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ZeroX2040

Canada's Pathway to Net-Zero for Medium- and Heavy-Duty Trucks and Buses

Part 2: Charging and Refuelling Infrastructure

Sarah McBain, Chandan Bhardwaj, Adam Thorn
November 2023

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The Pembina Institute is a national non-partisan think tank that advocates for strong, effective policies to support Canada's clean energy transition. We employ multi-faceted and highly collaborative approaches to change. Producing credible, evidence-based research and analysis, we consult directly with organizations to design and implement clean energy solutions, and convene diverse sets of stakeholders to identify and move toward common solutions.

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Dené. These Lands are also home to the Métis Nation of Alberta — Region 3 whose Peoples have deep relationships with the Land.

These acknowledgements are some of the beginning steps on a journey of several generations. We share them in the spirit of truth, justice, reconciliation, and to contribute to a more equitable and inclusive future for all of society.

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Executive summary

The transportation sector is responsible for approximately one-quarter of Canada's total greenhouse gas (GHG) emissions, the country's largest source of carbon pollution after oil and gas. The majority of transportation emissions stem from road vehicles, with medium- and heavy-duty vehicles (MHDVs) alone accounting for 37% of vehicle related GHG emissions. Since 1990, emissions from MHDVs have nearly doubled and if current trends continue, emissions from MHDVs are expected to surpass those of passenger vehicles by 2030 and become the largest source of emissions in the transportation sector. To achieve Canada's climate commitment to cut emissions by 40% to 45% below 2005 levels by 2030, and reach net-zero by 2050, it is increasingly urgent to drive down MHDV-generated greenhouse gases.

The Government of Canada has identified transitioning the MHDV sector to zero-emission vehicles (ZEVs) as critical to cutting transportation emissions. Canada's 2030 Emissions Reduction Plan includes targets for the transportation sector: 35% of new MHDVs sold must be zero-emission (ZE) vehicles by 2030, and 100% of MHDVs sold must be ZE by 2040 (based on feasibility). Clearly the need to manufacture ZE MHDVs — and the concurrent need for charging and refuelling infrastructure — is acknowledged at the federal level. However, there is no concrete, implementable plan in place that outlines how this transition will take place. The absence of a clear pathway puts the rate at which the transition will occur at risk and raises the prospect of failing to meet Canada's international pledge on a net-zero 2050.

Based on the Pembina Institute's research, analysis and stakeholder engagement, there is widespread concern within the transportation industry on whether the availability and pace at which charging and refuelling stations are built will be in tandem with the uptake of ZE MHDVS. A smooth transition away from fossil-fuel MHDVs requires both the production and purchase of ZE MHDVs and the infrastructure to power them. A significant scaling-up of private and public charging and refuelling stations is necessary to support widescale ZE MHDV adoption.

Given the importance of installing infrastructure that is built specifically for ZE MHDVs, the Pembina Institute recommends four sets of policy measures:

1. **Financial support and incentives** to address the costs associated with infrastructure deployment. Funding not only helps defray the cost of installing

charging and refuelling stations, it also attracts private investment in infrastructure development and incentivizes ZE MHDV adoption.

2. **Setting milestones and targets** for charging and refuelling stations. Clear goals attached to the location and number of charging and refuelling stations can facilitate the strategic deployment of infrastructure and ensure that access is evenly distributed from coast to coast.
3. **Standardization protocols and clear roles and responsibilities** for utilities so that there is a national network that is well-connected and reliable. Infrastructure standardization is critical to facilitating interoperability and reducing overall deployment costs.
4. **Capacity building supports and initiatives** to promote skills development and a ZEV-ready workforce. Creating a labour force equipped with the skills to support infrastructure is essential to the success of the ZE MHDV transition.

Canada can take advantage of the economic opportunities that will materialize with the build-out of infrastructure. We urge the federal government to adopt these recommendations and hasten the transition to clean transportation systems which are key to reducing GHGs by 40% to 45% by 2030 and to net-zero by 2050.

1. Introduction

Canada has committed to reducing its greenhouse gas (GHG) emissions by 40% to 45% below 2005 levels by 2030 and achieving net-zero emissions by 2050.[1] To meet these goals, the federal government released the 2030 Emissions Reduction Plan in March 2022, which set out ambitious targets to drive down greenhouse gases in key sectors of the economy. The government's plan includes targets that require 35% of new medium- and heavy-duty vehicles (MHDV) sold by manufacturers to be zero-emission (ZE) vehicles by 2030, and 100% by 2040 (based on feasibility).[2]

The transition to ZE MHDVs requires a two-pronged approach: the manufacturing of commercially viable ZE MHDVs and the build out of the charging and refuelling infrastructure MHDVs require. Manufacturing and infrastructure must be in sync to create a well-functioning ZE MHDV ecosystem, where there are enough vehicles made and purchased to justify investments in infrastructure and enough infrastructure that buyers and industry have confidence in the viability of ZE MHDVs.

