Green Fleet Best Practices Guide

Natural Resources Canada

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Glossary

AMP	Ampere
BEV	Battery-Electric Vehicle
CMS	Charging Management System
DC	Direct Current
DCFC	Direct Current Fast Charging
EMS	Energy Management System
ESS	Energy Storage System
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FCEV	Fuel-Cell Electric Vehicle
GHG	Greenhouse Gas
GoC	Government of Canada
HEV	Hybrid-Electric Vehicle
HVAC	Heating, Ventilation and Air Conditioning
ICE	Internal Combustion Engine
kVA	Kilo-Volt-Ampere
kW	Kilowatt
kWh	Kilowatt-Hour
LDV	Light-Duty Vehicle
MCS	Megawatt Charging System
MDBF	Mean Distance Between Failures
MHDV	Medium- and Heavy-Duty Vehicle
MVA	Megavolt-Ampere
NACS	North American Charging Standard
NRCan	Natural Resources Canada
NSS	National Safety and Security
OBD	On-Board Diagnostic
OCPP	Open Charge Point Protocol
OEM	Original Equipment Manufacturer
PHEV	Plug-In Hybrid Electric Vehicle
PPE	Personal Protective Equipment
RACI	Responsible, Accountable, Consulted, Informed
RCMP	Royal Canadian Mounted Police
RFID	Radio Frequency Identification
SAE	Society of Automotive Engineers
SoC	State of Charge
TCO	Total Cost of Ownership
V	Volt
ZEV	Zero-Emission Vehicle

About

Natural Resources Canada

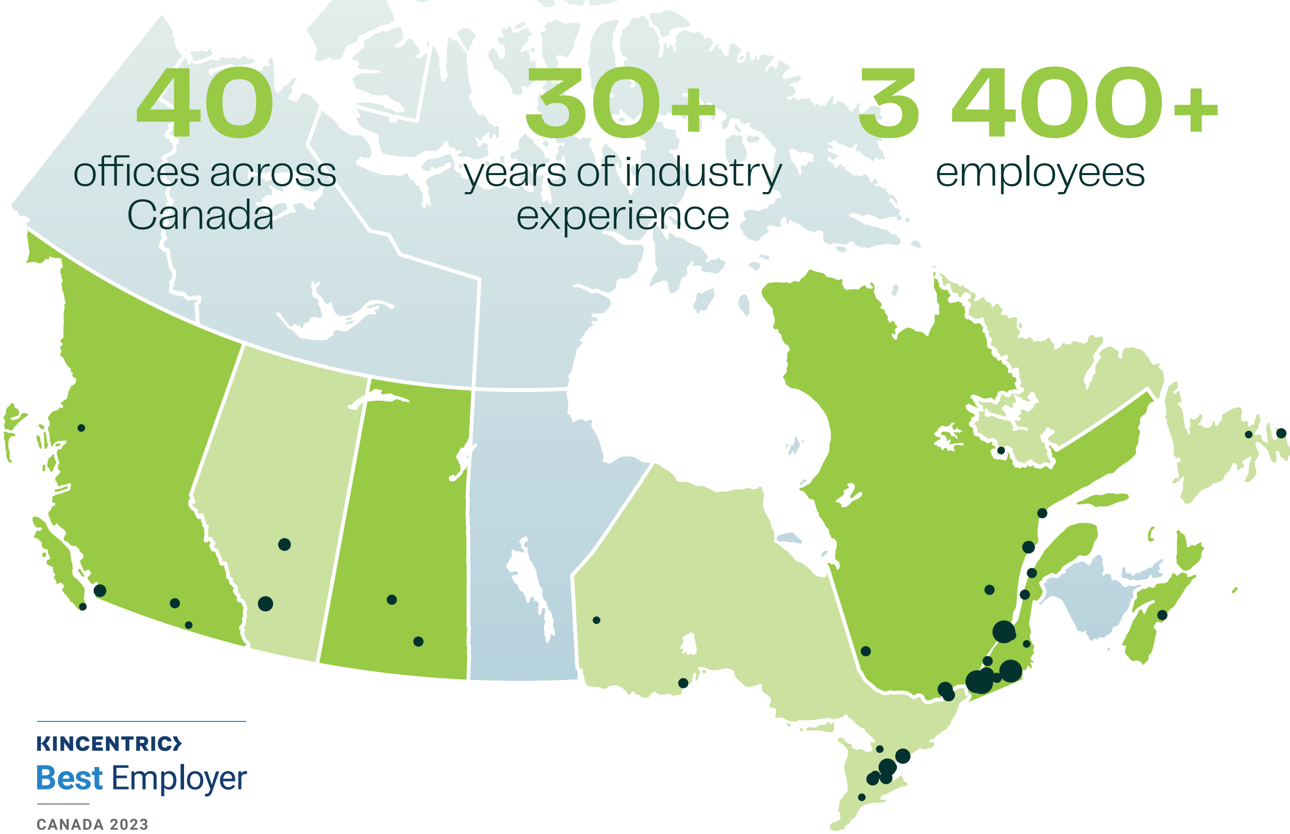
Natural Resources Canada's Greening Government Fleets Program helps federal organizations reduce their on-road greenhouse gas emissions by providing technical support for the planning and deployment of zero-emission vehicles and charging infrastructure in Government of Canada facilities. The program provides evidence-based analyses and consultation for the development of strategic fleet greening plans and works with fleet managers to find sustainable mobility solutions tailored to their operational needs.

CIMA+

CIMA+ offers comprehensive consulting engineering services in energy and resources, infrastructure, transportation, buildings, project management, digital technologies, and environmental solutions. Since 1990, our commitment to excellence has positioned us among Canada's largest private consulting firms, with 40 offices and over 3,400 employee-shareholders.

We are dedicated to sustainable solutions, believing that engineering is for people. Our expertise in fleet decarbonization includes 80+ specialists who have supported numerous fleet operators and facilitated the deployment of over 1,000 charging stations nationwide. [Our A-to-Z approach](#) covers strategy, design, procurement, systems engineering, change management, and construction oversight.

For more information, contact info@cima.ca or visit [cima.ca](#).



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Acknowledgements and Disclaimers

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Disclaimers

Fleet decarbonization is a broad and multidisciplinary endeavour that requires expertise from diverse backgrounds. This guide is primarily intended for fleet operators and managers directing decarbonization programs. It aims to provide up-to-date best practices and recommendations on how to effectively tackle fleet decarbonization projects and green fleet management more generally. The authors have strived to provide helpful and unbiased references based on information known at the time of publication to supplement certain sections when available.

The authors have deliberately chosen to maintain conciseness and relevance while offering sufficient technical depth where public information is lacking. While this guide cannot cover every aspect, it aims to highlight the information required to help ensure the successful implementation of a fleet transition to zero-emission vehicles.

Lastly, while this guide addresses all low-carbon and zero-emission technologies, it places a strong emphasis on electric vehicles and their related charging equipment. These technologies are expected to dominate fleet decarbonization over the next decade.

Executive Summary and Introduction

Executive Summary and Introduction

1 – Introduction

In 2022, the transportation sector accounted for 28% of Canada's greenhouse gas emissions with on-road transportation specifically accounting for 18% of national emissions. To achieve the goal of net-zero emissions by 2050, Canadians collectively need to turn to alternative forms of energy, including transitioning light, medium, and heavy-duty fleets to zero-emission vehicles across the country. For this transition, proactive fleet planning at vehicle, facility, and operational levels will be paramount.

While decarbonizing personal vehicles has its own set of challenges, fleet decarbonization comes with additional complexities due to varying operating configurations, range requirements, and the state of facility-level infrastructure which can often be undersized, outdated, and unable to meet the newest codes for installing alternative fuelling and charging equipment.

While this guide cannot offer a one-size-fits-all solution for fleet decarbonization, five necessary elements have been identified for a successful transition:

1. A clear commitment from the organization: This means setting clear, achievable targets and providing employees with the necessary time and resources to effectively tackle the transition to zero-emission vehicles.
2. Breaking down silos: Centralized collaboration between fleet, infrastructure, procurement, senior management, and other teams involved with decarbonization planning is integral, as decisions made by an individual group may have cross-cutting impacts.
3. Making decisions based on up-to-date information: With the rapidly evolving fleet management landscape, keeping apprised of improvements in vehicle technology, infrastructure, and data insight solutions are essential for long-term success.
4. Procuring vehicles and equipment that align with operational needs: Begin by prioritizing the replacement of internal combustion engine vehicles whose duty cycles can be performed with available zero-emission options. For segments of the fleet that are more difficult to decarbonize, develop a phased, data-driven plan for future vehicle replacements.
5. Planning for long-term success: The transition to ZEVs is never truly complete. Fleet managers must continually plan for future developments due to rapid advancements in vehicle performance and energy efficiency.

2 – Key Considerations for Fleet Transition Planning (Pre-Purchase Stage)

To ensure a smooth transition to zero-emission vehicles, fleet managers should assess their existing fleet composition and characterize current and future operational requirements. Tailored training programs should be developed internally to support change management and help operators and technicians adapt to new technologies. These programs should cover areas such as driving, maintenance, refuelling, and other disciplines related to zero-emission vehicle operation and green fleet management.

Procuring vehicles requires careful consideration of technology availabilities and timelines, total cost of ownership, and access to the requisite maintenance services. Procuring and installing chargers often requires significant upgrades to existing buildings and their electrical service. This guide provides a review of common base building upgrades and outdoor charging guidelines to help facilitate the deployment of on-site charging stations.

Getting the correct amount of power distributed to, and through, the fleet facility is key to a successful transition to zero-emission vehicles. Utilities need to be involved early and must be committed. Processes to contact and involve your local utility vary by province and local distributors. The infrastructure being put in place should be long term, and last for multiple vehicle lifecycles, making resilience a key consideration. If your fleet operates on rented or leased sites, there are options to proceed with the transition, including flexible charging systems that can be installed then relocated. Furthermore, negotiating with landlords can increase leasing capabilities and guarantees.

Fleet managers should also invest in new infrastructure and load management systems to optimize energy efficiency while limiting peak power usage. These systems often need to be integrated with existing databases and information technology systems, thus requiring systems engineering to ensure communication and cybersecurity protocols are optimized to support data-driven decision making.

Developing an effective and complete plan for your fleet transition helps to ensure that available budgets are aligned with operational needs, and that funding or financing options can be secured. Conducting cost-benefit and financial analyses are essential to this process as the shift toward transportation decarbonization introduces new paradigms in operational models and revenue generation. For example, electrification programs can be outsourced to turnkey providers or charging-as-a-service providers who can offset initial capital investment into recurrent operational expenditures. Lease-to-own options for fleet vehicles can be explored, and new revenue streams can be generated through carbon credits or by providing charging access to other fleet operators.

3 – Key Considerations for Green Fleet Management

Once zero-emission vehicles are procured and deployed, telematics can help monitor and analyze key performance indicators such as overall fleet energy consumption, route completion percentages, vehicle uptime, battery state of health, and mean distance between failures.

Ensuring that fleet operators receive the necessary training to maximize the efficiency of zero-emission vehicles and related charging infrastructure is crucial for success. Operating zero-emission vehicles in Canada requires unique considerations, including the greater demand for heating in the winter. To minimize winter range derating for electric vehicles, practices such as preheating vehicles before departure, battery preconditioning, and proper vehicle housing between trips are invaluable.

Effective vehicle dispatch management paired with an optimized charging strategy can significantly reduce both capital and operating costs. For larger fleets, consider the implementation of smart charging systems. These systems ensure vehicles are charged efficiently based on operational needs, while also supporting informed dispatching decisions.

4 – Guide Objectives

This guide is designed to provide an overview of best practices in fleet decarbonization and green fleet management. The following topics are included to help fleets navigate their transition to zero-emission vehicles: range anxiety, the impact of winter conditions on vehicle performance, total cost of ownership, funding and financing, infrastructure resilience, and charging system installations. This guide also addresses issues related to limited electrical capacity at fleet depots, limited space, fire risks, change management, evolving organizational roles and responsibilities, and cybersecurity concerns.

Together, we have the power to fuel the energy transition and achieve Canada's net-zero goals. Let's take the first step towards a brighter, cleaner future.

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Current Policies and Targets

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Current Policies & Targets

Key Messages

- In December 2023, the Government of Canada (GoC) published the Electric Vehicle (EV) Availability Standard, requiring automakers to meet annual light-duty zero emission vehicle (ZEV) sales targets. All new light-duty vehicle (LDV) sales must be zero-emission by 2035. Additionally, the GoC has committed to aligning its medium- and heavy-duty vehicle (MHDV) emissions standards with the most stringent performance-based standards in North America. This will result in a significant increase in zero-emission MHDV sales in the coming years.
- The Greening Government Strategy (GGS) includes an objective that the federal government's light-duty fleet comprises 100% ZEVs by 2030, and that at least 40% of new commercial MHDV purchases are zero-emission by the same year.
- Some provinces provide funding support and purchase incentives to encourage the adoption of EVs and accelerate the deployment of charging infrastructure.

1.1 Government of Canada ZEV Targets and Policies

The Government of Canada's ZEV and climate objectives are outlined in two policy frameworks: *The 2030 Emissions Reduction Plan* and *Canada's Action Plan for Clean On-Road Transportation*. These frameworks describe a whole government approach to reducing greenhouse gas (GHG) emissions from on-road vehicles and achieving net-zero by 2050.

A policy lever outlined in these frameworks is the introduction of a light-duty ZEV sales regulation. In December 2023, the GoC published *The Electric Vehicle Availability Standard*. This regulation requires auto manufacturers and importers to meet annual ZEV sales targets. The regulation stipulates that in 2026, 20% of new LDV sales must be zero-emission, increasing to 60% by 2030 and 100% by 2035. Environment and Climate Change Canada will also be broadly aligning the GoC's air pollutant and GHG regulations with the final U.S. Environmental Protection Agency performance-based CO2 standards. This is expected to result in a significant increase in medium-and-heavy duty ZEV sales between 2029 and 2032.[1] Figure 1-1 presents Canada's ZEV sales targets for light-duty vehicles from 2026 to 2035 [1].

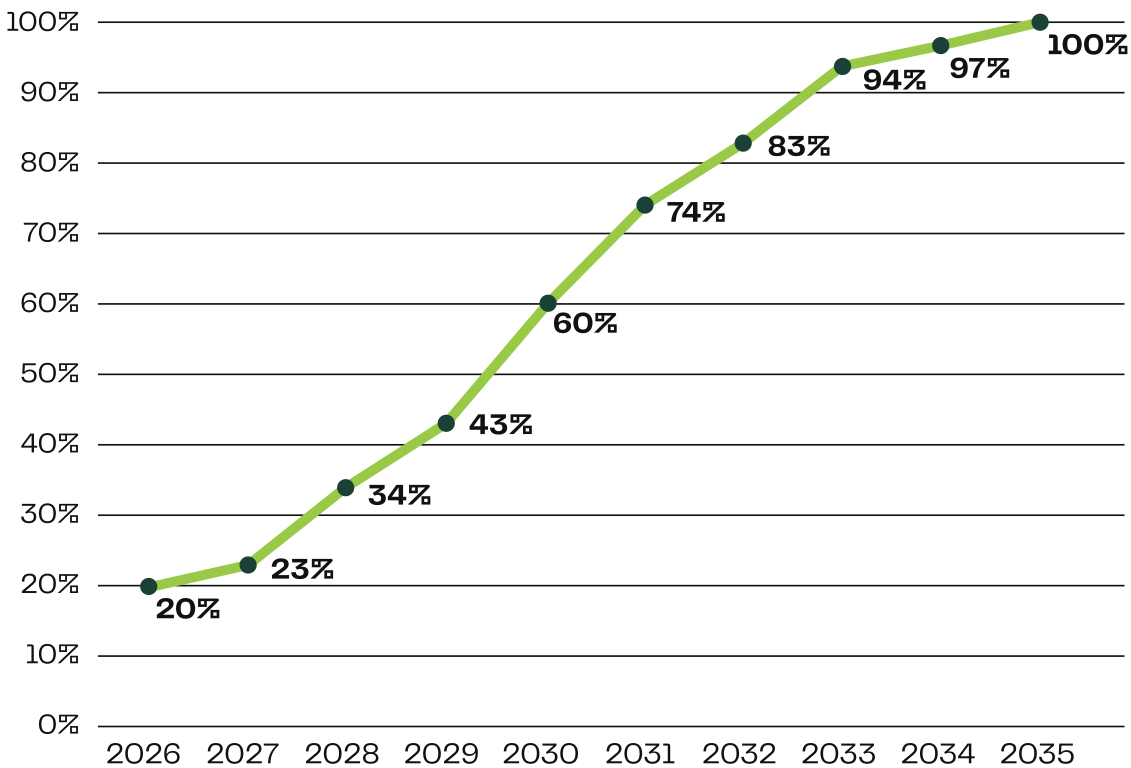


Figure 1-1: Canada's ZEV Sales Targets for LDVs

1 *In Canada, LDVs refer to vehicles with a Gross Vehicle Weight Rating (GVWR) of 4,536 kilograms (10,000 pounds) or less, encompassing GVWR Classes 1 and 2. MHDVs, in contrast, are vehicles with a GVWR greater than 4,536 kilograms, covering Classes 3 to 8.*

The GoC is leading by example through the development and implementation of its GGS, which stipulates that, starting in 2025, 100% of new light-duty federal fleet vehicle purchases be ZEVs with the objective that the GoC's light-duty fleet comprises 100% ZEVs by 2030 [2]. For the RCMP's national safety and security (NSS) fleet, the GGS commits to a 50% ZEV light-duty fleet by 2030, increasing to 100% by 2035. Nationally, the GoC operates over 17,000 conventional fleet LDVs and over 12,000 NSS LDVs. The GGS also includes a target for federal commercial MHDVs, requiring that at least 40% of new purchases be ZEVs by 2030.

