Infrastructure: Lowest Cost to Charge for Stockton Unified School District. Retrieved from: https://www.energy.ca.gov/publications/2023/blueprint-medium-and-heavy-duty-zero-emission-vehicle-infrastructure-lowest-cost

12 Infrastructure Canada (2025). Zero Emission Transit Fund. Retrieved from: https://housing-infrastructure.canada.ca/zero-emissions-trans-zero-emissions/index-eng.html

4 Depot Charging Scenarios

This section compares two charging strategies for the 22 electrifiable buses identified in the Calgary analysis. Each scenario accounts for:

- **Charging Equipment & Installation —** purchase and installation of depot chargers, networking, and commissioning.
- **Grid Upgrades —** transformer and service upgrades at the depot required by each scenario's peak demand.
- **Electricity: Energy Charges —** kWh consumption priced under the relevant tariff.
- **Electricity: Demand Charges —** peak kW charges

Depot electricity pricing is based on ENMAX's D310 time-of-use (TOU) tariff (**Figure 5**). Grid upgrade estimates are derived from modeled peak demand levels under each scenario.

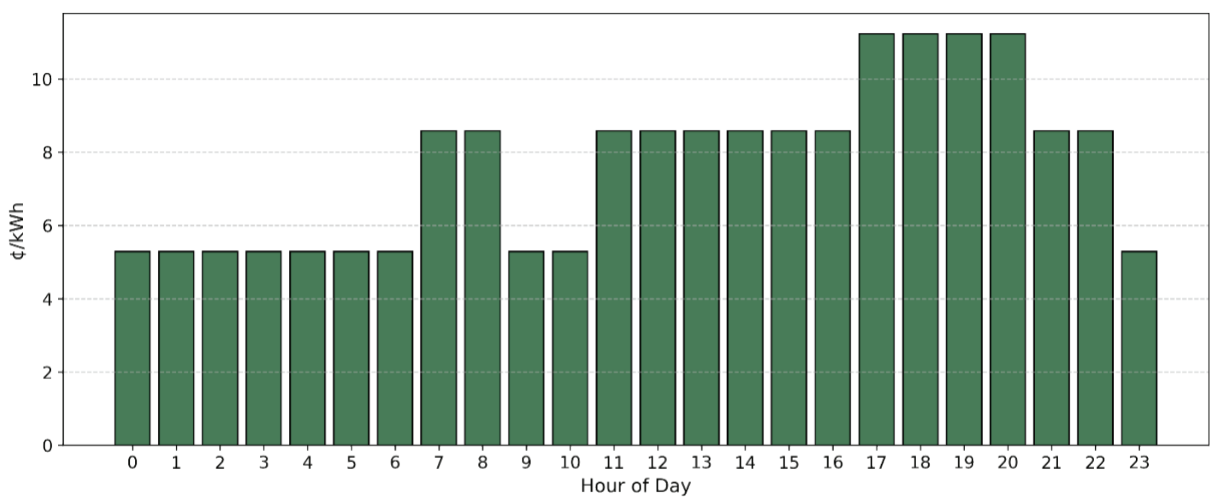
For both scenarios, it is assumed that all 22 buses charge at a central depot. Each bus is assigned a Level 2 (19.2 kW) charger, which was determined to be sufficient to meet daily energy needs without the use of DC fast charging. The primary difference between the scenarios lies in how charging sessions are managed.

The two modeled strategies are:

Non-Optimized Depot Charging: Buses begin charging immediately upon returning to the depot, regardless of the time of day. This results in overlapping charging sessions, higher peak demand, and an increased likelihood of costly grid upgrades.

Optimized Depot Charging: Charging is centrally coordinated using smart scheduling software. Sessions are staggered and shifted into off-peak hours, lowering peak demand, reducing electricity costs, and minimizing the scale of required infrastructure upgrades.

Figure 5: Time-of-Use Electricity Pricing (ENMAX D310 Tariff)



4.1 Non-Optimized Charging

In this scenario, buses begin charging as soon as they are parked at the depot, regardless of the time of day. Because many buses return at the same time after the afternoon run, charging sessions overlap heavily, creating a sharp evening demand spike.