The federal government, however, has yet to release a clear and comprehensive pathway to achieve the transition from fossil-fuel MHDVs to ZE MHDVs. To address this gap and the associated uncertainties, the Pembina Institute has developed the ZeroX2040 national strategy, *Canada's Pathway to Net-Zero for Medium and Heavy-Duty Trucks and Buses*. Our strategy takes the "beachhead" approach developed by U.S.-based CALSTART and the California Air Resources Board and adapts it to the Canadian context. The ZeroX2040 recommendations in this report focus on the deployment of charging and refuelling infrastructure, while our complementary report (*Part 1: Zero-Emission Vehicles*) proposes key policies to support the manufacturing and purchase of ZE MHDVs. Together, the two reports outline Canada's pathway to a ZE MHDV transition.

[1] Government of Canada, "Net Zero Emissions by 2050." https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/net-zero-emissions-2050.html

[2] Government of Canada, "2030 Emissions Reduction Plan." https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/climate-plan-overview/emissions-reduction-2030.html

The benefits of low- and zero-emission fleets

Lower greenhouse gas emissions: Multiple studies demonstrate that on a life-cycle basis, a typical ZE MHDV emits far fewer GHGs than a diesel-run MHDV.[3,4,5]

Positive health outcomes: Exposure to diesel exhaust from MHDVs has been linked to increases in the incidence of asthma, cancer, and other respiratory diseases.[6] ZE MHDVs have zero tailpipe emissions and hence significantly reduce (if not eliminate completely) the health risks caused due to exposure to diesel exhaust.

Less strain on the healthcare system and lower healthcare costs: ZE MHDVs promise substantial savings for Canada in avoided healthcare costs. In Canada, pollution-induced health-related economic costs amount to $120 billion (6% of the country's GDP),[7] most of which can be avoided by shifting to ZE MHDVs.

Lower fuel and maintenance costs: ZE MHDVs offer savings of thousands of dollars a year in fuel and maintenance costs. With government rebates and credits earned through the Clean Fuel Regulation, the total cost of ownership of ZE MHDVs (particularly buses and MDVs) is expected to reach parity with diesel vehicles by 2030.[8, 9, 10, 11]

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[3] Adrian O'Connell, Nikita Pavlenko, Georg Bieker, Stephanie Searle, *A comparison of life-cycle greenhouse gas emissions of European heavy-duty vehicles and fuels* (ICCT, 2023). https://theicct.org/publication/lca-ghg-emissions-hdv-fuels-europe-feb23/

[4] ICCT, "Battery electric trucks emit 63% less GHG emissions than diesel." https://theicct.org/battery-electric-trucks-emit-63-less-ghg-emissions-than-diesel/

[5] Taylor Zhou et al, "Life cycle GHG emissions and lifetime costs of medium-duty diesel and battery electric trucks in Toronto, Canada," *Transportation Research Part D: Transport and Environment,* 55 (2017). https://www.sciencedirect.com/science/article/abs/pii/S1361920916304175

[6] Health Canada, "Human Health Risk Assessment for Diesel Exhaust." https://www.canada.ca/en/health-canada/services/publications/healthy-living/human-health-risk-assessment-diesel-exhaust-summary.html

[7] Health Canada, *Health Impacts of Air Pollution in Canada* (2021). https://www.canada.ca/en/health-canada/services/publications/healthy-living/health-impacts-air-pollution-2021.html

[8] Catherine Ledna et al., *Decarbonizing Medium- & Heavy-Duty On-Road Vehicles: Zero-Emission Vehicles Cost Analysis* (NREL, 2022), 27. https://www.nrel.gov/docs/fy22osti/82081.pdf

[9] Vishnu Nair, Sawyer Stone, Gary Rogers, Sajit Pillai, *Medium and Heavy-Duty Electrification Costs for MY 2027- 2030* (Environmental Defense Fund, 2022), 80, 86. https://blogs.edf.org/climate411/files/2022/02/EDF-MDHD-Electrification-v1.6_20220209.pdf

[10] Hussein Basma, Felipe Rodríguez, Julia Hildermeier, Andreas Jahn, *Electrifying Last-Mile Delivery: A total cost of ownership comparison of battery-electric and diesel trucks in Europe* (ICCT, 2022), i. https://theicct.org/publication/tco-battery-diesel-delivery-trucks-jun2022/

[11] Andrew Burnham et al., *Comprehensive Total Cost of Ownership Quantification for Vehicles with Different Size Classes and Powertrains* (Argonne National Laboratory, 2021), 150, 151. https://publications.anl.gov/anlpubs/2021/05/167399.pdf

Windfall opportunity for Canada's mining industry: Demand for ZE MHDV manufacturing, and, in turn, for the critical minerals needed for ZE MHDV manufacturing (such as copper and aluminum) and battery manufacturing (such as lithium and cobalt), is anticipated to grow exponentially as global markets pivot to electrification across all vehicle types.[12] Canada is a global player in the mining sector. The country ranks among the top 10 producers of graphite, nickel, cobalt, and aluminum and has one of the world's largest identified lithium reserves.[13,14] ZE MHDV production, from extraction to final product, is a windfall opportunity for Canada's mining and minerals sector.