The GoC also offers several financial programs to support Canadians and Canadian organizations in their transition to ZEVs. These programs aim to make ZEVs more affordable and accessible while also supporting the deployment of infrastructure necessary for widespread adoption.

- Funding and financing programs such as the Zero-Emission Vehicle Infrastructure Program [3] and Canada Infrastructure Bank Charging and Hydrogen Refuelling Infrastructure Initiative [4], support charging infrastructure deployments for public and private entities.
- The Incentives for Zero-Emission Vehicles Program or iZEV [5] offers a purchase rebate of up to $5,000 per vehicle for eligible consumers who buy or lease an eligible ZEV. Businesses can also take advantage of a temporary first-year tax write-off for new and used light-duty and medium-and-heavy duty ZEVs [2].
- The Zero-Emission Transit Fund [6], and Canada Infrastructure Bank's Zero-Emission Bus Initiative [7] work together to support the transition to ZEVs for transit fleets through funding and financing initiatives.
- The GoC has committed $1.2B in funding to support the deployment of public and private EV charging infrastructure across Canada.
- The Zero-Emission Vehicle Awareness Initiative (ZEVAI) supports projects that enhance awareness, knowledge, and public confidence in zero-emission vehicles and infrastructure, funding outreach, education, and capacity-building activities to promote their nationwide adoption in Canada [8].

Additionally, under Canada's Clean Fuel Regulations, charging-site hosts can create new revenue opportunities by displacing the use of liquid fuel in Canada for electricity. This means that fleets can take advantage of generating and selling carbon credits as they install charging infrastructure as part of their transition to ZEVs [9].

While these incentives may change over time, the latest updates on incentives and financing options are available via the GoC's website [10].

[2] *As of January 13th, 2025, the Incentives for Zero-Emission Vehicles (iZEV) Program funds have been fully committed. Consequently, the iZEV Program has now officially paused.*

1.2 Canadian Provincial Government Targets and Policies

British Columbia and Québec are leading the country in ZEV adoption. This is due to the substantial ZEV purchase incentives they offer, the investments they have made in charging infrastructure and the introduction of their own provincial ZEV sales mandates for LDVs [11].

Québec ZEV Sales Targets

- LDV – Increase the number of ZEVs on the road to 2 million by 2030, and have 100% of new LDV purchases be zero-emission starting in 2035 [12].
- Buses – 55% of urban bus fleets and 65% of school bus fleets will be zero-emission by 2030 [13].

Various financial incentive programs are offered to citizens, businesses, and public entities, including programs such as Roulez Vert [14] and Écocamionnage [15]. In addition, the Government of Québec will no longer subsidize internal combustion engine (ICE) buses after 2025, offering incentives only to EVs to accelerate the transition to zero-emission buses for transit and school bus applications. Additionally, Québec has implemented a cap-and-trade system linked to California's carbon market (Western Climate Initiative), creating opportunities for fleet owners to generate additional revenue as they progressively decarbonize their operations.

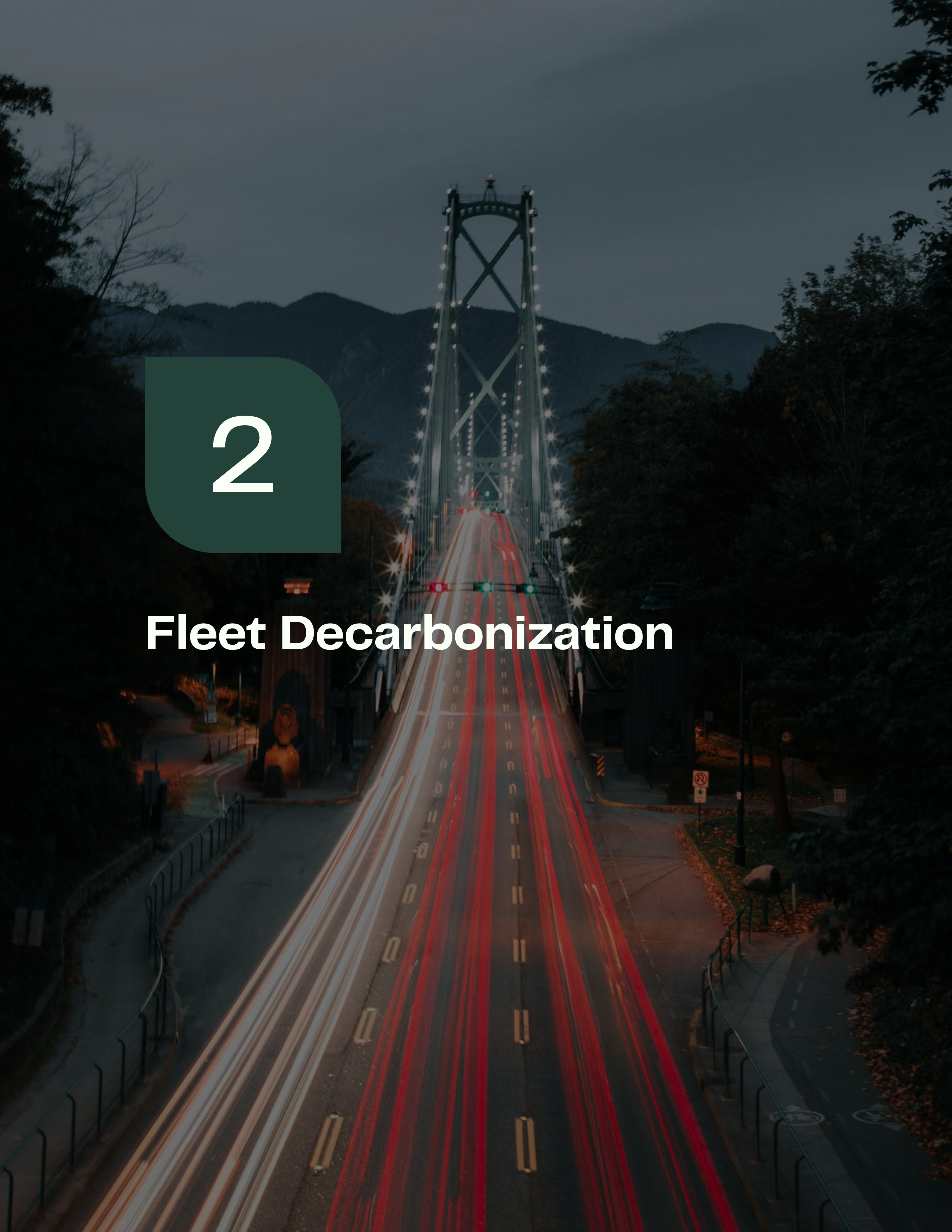
British Columbia ZEV Sales Targets

- 26% of new LDV sales must be zero-emission by 2026.
- 90% of new LDV sales must be zero-emission by 2030.
- 100% of new LDV sales must be zero-emission by 2035.

Financial incentives are offered to citizens, businesses and public entities through programs such as the CleanBC Go Electric Commercial Vehicle Pilots Program [16], the CleanBC Go Electric Rebates Program [17], and the CleanBC Heavy-Duty Vehicle Efficiency Program [18]. BC Hydro also has incentives related to fleet decarbonization planning and the implementation of charging stations [19]. Lastly, BC implemented a Low Carbon Fuel Standard, allowing EV charging station owners to generate credits for their charging stations that support on-road vehicles, representing a new potential revenue stream for fleets in the province.

Other Canadian Provinces and Territories

- Nova Scotia, Yukon, Manitoba, New Brunswick, Prince Edward Island, Newfoundland and Labrador, and the Northwest Territories also offer rebates and purchase incentives for ZEVs. Additionally, BC, Ontario, Québec and Nova Scotia have made investments in charging infrastructure programming.
- Provincial incentives often evolve. At the time of writing, some incentive programs have announced a gradual reduction in the amount of financial assistance granted for the purchase of ZEVs. Therefore, visit your provincial government's website for the latest updates on incentives and financing options.



2

Fleet Decarbonization

2

Fleet Decarbonization

2.1 Capacity Building

Key Messages

- Dedicating the right resources and implementing effective change management strategies are the building blocks of a successful fleet transition. Larger fleets will need to dedicate a full-time employee or team to support changes to operations and infrastructure.
- Establishing a multidisciplinary steering committee to bridge fleet and infrastructure operations as well as oversee overall program planning will help ensure a smooth transition to ZEVs.
- Planning for and managing a fleet decarbonization project is a full lifecycle endeavour; from initial implementation until infrastructure and vehicles are ready to be retired.

2.1.1 Key Stakeholders

Fleet decarbonization projects are inherently multidisciplinary, influencing facilities, operations, infrastructure, and more. To ensure success, engage key internal and external stakeholders at the appropriate times and clarify their roles and responsibilities. Without this, there can be increased internal resistance and slower approvals, resulting in potential delays and cost increases.

Table 2-1 outlines the key internal stakeholders (in no particular order) typically involved with the planning and implementation of fleet decarbonization projects. This list can be adjusted based on your fleet size as a single individual can be assigned multiple roles.

Table 2-1: Key Internal Stakeholders and Their Role in Fleet Decarbonization

Key Internal Stakeholder	Role
Program Manager	Plans the overall ZEV transition, coordinates all disciplines, secures commitments and budgets, tracks the decision-making process, and ensures the project's overall success. In the case of leased facilities, the Program Manager must ensure the lease agreement supports the adoption of charging infrastructure.
ZEV Operators	Provide feedback on vehicle performance, operational requirements, charging convenience, and user experience to inform future improvements.
Fleet Management / Fleet Maintenance Team	Oversees day-to-day fleet operations, ensures vehicle availability, fuels/charges vehicles, conducts performance monitoring, and acquires vehicles through established procurement mechanisms. Responsible for the maintenance and repair of ZEVs and addressing technical issues related to electric drivetrain components. Monitors the service life of vehicles in accordance with organizational directives, such as materiel management guidelines, which often dictate the timing for vehicle replacement.
Facility / Real Property Manager	Manages and oversees construction-related activities for the installation of charging infrastructure. Ensures proper integration of electrical distribution systems and charging equipment in existing facility/parking areas.
Senior Management Team	Approves key decisions, budgets, and timelines, and ensures alignment of the decarbonization project with the organization's sustainability goals. Drives messaging to all staff that the organization is serious about this change. Supports proposed solutions as challenges arise.
Project Sponsor	Member of the Senior Management Team or Sustainability Manager. Ensures that the Program Manager receives sufficient support from leadership, facilitating effective decision-making and smooth project progression.
Sustainability Manager & Marketing / Communications Team	Tracks project progress to ensure alignment with the organization's GHG emissions and climate impact reduction goals. Contributes to the development of internal and external communications regarding project successes.

Procurement Team	Ensures the adequate and timely establishment of ZEV and charging infrastructure procurement instruments. Selects vendors and negotiates contracts to acquire vehicles, equipment and services. The procurement team liaises with fleet management to ensure the vehicles being sourced are viable for deployment within the organization.
IT Manager	Ensures integration of telematics, charging management systems, and other data analytics platforms, while maintaining cybersecurity protocols.
Data Analyst	Periodically reports on energy consumption and tracks both electricity usage and energy costs.

Fleet decarbonization also requires the involvement of various external stakeholders, as outlined within Table 2-2.

Table 2-2: Key External Stakeholders and Their Role in Fleet Decarbonization

External Stakeholder	Role
Power Utilities	Ensure adequate power supply and outline timelines and costs for grid connection upgrades.
Authority Having Jurisdiction	Responsible for permit approvals and enforcing building codes, fire safety regulations, electrical standards, etc. This role can be entities such as municipalities, fire departments, and other regulatory bodies.
Landlords	Owner of leased sites. Required to support refuelling/charging infrastructure installation(s) at leased locations.
Funding and Financing Organizations	Provide options for funding and financing.
Insurance Companies	Assess potential increases in monthly fees due to fleet decarbonization. Existing clauses might prevent the adoption of ZEVs and need to be checked.
Vendors	Provide ZEVs, charging infrastructure, electrical distribution hardware, telematics, supporting software, and turnkey solutions such as charging-as-a-service.
Specialized Service Providers	Offer expertise in project management, engineering, and construction.

Best Practices for Successful Stakeholder Engagement

- Involve key stakeholders as early as possible in the process to enhance their understanding of the goals, expected outcomes, and specific project roles and responsibilities. Highlight the benefits of the ZEV transition: both for stakeholders and the organization as a whole.
- Establish a multidisciplinary, internal steering committee, or working group, with representatives from fleet, infrastructure, operations, finance, procurement, information technology (IT), and if applicable, corporate management to discuss ongoing fleet transition efforts.

2.1.2 ZEV Transition Plan

Each fleet organization should have a unique plan tailored to their specific needs. Planning is a recurring theme in fleet decarbonization and should be seen as an evolving and ongoing process; completed only when the ZEVs and chargers are retired and properly divested/disposed of.

The first step of a fleet decarbonization program is to develop a ZEV Transition Plan outlining the objectives, expected outcomes, benefits, stakeholders' roles, as well as project context and phasing. This plan can be integrated into a broader decarbonization strategy such as an organization's portfolio-wide emissions reduction plan.

By establishing this plan, the organization demonstrates its ambition and vision for the fleet transition while phasing the deployment in alignment with provincial and federal ZEV sales targets and regulations. The plan will also help to ensure that infrastructure is ready in time and that personnel are properly trained to welcome the addition of new vehicles and powertrains.

A ZEV Transition Plan should establish a corporate framework for the transition and address potential safety issues, as shown in Figure 2-1. It can include a risk mitigation plan and define responsibilities in the event of an operational fault or accident with a ZEV and/or charger.

The plan can identify how to monitor the organization's progress and lessons learned, in addition to governance and reporting procedures to assess the success of the decarbonization program. More information on which key performance indicators to track can be found in Section 3.

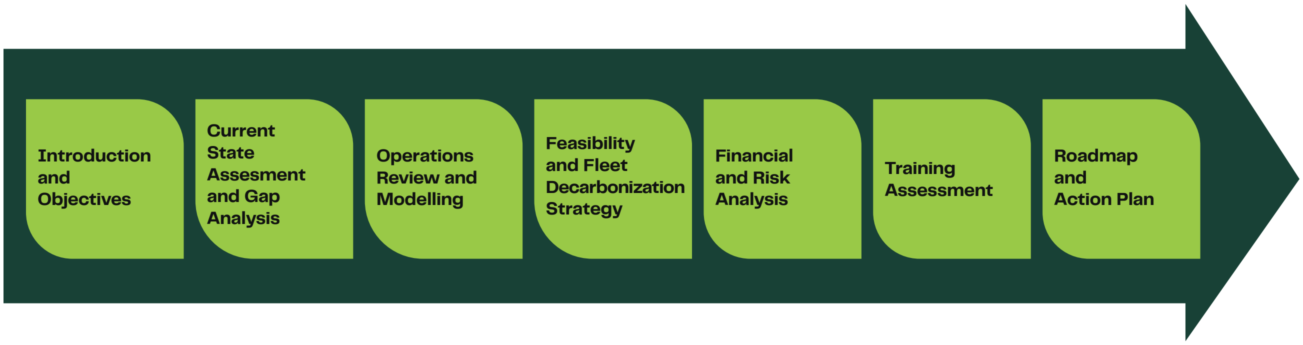


Figure 2-1: Recommended Structure for Developing a ZEV Transition Plan

Scaling the organization's vehicle replacement strategy to include annual ZEV targets can provide clear visibility on the deployment pace. Annual targets/milestones also help stakeholders stay coordinated and committed to a shared, transparent goal for ZEV adoption.

Utilities, governments, and industry associations have developed excellent resources detailing the requirements for a robust fleet decarbonization planning process. These can be accessed in the following references: [20] [21] [22] [23] [24].

Best Practices for Developing a ZEV Transition Plan

- Include in the plan a characterization of current operations to determine vehicle requirements and facility electrical needs. Identify mitigation measures for power outages and equipment failures. Adopt a long-term (up to 10 years) and phased plan for anticipated refuelling and charging needs.
- Strike the right balance between planning and project initiation as excessive planning can hinder progress by slowing momentum and reducing motivation, while insufficient planning often leads to higher costs and missed opportunities. Since it is difficult to have every question answered before the project begins, start with a small-scale pilot to minimize risk and build familiarity with modern technologies, processes, and procedures.

2.1.3 Evolving Roles and Responsibilities

The transition to ZEVs introduces new operational dynamics and requires a shift in roles and responsibilities across the organization. This shift necessitates the development of new skills and close collaboration between teams, particularly infrastructure and fleet teams, as ZEV operations are highly dependent on the availability and efficiency of charging infrastructure.

As roles and responsibilities evolve throughout the transition, initiating dialogue with trade unions is encouraged to facilitate the seamless integration of new skill sets among staff. Recurring cross-department meetings to discuss procedural changes are also recommended to facilitate smooth communication and collaboration between teams. The following list provides examples of new responsibilities created by the shift:

- Fleet and Maintenance Managers: Operations adjustments, including changes to route schedules and vehicle reassignments due to lower operating ranges, longer refuelling times, new maintenance needs, etc.
- Technicians: Maintenance of new powertrain technologies and infrastructure specific to ZEVs, management of charging station energy load, etc.
- IT and Data Management Team: Integration of big data management, including telematics, charging management systems, route schedules, vehicle and spare part inventories, etc.
- ZEV Operators: Adaptation of driving behaviours to optimize vehicle energy efficiency, range, and infrastructure usage.