This unmanaged approach results in:

- High simultaneous power demand, triggering more extensive grid upgrades.
- Elevated monthly demand charges, since billing is set by the single highest 15-minute draw.
- Minimal operational complexity, as no charging management software and staff training is required.

The modeled demand profile shows a peak of 336 kW at 7:00 PM, when 21 buses are charging simultaneously.

4.2 Optimized Charging

In this scenario, all buses charge at the depot, but sessions are coordinated using smart scheduling software. The system staggers charging and shifts demand into off-peak hours, ensuring vehicles are ready for service while minimizing costs.

This coordinated approach results in:

- Lower peak demand, reducing both grid upgrade requirements and demand charges.
- Reduced electricity bills by shifting charging into lower-cost TOU periods.
- Moderate operational complexity, requiring software setup, monitoring, and staff training.

The modeled demand profile shows a peak of 176 kW at 12:30 AM, with no more than 9 buses charging at once.

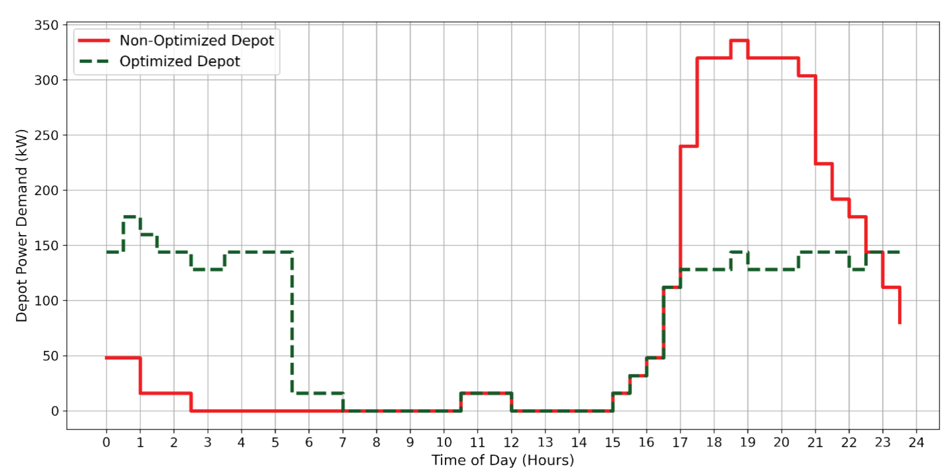
4.3 Comparative Cost and Demand Impacts

While the charging hardware is identical in both optimized and non-optimized scenarios, the way charging is managed has major implications for overall costs. The differences emerge not from the equipment itself but from the downstream impacts on the electrical system and utility bills. In particular, unmanaged charging drives higher peak loads, which can require more extensive grid upgrades and trigger steep monthly demand charges. By contrast, optimized charging reduces peak demand and shifts consumption into lower-cost periods, cutting both grid upgrade requirements and ongoing electricity expenses. The following subsections compare these impacts in terms of power demand, monthly and capital costs, and long-term lifecycle savings.

4.3.1 Depot Power Demand

Figure 6 shows the modeled hourly depot power demand for both approaches. In the non-optimized scenario, peak demand reaches 336 kW at 7:00 PM, when 21 of the 22 buses begin charging simultaneously after their afternoon run. In contrast, the optimized scenario limits peak demand to 176 kW at 12:30 AM, with no more than 9 buses charging at once.

Figure 6: Depot Daily Charging Demand Profiles: Non-Optimized vs. Optimized



This nearly 50% reduction in peak demand has two direct financial consequences: it lowers the one-time grid upgrades required to support the depot and reduces the recurring monthly demand charges on the utility bill. These differences in peak load are the main drivers of the cost outcomes summarized in **Table 2**.

Table 2: Depot Charging Costs Under Non-Optimized and Optimized Scenarios

Cost Component	Non-Optimized Depot	Optimized Depot	Percent Change
One-Time Grid Upgrades	$100,000	$65,000	-35%
Monthly Energy Charges	$3,618	$2,760	-24%
Monthly Demand Charges	$5,477	$2,869	-48%

4.3.2 Capital and Operating Costs

The demand differences shown in **Figure 6** translate directly into cost outcomes. **Table 2** summarizes how peak load reduction lowers grid upgrade needs and utility charges under the optimized scenario.