Potential for reviving the MHDV manufacturing sector in Canada: In a recent Ontario-based analysis, we found that investing in the production and sales of electric school buses has the potential to make a significant contribution (by creating up to 13,0000 jobs and adding up to $2 billion in economic output by 2030) to the revival of Ontario's commercial vehicle manufacturing industry and help secure economic benefits and stability for its small- and medium-size business sector.[15] Arguably, similar benefits could be replicated across Canada if investments are made in the production and sales of zero-emission vehicles in other MHDV categories. Given the recent challenges with the Canadian MHDV manufacturing sector (dominated by conventional non-ZE MHDV manufacturing), a transition to ZE MHDV manufacturing could offer one way to help stem the current decline of the MHDV manufacturing sector.

[12] International Energy Agency, "The Role of Critical Minerals in Clean Energy Transitions," 2021, https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions

[13] Natural Resources Canada, "Minerals and Metals Facts." https://natural-resources.canada.ca/our-natural-resources/minerals-mining/mining-data-statistics-and-analysis/minerals-metals-facts/20507

[14] Natural Resources Canada, "Annual Statistics of Mineral Production." https://mmsd.nrcan-rncan.gc.ca/prod-prod/ann-ann-eng.aspx?FileT=2019&Lang=en

[15] Chandan Bhardwaj, Donald Jantz, Priyanka Lloyd, *Power Boost: Electric school buses and the revitalization of small- and medium-size businesses in Ontario's auto industry* (Pembina Institute, 2023). https://www.pembina.org/pub/power-boost

2. A strategic approach to the ZE MHDV transition

The ZeroX2040 strategy presents an efficient and cost-effective means of ushering in the transition from fossil fuel powered heavy-duty vehicles to zero-emission MHDVs.[16] In accordance with the strategy, investments and resources should initially target ZE technology that is commercially viable now as the first stage in implementing the transition to a zero- and low-carbon transportation system. For example, ZE transit and school buses can be phased in almost immediately. ZE buses are available in a variety of models, have relatively short and predictable routes, and return to a depot every night with sufficient time to recharge overnight. Accelerating the deployment of ZE buses in the near term will allow for learnings and technological developments to the benefit of vehicle categories where switching from fossil fuels to ZE is more difficult.

Described in greater detail in our *Part 1: Zero-Emission Vehicles* report, the Pembina Institute proposes a ZE MHDV sales standard that would require:

- Nearly 100% of bus sales are ZEVs by 2030
- 50% of urban MDV sales are ZEVs by 2030, rising to nearly 100% by 2040
- 10% of HDV sales are ZEVs by 2032 and near 100% by 2040

The implementation of Pembina Institute's proposed ZE MHDV sales standard would result in significant GHG reductions (Figure 1).

[16] CALSTART, *The Beachhead Strategy: A Theory of Change for Medium- and Heavy-Duty Clean Commercial Transportation* (2022). https://calstart.org/beachhead-model-background/

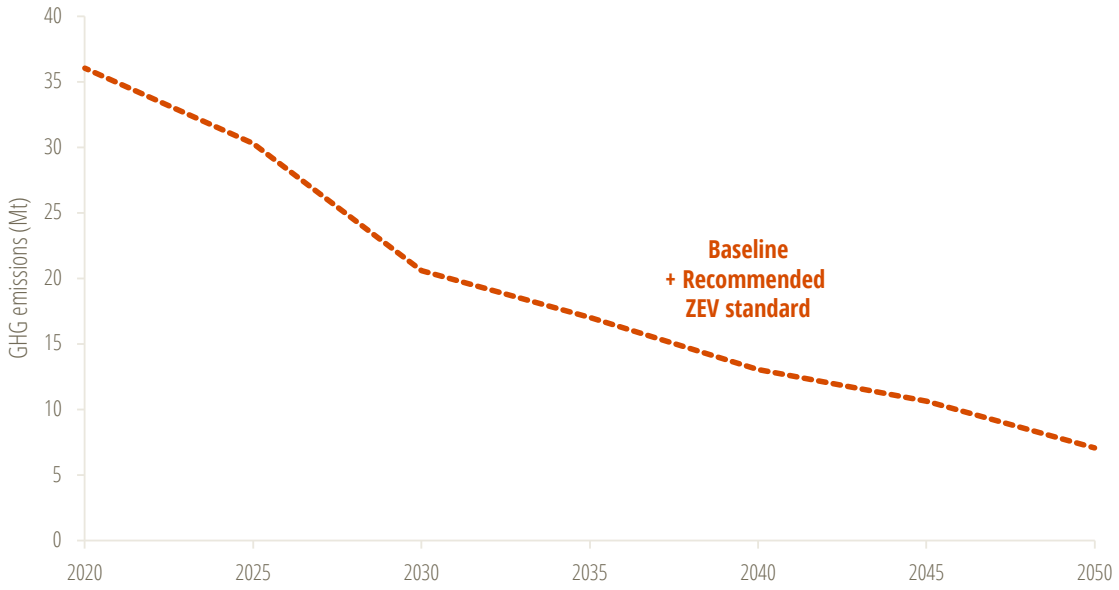

Figure 1. GHG emissions from the MHDV sector if the recommended ZEV sales standard is added to current policies in Canada