Best Practices in Support of Change Management

- Identify and clarify new roles and responsibilities to ensure project success. The Responsible, Accountable, Consulted, Informed (RACI) matrix tool can be useful to clearly articulate new roles [25].
- Dedicate full-time resources to the project, which might require the onboarding of additional staff.
- Allocate dedicated time for resources involved in project governance tasks, including the organization of steering committees, corporate reporting, and consultant/engineer management.
- Develop tailored communication and training programs to support change management.

2.2 Vehicle Usage, Operational Requirements, and Inventorying

Key Messages

- Deploying telematics in ICE vehicles scheduled to be replaced is an increasingly widespread practice to ensure the operational suitability of new ZEVs in the fleet.
- Analyzing collected data can help characterize current and future maintenance requirements and energy demands.
- Transitioning to ZEVs may increase the number of vehicles required to deliver the same services, thus impacting operations, budgets, and space allocation.

2.2.1 Vehicle Usage Metrics

When planning the transition to ZEVs, a key step is to analyze collected data to help characterize vehicle usage patterns. This will provide a solid foundation for identifying the most operationally suitable ZEVs and refuelling strategies.

Key metrics include:

- Hours of operation
- Average daily idle time, including the number and location of idling events
- Average daily vehicle kilometres travelled
- Daily/monthly fuel consumed, and fuel efficiency relative to available published ratings (litres per 100 km)
- Trip characterization (short haul, last mile, long haul, return-to-base, etc.)
- Average payload
- Variations in ambient temperature
- Average and top speed
- Daily dwell events and vehicle downtime schedules
- Seasonal variations and peak usage periods

These data will help model future energy consumption and range requirements, determine the necessary electrical capacity upgrades, and plan for potential task adjustments specific to each vehicle category. Additionally, documenting operational changes for an existing fleet, such as seasonal variations, peak times, and the average number of towing events per year (when applicable), can help assess how ZEVs will perform during periods of high and low usage.

Data can also be collected on charging equipment and electricity distribution hardware to assess utilization, performance, and the potential for future failure. This topic is further discussed in the section on *Energy Management Systems, Load Balancing, and Smart Charging.*

Best Practices in Collecting Vehicle Usage Metrics

- Collect baseline ICE vehicle data on fuel consumption, vehicle kilometres travelled, idling events, and dwell times, to enable data-driven decision making.
- Establish a habit of collecting and post-processing operational data. Categorize data by vehicle type, specific location (building/depot), and use case.
- If operational data are unavailable, make informed assumptions based on qualitative information, such as driver feedback on vehicle utilization, condition, fuel/energy consumption, payload, distance travelled, etc. Evaluate these assumptions during the initial ZEV deployment phase and adjust accordingly.

2.2.2 Telematics Implementation and Benefits

Telematics devices collect real-time data from a vehicle's onboard sensors and control systems, such as speed, location, and diagnostic information. A telematics device connects to a vehicle's on-board diagnostic (OBD)-II port and/or Controller Area Network (CAN) bus to access vehicle data, processing key metrics like battery state of charge (SoC), fuel system status, diagnostic trouble codes, and engine or battery state of health.

The device transmits data over cellular or satellite networks to a remote server where they can be stored and analyzed. If the vehicle operates in a remote area with no cell service, the data can be collected offline and subsequently uploaded to the cloud when the vehicle returns to a connected area.

One of the primary advantages of using telematics to guide your fleet's transition is their ability to inform vehicle replacement and fleet charging strategies. For ICE vehicle fleets, telematics data provide valuable insights into vehicle utilization, helping to determine the range necessary for daily operations. As you transition your ICE fleet to ZEVs, telematics offer visibility into each vehicle's SoC and the approximate time required for a full charge. Telematics can also help prioritize charging schedules and inform dispatching decisions.

Telematics can contribute to improved return on investment by providing data-driven insights that help fleet managers optimize fleet size and ensure that each vehicle is best suited for its specific task(s). In addition, they support the ability to implement and monitor eco-driving programs (see the section on *Strategies to Reduce Energy Consumption and Optimize Range* for more information).

Starting with a telematics pilot program enables fleet operators to adopt the technology in a controlled and manageable way. A smaller-scale rollout helps staff become comfortable with the software and technology, identify the most effective uses for the data, and avoid initial information overload. A pilot project allows operators to focus on specific goals — such as optimizing vehicle utilization or tracking maintenance — while addressing potential challenges early on.

A challenge for telematics providers supporting ZEV fleets, especially those composed of MHDVs, is the lack of standardized communication protocols. Unlike ICE vehicles, ZEVs generate data in various formats, making it difficult to harmonize data communications across different models. ZEV-specific data formats may require custom configuration or firmware updates to ensure the telematics system can interpret key metrics accurately.

Best Practices in Implementing Telematics

- Allow sufficient time for data collection. Generally, a minimum of 3 months of data are required to generate useful reports, however, a full year is ideal to account for seasonal variations in operations.
- Ensure communication compatibility between the telematics device and Original Equipment Manufacturer (OEM) systems (i.e., OBD-II and CAN bus) when sourcing telematics for EVs. This is accomplished during procurement.
- Communicate to operators when their vehicles are equipped with telematics devices to inform them about privacy implications, the type of data being collected, and how it can benefit their work. This includes improving driving habits, optimizing routes, and enhancing overall safety.

2.2.3 Fleet Composition Considerations

When transitioning from ICE vehicles to ZEVs, several factors will influence what constitutes the ideal fleet composition. In the preliminary stages, particularly for MHDVs, a one-for-one replacement of ICE vehicles with ZEVs may not be feasible. At time of writing, fully electric MHDVs such as Class 8 trucks generally have lower ranges and payload capacities compared to their ICE counterparts. This is especially relevant for operations requiring long trips, heavy loads, and/or 24/7 vehicle availability. In cases such as these, delivering the same level of service may require additional vehicles, potentially creating challenges with space allocation, and access to spare parts and chargers. This emphasizes the value of a ZEV Transition Plan that models current operations while taking such limitations into account. With vehicle ranges increasing [26], this consideration is expected to become less and less significant over the coming years.

Operating a mixed fleet of both ICE vehicles and ZEVs is common during the transition period and may require additional logistical considerations such as assigning certain powertrains to specific routes. This will become even more relevant as a fleet ages and electric vehicles experience battery degradation and reduced ranges.

For more information, refer to the section on *Mitigating Battery Degradation*.

If fleet vehicles are housed indoors, distinct areas (or lanes) can be dedicated to ZEVs to separate them from ICE vehicles. This allows for the concentration of chargers and specialized fire safety equipment in one location. Related to fire hazards and safety, research from EV Fire Safe, an organization funded by the Australian Department of Defence shows that, since 2010, 511 incidents of thermal runaway have occurred in passenger battery-electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) globally out of the roughly 40 million EVs on the road [27]. Therefore, battery fires remain a rare occurrence today. However, this finding should be interpreted with some degree of caution, as most EVs on the road are new, while many fires in ICE vehicles are associated with older models, where components are more susceptible to wear and failure [28].

When battery fires do occur in light-duty EVs, they require up to 150,000 litres of water to extinguish compared to up to 1,900 litres for an equivalent ICE vehicle [29] [30]. Appropriate safety measures should therefore be put in place, especially when vehicles are parked indoors.

More information on base building upgrades for fire safety is presented in the section on E*VSE Installation, Base Building Upgrades, and Hardware Costs*.

Fleet decarbonization also brings opportunities to assess the viability of alternative means of transportation, including active transportation and micromobility solutions such as e-bikes, cargo bikes, and scooters.

Best Practices in Planning for Fleet Operations with Mixed Powertrains

- Determine the extent to which additional vehicles may be needed to maintain service continuity early in the transition by assessing vehicle utilization, range requirements, and potential refuelling durations.
- Develop flexible charging protocols during the planning process to account for the evolving needs of the fleet. As more ZEVs are added, newer vehicles may feature different charging speeds compared to older models. Charging protocols should be periodically reviewed and adjusted to ensure compatibility and efficiency as the fleet grows.
- Analyze the potential and feasibility of supplementing operations with alternative means of sustainable transportation.

2.3 Vehicle Replacement Considerations

Key Messages

- Each vehicle powertrain type presents its own advantages and disadvantages. Therefore, fleet managers must be mindful of their organization's emissions targets, operational requirements, and access to necessary infrastructure when evaluating their options.
- Alternative vehicle ownership models such as leasing, and lease-to-own arrangements can help facilitate the transition to ZEVs, de-risk procurement, and reduce capital investment.
- Carbon pricing mechanisms, grants, and other funding opportunities should be considered when calculating potential total cost of ownership (TCO), as they can help offset a portion of the costs associated with purchasing ZEVs.

2.3.1 Vehicle Powertrains

Hybrid-Electric Vehicles (HEVs) use a combination of an ICE and electric motor to improve fuel efficiency and reduce emissions. HEVs are not considered ZEVs because they cannot run solely on a non-emitting power source. HEV batteries are recharged through regenerative braking and by running the ICE. HEVs cannot be charged by plugging into the grid. The electric motor in a HEV is primarily engaged in stop-and-go traffic and lower-speed scenarios where it offers the most energy-efficient operation. The ICE takes over during higher speeds or when the battery needs recharging, often working together with the electric motor during acceleration or when additional power is required. HEVs are most beneficial in urban settings where frequent stops allow the electric motor to function more often. By lowering idling emissions and utilizing both power sources efficiently, HEVs can offer a 20-40% improvement in fuel efficiency over equivalent ICE vehicles [31].

Plug-in Hybrid Electric Vehicles (PHEVs) combine hybrid and battery-electric powertrains. PHEVs have larger battery packs[3] that can be charged by plugging into the grid, allowing them to run on electric power alone for short distances. This capability offers an extended electric range, while reducing overall fuel consumption and emissions for daily trips. If the battery is depleted, PHEVs automatically switch to operate like conventional hybrids, using the ICE when necessary. This dual-mode operation provides flexibility to operators while eliminating range anxiety. Although PHEVs do not need to be plugged in to operate, regular charging maximizes their efficiency and reduces operating costs and on-road emissions. An analysis conducted by the International Council on Clean Transportation showed that PHEVs can have between 15%-55% lower $CO2$ emissions compared to equivalent ICE vehicles [32]. PHEVs can also rely on their ICE motor to extend their overall range in winter conditions.

[3] *A battery pack refers to a collection of individual batteries or cells grouped together to store and provide electrical energy.*

There are two types of PHEV powertrains. Series PHEVs rely solely on their electric motor to drive the wheels, with the ICE functioning as a generator to produce electricity to help charge the battery. In contrast, blended PHEVs use both the engine and the electric motor to drive the vehicle depending on driving conditions. Blended PHEVs can operate in electric-only mode, gasoline-only mode, or a combination of both, optimizing performance based on the battery SoC and driving needs. This distinction helps consumers select a PHEV tailored to their driving habits and efficiency preferences.

Battery-Electric Vehicles (BEVs) rely entirely on batteries and electric motors for propulsion and produce no tailpipe emissions. These vehicles must be plugged in to the grid as they do not use an ICE for power generation or propulsion. Since electric motors provide instant torque, BEVs offer a responsive and engaging driving experience. They are cheaper to maintain due to fewer mechanical parts, and the cost of electricity per kilometre can be significantly lower than gasoline, depending on the province, time of use, and utility rates [31]. Much like HEVs and PHEVs, BEVs use regenerative braking to recapture kinetic energy during deceleration and transform it into electrical energy to charge the vehicle. Regenerative braking typically occurs when the operator stops pressing the accelerator pedal. The driving range of BEVs, as shown in Figure 2-2, has significantly increased over the years, with the maximum range of recent models reaching in excess of 800 kms.

A vehicle's driving range can vary relative to its published estimated range due to factors such as driving habits (speed/acceleration), cargo weight, and ambient temperature.

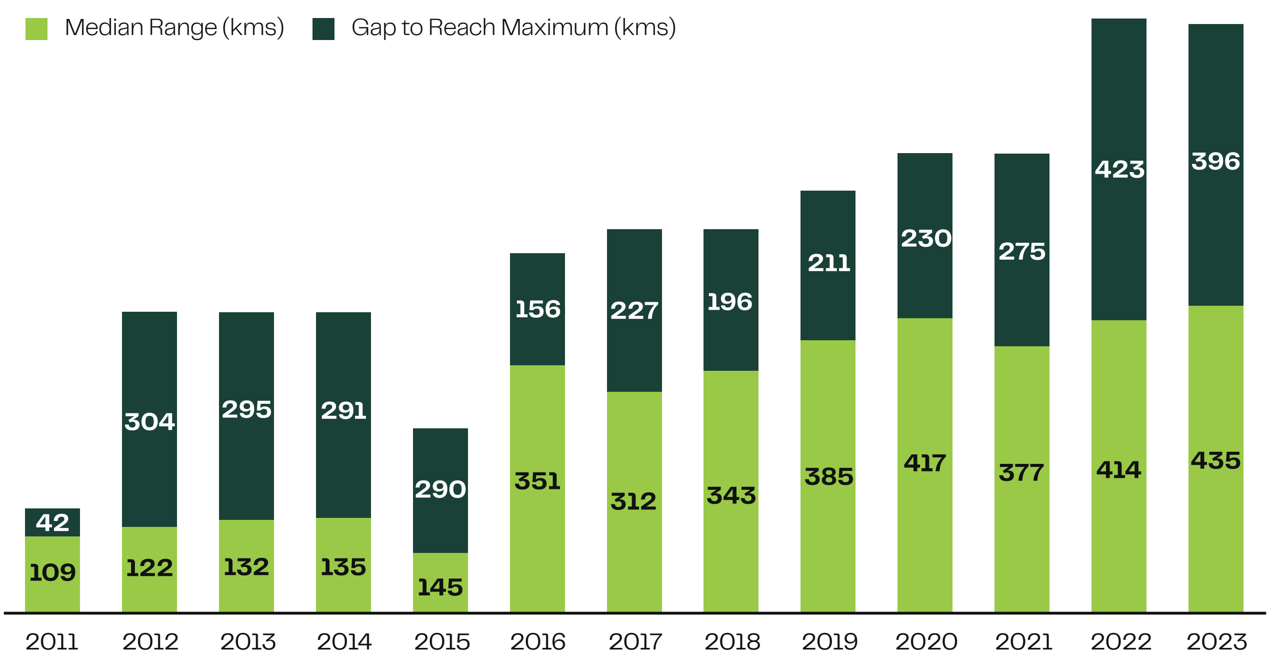


Figure 2-2: Historical Median and Maximum Range (Kilometres) of Light-Duty BEVs Offered for Sale in the United States - Model Years 2011-2023 [33]

Fuel Cell Electric Vehicles (FCEVs) are powered by compressed hydrogen gas that reacts with oxygen in a proton exchange membrane fuel cell to produce electricity that drives an electric motor. These vehicles have, in essence, electric powertrains that produce no tailpipe emissions. In modern FCEVs, particularly in heavy-duty models, the fuel cell works in tandem with smaller batteries to continuously recharge them during operation to maintain maximum efficiency. The fuel cell therefore acts as a range extender. This combination allows FCEVs to offer high driving ranges and fast refuelling times, making them suitable for long-haul journeys. There are currently only a few hydrogen refuelling stations in Canada, and while that number continues to grow, infrastructure availability and the cost of hydrogen remain barriers to broader adoption.

2.3.2 Strategic Acquisition Planning

Management practices such as fleet rightsizing, where a fleet size is tailored to meet operational requirements while minimizing superfluous assets, can reduce costs and fleet lifecycle emissions. Fleet costs and emissions can also be reduced through individual vehicle rightsizing, where managers select the most energy efficient vehicles that still meet their operational needs.

Once the ideal number of vehicles and vehicle types have been established, multiple ownership options can be considered, as described in Table 2-3. Procurement methods depend on the type of organization, but Requests for Proposal or Requests for Quotation are commonly used methods to competitively obtain multiple quotes from several suppliers.

Table 2-3: Vehicle Ownership Models

Vehicle Ownership Type	Pros	Cons
Option 1: Purchased and owned by the organization	• Fleet owner retains full control of the asset	• Fleet owner assumes all risks, is responsible for maintenance and ensuring appropriate insurance coverage is acquired
Option 2: Leased (short or long term)	• Easier to deal with battery degradation, repairs, etc. • Less upfront costs compared to option 1	• Higher long-term costs due to interest and leasing service fees
Option 3: Leased-to-own	• Fleet owner owns the vehicle at the end of the lease term • Less upfront costs compared to option 1	• Long-term contract commitment with limited flexibility

Multiple incentives and financial options are available for vehicle purchases at the time of writing this report. Low interest loans, rebates, and grant programs are available via municipal, provincial, and federal governments. Each program should be reviewed carefully as some require upfront payment with reimbursement issued later while others offer direct rebates through approved OEMs. Verify eligibility criteria for incentive programs as well since certain organizations may not qualify depending on the funding source or program terms and conditions.