Optimization reduces costs across all three categories. Grid upgrades fall by $35,000 (35%), reflecting the lower peak demand the depot must be designed for. Monthly energy charges drop by $858 (24%) as charging is shifted into cheaper off-peak hours. Demand charges decline most dramatically, falling by $2,608 (48%) due to staggered charging.

When combined, the total monthly electricity bill falls from $9,095 under non-optimized charging to $5,629 under optimized charging — a saving of $3,466 per month (38%), or more than $41,000 annually. Importantly, optimization also changes the structure of the bill: in the unmanaged case, demand charges dominate at nearly 60% of monthly costs, while in the optimized case demand and energy are more balanced, making expenses more predictable.

Operating smart charging does require new routines. Software licensing typically costs $15-25 per bus per month, or about $4,000-7,000 annually for the 22-bus depot. Even after accounting for these expenses, the net savings remain an order of magnitude larger, making optimization highly cost-effective. The approach does, however, require chargers to maintain reliable internet connections, drivers to plug into designated stalls, and managers to actively monitor dashboards to ensure readiness for service.

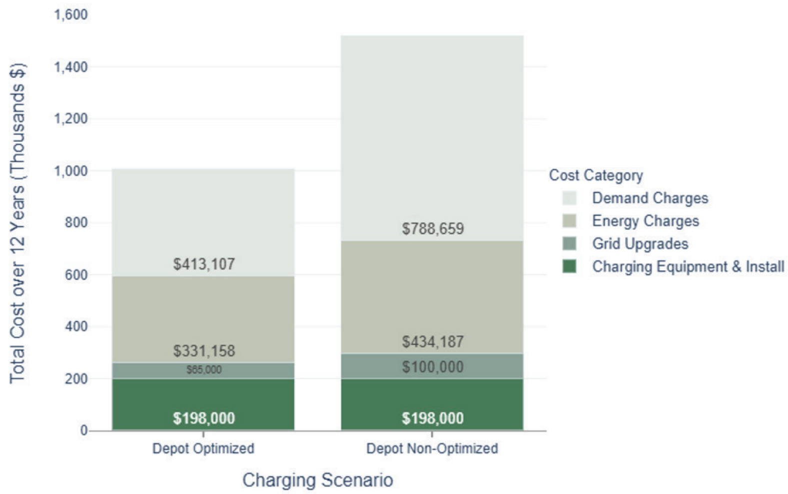
4.3.3 Lifecycle Cost Comparison

The monthly and annual savings outlined above compound significantly over the service life of the fleet. Although upfront capital costs often dominate planning discussions, evaluating charging strategies over a 12-year horizon shows the significant impact of ongoing demand and energy charges. **Figure 7** compares the total non-discounted lifecycle costs of Depot Optimized and Depot Non-Optimized Charging for the same fleet of 22 buses.

The results show that optimized charging delivers substantial financial benefits. Total costs under the Optimized Depot scenario are about $1.01 million, compared to $1.52 million under the Non-Optimized scenario — a reduction of more than $500,000 (≈34%) across the service life of the fleet. The savings are driven mainly by sharply lower demand charges ($376,000 avoided) and smaller grid upgrades ($35,000 avoided), with additional reductions in energy costs achieved by shifting charging into lower-cost overnight hours. Equipment and installation costs remain constant between the two cases, underscoring that the difference arises from how charging is managed rather than the hardware itself.

Optimized charging does introduce an additional line item: the cost of charging management software. For a 22-charger depot, subscription and connectivity fees are expected to total about $50,000–80,000 over 12 years. While this narrows the margin slightly, it represents only a fraction of the avoided utility charges.

Figure 7: 12-Year Lifecycle Cost Comparison: Non-Optimized vs. Optimized Depot Charging



Beyond the direct savings, optimized charging creates a foundation for future depot upgrades such as battery energy storage systems (BESS), solar PV, backup generation, or vehicle-to-grid (V2G). While these technologies can technically be added to any depot, their ability to reduce peak demand, defer upgrades, and support resilience depends on having predictable and controllable charging patterns. Unmanaged charging makes it much harder to coordinate these resources effectively, whereas optimized charging enables them to meaningfully lower system costs and support long-term scalability.