Baseline scenario comprises all policies currently in place in Canada including the federal carbon tax, the Clean Fuel Regulation, and the heavy-duty vehicle GHG emissions standard.

Infrastructure build-out will need to occur in conjunction with the above targets. Here again, the ZeroX2040 strategy offers guidance on how and where to install charging and refuelling infrastructure to match the type of vehicle that will require access and where those vehicles are most likely to be using it.

In the near term, infrastructure will be installed primarily in depots servicing private fleets as ZE buses and MDVs are the first categories to require substantial scaling up of infrastructure. Subsequent stages will see growth in ZE HDVs. At this point, investment should pivot to the deployment of publicly accessible, high-power charging and refuelling stations. Given the long distances that HDVs tend to travel, access to infrastructure enroute will be critical.

MHDV vehicle classes

Buses

There are approximately 49,000 school buses and 32,000 urban transit buses in Canada. Their operating conditions — short to medium distances travelled along fixed routes coupled with return-to-depot operations — make transit and school buses prime candidates for electrification. For both school and transit buses, provincial governments provide most or all the funding for bus purchases and charging infrastructure.

Medium-duty vehicles (MDVs)

There are about 650,000 MDVs in Canada used to transport freight, such as urban delivery vans and short-haul and regional freight trucks. The charging needs of MDVs are best supported by overnight charging in privately owned fleet depots. Arguably, larger, well-capitalized fleet owners can be expected to pay — at least partially — for private depot infrastructure. However, partial funding from government can incent private investment to cover the balance in infrastructure costs and encourage ZE MDV adoption.

Heavy-duty vehicles (HDVs)

HDVs are largely privately owned and include short- and long-haul tractor-trailers. There are about 600,000 HDVs in Canada. With average daily routes greater than 250 km, most HDVs will rely heavily on publicly accessible, high-power charging and refuelling infrastructure if they are to convert to zero-emission, and government support and collaboration will be critical. Related work by the Pembina Institute estimated that nearly half of the HDVs on Canada's roads in 2050 will be battery electric, with the other half being hydrogen fuel cell vehicles[17].

A successful transition to ZE MHDVs entails an infrastructure development strategy that matches the evolving needs of the sector. Based on interviews and focus group discussions with fleet operators, charging service providers, and experts from ENGOs , we understand that there is widespread concern about the availability and rate of deployment of the infrastructure necessary to support zero- and low-carbon fleets. To respond to anticipated levels of adoption between 2030 and 2050, we estimate[18] that:

- By 2030, 70,000 Level 2 (50 kW or higher) private, fleet depot chargers will need to be in place, with 450,000 needed by 2050.
- Approximately 6,500 Level 3 (100 kW or higher) public chargers will need to be installed by 2030, increasing to 34,000 by 2040 and 50,000 by 2050.
- Hydrogen stations for refuelling may need to increase from 2,000 in 2030 to 17,000 in 2040 and 30,000 in 2050.

The key challenges to infrastructure deployment are outlined below.

[17] Kasteel, Colton, Sarah McBain and Chandan Bhardwaj, *Towards Clean MHDVs: Preliminary policy solutions to decarbonize Canada's MHDVs*, (Pembina Institute, 2022). https://www.pembina.org/reports/towards-clean-mhdvs-recommendations.pdf

[18] Colton Kasteel, Sarah McBain and Chandan Bhardwaj, *Laying the Groundwork: Exploring the challenges and opportunities in the transition to zero-emission medium- and heavy-duty vehicles*, (Pembina Institute, 2022). https://www.pembina.org/reports/laying-the-groundwork-mhdvs.pdf