An effective procurement strategy should address all factors unique to the various powertrain options:

- Confirm that the battery warranty conditions set by the OEM are clear and acceptable.
- Ensure that the battery can be replaced in longer-lifespan vehicles to mitigate the risk of early asset retirement.
- Ensure that electric vehicle supply equipment (EVSE) is compatible with the vehicle, as in certain cases, customizations are required to accommodate larger vehicles (e.g., combo ports on one or both sides of heavy-duty vehicles, ceiling-mounted rails, pantograph rails, inductive charging receptacles, etc.).
- Establish a plan for spare part availability and warranty for key components.

Procurement timelines should also synchronize vehicle deliveries with infrastructure readiness and factor in potential lead times. At the time of writing, battery-electric buses and Class 8 trucks may have delivery times of 1.5 to 2 years, depending on the model. More information on ZEV availability is discussed in the next section.

Retrofitting fleet vehicles is another option. This concept is fairly new, primarily piloted within the transit space, and relies on the fact that some existing, well-conditioned ICE vehicles can be retrofitted with ZEV powertrains [34]. This type of transition requires its own procurement approach and presents several advantages, including shorter lead times (under 1 year), immediate emissions reductions, and lower lifecycle emissions due to the reuse of vehicle chassis and materials.

Based on findings from the Institut du Véhicule Innovant Rechargeable Fleet program, the optimal duty cycle conditions for electrifying today’s MHDV fleets include driving distances of less than 200 kms/day and returning to base overnight. Operating models that can be electrified with today’s technology without requiring significant changes to daily operations include those utilizing dry box configurations (without power take-off, transport refrigeration units, or dumpers) and maintaining low to medium payloads [35].

Best Practices in Strategic Procurement Planning

- Choose ownership models that suit your needs. Leverage different ownership models, where appropriate. Keep in mind that your choice will influence which funding and financing opportunities are applicable.
- Base ZEV selection on projected availability, TCO estimates, and operational compatibility.
- Address charger compatibility, including hardware, power level and connector type, during the initial procurement phase of the project as it will be more complex to retrofit vehicles later. This is particularly beneficial for heavy-duty ZEVs, as many require custom charging equipment.
- Align timelines for vehicle acquisitions and infrastructure installations. Without chargers, you will not be able to operate fully electric vehicles. As straightforward as it may seem, timeline misalignment remains a common pain point for fleets transitioning to ZEVs.

2.3.3 Current and Projected ZEV Market Landscape

ZEV Availability

According to a report from Transport Canada, inventory levels for LDVs saw a significant increase in 2023 compared to previous years, with ZEV purchases representing close to 12% of the total LDV market that year [36]. At the time of writing this report, current trends indicate improved wait times and a reduction in the percentage of dealerships without ZEVs in stock, which has fallen to 47% — the lowest level reported to date.

For MHDVs, over 150 ZEV models are either currently available or anticipated soon [37]. However, wait times for these vehicles remain highly variable ranging from 60 days to as long as 36 months, depending on the model and manufacturer. Supply chain issues also continue to affect distribution, inventory levels, and regional accessibility, especially outside of provinces like BC and Québec, where ZEV incentives and sales mandates are strongest.

Canada is currently making strong efforts to support the battery supply chain and ZEV industry more generally to help shorten delays. The ZEV sales mandate is expected to provide manufacturers with valuable insight into market demand, enabling them to plan production and distribution strategies more effectively to increase ZEV availability in Canada.

ZEV Availability Projections

ZEV availability in Canada is heavily influenced by North American automakers' manufacturing capacities, which are shaped by Canadian and U.S. federal and state regulations. For example, California's medium-and-heavy-duty ZEV sales mandate (Advanced Clean Fleets) will compel automakers to expand their production capacity to meet the state's target of 100% ZEV sales by 2036 [38].

ZEV sales mandates and other regulations may also affect funding available through provincial and federal programs. For example, in 2021 the Government of Québec mandated that all newly purchased school buses must be ZEVs to qualify for funding while discontinuing financial support for the purchase of ICE school buses [39]. Figure 2-3 provides a timeline of the impact this announcement had on the school bus market in Québec.

2015	2021	2022	2023	2024
Quebec's first electric school buses	1% of school buses are electric. 2030 target: 65% of school buses powered by electric motors, 2035 target: 100%. New program: $250 million invested	Decarbonization program boosts thermal bus sales by 74% (reverse rebound effect)	6.6% of the school vehicle fleet is electric.	1 606 school buses in Quebec are electric (close to 15% of the fleet)

Figure 2-3: Evolution of Electric Bus Adoption Over Time in Québec

The first official deployment of an electric school bus in Québec was part of a 2015 pilot project aimed at demonstrating the feasibility of electrifying school transportation [40]. Before the sales mandate was announced, less than 1% of Québec's school bus fleet was electric. Initially, the announcement led to a marked surge in the purchase of ICE school buses, with sales increasing by 74% in one year. However, just four years later, nearly 15% of the school bus fleet in Québec was zero-emission. School bus OEMs were able to scale up production in under two years, leading to the introduction of more models. New business and financial models such as leasing programs also emerged to support this transition, highlighting how regulations can accelerate ZEV adoption and prompt the market to adapt rapidly to meet new requirements.

A similar trend can be seen in the LDV market. Following the adoption of the Electric Vehicle Availability Standard in 2022, light-duty ZEV sales in Canada increased by close to 3% in 2023. By February 2024, ZEVs were on offer by 13 distinct automakers compared to only 10 in the three months prior.

While forecasting future vehicle availability remains complex due to factors beyond Canada's control, the trend over the past five years shows a marked improvement in ZEV availability and model diversification.

ZEV Prices and TCO

Given the financial differences between ZEV and ICE vehicles – such as the higher purchase costs and lower operating costs of ZEVs – a fleet TCO analysis is essential to understanding the CAPEX and recurrent OPEX implications of fleet decarbonization. This analysis helps identify savings opportunities and cost drivers, thus providing insight into which vehicles a fleet should replace, retain, or divest entirely. Forecasting acquisition and operating costs enables fleet managers to estimate the lifecycle savings and payback periods associated with the transition to ZEVs.

Establishing the fleet's financial baseline, or Business-as-Usual scenario, is essential for a meaningful TCO analysis. The Business-as-Usual scenario serves as a financial reference point for comparing ZEVs to ICE vehicles, and includes costs such as vehicle acquisition, fuel, and maintenance. Without this baseline, it is impossible to quantify cost differentials or accurately assess the budgetary impact of transitioning to ZEVs.

A 2022 TCO analysis completed by Clean Energy Canada showed that the TCO for a light-duty EV was 30% lower than that of ICE vehicles in Canada[4] due to lower fuel and upkeep expenses combined with government incentives [41]. Based on average retail prices for regular gasoline ($1.45/L, April 2021 to March 2022 [42]) and residential electricity rates ($0.13/kWh [43]), the higher initial cost of an EV is offset by its lower operating costs compared to a conventional gasoline vehicle.

TCO for zero-emission MHDV fleets varies more significantly from province to province compared to LDVs. This is due to factors such as local utility policies and regional regulatory credit programs for clean fuels. The International Council on Clean Transportation predicts that by 2030 the TCO of battery-electric long-haul trucks will likely be lower than that of their diesel counterparts in the U.S. [44]. The TCO for electric vans and pickup trucks with a 320 km range is already lower than that of their diesel counterparts [45].

A comprehensive TCO analysis for zero-emission fleets should account for critical factors such as vehicle utilization rates, local electricity pricing, and the choice between rapid and slower charging options, as these elements drastically impact long-term cost projections.

Additionally, regulatory credit programs like Canada's Clean Fuel Regulations, Québec's Cap-and-Trade System, and British Columbia's Low Carbon Fuel Standard provide fleet owners with new revenue opportunities by granting credits for using lower-emitting fuels. These credits can be sold in the carbon market, offering a means to offset costs.

To further drive down TCO, emerging solutions like vehicle-to-grid capabilities[5] offer a strategic opportunity to leverage EVs for energy storage with the potential to resell the electricity during

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4 *As a result of a comparison between a 2022 Chevrolet Bolt and 2022 Toyota Corolla Hatchback for a total covered lifecycle distance of about 160,000 km. This analysis excluded the resale value at the end of the fleet vehicle's lifecycle.*

5 *Vehicle-to-Grid technology allows EV owners to earn revenue by selling stored energy back at higher peak prices, turning the EV into a potential income source.*

peak demand periods, thus creating additional revenue streams. Vehicle-to-Grid capabilities could be helpful for fleets that have high dwell times in provinces that offer time-of-use electricity rate structures, such as with school buses in Ontario.

While TCO typically does not include the cost of infrastructure installation and maintenance, it does include the cost of the energy powering the vehicles. High upfront capital costs for charging infrastructure can be a barrier, particularly for smaller private fleets, public sector fleets, and fleets that face high one-time utility connection costs.

Best Practices in Developing a TCO Analysis

- Consider the potential for new business models, including the use of carbon credits or other funding incentives.
- Partner with a consultant to develop a TCO calculator tailored to ZEVs or use online resources available for free, including National Renewable Energy Laboratory's Transportation Technology Total Cost of Ownership model [46].
- Ensure TCO analyses evaluate financing options available through turnkey solution providers for both infrastructure and vehicles.

2.4 Facility-Level Planning and Depot EV-Readiness

Key Messages

- Both current and future needs should be considered when selecting the appropriate level, type, and quantity of EVSE.
- Smart charging via an energy management system (EMS) can help manage peak demand, balance loads, and reduce energy costs. Integrating hardware and software to monitor and control energy flow can inform operational needs and costs.
- Selecting an EVSE ownership model requires a balance between control, cost, and operational requirements. Ownership models range from full ownership to third-party and utility ownership, each offering varying levels of autonomy and risk management.
- Carrying over site assessment recommendations into pre-design and feasibility work ensures accurate scalability and alignment with future fleet needs. The pre-design phase is typically followed by engineering design, permitting, construction, and commissioning for more complex projects, thus requiring multidisciplinary expertise in civil, electrical, mechanical, and structural engineering.
- Implementing networked EVSE systems enables live monitoring, billing, and load management, but requires careful selection of compatible equipment, and communication protocols to maintain operational readiness and ensure adaptability to future needs.

2.4.1 EVSE Typology, Novel Charging Solutions, and Electrical Literacy

Key Terms:

- A **volt (V)** is a unit of measurement for electric potential, electric potential difference, and electromotive force.
- The **ampere (A)** is a measure of the amount of electric charge in motion per unit time or electric current.
- The **volt-ampere (VA)** is a unit of measurement for apparent power, or the total amount of power being used in a system, with 1,000-volt amps equal to 1 kilovolt-ampere (kVA), and 1,000 kVA equal to 1 megavolt-ampere (MVA).
- **EVSE** supplies electricity to the electric vehicle. Commonly called charging stations or charging docks, they provide electric power to the vehicle to recharge the vehicle's batteries. EVSE systems include the electrical conductors, related equipment, software, and communications protocols that deliver energy efficiently and safely to the vehicle [47].

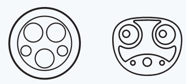
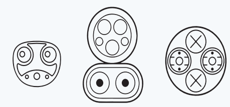
Two key units are used to describe EV and EVSE charging capabilities.

- First, the **kilowatt (kW)** is used to measure electrical power. Second, the **kilowatt-hour (kWh)**, is used to define the amount of electrical energy stored by a vehicle's on-board battery. A simple analogy to differentiate these units is to think of kW as the rate at which water flows through a pipe, and kWh as the total volume of water flowing out of a pipe, over a specific period of time.
- Energy consumption is expressed using **kWh/100 km**, which can be translated to a fuel equivalent in **Le/100 km**. For example, an ICE vehicle with an average fuel consumption of 10.86 L/100 km compared to an EV of equivalent size consumes, on average, 2.3 Le/100 km, saving an exceptional amount of energy [48].

Both kW and kWh units are used to describe electricity use, so the rate applied by utilities measures both parameters when billing a customer. Utilities charge customers on both the highest power demand in a billing period (peak demand) and the total amount of electrical energy consumed. The different EVSE power capacities are classified in four types of charging levels, as shown in Table 2-4.

Table 2-4: EVSE Typology

	Level 1	Level 2	Level 3 / Direct Current Fast Charging (DCFC)	Ultra-Fast Charging (Megawatt)
Charging Power	• 1.5 kW to 1.8 kW	• 7.2 kW to 19.2 kW	• 24 kW to 350 kW	• 350 kW to 4.5 MW
Power Supply	• 120-V AC power outlet *such as wall outlets or block heaters)	• 208/240 V, 15 to 80A	• Varies according to the type and number of chargers	• Varies according to the type and number of chargers
Electrical Infrastructure	• Level 1 charger • Power outlet for continuous 15A use	• Level 2 EVSE • Adapted electrical infrastructure	• DCFC EVSE • Adapted electrical infrastructure (distribution and/or transformer)	• MW EVSE • Adapted electrical infrastructure (medium-voltage power supply + transformer)
Plug Connector	• J1772 • Tesla NACS (North American Charging Standard) SAE J3400	• J1772 • Tesla NACS SAE J3400	• Tesla NACS SAE J3400 • SAE J1772 Combo CCS1 • CHAdeMO • SAE J3105 • SAE J2954-2	• Megawatt Charging System (MCS) – SAE J3271 in development

Connector Type for LDV [49]	 • J1772 and J3400		 • J3400, Combo, CHAdeMO	N/A
Range Gain (per hour of charging) [50]	• 3 km to 8 km	• 16 km to 50 km	• Up to maximum driving range of vehicle*	• Up to maximum driving range of vehicle*
Pros	• Low installation cost	• Moderate installation cost per station • Accelerated charging	• Fast charging	• Ultra-fast charging
Cons	• Slow charging, not adapted for commercial or corporate fleet	• Less adapted to MHDV with high usage and little time for recharging	• Higher installation costs • Operating costs can be high without adequate peak demand management • Most PHEVs are not compatible with DCFC	• Complex installation • High installation cost • High operating costs • Reduced vehicle compatibility

**Note: The range gain from fast charging is non-linear and decreases significantly once the battery's SoC exceeds 80%.*

When planning EVSE deployment, it is important to consider infrastructure compatibility from both a vehicle and connector perspective to ensure seamless interoperability.

Table 2-4 highlights several connector standards existing in North America. Connector compatibility varies depending on charging networks and the make of the vehicle. Recently, automakers have been moving towards the adoption of the North American Charging Standard (NACS), especially for LDVs, although charging station adaptors for J1772 and NACS are also available.

Charging network compatibility is also supported through open-source communication protocols introduced by the ZEV industry such as the Open Charge Point Protocol (OCPP). OCPP enables EV drivers to seamlessly access different charging networks across Canada by standardizing communications between charging stations and management systems from different providers.

Off-Site Charging

One possible charging strategy is for fleet vehicle drivers to charge their EVs while away from depot. Public charging stations are often strategically located along arterial roads and highways for drivers to quickly charge their vehicle during stops. This method typically relies on higher charging power relative to depot charging to replenish the battery as quickly as possible without impeding operations or requiring a return to base. Maximizing the use of public chargers also reduces the need to invest in on-site infrastructure.

Public charging stations can be installed by municipalities, utilities, or private operators, and typically target locations either along major roadways or near accommodations and activity centres, such as gas stations or malls. Accessing these chargers often requires payment, which can vary. Fees may be calculated per charging session, per unit of electricity consumed (e.g., kWh), or based on the time spent connected to the charger. Payment methods also vary, including mobile apps, radio frequency identification (RFID) cards, or by credit card, which can pose challenges for fleets managing diverse payment requirements across multiple operators.

If off-site charging becomes part of a chosen strategy, establish dedicated guidelines, as the associated costs can vary. Communicating to drivers how they can locate available public chargers using specific mobile apps or locator maps, such as the Electric Charging and Alternative Fuelling Stations Locator provided by NRCan[6] is also advisable. While LDV charging options are increasingly available, public MHDV charging stations along key freight corridors are still in the early stage of development [51].

Depot Charging

Depot charging can take place at designated fleet parking spots on-site, inside garages, or in parkades, and is mostly practiced by fleets with return-to-base operations with long dwell events between trips. Charging EVs on base typically imposes a high electrical load on properties originally designed for ICE vehicles. To effectively supply power with the appropriate voltage and current to EVSE, tailored electrical distribution infrastructure is necessary. While existing electrical systems can sometimes be used to connect the chargers, electrical upgrades are often necessary to meet increased power demands.

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[6] *Electric Charging and Alternative Fuelling Stations Locator*

The electrical distribution infrastructure required to feed the chargers comprises the following components, which can be costly and space-intensive, depending on the magnitude of the project:

- Meters and submeters used by utility companies for energy measurement and billing
- Step-down transformers to adjust the supply voltage to the required level
- Safety switches to isolate certain parts of the electrical circuits
- Distribution panels to deliver electricity to various circuits
- Circuit breakers to divide circuits and protect equipment from overcurrent and shorts
- Conduit piping to protect and enclose electrical wiring
- Wiring to conduct electricity across circuits to outlets and equipment

These key components are needed and can be costly and space-intensive depending on the magnitude of the project.

The utility supply depends on the building location, use, and electrical load measured in watts (W) or kilowatts (kW). Commercial and small industrial facilities are typically supplied with 600 V 3-phase power which provides capacity for numerous commercial and industrial applications and can be used for EV charging. Figure 2-4 presents an illustration of a simplified electrical distribution system to supply 50 kW charging equipment.