The analysis shows that optimized charging cuts peak demand nearly in half, reduces monthly electricity costs by almost 40%, and lowers total lifecycle expenditures by more than $500,000, making smart scheduling a decisive factor in the long-term economics of depot electrification.

4.3.4 Diesel Benchmark for Context

While this study focuses on comparing electric charging strategies, it is useful to benchmark these results against the cost of operating a conventional diesel school bus fleet. Fuel represents the largest ongoing operating expense for diesel school buses, and serves as an important reference point for the total cost of ownership.

A typical Type C school bus consumes approximately 25–35 litres of diesel per 100 km.[13] Based on the operational profile of this fleet—2,213 km per active day, over 190 days per year—the 22-bus fleet travels about 420,470 km annually. This corresponds to a total diesel consumption of approximately 105,000–147,000 litres per year. At a conservative long-term diesel price of $1.40/L, annual fuel costs are in the range of $147,000–206,000 for the fleet.[14]

Over a 12-year period, this translates to $1.8–2.5 million in undiscounted fuel costs. By comparison, even under the Non-Optimized Depot Charging scenario, electricity costs (energy + demand) total about $1.22 million over the same period, with further reductions to $0.74 million in the Optimized Depot case.

This benchmark highlights that, regardless of charging strategy, electrification cuts fueling costs by more than half relative to diesel. In addition, electrification stabilizes costs by reducing exposure to global oil price volatility and allowing fleets to benefit from predictable electricity tariffs. Despite these savings, the upfront purchase price of an electric school bus remains higher than that of a diesel equivalent, though costs are expected to decline over time as technology matures and production scales increase.

13 Mobility Futures Lab (2024). AltFleet Economic Insight Tool. Retrieved from: https://altfleetinsight.mobilityfutureslab.ca/

14 Argonne National Lab (2023). Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool. Retrieved from: https://afleet.esia.anl.gov/afleet/

5 Conclusion

This case study of a Calgary school bus fleet highlights that charging infrastructure decisions must be grounded in local operational realities. The best candidates for electrification are routes with modest daily energy requirements and sufficient dwell time to fully recharge on lower-power, lower-cost chargers. In this fleet, 22 of 35 buses (63%) were electrifiable under current routing and depot access patterns without operational changes with a usable battery capacity of 170 kWh.

The comparison of non-optimized and optimized depot charging underscores the critical role of smart charging management in cost control. Without optimization, simultaneous plug-ins created evening demand spikes of 336 kW, driving higher grid upgrade requirements and monthly demand charges. With coordinated charging, the peak was reduced to 176 kW, cutting monthly demand charges by nearly $2,600 (≈$31,000 annually) and lowering overall electricity costs by 38%, while also reducing grid upgrade expenditures by $35,000. Over a 12-year service life, optimized depot charging lowers charging- and infrastructure-related costs by more than $500,000 (≈34%) compared with unmanaged charging.

Importantly, optimization transforms charging into an actively managed system. Charging management software and reliable connectivity are essential to scheduling sessions, monitoring performance, and ensuring buses are charged and ready each morning. This requires both modest ongoing subscription costs and operational discipline from staff, but the financial and operational benefits outweigh the added complexity.

Depot-based charging also provides the strongest foundation for long-term resilience and scalability. Centralized infrastructure makes it far easier to integrate BESS, solar PV, backup generation, or V2G, all of which can further reduce costs and improve reliability. These capabilities are difficult to implement effectively in unmanaged setups but will become increasingly important as fleets grow and grid pressures intensify.

Each fleet must weigh capital costs, electricity tariffs, depot ownership or lease terms, and long-term resilience needs. However, within the electrification pathway, this analysis shows clearly that smart, optimized depot charging is not only the lowest-cost strategy but also the most adaptable path forward. Once fleets begin to scale beyond a handful of vehicles, smart charging becomes increasingly important rather than optional. Early coordination with the local utility is also essential, as confirming available capacity and upgrade timelines upfront helps avoid costly delays and ensures charging plans are realistic and scalable.