Table 1. Key challenges to installing Canada-wide infrastructure

Challenge	Description
Shortfall in private and public funding	The funding provided through Canada's Zero Emission Vehicle Infrastructure Program (ZEVIP) is not nearly enough to cover the anticipated cost of the infrastructure that will be required to support a ZE MHDV transition. Sufficient public funding is necessary in the short term without which the transition to ZEVs would not move forward at the pace and scale required. The caveat is that the federal government cannot finance the expansion of the charging network indefinitely. Private investors will also need to finance the network and will do so once a strong business case can be made demonstrating a rate of return that justifies the upfront capital costs. Funding needs will differ depending on the category of MHDV. **Buses:** The provincial government funds school and transit bus purchases and the infrastructure for both, either via municipalities (for transit) or via provincial ministries of education (for school buses). **MDVs:** Larger, well-capitalized MDV fleet owners can be expected to pay — at least partially — for infrastructure to power their fleets. Funding from government can catalyze private investment and incentivize ZE MDV adoption. Smaller, less well-capitalized fleets may require additional support. **HDVs:** As with MDVs, large well-capitalized HDV fleet owners may be able to partly finance charging or refuelling infrastructure at private depots. However, long-haul HDVs need public infrastructure along highways and key corridors. Private investment is unlikely to be directed to public infrastructure without the justification of a good business case**.**
Lack of standardization for chargers	Charging station connectors, software and maintenance are not standardized in Canada. Standardizing all the components of charging infrastructure is essential to realize economies of scale, facilitate interoperability, and reduce deployment costs.
Insufficient planning for transition	Canada lacks a clear roadmap to guide the build out of infrastructure needed in tandem with production and uptake of ZE MHDVs. Without a plan outlining the number of charging and refuelling stations needed, as well as strategic mapping of infrastructure development, Canada risks uneven and possibly inadequate access to infrastructure across regions. Such a roadmap will need to incorporate differing requirements among MHDV types. **Buses:** ZE (mainly battery electric) transit and school buses are market-ready, but transit agencies and school boards have yet to receive direction for procurement and infrastructure installation. **MDVs:** As with buses, many ZE MDVs are market-ready. Because MDVs vary significantly in weight, class, and usage, infrastructure requirements will likewise vary. Clear roadmaps, knowledge sharing, and case studies will help provide the direction needed for a strategic deployment of charging/refuelling infrastructure. **HDVs:** HDVs, particularly long-haul trucks, will rely on public infrastructure for long-distance travel. However, there is no plan establishing locations for charging and refuelling stations or timelines for when they should be installed. Because the HDV sector is made up of many, small-scale owners and operators — as distinct from the

	MDV sector, where there are fewer, bigger owner/operators — the transition is inherently more challenging.
Shortfall in ZEV-ready skilled workers	Investments need to be made to build capacity to establish a ZEV-ready workforce. Planners, fleet managers, truck operators, engineers, mechanics, and other technical workers may have little or no experience with new and emerging ZEV technology and infrastructure requirements.
Limited utility-side grid readiness	Charging ZE MHDVs will very likely be a stress on grids across Canada, which are not necessarily built to accommodate increased loads. Grid capacity must be upgraded. Failing to do so will slow the transition to low-carbon MHDVs.
Lack of clarity regarding electricity rates	It is unclear how electricity rates for charging ZE MHDVs will be structured. Governments need to work with utilities to establish rate structures that strengthen the business case for installing charging stations and encourage charging during off-peak periods to minimize stress to the grid.

To overcome the challenges listed above, the Pembina Institute has identified four sets of policy tools:

1. **Financial support and incentives** to address the costs associated with building out an infrastructure network (Section 3.1).
2. **Establishing milestones and targets** that set out where and when charging and refuelling stations should be installed (Section 3.2).
3. **Standardization protocols for chargers and a clear outline of utility responsibilities** to support a well-connected and reliable network (Section 3.3).
4. **Capacity building supports and initiatives** specifically designed to upskill and prepare a ZEV-ready labour force (Section 3.4).

3. Recommendations

3.1 Financial support and incentives

Buses

> Recommendation: Allocate $1 billion under the Zero Emission Transit Fund by 2030 toward the deployment of chargers for transit and school buses.

Challenge addressed: Shortfall in private and public funding

Through the Zero Emission Transit Fund (ZETF), the Government of Canada is investing $2.75 billion over five years, starting in 2021, to help public transit and school bus operators plan for electrification, including plans to install chargers, assessing grid capacity and planning for possible upgrades. ZETF can also be directed to purchasing 5,000 zero-emission buses by 2026 and building infrastructure and facility upgrades.[19] To reach the goal of 100% new ZE transit and school bus sales by 2030, the federal government will need to dedicate a portion of the ZETF to utilities and school districts for charging infrastructure installation. Funding under ZETF dedicated to infrastructure should be approximately $1 billion by 2030.

Federal and provincial governments will need to directly fund, mostly through grants, the purchase of electric buses and installing chargers for transit buses. Because public transit authorities across Canada are still experiencing financial shortfalls in the aftermath of the pandemic,[20] ZETF funding can facilitate both a financial recovery and a transition to ZE buses.

[19] Infrastructure Canada, "Zero Emission Transit Fund." https://www.infrastructure.gc.ca/zero-emissions-trans-zero-emissions/index-eng.html

[20] Deloitte, *COVID-19: Tackling public transit's funding gap during the recovery* (2020). https://www2.deloitte.com/ca/en/pages/public-sector/articles/public-transits-funding-gap.html

Medium- and heavy-duty vehicles (classes 2b-8)

Recommendation: Extend the Zero Emission Vehicle Infrastructure Program to support private depot charging infrastructure.