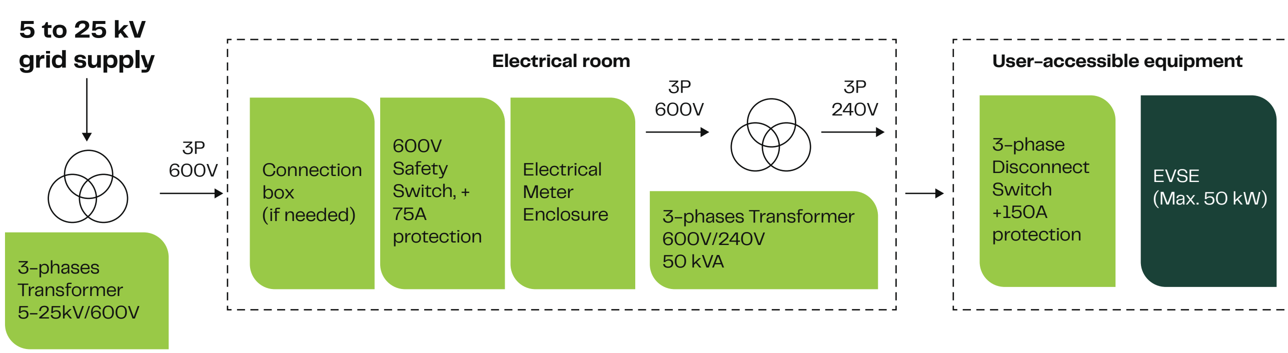

Figure 2-4: Simplified Electrical Distribution Components for an EVSE (Hydro-Québec, 2015 [52])

Larger industrial and commercial buildings are supplied with medium voltage from 2.5 kV and above, typically when their load exceeds 2 MVA. Note that, in Canada, most power delivered to sites from utilities is rated at 600 V while some fast-charging equipment, developed mostly for the U.S. market, requires a 480 V supply. This creates the need for additional step-down transformers to supply the chargers.

Depending on the existing electrical service, capacity can be limited on the utility side and additional processes may be needed to secure a service upgrade with a local utility.

Innovations and Technology Improvements

The EVSE market has been evolving rapidly in recent years to solve EV charging challenges and offer new features to users. For instance, the charging power output of equipment has increased, standardized charging communication protocols such as the OCPP have been adopted, and automated power distribution configurations with power unit-dispensers have been realized. A key research topic today is the development of the ultra-fast megawatt charging system that aims at pushing the limits of charging for MHDVs.

A wide range of innovative solutions exist today, catering to various fleet types and needs, including:

- Portable or rolling EVSE: Consists of a cart with charging ports, with the unit itself being connected to a power outlet (socket) via an extension cable. These offer a mobile charging solution inside a premises.
- Variable power input capacities for future expansion: Some EVSE can be installed and connected to your facilities with their power output deliberately reduced to limit the impact on upstream infrastructure while waiting for an upgrade of the transformer or electrical connection.
- Compact wall-mounted units: These are installed directly on the wall, thus requiring no pedestal or footprint.
- Wireless charging: Uses induction to transmit energy. A specialized EVSE module is embedded into the floor and connects to a receptor on the vehicles.
- Dual port or multi-dispenser chargers: Use the same charging unit to supply several vehicles at the same time through cables and plug connectors. Up to four dispensers can be connected to a single charger.
- Built-in energy management systems (EMS): Commonly found in multi-dispenser EVSE, built in EMS can share power by splitting it dynamically between several vehicles charging at the same time based on multiple criteria such as the SoC of each vehicle, the dispatch schedule for the next day, vehicle charging speed constraints, etc.
- Predictive maintenance: While still in its infancy, predictive maintenance has immense potential to minimize costs and extend the lifespan of charging infrastructure. It uses various technologies including the Internet of Things and artificial intelligence to leverage historical performance data and live condition monitoring to predict future maintenance needs before failures occur. Predictive maintenance can also be used to monitor transformers, switchgears, and every component involved in electrical distribution.
- Centralized direct current (DC) distribution: Converts alternating current to DC through rectification centrally rather than in the charging units, thus saving space.
- Bidirectional charging: Allows EVs to not only draw power from the grid, but also backwards through EVSE, supplying power to buildings, homes or other devices.

Some of these features can be particularly useful for facilities with limited power capacity as they help optimize and distribute energy usage.

Dedicated, Sequential, Parallel and Staggered Charging

Depot charging can utilize several configurations:

- Dedicated Charging: One charger is tied to one dispenser, or a single point of connection with one vehicle.
- Distributed Charging: One charger has multiple dispensers and can connect to up to four vehicles, offering multiple modes:
  - Sequential Charging: The charger supplies one vehicle at maximum charging capacity until fully charged and, once complete, the second vehicle gets charged, then the third, etc. This mode can offer a charging rate at the maximum output capability of the charger.
  - Parallel Charging: The power of the charger is divided so that multiple vehicles charge simultaneously. In this configuration, the vehicles do not receive the full charger power; instead, each shares the power at a reduced output.
  - Staggered Sequential Charging: The charger sends full power to each shared dispenser at alternating time intervals, instead of fully charging one vehicle before moving to the next.

Distributed charging offers several benefits, including the ability to optimize charging sequences across a fleet which minimizes the number of chargers needed. This optimization reduces initial investment, operational costs, and the space required in parking areas. However, implementing this technology adds complexity as the charging management system must automate the process across all EVSE. As North American charging management technology is still under development, dedicated charging is currently used for most fleets.

Systems Resilience and Redundancy

Plan for redundancy and resilience in your EVSE. While these terms are often used interchangeably, they refer to distinct concepts. Redundancy in a system means ensuring that, if one component fails, a secondary system can take over. For example, incorporating multiple smaller transformers can provide design redundancy in that, should one transformer fail, some charging capability is retained.

Resilience, on the other hand, refers to the system's ability to continue functioning despite changes in operating conditions. In the context of EVSE systems, resilience often describes a system's capacity to withstand various levels of power outages.

Figure 2-5 illustrates typical power utilization for a transit agency fleet of 300 buses. While prolonged power outages are rare, a power interruption lasting just a few hours during a peak operational period can be disruptive and have repercussions that last for several days.

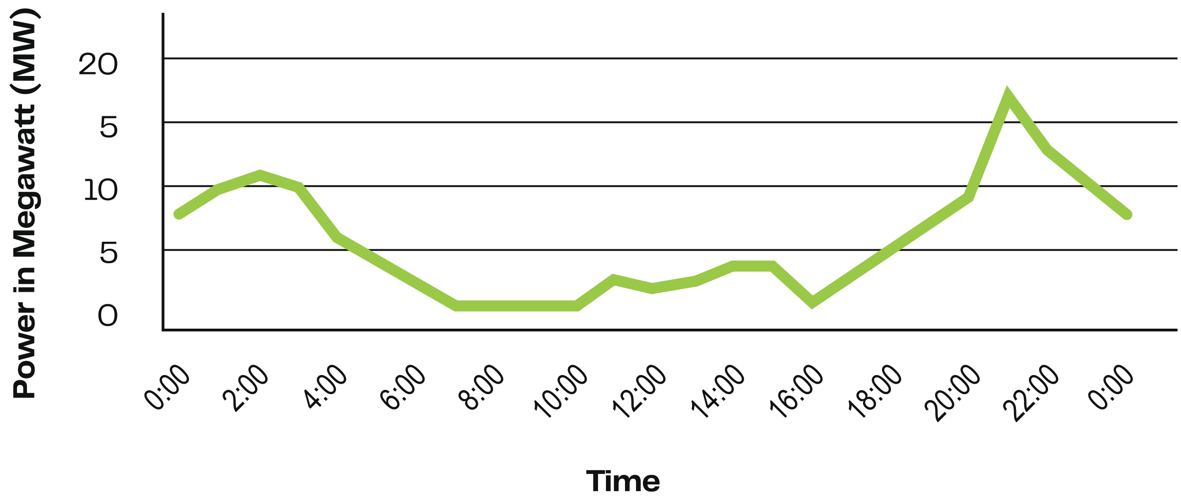

Figure 2-5: Typical Power Utilization for a Day of Transit Fleet Operations

For extended outages, local solutions such as natural gas generators may be necessary, while short-term blackouts can be managed with energy storage systems (ESS). When properly utilized, ESS can also help offset peak energy demand and potentially reduce overall electricity costs. However, these systems can also be expensive and are often not sized to meet the full power requirements of the fleet. For example, some transit agencies design their resilience systems to sustain only 30% of their services. Incorporate a cost-benefit analysis into your planning process when evaluating backup power and resilience systems to ensure they are appropriate for your fleet.

Best Practices for Charging Strategy Planning

- Develop a fleet charging strategy that aligns with operational needs, and accounts for existing infrastructure conditions and futureproofing. For fleets with daytime operations and daily return-to-base routes under 200 kms, a simplified strategy using Level 2 chargers may suffice. However, fleets with more varied operations will require more thorough planning.
- Plan to incorporate resilience features such as specialized on-site battery packs for energy storage to maintain operations during power outages, even if at a reduced capacity. Leverage public charging infrastructure as a transitionary or back-up solution to ensure vehicles have access to EVSE at all times.
- Keep up with advances in technology to optimize your charging strategy. Electrical distribution systems are becoming increasingly more efficient and EVSE for MHDVs is reaching 1 MW and beyond.

2.4.2 Energy Management Systems, Load Balancing, and Smart Charging

Electrical peak demand management represents a challenge from both an infrastructure planning and operating cost perspective. When installing and using multiple chargers at once, the total power required may increase, potentially adding stress to electrical infrastructure and increasing utility costs. Energy management systems (EMS) can help mitigate these problems by monitoring and controlling the energy flow of electrical infrastructure.

The primary goal of EMS is to reduce the overall peak energy demand by using a set of controls and measuring devices to manage energy distribution, utilization, and storage via load management and balancing. For charging infrastructure, EMS focus on regulating charging processes depending on physical and operational constraints such as output power, priority between charging outlets, etc. The monitoring and automated control of charging is commonly referred to as "smart charging."

Energy management features can be provided by both networked and non-networked components.

Non-networked components can provide energy management functions directly on their own and do not require external software to perform load management, load shedding, and load sharing. They are also more resilient towards network and data security issues as they do not communicate with external network connections. However, their inability to communicate with other systems limits their energy management features.

Networked components can be connected via wireless, cellular, or cabled connections and usually provide distinct functions through software in the form of cloud-based or local network online platforms. The software works with networked hardware and uses real-time data to provide load management features. The networked charger enables the EMS to adopt a wider range of inputs and operating constraints to offer custom smart charging processes with finer tuned outputs in accordance with operations. This type of system can be supplied by dedicated software providers, or EVSE suppliers, and comes with a recurring fee that typically depends on the number of charging stations in scope. For resilience, cloud-based systems should also be able to run locally to maintain operations when cloud-based services are unavailable.

The benefits of installing EMS for large ZEV fleets with mixed EVSE types or models are as follows:

- EMS provide a way to control operations under one system, reducing charging costs, and optimizing operations.
- EMS enable the supervision of several sites simultaneously, thus providing an overall vision of the assets' status and use.
- EMS are charger-agnostic as they use standard communication protocols to post-process real-time data and provide user dashboards.
- EMS enable identification features for the prioritization of charging, billing, and energy metering specific to each user.

Implementing EMS can be done in phases. The initial phase can focus on basic charging monitoring with dedicated data-sharing for operators. Subsequent phases can involve enhancing functionality by integrating and correlating multiple data sources to enable better control and more advanced capabilities. A phased and agile approach to EMS allows teams to gradually familiarize themselves with the technology, which helps optimize its integration into operations over time.

While there is no rule of thumb to determine the necessity of EMS, its implementation should not overcomplicate operations. An EMS is likely not required if charging can be easily executed without adding an additional layer of complexity, or if there is sufficient existing capacity to meet the needs of all chargers working together simultaneously.

Best Practices in Implementing EMS

- **Determine the extent to which an EMS is required to meet operational needs, as they should only be implemented when necessary. The operations of many smaller fleets are unlikely to require a full EMS.**
- **For larger fleets, ensure EMS software is fully integrated with the IT architecture of other relevant systems.**

2.4.3 Considerations for Pre-Design and Feasibility Work

When planning for EVSE installations, a comprehensive pre-design and feasibility assessment is prudent. These assessments can take 2 to 6 months depending on the complexity of the site and fleet operations, and typically involve the following steps:

1. Begin the process with a site visit to evaluate the physical layout, available space, and existing electrical infrastructure. This assessment includes checking available areas for infrastructure upgrades, ensuring the site is convenient and accessible for EV users and maintenance teams, and verifying compliance with local regulations and safety standards.

2. Following the site visit, an electrical assessment is conducted to measure the existing electrical load and capacity. This step is necessary to determine how many chargers can be supported without requiring upgrades to the existing electrical distribution system. Depending on the type of EVSE and the magnitude of the project, pre-feasibility will be evaluated from a structural and mechanical perspective. Experienced professionals can help identify future challenges early in the process.

3. Next, assessing the number and types of chargers required is essential. Analyzing historical vehicle usage data can help forecast future charging needs. This analysis helps determine the appropriate mix of Level 2 and fast chargers based on expected usage patterns. Additionally, consider factors such as EV adoption rates within the fleet, vehicle replacements, and technological advancements when providing 5- and 10-year predictions for charging needs.

4. Developing a phased strategy and site location plan is next. A phased implementation approach provides a long-term vision for the gradual installation of chargers, starting with a smaller number and scaling up as demand increases. Engaging in early discussions with a utility provider is necessary to understand their capacity for supporting additional load and any planned infrastructure upgrades. This dialogue helps identify the steps and costs involved in connecting the final installation to the grid. Furthermore, incorporating futureproofing strategies, such as designing sites to accommodate potential future expansions, and staying adaptable to emerging technologies, ensures the infrastructure remains relevant and cost-effective over time.
5. Another critical step is financial forecasting, where preliminary cost estimates for capital expenditures, construction, and operational expenditures are provided. Developing a budget that includes contingencies for unexpected costs ensures financial preparedness and project viability. As part of the financial forecast, revenue generation modelling should also be conducted. This involves estimating potential revenue from charging fees or carbon credit revenues based on projected usage. Also consider available incentives, grants, and subsidies that could offset costs. It is advised to receive capital and operational expenditure estimates from professionals such as engineers or consultants. At this stage of the project, with cost estimates and TCO analyses complete, the team should be capable of estimating changes in energy, maintenance, and other operational expenses. This will help inform estimates for the overall cost of transitioning to ZEVs.
6. Finally, assess the benefits of fleet decarbonization as it can help an organization compare and prioritize the transition to ZEVs relative to other strategic projects. Estimating the cost per tonne of potential GHG emissions reduced is one metric that can help prioritize project phasing. Establishing a baseline of current GHG emissions and calculating potential reductions can also provide a clear picture of the project's contribution to organizational sustainability goals.

Best Practices for Pre-Design and Feasibility Work

- Have a comprehensive pre-design feasibility assessment conducted to identify potential site-level infrastructure upgrades necessary for the installation of EVSE.
- Take a phased implementation approach when planning for EVSE that leverages historical fleet utilization data and considers futureproofing.
- Utilize the expertise of professionals to identify technical bottlenecks and infrastructure gaps.
- Evaluate necessary capital and operating costs, including potential site capacity upgrades, electrical distribution hardware, and EVSE options.

2.4.4 EVSE Installation, Base-Building Upgrades, and Hardware Costs

Key Messages

- Documenting all site-specific and operational complexities involved in charger deployment, particularly when a significant number of chargers need to be installed indoors, is critical to accurately account for potential challenges.
- Installing fleet EVSE requires expertise from several disciplines, and a complete vision of the impact it will have on a building's electrical systems, physical layout, and operational workflows.

The key steps involved in typical EVSE Installation and Base Building Upgrades are the following:

- Detailed Engineering Design: This phase involves the development of multiple iterations of detailed drawings for installation, culminating in "Issued for Construction" drawings. For larger fleet decarbonization projects, this process encompasses various disciplines including electrical, mechanical, structural and civil engineering as well as telecommunications experts and architects, if required. For smaller projects, such as the installation of fewer than ten Level 2 chargers, a contractor can directly manage this process.
- Procurement: This process involves developing a Request for Proposal or Request for Quotation to select the appropriate charging and distribution equipment. The Procurement phase can also be used to select the contractor or alternative business models such as turnkey solution providers.
- Permitting: This phase occurs early in the detailed engineering design phase. Requirements vary depending on province, municipality, and project scope.
- Contract Administration: This ensures that construction proceeds as planned and in accordance with approved engineering designs. For more complex projects, external teams may be needed if the fleet and/or real property manager lack construction experience.
- Commissioning: This final quality assurance step involves a series of tests to ensure chargers are installed correctly and are functioning as planned.

Outdoor EVSE Installation

Typical upgrades for outdoor installations include new concrete bases for EVSE pedestal mounts, bases for standalone EVSE, backfilling material following excavation, asphalt for new paved areas, installation of new signage and traffic protection (bollards), painting for reserved parking spots, and the installation of proper lighting.

The following considerations should guide outdoor EVSE installations:

- Locate underground utilities to assess existing conditions and minimize the risk of damage and additional civil work. This can present challenges if the building and electrical plans are outdated.
- Assess potential on-site soil contamination as additional remediation efforts may be required, if found.
- Evaluate the source of base power and implement secondary metering where possible. Some utilities, like Hydro-Québec, offer advantageous rates for secondary metering [53].
- Keep in mind that Canada's construction season is limited. Therefore, plan design and implementation timelines carefully. If not coordinated properly, the project will suffer delays or additional costs for winter construction (if possible).
- Ensure proper dewatering of the site and avoid proximity to fuel sources or hazardous areas for the installation of EVSE.
- Account for potential equipment delivery delays, particularly for transformers, in project phasing.
- Prioritize the user experience and accessibility as key design criteria for EVSE installations.