However, the higher upfront cost of electric school buses remains the primary barrier to adoption today, and charging optimization addresses only the fueling and infrastructure side of the equation. As vehicle prices decline over time, fleets with reliable, well-managed charging systems will be positioned to capture benefits of electrification more quickly and at lower overall cost. Through thoughtful route selection, scheduling, and infrastructure deployment, school bus operators can materially reduce both capital and operating costs while enabling reliable zero- emission fleet operations.

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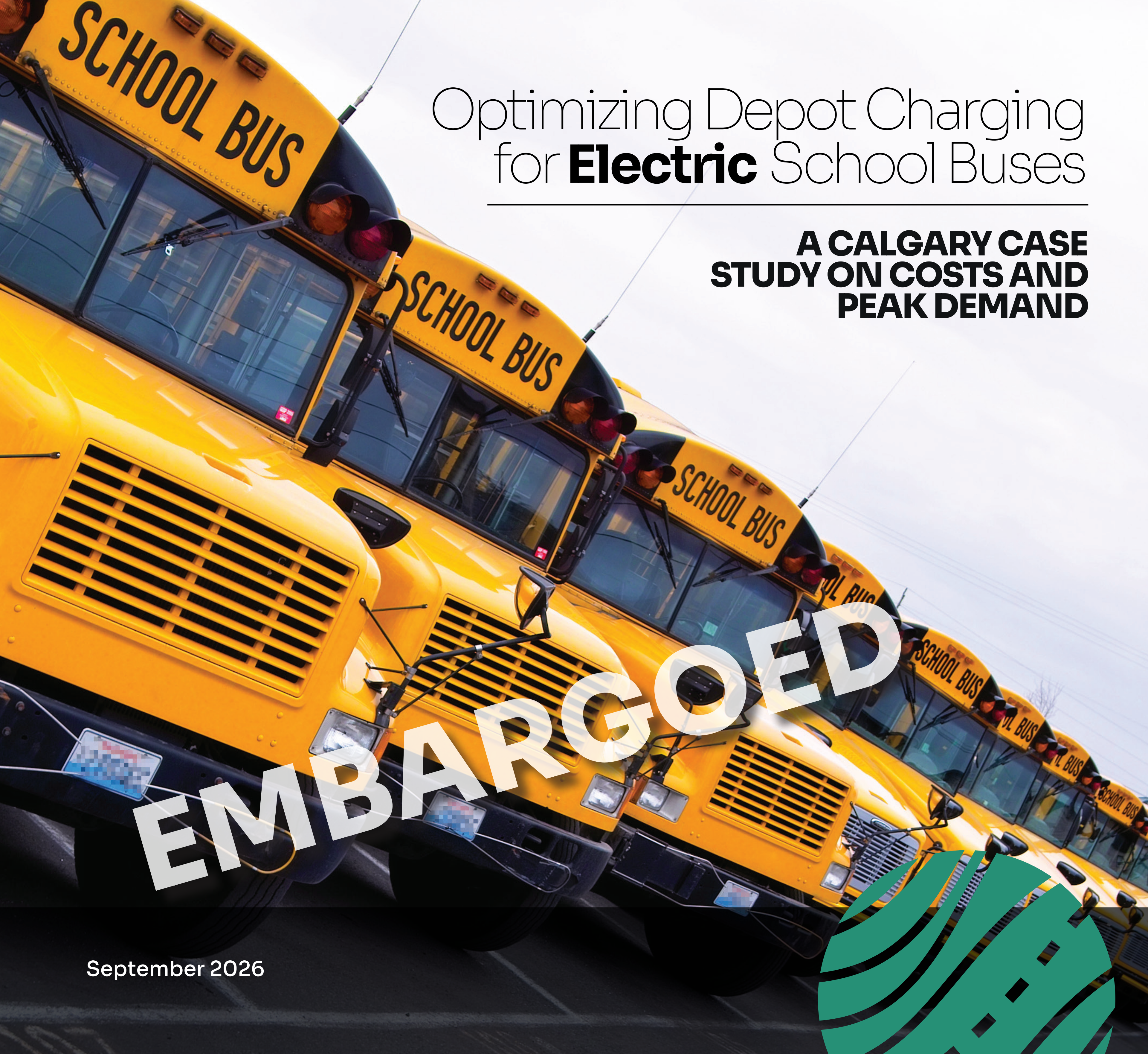

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