Challenge addressed: Shortfall in private and public funding

Through the Zero Emission Vehicle Infrastructure Program (ZEVIP), the Government of Canada is directing financing to charging and refuelling infrastructure for all medium and heavy-duty vehicle types (except transit and school buses), with an investment package of $680 million available until 2027.[21] We recommend an increase in funding through the ZEVIP and that the federal government additionally look for funding opportunities and revenue streams to ensure adequate support for the required infrastructure. We also recommend that ZEVIP create funding streams that differentiate between MDVs and HDVs. Our analysis of the level of investment required shows that to meet the needs of ZE MHDV sales targets, approximately $3.5 billion in total is required to support infrastructure deployment.

For MDVs, our analysis demonstrates that approximately $2 billion between 2027 and 2030 is needed to ensure that there is enough infrastructure to support the number of MDVs on the road, assuming the target of 50% of MDV sales are ZEVs by 2030 is met.

For HDVs, again assuming that ZE sales targets are met, between 6,000 and 10,0000 public charging stations (assuming power capacity of 330 kW to 1 MW and capacity utilization of between three to five per station) and approximately 1,000 hydrogen refuelling stations will need to be installed by 2030. The cost of installation is estimated to exceed $2 billion for chargers and will land at nearly $1 billion for refuelling stations. Collective efforts will be required to source necessary funding across all levels of government, including identification of new revenue sources and partnerships with the private sector.

We further recommend that a dedicated revenue stream under ZEVIP be allocated to infrastructure projects that support small owner-operators whose businesses tend to operate on thin margins and who have been chronically underserved by clean energy and clean technology investments. International best practices recognize that

[21] Government of Canada, “Zero Emission Vehicle Infrastructure Program.” https://natural-resources.canada.ca/energy-efficiency/transportation-alternative-fuels/zero-emission-vehicle-infrastructure-program/21876

investments and financing opportunities should be equally accessible to small and large fleet operators. Examples of programs that either directly provide funding for small owner-operators or incorporate a minimum allocation toward such groups can be found in the Pembina Institute's report *Zero-Emission Vehicle Awareness & Education*.[22]

Recommendation: Direct Canada Infrastructure Bank to offer financing mechanisms to encourage private investment in infrastructure deployment.

Challenge addressed: Shortfall in private and public funding

The Canada Infrastructure Bank (CIB) should offer financing mechanisms designed to encourage investments by private operators over and above government funding. CIB already offers soft loans to bus operators to purchase electric transit or school buses and charging infrastructure.[23] CIB has made an investment commitment of $1.5 billion[24] in the form of direct loans to help cover the upfront capital costs of ZE buses.[25] Our recommendation is that CIB broaden the scope of its loans to include infrastructure projects for other MHDV classes, including MDVs and HDVs.

Further, we recommend that CIB explore innovative financing mechanisms involving partnerships between governments, utilities and the private sector, spurring additional investment in infrastructure. Examples of innovative financing includes utilization loans, where, because the return on investment in charging stations via energy usage prior to a full switch to ZE is low, repayment schedules kick in only after a base utilization level is met.

On-bill financing is another option. In this case, fleet owners repay loans in installments through their utility bill. Utilities, in turn, realize another source of revenue by providing a financial service. Yet another option is to leverage public-private partnerships through land tenders. This option allows charge point providers to install infrastructure on underutilized public land.

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[22] Sarah McBain, *Zero-Emission Vehicle Awareness & Education: Towards inclusive and equitable outcomes in a decarbonized MHDV sector* (Pembina Institute, 2023). https://www.pembina.org/pub/zero-emission-vehicle-awareness-education

[23] Mehanaz Yakub, "Canada Infrastructure Bank to fund 4,000 electric school buses in Quebec," Electric Autonomy, November 24, 2021. https://electricautonomy.ca/2021/11/24/cib-4000-electric-school-buses-quebec/

[24] "Zero Emission Transit Fund."

[25] Canada Infrastructure Bank, "Public Transit." https://cib-bic.ca/en/sectors/public-transit/

3.2 Establishing milestones and targets

Buses

Recommendation: Designate model cities across Canada that must achieve 100% ZEV infrastructure readiness for urban buses by 2028.

Challenge addressed: Insufficient planning for transition

The transition from fossil-fuel powered vehicles to ZEVs will occur more quickly and in greater number in urban centres relative to rural areas. Knowing this, the federal government, in coordination with utilities, provincial governments and city planners, should identify model cities across the provinces as first movers in an accelerated uptake of ZE urban transit buses and related infrastructure, with 100% of all urban transit being ZE by 2028. The model cities will need to initiate infrastructure development at transit depots, where city authorities and utilities will need to accelerate the process of installation. This may involve streamlining the approval process, site planning, system upgrades and interconnection with the grid, as well as setting up software.