Outdoor installations typically cost less than indoor installations with pricing dependent on site conditions, excavation and trenching requirements, electrical capacity, and transformer types. The budget for engineering, installation, and commissioning of a single-connector Level 2 charger is often 1 to 5 times the charger cost.

Indoor EVSE Installation

Dedicating space to electrical equipment is often a challenge inside garages or depots where free space can be limited. The placement of EVSE on roofs or suspending chargers from ceilings often requires costly structural reinforcements due to the added weight. A potential solution is to develop a separate structure to support pull-down dispenser cables or pantographs. In sites where space is limited, plan for future charger deployment before installing any EVSE.

In addition to the main parking garage, other areas of the building such as maintenance areas may require upgrades to meet safety protocols related to battery thermal runaway and personal protective equipment (PPE) utilization. Hoists may need to be upgraded if required to repair ZEVs, which are typically heavier than ICE vehicles. If batteries are located on vehicles' roofs, then a specific gantry platform will need to be procured to access this area.

Lastly, the addition of electrical equipment that generates heat can affect building temperatures, especially in smaller secondary electrical rooms, which may ultimately have an impact on the Heating, Ventilation and Air Conditioning (HVAC) system's performance. HVAC systems are typically designed to handle exhaust emissions from ICE vehicles and may need to be adjusted to accommodate ZEVs and charging systems. Hydrogen vehicles, in particular, require additional venting and roof modifications to prevent the formation of hydrogen pockets.

Key considerations for base building upgrades when installing an indoor EVSE system include:

- Adding electrical rooms may be necessary to house equipment which may require building expansions.
- Review the National Fire Protection Association guidelines as there are currently no established Canadian codes for fire protection specific to EVSE systems. As mentioned in the section on *Fleet Composition Considerations*, while battery fires in BEVs are rare, they are onerous to extinguish.
- Upgrade the HVAC system to accommodate excess heat generated by charging systems and electrical equipment.
- Ensure maintenance areas are upgraded to meet safety protocols required to repair ZEVs, and properly equipped to service heavier vehicles.
- Mobile chargers can be purchased for maintenance areas, if needed.
- Installing hydrogen gas detectors, alarms and permanent vents at the highest point of the ceiling can provide a direct path for safe hydrogen venting.

Hardware costs depend on the type, power, amount of EVSE, usage scenario, resilience requirements, and potential addition of electrical services. These costs are mainly driven by electrical parts and labour but can also include mechanical and structural costs for indoor installations. Civil work costs arise from outdoor installations and adjustments to existing facilities per new architectural designs or code compliance (i.e., access for those with reduced mobility). Providing a budget range in this guide is challenging due to varying factors including types of charging installations, building conditions, and existing electrical systems.

Best Practices for EVSE Installation and Base Building Upgrades

- Evaluate all potential impacts on facilities related to installing EVSE and operating ZEVs, including electrical distribution, allocation of space, maintenance area modifications, fire suppression and HVAC system upgrades, etc.
- Future-proof the (indoor or outdoor) site to better tailor the deployment of electrical infrastructure and ensure future expansions can be implemented more efficiently.

2.4.5 EVSE Network Considerations

A networked EVSE system suppozrts live monitoring of assets, failure detection, billing, authentication, and load management. Networking can be a key component of charging infrastructure operation, but it comes with the added cost of purchasing smart equipment and software licensing. Opting for manufacturer-agnostic solutions helps avoid vendor lock-in and supports long-term adaptability.

When planning to network EVSE, ensure sites have reliable internet access via ethernet, cellular, Wi-Fi, or satellite networks (if remote). Networking EVSE also exposes operations to a new set of risks linked to cybersecurity and the reliability of telecommunications infrastructure to maintain continuity of operations.

EVSE networking can also be done locally between several devices, reducing dependence on external communications; however, this also limits external control and monitoring capabilities.

Best Practices When Considering EVSE Networking

- **Implement an EVSE network according to the needs of your operations.**
- **Build resilience into your EVSE network with equipment and process backups to ensure continuity in the event of network failure.**
- **Ensure networks have sufficient protocols in place to prevent cyberattacks on EVSE and related databases.**

2.4.6 EVSE Ownership Models

When selecting an EVSE ownership model, consider access to capital, constraints imposed by the site owner (if the site is leased), readiness to assume risk and build internal capabilities, and the desired level of autonomy for managing and maintaining the chargers.

The following list highlights the main EVSE ownership models:

1. Complete Ownership and Operation: The fleet organization purchases and operates charging stations, granting them full control over the EVSE, and retention of any revenue generated. However, it also places the highest level of responsibility on the owner, including risks related to upkeep, management, and potential future obsolescence. It assumes that the organization has the necessary internal capabilities to manage the operation, maintenance, and eventual replacement of the chargers.

2. Infrastructure-as-a-Service / Charge-as-a-Service: This involves turnkey charging-as-a-service providers retaining ownership of the EVSE, leasing it to a site host under a service agreement and may also include operational and maintenance support. There are various delivery models within this approach, each with differing levels of organization participation and risk transfer. The advantages for fleet owners are reduced upfront capital costs for infrastructure, reduced financial risks, and the externalization of the required skills and capabilities to lead infrastructure deployment and maintenance. The service provider effectively converts capital expenses into operating costs, passing them on to the organization through a monthly fee which includes a service charge. While this option may result in higher long-term costs due to service fees, it remains attractive for fleet operators that prioritize minimizing initial expenditures and reducing risks related to charger installation and operation.
3. Third-Party Ownership: The organization collaborates with a third-party organization to manage some or all aspects of ownership, operation, maintenance, and billing for the charging stations. This model offers flexibility as the two parties can negotiate and define their respective roles and responsibilities. It often involves partnerships with EV service providers to streamline these operations.
4. Utility Ownership: The electric utility assumes ownership of the charging station. The utility can either lease the chargers to the organization or develop its own sites and charging network. For non-utility entities leasing the chargers, this arrangement helps reduce the risks related to maintenance and potential obsolescence of the equipment.

There can be many variations of the existing ownership models as each organization negotiates its preferred balance between cost responsibility and autonomy.

If the organization decides to own the chargers, this decision can offer opportunities for revenue stream diversification. For example, the entity could explore partnerships with local businesses or municipal programs to provide public access to charging stations after operating hours.

Best Practices When Selecting an Infrastructure Ownership Model

- Consider sharing operational ownership of your charging assets. While partnering is not mandatory, it is often the preferred approach, especially for small-to-mid-scale fleets.
- Select an ownership model based on what fits your needs and what is available in your region. Turnkey solution providers can cover all of Canada.

2.4.7 Property Interest Types and Their Significance

There are multiple real property interest types that may be relevant to fleet-owning organizations, including full facility ownership, land use permits, and several forms of lease agreements. This section applies to fleets that do not own their facilities or the parking lots where the vehicles are housed. As it is the landlord who determines the lease terms for charger installation, it is important for fleet managers to align their interests and negotiate mutually acceptable project conditions.

Table 2-5 highlights actions available to fleet managers or other representatives of an organization navigating the negotiation process.

Table 2-5: Considerations for Securing Charging Solutions at a Leased Facility

	Action	Description
1.	**Review Your Options**	For more permanent installations, existing electrical infrastructure can be upgraded to increase capacity to meet the power demands of EV chargers over the long term. Two temporary options include individual battery-integrated chargers and shipping containers configured with up to 20 Level 2 chargers. They both offer the owner flexibility since they are designed to be relocated as needed, at an additional expense. Shipping container charging solutions have been deployed in Québec, primarily in support of school bus electrification. One challenge with this application is the secondary connection required to link the container to the grid. For example, in Ontario, most local utilities have conditions of service that limit each property/parcel of land to one point of connection. Other options include negotiating with the landlord to take actions to install permanent EVSE with financial support from the tenant and/or guarantees of long-term rent.
2.	**Build Your Business Case**	Identify risks when developing a business case. For example, installing costly charging infrastructure at locations where a landlord could terminate an existing lease carries inherent risks. Additionally, there may be delays in obtaining necessary permits if a landlord does not prioritize your requests regarding on-site EVSE. Remind your landlord that they may qualify for grants and/or contributions that are not accessible to the end user.
3.	**Address Any Landlord Concerns**	After presenting the project vision and ambition to the landlord, the fleet manager should address any concerns regarding the installation of EVSE. At this step, show the landlord all benefits of charger deployment to facilitate buy-in (i.e., future-proofing the property, contributing to sustainability goals, future leasing value/increased property value, etc.).

4 .	**Define the Cost Breakdown**	After completing a project proposal, including scope of work, potential electricity upgrades, required construction, timelines, and project costs, the fleet manager should review and negotiate the existing lease contract, define the cost breakdown, and specify which party is responsible for various aspects of the project.
5 .	**Address Charger Ownership**	Clearly define who will own and maintain the chargers after installation.
6.	**Address Legal Terms**	Ensure that all legal terms, including liabilities, warranties, and indemnification clauses are addressed to protect both parties and update the lease contract to reflect infrastructure added to the site. If a lease ends, including provisions about the removal or transfer of chargers can be helpful. Consult with legal personnel, if necessary, at this stage.
7.	**Address Insurance Terms**	Insurance coverage should be carefully evaluated to cover potential damages resulting from charging issues.
8 .	**Keep the Landlord Informed**	Provide regular updates to the landlord throughout the installation process, including timelines, potential delays, and required adjustments, if applicable.

To avoid delays in the permitting and compliance process, fleet operators can take leadership of obtaining all necessary permits, with the property owner's approval. This is applicable even when working through contractors such as engineering or construction firms rather than relying solely on the property decision-maker.

Best Practices for Charger Deployment at Leased Facilities

- Consider implementing battery-integrated chargers or shipping container charging solutions if feasible.
- Review lease terms to ensure there is no need to vacate the site in the near term, even if installing a container solution.
- Secure written approval of the electrification plan from the landlord prior to moving forward.
- Maintain frequent communications with the landlord to keep them involved at each stage of the process, thus facilitating smoother negotiations.
- Define the responsibilities for charger installation and operation including all associated costs and legal terms to address potential disputes or issues.

2.5 Considerations for Law Enforcement Fleets

Key Messages

- Accounting for the unique operations of law enforcement vehicles (high-speed chases, prolonged idling, urban patrols around the clock, specialized on-board equipment, etc.) can help to anticipate charging needs more accurately.
- Collaborating closely with OEMs can help tailor ZEV upfits to specialized operational requirements.
- Implementing Level 3 EVSE may be needed to support fast charging during brief visits to base as well as rapid, emergency deployments.
- Developing a backup charging plan may be necessary to maintain 24-hour fleet operations in the event of unexpected utility outages.
- Telematics can effectively monitor energy consumption to help manage emergency equipment, shift planning, and ZEV performance optimization. To ensure consistent vehicle availability within a law enforcement fleet, precise charging management can be helpful to prepare vehicles for emergency deployments. Telematics devices, which may track sensitive police data will require more strict security measures.
- Providing ZEV operators with specialized training around the characteristics of electric powertrains (i.e., instant torque, regenerative braking, etc.), can optimize driver performance, particularly for pursuit and stealth operations.

2.5.1 Fleet Decarbonization (Pre-Purchase Phase)

Law enforcement vehicles often operate with unique driving profiles requiring quick acceleration, long idling times and quick refuelling periods. Additionally, law enforcement vehicles require a suite of specialized on-board auxiliary equipment to perform policing duties including lights, sirens and ample export power for laptops, printers, etc.

Collaborating closely with OEMs ensures that upfit kits are compatible with the chosen ZEV models. This includes verifying that electrical systems can support additional loads without noticeably reducing vehicle range. Also consider ergonomics during upfitting, as officers with all the necessary equipment will need adequate space. Modifying the reverse speed limiter in ZEVs may also be required, as OEMs typically set it at a default between 10 and 15 km/h, which may impact operations. As such, this modification might require consultation with OEMs.

Given the higher energy consumption profile of law enforcement duty cycles, the key challenge for fleet decarbonization is ensuring that charging infrastructure can support emergency operations and shift changes when rapid vehicle deployment is necessary. Fast charger availability at key locations can ensure readiness for high-priority calls.

Aligning charging strategies with operational demands is paramount. For example, fast chargers should be made available to vehicles that are hot-seated (i.e., where a single vehicle is used by multiple officers back-to-back) or dedicated to emergency response, while vehicles used for general-duty tasks can be charged with Level 2 EVSE.

Telematics systems collect sensitive data, such as police vehicle routes and Global Positioning System (GPS) coordinates for surveillance. Fleet managers should ensure, in coordination with OEMs and/or the telematics provider, that all collected data are securely protected, hidden, purged and/or accessible only to authorized personnel.

To date, only a few municipalities and operators have experimented with zero-emission law enforcement vehicles, such as the City of Repentigny in Québec. The City's pilot project report [54] highlighted that current EV technology, specifically the Ford Mustang Mach-E, effectively met the operational needs of police patrols with charging requirements sufficiently fitting into schedules, even in 24/7 winter operations. A dedicated 50 kW fast charger was used as the primary source of charging.

The Royal Canadian Mounted Police continue to deploy more ZEVs within their fleet for traffic and general-duty purposes. Early data from RCMP's West Shore detachment, suggest that electrical demands from driving, idling and auxiliary equipment have not dramatically impacted battery state-of-health, or vehicle range requirements [55].

Best Practices to Plan for Decarbonizing Law Enforcement Fleets

- Assess ZEV and infrastructure compatibility with the operational requirements of law enforcement driving cycles.
- Ensure that ZEV upfits meet operational demands, and that data are sufficiently protected by collaborating with OEMs and telematics providers, respectively.

2.5.2 ZEV Fleet Management and Operation for Law Enforcement (Post-Purchase Phase)

Analyzing telematics data can help fleet managers track the impact that equipment such as HVAC, radios, onboard computers, and emergency lighting has on vehicle energy consumption. Using these data, adjustments can be made to shift assignments or operational strategies to optimize ZEV performance [56].

A comprehensive charging strategy is a priority for law enforcement vehicles, as they often need to be ready for deployment at a moment's notice. Effective charging schedule management can be facilitated by setting up alerts for when vehicles are dwelling for extended periods of time without charging [54].

Law enforcement operations necessitate exceptional driving demands such as high-speed acceleration (including in reverse), stealth operations, off-pavement use, and precision immobilization techniques where ZEVs behave differently than traditional ICE vehicles. This difference suggests a need for tailored training programs for officers, with a focus on handling the instant torque of EVs, managing regenerative braking, and understanding the limitations of ZEVs in pursuit situations. Training should also address the optimal use of heating and cooling systems to extend vehicle range during prolonged shifts.

Law enforcement vehicles often have high utilization rates which can accelerate degradation of batteries and tires relative to civilian use. Developing a proactive maintenance strategy for battery health monitoring is necessary for managing long-term operational costs and ensuring fleet readiness. Incorporating battery state-of-health monitoring as part of regular maintenance routines can help mitigate battery degradation and guide decisions on battery replacements or deployment schedule adjustments for duty cycles nearing the limit of the vehicles' range capabilities.

Best Practices for Managing ZEV Law Enforcement Fleets

- Utilize fast chargers, whether on base or at strategic public locations, for rapid response readiness.
- Manage charging schedules based on usage patterns to optimize vehicle availability and reduce operating costs.
- Develop ZEV-specific driver training to maximize vehicle performance (range, handling, etc.) when charging, driving and idling during operations.
- Develop a structured decision-making framework for vehicle deployment, ensuring ZEVs are assigned to duties within their operational capabilities, while reserving ICE vehicles for tasks requiring extended range or specialized performance, such as interprovincial operations or long-distance assignments.
- Develop a strategy for monitoring battery health, including planning for replacements and managing the impact of high utilization on battery life.
- Anticipate extreme weather conditions and develop protocols for maintaining ZEV performance and safety during cold or hot temperatures.
- Ensure charging infrastructure, vehicle range, and operational strategies support effective ZEV deployment in isolated or rural areas.

3

Green Fleet Management

3

Green Fleet Management

3.1 Driver Training and ZEV Operation

Key Messages

- Implementing eco-driving practices can significantly reduce energy consumption in ZEVs with potential fuel savings of up to 30%.
- Maintaining battery health through optimal charging and discharging practices (e.g., avoiding overcharging and discharging below 20-30%) and following manufacturer guidelines can limit annual degradation to around 2% and help extend the battery's lifespan.
- Mitigation strategies are necessary to account for winter conditions that can reduce ZEV range by up to 30% due to increased heating needs, battery conditioning, and higher rolling resistance. Preheating ZEVs while plugged in, using efficient cabin heating solutions such as heated seats, and practicing proper tire maintenance can optimize range and ensure safety.
- Offering comprehensive training to operators and maintenance staff can ensure ZEVs are driven, charged, and maintained effectively.
- Monitoring key performance indicators such as vehicle uptime and mean distance between failures can optimize ZEV reliability and efficiency.

3.1.1 Strategies to Reduce Energy Consumption and Optimize Range

Factors that help maximize energy efficiency in ZEV powertrains include higher regenerative braking utilization and eco-driving practices. Eco-driving encourages smooth acceleration, maintaining a consistent speed, anticipating traffic and avoiding hard braking. Driving at moderate speeds and reducing the use of high-energy features like air conditioning and heating also help conserve energy. To ensure that ZEV operators effectively apply eco-driving practices, they should be provided with specialized driver training.

Fleet managers should provide drivers with feedback, based on real-time driving data, to optimize safety and energy efficiency. Continuous feedback on driving performance can only be provided if the right telematics system is in place. By providing real-time data on driving behaviours, such as speed, braking, route efficiency, and idle time, telematics can help identify and correct energy intensive driving habits. Additionally, monitoring battery health and charging patterns can enable fleet managers to plan routes that maximize range while minimizing unnecessary energy usage.

While the percentage of energy savings from eco-driving can vary depending on vehicle type, driving patterns, and the nature of the duty cycle, a study conducted by the Society of Automotive Engineers [57] showed that the application of eco-driving can generate up to 22% energy consumption savings.[7] For MHDVs, pilot projects completed in the U.S. through Run on Less tested zero-emission heavy-duty trucks and saw an average of 16% [58] energy recovery and even up to 30% in some instances.

Energy consumption for ZEVs can be highly influenced by operator behaviour and heating/cooling utilization. Figure 3-1 provides a typical example of energy consumption pathways between key components of the electric drivetrain. In this example of an electric bus in Switzerland, traction power is 21% of energy consumed, heating is 32%, auxiliaries are 19%, and the rest are other losses (such as internal resistance losses). Limiting energy lost to motive power and HVAC is critical for range optimization.

To improve HVAC efficiency and reduce battery drain due to heating or cooling, operators can pre-condition EVs while charging. Using moderate temperature settings, seat heaters, and natural ventilation, when possible, can also lower energy consumption. Minimizing idle time in extreme temperatures also helps conserve energy and extend range.

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7 *This study was conducted using a Chevrolet Bolt, connected with vehicle-to-infrastructure communications systems, covering a 3.7 km track with various stop signs, traffic signals, and speed limits.*

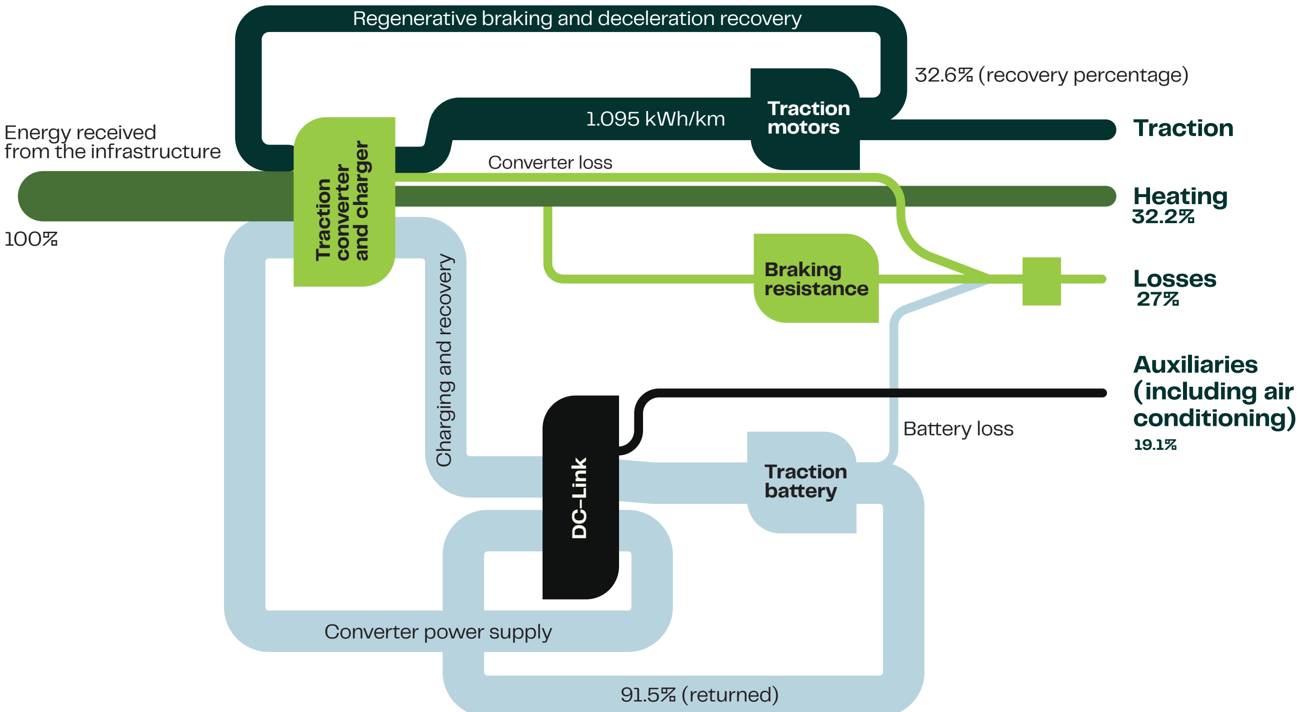


Figure 3-1: Energy Consumption Pathway on a ZEV Powertrain (Adapted from the Outcomes of a Transports Publics Genevois Presentation on their Trolleybus Optimisation Systême Alimentation Project)

Best Practices for Reducing ZEV Energy Consumption

- Include eco-driving as part of your operator training.
- Encourage ZEV operators to adjust their driving patterns based on telematics system recommendations and feedback.

3.1.2 Mitigating Battery Degradation

Battery degradation refers to the reduced accessible capacity of the ZEV's onboard battery over time. A report from Geotab monitoring thousands of light-duty EVs indicates yearly average battery capacity losses of less than 2% [59]. However, even a 2% annual degradation translates to 20% over a 10-year service life, which can materially impact operations.

The effects of battery degradation extend beyond reduced range; it also increases charging time due to higher resistivity[8] and decreases the output power delivered by the battery which impacts vehicle performance (e.g., payload and acceleration capabilities).

[8] *Resistivity refers to a material's property that resists the flow of electric current. In the context of batteries, it is the measure of how strongly the battery's internal components oppose the movement of electrical charge.*

Several strategies can mitigate the impact of battery degradation. For instance, avoid charging a vehicle when its SoC is at 100%, as overcharging can lead to lithium plating which accelerates battery degradation. Most modern chargers will automatically reduce the charge rate to a minimum once full charge is reached in a process known as residual charging, or you can simply unplug the vehicle after achieving a full charge. Similarly, it is ideal to avoid discharging the battery below a certain threshold; typically, less than 20–30%, as this stresses the battery and shortens its lifespan. Each manufacturer will recommend slightly different SoC thresholds for optimizing battery health.

Telematics systems help monitor battery health, but for a more comprehensive understanding, real-time battery monitoring and analytics platforms are also necessary. These systems can either be integrated into the vehicle's information system or be provided with separate tools from third-party suppliers, offering detailed insights into battery performance, health, and usage patterns. They use indicators such as cell voltage and amperage to estimate the remaining lifecycle of a battery based on existing driving cycles or historical trends. They are also used to monitor for potential battery fires by collecting real-time information on battery temperature.

Best Practices for Mitigating Battery Degradation

- **Operate with a vehicle SoC between 30% and 80% to extend battery life. Each OEM has specific recommendations; follow their guidelines.**
- **Plan for and budget battery replacement or additional extended warranty coverage if the vehicle's lifecycle is expected to exceed 10 years.**

3.1.3 Winter Range Derating and Extreme Weather Considerations

Fleet operators should be aware that winter conditions impact the driving range of ZEVs due to the following:

- Increased cabin heating due to lower ambient air temperatures can reduce vehicle range by up to 30% when temperatures are below -1°C, depending on the vehicle heating capacities and heating technology [60]. Since ZEVs are more efficient and produce less heat waste than ICE vehicles, they do not generate sufficient heat to be repurposed for heating the cabin.
- The higher rolling resistance of winter tires and the reduced traction on winter surfaces require increased energy.
- Slippery driving conditions reduce the potential energy recovery from regenerative braking. As part of a vehicle's traction control system, ZEV manufacturers may disable regenerative braking when slipping to mitigate the risk of wheel lock up.

- Longer charge times may occur if the battery is not preconditioned beforehand, as it needs to heat itself up before the charging speed can increase [60].
- Maintaining the battery temperature in cold weather requires more energy. Moreover, charging an EV in the winter is more energy intensive and expensive.

To mitigate the impacts of cold temperatures on battery health and preserve vehicle range, preheat the vehicle while plugged in. This is referred to as preconditioning and helps the vehicle and battery reach an optimal driving temperature. Regular maintenance checks, including monitoring tire pressure and battery health, are imperative to help operators maximize the efficiency and range of their ZEVs in cold temperatures.

Tire pressure impacts efficiency by affecting rolling resistance. Underinflated tires increase resistance, requiring more energy to propel the vehicle and reducing range as a result. Cold temperatures lower tire pressure, making regular checks essential for maintaining efficiency and range. Tire pressures should be measured at least once every month and more often with extreme temperature changes to ensure proper inflation. Operating a vehicle with tires under-inflated by 56 kilopascals (8 psi) can increase fuel consumption by up to 4% [62].

For specific vehicles such as transit buses and school buses that need to heat larger spaces throughout the day, auxiliary diesel heating systems are often used to supplement resistive electrical heating or heat pumps. While not a zero-emission solution, diesel heating reduces the demand on the vehicle's battery and helps extend its range.

Based on discussions with Canadian fleet operators, winter conditions do not affect the performance of chargers, as these are generally rated for temperatures as low as -40°C. However, winter conditions can make chargers more difficult to handle for users if snow or ice collects on and/or around the cable and plug. Installing canopies above outdoor charging systems can help mitigate this issue.

Ensure snow is removed from areas near and in front of chargers to leave clear access. For shared public chargers, one of the most common causes of damage in winter is snowplows driving into charging equipment. It is important to ensure accessibility is maintained throughout the winter, as snow can often accumulate around chargers in parking lots.

While this section discusses the impact that low temperatures have on range, some studies suggest that air conditioning consumes more energy per degree cooled than heaters do per degree heated [60]. In all conditions where the ambient air temperature differs greatly from comfortable cabin temperature, air conditioning use will significantly impact vehicle range.

Best Practices for Mitigating the Impact of Winter Conditions

- Preheat the vehicle for 20–30 minutes before departure while it remains plugged in.[9]
- Prioritize vehicles equipped with heated seats, heated steering wheels, or directed heating systems (such as a directed fan heater for the driver) to minimize the need for full cabin heating. This is particularly important when procuring vehicles for applications that require large cabins, such as in the delivery sector, where the focus should be on keeping the driver warm rather than heating the entire cabin. If available from manufacturers and suitable for the vehicle application, choose models with heat pumps, as they are more energy-efficient than resistive coil heaters.
- Regularly monitor tire condition and pressure to help optimize winter range.
- To preserve range in warm temperatures, encourage operators to minimize air conditioning use and to use energy-efficient cooling strategies such as direct natural ventilation or pre-cooling the vehicle while plugged in.

9 Preheating refers to warming up the vehicle's cabin and battery system before departure while it is still plugged into a charging station.

3.1.4 General ZEV Operation and Maintenance

General ZEV Operation

To ensure reliable and optimal vehicle performance, the following actions are recommended:

- Implement training on charging system safety protocols and charging etiquette.
- Communicate to operators that driving a ZEV is similar to driving an ICE vehicle while also highlighting the differences, such as their higher torque, quieter ride, and one-pedal driving features.
- Implement a charging schedule to enable load balancing and reduce peak demand.
- Ensure ZEVs are sufficiently charged to complete routes by checking their SoC prior to use. Depending on the fleet size and operations, this check can be performed by the operator (e.g., verifying the battery is at a predetermined charge level before departure) or automated through a dispatch and monitoring system. Such systems can alert fleet managers if a vehicle lacks the necessary charge to complete an assigned route.
- Inform operators about the availability of public charging infrastructure, as well as related procedures and resources such as payment cards, charging network smartphone applications, and roadside assistance for critical SoC situations.

- Regularly analyze data collected through the charging management system (CMS), EMS, telematics systems, and other available tools to prevent failures, optimize vehicle performance and charging schedules, improve operator behaviour, reduce energy consumption, and extend ZEV lifespan.

Fleet managers should also regularly monitor the following key metrics:

- Energy Consumption: This can help identify driving behaviours such as heavy idling and allow fleet managers to encourage operators to practice eco-driving where necessary.
- Vehicle and Charger Uptime: The amount of time a vehicle or charger is operational and available for use should be monitored to assess daily utilization and ensure vehicles are meeting performance expectations.
- Mean Distance Between Failures (MDBF): This metric can be tracked annually to ensure that vehicles are meeting performance expectations and that maintenance protocols are sufficient. It is calculated by dividing the total distance traveled by the number of failures. This requires implementing a tracking system to record the number of failures that necessitate the vehicle being out of service.
- Usage Patterns and Distance Travelled: This helps to optimize vehicle deployments and ensures EVs are assigned to routes and tasks that match their range and operational capabilities.
- PHEV charging events: This information provides insight into the extent to which ZEV operators utilize the electric motor in PHEVs to save fuel and reduce GHG emissions.

ZEV Maintenance

ZEVs typically require less maintenance than ICE vehicles, in part due to requiring fewer fluids, experiencing reduced brake wear due to regenerative braking, and having fewer moving parts [63]. Key components of the powertrain, such as the motor, inverter, and inductors can typically last the full lifecycle of the battery. ZEVs are subject to specific safety requirements and protocols to appropriately deactivate and handle high voltage electrical systems. Maintenance procedures involving high voltage necessitate the use of PPE and appropriately insulated tools.

Technician training programs are offered in various locations across Canada and should be mandatory for maintaining ZEVs. A maintenance team should also be trained and equipped to handle emergency responses to battery-related incidents, such as thermal runaway.

Depending on a vehicle's operations, one or more battery replacements may be needed over its lifecycle. If that is the case, a dedicated temperature-controlled space easily accessible to firefighters should be available to store used batteries before they are transported away for disposal. For more details, refer to the section on *Battery Recycling and Disposal*.

To ensure maintenance practices are tailored to the unique requirements of ZEVs, the following practices are recommended:

- Preventive Maintenance: Vehicle (and charger) manufacturers usually provide specific maintenance and inspection schedules involving regular checks of high-voltage components including the battery, motor, and wiring, as well as the cooling systems to ensure optimal battery temperature is maintained.
- Corrective Maintenance: One of the main differences between maintaining a ZEV relative to an ICE vehicle is that ZEV corrective maintenance heavily revolves around troubleshooting vehicle data and dashboard alerts to reach a diagnosis.
- Charger Maintenance: Conduct regular inspections of charging equipment per manufacturer recommendations, including checking the condition of cables, examining plug contacts for wear or damage, ensuring proper fit of plug receptacles, and maintaining cable management components. For Level 3 chargers, air filter checks are essential to ensure the optimal performance of the cooling system and prevent overheating.

Access to skilled ZEV maintenance technicians in remote areas can be limited, as specialized training is required. This should be addressed and mitigated in the maintenance plan. Options may include developing tailored training programs for operations and maintenance staff or, if feasible, outsourcing maintenance to the OEM or an external partner.

Best Practices for General ZEV Operation and Maintenance

- Develop an internal concept of operations to map out the characteristics of each system, define related operating processes for ZEVs, and outline emergency response plans, including flow charts for ZEV users and staff working near them.
- Develop training programs for staff members to ensure the safe and optimal operation of vehicles and chargers.
- Ensure effective ZEV maintenance and operation by regularly tracking key performance indicators such as vehicle uptime, MDBF, and charger utilization.
- Ensure a local firefighting authority is aware of emergency response plans as they will provide support in an emergency.
- Collaborate with public and private partners, including utilities, to identify and assess potential locations for public rapid charging infrastructure for MHDVs in municipalities, gas stations, and recreational areas [64]. Integrate these locations into the overall charging strategy for the fleet, considering them as primary charging sites or as a backup.

3.2 EVSE Management and Use

Key Messages

- Prioritize overnight charging and utilize automated tools (e.g., EMS/CMS), to reduce your own peak demand usage and lower operating costs.
- Implementing workplace charging for employee-owned vehicles involves assessing costs, charger types, and installation logistics while ensuring fleet operations remain prioritized. Offering employee access to EV chargers can provide potential revenue streams for fleets, while strategically managing access can reduce interference with fleet needs during peak operating hours.
- Ensure fair access and charger longevity by communicating proper charging etiquette to employees such as unplugging when charging is complete, respecting charging time limits and securely storing charging cables. The installation of proper signage and informing employees on how to report damaged EVSE is also recommended.
- Allowing home charging for fleet vehicles may require employer-funded Level 2 EVSE installations or permissions to proceed with Level 1 home charging to avoid costly infrastructure upgrades. Policies should align with job requirements, include fair reimbursement strategies, and consider tax implications for provided benefits.

3.2.1 Effective Depot Charging

Effective depot charging requires that stakeholders can adapt to innovative technologies and systems. Additionally, operators, maintenance crews, and supervising teams must understand their roles and follow operational guidelines. These guidelines can be reinforced with physical signage on-site indicating tasks and designated parking spaces.

Monitoring and controlling on-site charging activities using automated EMS or CMS tools can be effective for meeting charging demands while minimizing the number of chargers required. These tools enhance efficiency by automating vehicle identification, SoC, usage, and energy management while streamlining the charging process and helping to detect malfunctioning equipment and operational issues. Additionally, EMS collect the energy usage of the building and can help fleets take advantage of local power generation from solar panels or wind turbines as well as energy storage systems when needed.