Federal and sub-national governments can support utilities by providing guidance, removing regulatory bottlenecks, and offering funding support. Criteria such as grid readiness and ZE MHDV density can inform city selection. The Toronto Transit Commission, for instance, has put electric buses on the road, demonstrating that the technology is market-ready. Their key performance indicators — operator experience, customer satisfaction, charging reliability and vehicle performance[26] — show that the switch to electric has been successful. The model cities should engage in knowledge sharing, ideally as part of a dedicated coalition/taskforce, supporting each other so that charger installation and system upgrades can happen with greatest efficiency.

A notable first step in this direction is the creation of a network of cities across Canada, called the Low Carbon Cities Canada (LC3)[27]. This Government of Canada sponsored initiative brings together members from seven Canadian cities. LC3 members work in partnership, including sharing methods for collaboration and networking to ensure that

[26] Mobility Innovators, "Toronto Transit Commission Electric Bus Program: Head-to-Head Evaluation of Electric Buses," May 16, 2022. https://mobility-innovators.com/toronto-transit-commission-electric-bus-program-head-to-head-evaluation-of-electric-buses/

[27] Low Carbon Cities Canada, "Home." https://lc3.ca/

local initiatives on climate action are scaled nationally. The federal government could empower this network further to work closely with utilities so that there is sufficient ZEV-ready infrastructure in place.

> Recommendation: Encourage provinces to require school districts across Canada to install at least one fast charger by 2027.

Challenge addressed: Insufficient planning for transition

The federal government will need to coordinate with provincial governments and their ministries of education to ensure that all school districts install at least one fast charger by 2027. We note that private operators own most school buses in Canada, and ZE buses (mainly battery electric vehicles) will typically charge overnight at private depots. However, to ease range anxiety and to supplement the chargers at private bus depots (funding for which is covered under the Zero Emission Transit Fund, along with additional support from provincial programs), each school district should install at least one fast charger (>350 kW). By 2030, this requirement should increase to one charger for every 10 buses.

Medium-duty vehicles (classes 2b-6)

> Recommendation: Partner with provinces to establish targets for the number of chargers installed for federal, provincial, and municipal-owned ZE MDV fleets.

Challenge addressed: Insufficient planning for transition

As with buses, ZE MDVs have been identified as market-ready. Consequently, this is an opportune time for the near-term scaling up of infrastructure. The federal government, in collaboration with provincial and municipal governments, should encourage setting a target for the number of chargers that should be installed to support the transition of local, provincial, and federal MDV fleets to zero-emission. Targets should also be set for government-owned entities and crown corporations that own and operate 50 or more MDVs. The number of charge points required to support the electrification of 50% of a fleet determines the number of chargers that will need to be installed.

Federal-provincial collaboration will entail addressing regulatory bottlenecks that hinder timely infrastructure deployment, such as site and permit approvals. The State of

California's Assembly Bill No. 1236 shows how red tape can be reduced. The bill requires cities and counties to adopt an ordinance that creates an expedited, streamlined permitting process for charging infrastructure and equipment.[28]

Heavy-duty vehicles (classes 7-8)

Recommendation: Establish at least one charging and refuelling station serving ZE HDVs every 60 km along key sections of the Trans-Canada highway and the Ontario-Quebec Continental Gateway by 2030.

Challenge addressed: Insufficient planning for transition

The federal government needs to set targets for the minimum capacity and maximum distance between charging and hydrogen refuelling points. The charging capacity of the charging pool at each station should be 1400 kW or higher. In addition, by 2030, a charging station should be installed every 60 km along key sections of the Trans-Canada highway and the Ontario-Quebec Continental Gateway with the highest traffic flows. For hydrogen refuelling stations, the distance between each station should be 150 km (or less), and each station should have refuelling capacity greater than 2 tonnes/day.

The Trans-Canada highway runs through all 10 Canadian provinces, and the Continental corridor is the busiest highway in North America, serving the movement of goods and people for nearly half of the Canadian population. Public charging and refuelling stations are a prerequisite for heavy-duty ZEVs to travel long distances. Prior to 2030, uptake of ZE HDVs will be low (less than 10%). Nevertheless, governments must start building infrastructure soon in anticipation of rapid uptake post-2030.

In the short term, governments should prioritize the busiest goods movement corridors and highways. The EU has adopted this approach. In October 2022, the European Parliament passed the Alternative Fuels Infrastructure Regulation (AFIR), requiring the deployment of infrastructure for both battery electric and fuel-cell electric heavy-duty

[28] State of California, "Permitting Electric Vehicle Charging Stations: Best Practices." https://business.ca.gov/industries/zero-emission-vehicles/plug-in-readiness/permitting-electric-vehicle-charging-stations-best-practices/

vehicles along the Trans-European Network (a network of key highways connecting major European cities).[29]

> Recommendation: Partner with provinces to identify additional trucking corridors and arterial roads to install charging and hydrogen fuelling stations by 2025.