Planning for effective depot charging also involves risk mitigation strategies and emergency procedures. Organizations must be prepared for potential equipment failures (e.g., EVSE, vehicles, software, power grid, etc.) and have contingency plans in place to maintain operations. Redundant systems with multiple charging solutions and mobile EVSE help personnel face equipment failure with increased confidence. Compatibility of equipment is also key to handling failures and effectively anticipating maintenance. Continuously monitoring battery temperatures and ensuring the system can immediately alert the driver and the authorities having jurisdiction in cases of malfunction is also integral to managing on-site charging events.

By prioritizing overnight or off-peak charging when grid demand is lower, fleet managers can reduce demand during peak operating hours and take advantage of lower electricity rates (depending on their utility), thereby avoiding high energy fees; especially in jurisdictions where the Global Adjustment Rate is in effect (e.g. Ontario).

Best Practices for Effective Depot Charging

- Update your existing concept of operations to accommodate changes required for managing a fleet of ZEVs and ICE vehicles, including the use of chargers.
- Automate operations as much as possible and develop a system for charging in accordance with your needs.
- Continuously monitor ZEV battery health to mitigate risk of malfunction or failure.
- If implementing an EMS, do so in phases to allow end users to gradually familiarize themselves with the technology and adapt their operations accordingly.

3.2.2 Employee and Public Access to EVSE

Light-duty ZEV adoption in Canada rose to 16.5% in the third quarter of 2024 [65], making it increasingly likely that non-fleet employees will also want to make use of on-site EVSE. A key consideration for serving employee charging needs is the commuting distance of employees and their access to at-home charging. Sites with little or no nearby public EVSE and longer employee commuting distances could consider enabling employee access to their EVSE or installing dedicated EVSE for employee vehicles.

Employee vehicle powertrains should be inventoried when planning for charging needs. PHEV owners typically rely less on workplace charging, as their vehicles can switch to gasoline when the battery is depleted. In contrast, BEV owners are entirely dependent on access to chargers, especially if they have limited or no at-home charging options.

The deployment of employee-dedicated EVSE requires a detailed assessment of installation operation, and maintenance costs. Charger selection should be tailored to employee use cases. For instance, while Level 2 chargers might be more costly, they offer faster charging times compared to Level 1 chargers.

Level 1 EVSE is more suitable for employees working full days at the office as it allows for long-duration parking and gradual charging of vehicles over an ~8h work shift. Employers aiming to provide Level 1 charging access for employees should be aware that tracking energy usage and implementing a payment system can be challenging, as Level 1 chargers are not designed to be networked.

Employee or public access to on-site EVSE should be structured to ensure fleet operations remain top priority; particularly during peak fleet vehicle charging times when availability is limited. A potential constraint for public access is the physical layout of the site, as fleet parking can be purposely separated from other areas. A clear protocol is needed to prioritize fleet vehicles' access to chargers during high-demand periods. For example, charging stations can be configured to restrict charging from public users during certain hours, ensuring that fleet vehicles are always prioritized. When EVSE is not in use by the fleet, public access can be allowed, providing a supplementary revenue stream while maintaining the primary function of supporting fleet vehicles.

Enabling employee access to fleet EVSE can have other implications. For example, it could be considered a taxable benefit if no fee or a fee less than market value is charged to the employee. Implementing a fee for charging requires additional technologies to enable accurate fee collection.

Public chargers can be a viable solution for fleet vehicles if they are strategically positioned along ZEV routes, in urban areas, or as a back-up option when a vehicle has a low SoC far from its primary source of charging. When public charging infrastructure is used, operators should ensure they move a vehicle from a parking space before it is fully charged as most municipalities impose an extra fee for occupying the parking space beyond that period for residual charging. For example, BC Hydro charges an idle fee of $0.40 per minute, starting five minutes after your vehicle stops charging [66].

Best Practices for Workplace Employee Charging

- **Prioritize workplace charging solutions that address the specific needs of BEV owners, ensuring equitable access for employees without at-home charging options.**
- **Assess current and future fleet charging needs and establish clear conditions of use before permitting employees to access workplace EVSE.**

3.2.3 Charging Etiquette

To ensure fairness for all ZEV users, explicit, well-communicated and enforceable rules on charging station use and etiquette are necessary. When developing charging etiquette guidelines, fleet managers should consider the following:

- Operators should unplug and move their vehicles as soon as they reach a sufficient SoC for their immediate needs or when the designated time limit for the charging session expires, whichever comes first. A 'sufficient SoC' refers to the minimum charge level required to meet the operator's next planned use of the vehicle, ensuring the charger is freed up promptly for others.

- Use only designated charging stations, especially if some are reserved for fleet vehicles during peak operating hours.
- Operators should neatly store charging cables after use to maintain equipment, prevent damage and avoid tripping hazards.
- A system for users to flag or report damages or malfunctions should be implemented through a smartphone application or a clearly defined and well-communicated process.
- Develop effective signage communicating any parking space restrictions or guidelines.

3.2.4 Home Charging

Under specific scenarios, fleet managers may allow operators to drive their fleet vehicles home. For instance, municipal or construction employees might be permitted to take their professional vehicles home to avoid picking up tools from the shop in the morning.

Similarly, executive fleet vehicle operators, such as those driving ministers, may occasionally need to charge a vehicle at an executive's residence to ensure it is ready for long or unpredictable shifts. While these instances are exceptions rather than the norm, there are solutions to accommodate such situations.

When at home, employees are encouraged to charge using Level 1, making use of existing 120 V outlets. Level 1 charging is preferred to forgo the need for 220 V electrical power and panel upgrades and residential Level 2 EVSE installations. Overnight Level 1 charging is suitable for LDVs and daily usage under 100 km (considering 15 kWh charged overnight). However, obtaining energy consumption readings from EVSE to reimburse employees requires additional steps and devices as the charging cords are not equipped with energy monitors.

Employers may pay for the installation of Level 2 residential chargers, if needed. These chargers can provide accurate energy consumption readings to facilitate the monitoring and reimbursement of employees' electricity usage.

Providing home charging equipment and covering electricity costs could be deemed a taxable benefit. Defining which employees are eligible for home charging should align with internal policies and operational requirements and account for driving patterns and the feasibility of home charging (tenant versus owner, single detached home vs. condominium, etc.).

Internal policies should clearly define authorized use for fleet vehicles to ensure they are used appropriately. A fair reimbursement strategy for electricity costs must also be included, with actual cost reimbursement based on metered usage being the most equitable method, depending on the level of charging.

3.3 Environmental Stewardship

Key Messages

- ZEV lifecycle analysis should consider the type of asset, its usage, and battery requirements. This is particularly relevant for vehicles with expected lifespans exceeding 10 years. Preventive and predictive maintenance programs can help extend the lifespan of both vehicles and charging infrastructure.
- Collaboration with OEMs and certified recycling facilities can ensure ZEV batteries are properly recycled in compliance with local and federal regulations. Secured services for battery storage and transportation must be in place for compliance and safety.
- Calculating asset divestiture timing can be aided by assessing remaining vehicle service life and conditions annually. Operational vehicles can be sold through the OEM or second-hand markets, while non-repairable vehicles can be taken to recycling centres.

3.3.1 ZEV and EVSE Lifecycle Considerations

The lifespan of a vehicle depends on factors such as usage and charging behaviour. Decisions regarding battery replacement during the lifecycle of a ZEV can significantly impact its cost effectiveness. MHDVs typically operate under more demanding conditions, leading to faster battery wear and reduced performance over time. As ZEVs are just beginning to be decommissioned, best practices for lifecycle improvements are still being studied. Therefore, the following insights are based on general guidelines rather than lessons learned.

For highly utilized vehicles and for those whose service life exceeds 10 years, at least one battery replacement may be necessary. Account for battery compatibility as certain chemistries or battery packs might not be available for purchase five, seven, or even 10 years in the future. Address this in your procurement documentation to ensure future compatibility and commitment from the manufacturer to provide replacement batteries.

The OEM environment will probably evolve over the next 5 to 10 years as hardware vendors supplying parts to OEMs are likely to innovate to keep up with demand for more efficient, affordable, and diverse vehicle class options.

Implementing preventive maintenance programs helps to extend the lifecycle of both vehicles and EVSE. Follow your manufacturer's recommended maintenance schedule. Predictive maintenance also offers opportunities to extend asset lifespans by monitoring battery health and indicating when a replacement may be needed.

3.3.2 Battery Recycling and Disposal

Fleet managers should communicate with OEMs prior to the acquisition of the vehicles to explore end-of-life options for EV batteries. Batteries that are no longer suitable for vehicle use can still retain ample capacity and can be used in second-life applications, including stationary ESS. Repurposing batteries not only extends their useful life, but also helps to balance grid demands by storing energy during off-peak hours.

Once a battery has reached the end of its useful life, it can be disposed of and recycled. A clear protocol for managing battery recycling is required to properly conduct the process. This should comply with local and federal regulations, such as those under the *Canadian Environmental Protection Act, 1999*. The following tasks can be undertaken for battery recycling:

- With the support of the OEM, conduct a health check on the battery cells to determine if it can be repurposed or must be recycled. Typical battery chemistries found in ZEVs are LTO ($Li_4Ti_5O_{12}$), LFP ($LiFePO_4$), NMC ($LiNiMnCoO_2$), and NCA ($LiNiCoAlO_2$). Understanding this information will guide the recycling and disposal processes.
- Battery removal should be handled by trained personnel and follow manufacturer safety guidelines. This is typically undertaken through a third-party contract with the OEM.
- Store end-of-life batteries in secure, fire-resistant containers at designated areas before transport. These storage areas should be well ventilated to prevent thermal events.
- If the batteries are being recycled, seek certified recycling facility partners that use methods like hydrometallurgy to maximize material recovery, including lithium and cobalt. This ensures compliance with provincial and federal regulations for hazardous materials.
- As lithium batteries are considered dangerous goods under the Transportation of *Dangerous Goods Act, 1992*, use certified carriers for battery transport. Also, maintain clear records of each transport stage to meet regulatory requirements and document the disposal progress.

Although the Canadian battery recycling industry is still in its infancy, battery recycling plants have started operating in Canada, such as Lithion Technologies in Saint-Bruno-de-Montarville, Québec. Additionally, several recycling plants are currently under construction in Québec, Ontario, and BC.

3.3.3 Asset Divestiture

Depending on a vehicle's remaining useful life, there are several options for asset divestiture. If a vehicle (zero-emission or ICE) is still operational but needs to be decommissioned due to underperformance or fleet right-sizing, fleet managers can contact the OEM or a second-hand market dealer to explore selling opportunities and potential rebates for new purchases. Some large fleet-owning entities have built-in divestiture programs, such as GCSurplus for federal government fleets. If you are operating ZEVs for a large-scale company, some divestiture programs may be available internally.

Resale value will depend on several factors including a vehicle's remaining lifespan, make and model, age, overall condition, aftermarket support, and availability of spare parts. Disclosing details to resellers and interested buyers around warranty status of key components and the overall condition of the vehicle helps determine the asset value. While the residual value of a vehicle will vary depending on the market and the vehicle condition, there is already a strong demand for used vehicles today; especially LDVs [67].

ZEVs tend to depreciate faster than ICE vehicles due to rapid technological advancements and higher initial costs. Concerns about battery degradation and the availability of incentives for new ZEVs further reduce the resale value of used models [68].

If the vehicle is no longer drivable or repairable, the simplest option may be to take it to a dismantling or recycling centre. Some centres may offer a small payment based on the value of its parts.
In many cases, local associations, such as the Ontario Automotive Recyclers Association, or government entities like the Société de l'Assurance Automobile du Québec, offer a 'one-stop-shop' for asset divestiture, including transportation, deregistration, and more.

4

Conclusion

4

Conclusion

Transitioning fleets to ZEVs aligns with Canada's commitment to achieving net-zero GHG emissions by 2050 and contributes to global efforts in combating climate change. This guide provides fleet managers with practical strategies to support this shift while recognizing that each fleet's transition must be tailored to meet specific operational needs and challenges.

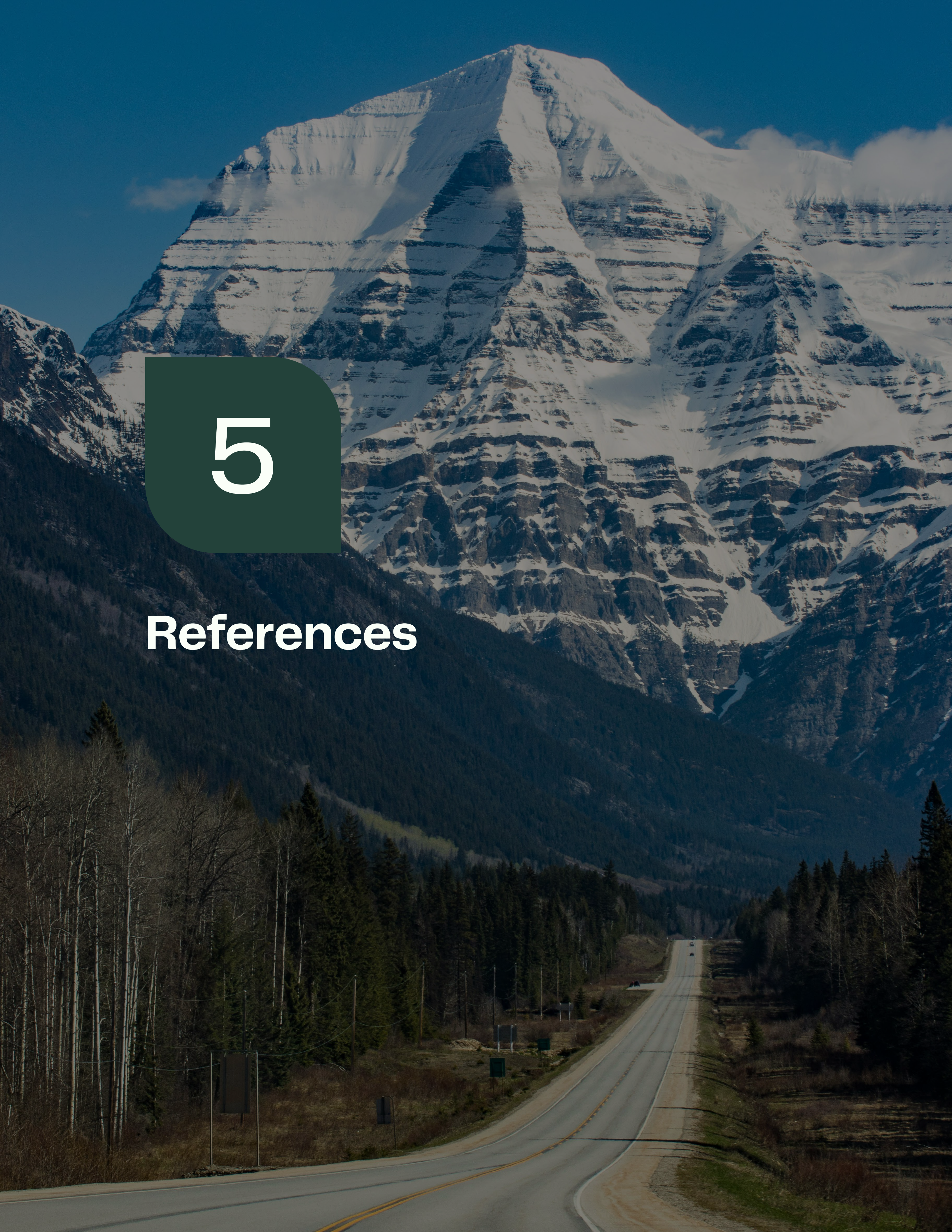
As ZEV technology continues to improve in terms of range and charging capabilities, many current challenges relevant to fleet decarbonization may be minimized or cease to exist entirely in the future.

Here are the key takeaways:

- Effective planning is necessary for a greener fleet. Start by conducting thorough assessments of fleet composition and operational needs. Integrating TCO analyses that include vehicle costs and infrastructure investments can help achieve long-term cost savings. Infrastructure readiness, including charging station installations and necessary building and electrical upgrades, is important as is early collaboration with utility providers and incorporating EMS when necessary to support efficient charging strategies and long-term resilience.
- When developing a ZEV Transition Plan, the availability of ZEV models must be fully understood relative to fleet needs. A five-year historical trend in ZEV supply shows improved availability driven by the introduction of regulations and increased production capacity
- Establishing effective change management programs and providing staff training for the safe and efficient use and maintenance of ZEVs and related infrastructure are critical to ensuring a successful transition. A strong organizational commitment and cultural shift are essential, as operational and procurement procedures will need to be tailored to accommodate innovative technologies.

- Specialized fleet applications, such as law enforcement, involve unique operational requirements that must be addressed through careful planning.
- Managing a ZEV fleet involves ongoing attention to performance and maintenance. Implementing telematics and data monitoring systems to track vehicle utilization, uptime, and MDBF can inform optimal charging and maintenance strategies.
- Adopting practices such as eco-driving and strategic charging schedules can help extend vehicle range and reduce energy consumption.
- Automated tools and CMS can help prioritize schedules and streamline operations to reduce peak demand costs.
- To mitigate the impact that winter has on ZEV range, implement strategies such as preheating vehicles while plugged in, selecting vehicles with heat pumps, and practicing proper tire maintenance.
- Regular preventive maintenance and optimal charging practices help to limit battery degradation and extend the lifespan of both vehicles and infrastructure.

As you reflect on the insights provided in this guide, recognize that fleet decarbonization is not a one-time occurrence, but rather an iterative journey of adaptation and growth. By taking informed and deliberate steps, fleet managers can contribute not only to achieving Canada's net-zero goals, but also to creating a resilient and sustainable future.



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