Challenge addressed: Insufficient planning for transition

In coordination with provincial and municipal governments and utilities, the federal government needs to identify places along in-province trucking corridors and arterial roads for charging and refuelling stations for ZE HDVs. Our analysis shows that some 11,000 public charging and refuelling stations will be required by 2030 given the anticipated number of ZE HDVs on the road. Because it takes years to plan and install stations, we recommend that, by 2025, geospatial maps of proposed public charger station sites (to be activated by 2030) be made publicly available and for public consultation. Further, provinces should develop plans detailing the types of chargers to be installed, their power capacity, activation dates, operational costs, etc. Public availability of the charger location maps will allow truckers to optimize their delivery routes.

3.3 Standardization protocols and clear utility responsibilities

All vehicle classes (Buses, MDVs, HDVs)

> Recommendation: Establish clear and consistent standards for charging infrastructure.

Challenge addressed: Lack of standardization for chargers

Standardizing charging infrastructure is essential to extending the charging network, interoperability, and reducing deployment costs. In the U.S., the U.S. Federal Highway Administration and the Department of Transportation released national infrastructure

[29] European Commission, "European Green Deal: ambitious new law agreed to deploy sufficient alternative fuels infrastructure," March 28, 2023. https://ec.europa.eu/commission/presscorner/detail/en/ip_23_1867

standards for light-duty vehicles effective March 30, 2023.[30] Similar standards, applicable to high-power charging infrastructure for ZE MHDVs, is likewise necessary. Several groups are now developing standards for ZE MHDV charging, including CharIN's Megawatt Charging System.[31,32] Federal and provincial governments can work closely with a range of stakeholders, including Canadian Standards Association, Measurement Canada, relevant government departments and industry representatives to develop standardization protocols applicable across the country.

Recommendation: Require that utilities ensure grid readiness for electric vehicles.

Challenge addressed: Limited utility-side grid readiness

The extent of grid upgrades that will be required to cope with increased loads from the transition to ZE MHDVs will range considerably from minor to major. Consequently, grid planning should begin immediately as upgrades can be costly and time-consuming. Critical to this process is the need for coordinated planning between relevant stakeholders and clear identification of responsibilities.

As a first step, utilities will need to know anticipated energy demand from ZE MHDVs in different regions. Drawing from the ICF's 2020 Grid Readiness Report, ☒ ongoing assessment of grid readiness needs to happen at both the wholesale/transmission level and the distribution level. To ensure grid upgrades are made, the federal government, in coordination with provincial and municipal governments, should establish clear lines of responsibility for the provision of grid infrastructure. As an example, the California Public Utilities Commission approved a new tariff bill in 2021 requiring investor-owned utilities to pay for the build-out of grid infrastructure, including distribution lines, transformers, trenching and construction.[33]

[30] Federal Highway Administration, *National Electric Vehicle Infrastructure Standards and Requirements,* 88 FR 12724 (2023). https://www.federalregister.gov/documents/2023/02/28/2023-03500/national-electric-vehicle-infrastructure-standards-and-requirements

[31] CharIN, "Megawatt Charging System (MCS)." https://www.charin.global/technology/mcs/

[32] Mehanaz Yakub, "CharIn stages North American launch of its universal charging standard for commercial heavy-duty vehicles," *Electric Autonomy*, October 13, 2022. https://electricautonomy.ca/2022/10/13/charin-megawatt-charging-system-standard-north-america/

[33] Miles Muller and Max Baumhefner, "CA Approves New Rules to Support EV Charging Infrastructure," *NRDC*, October 8, 2021. https://www.nrdc.org/experts/miles-muller/ca-approves-new-rules-support-ev-charging-infrastructure

Recommendation: Encourage utilities to set competitive rates for electricity to help incentivize private investment in infrastructure for ZE MHDVs.

Challenge addressed: Lack of clarity regarding electricity rates

Electricity rates can be determined by demand charges which are triggered when there is a spike in energy use. In these cases, rates are based on peak power usage rather than overall energy consumption, a disincentive for private investment in charging infrastructure and overall fleet electrification. It is difficult to make the business case for installing charging infrastructure or for investing in the electrification of fleets when utilities set rates that are too high or which fail to include favourable rates during off-peak periods. While Quebec, B.C. and Alberta have introduced flexible rates, a more comprehensive approach is needed. Utilities in general should consider offering favourable overnight charging rates, for instance, to encourage charging during off-peak hours and alleviate stress on local grids.

A good example of how different levels of government can work together to introduce charging rates that incentivize private investment and support grid stability can be found in the U.S. Amendments to the Public Utility Regulatory Policies Act through the Bipartisan Infrastructure Law which now require that utility regulators in every state initiate a consideration of rates that will encourage electric vehicle adoption.[34]

3.4 Capacity building supports and initiatives

All vehicle classes (Buses, MDVs, HDVs)

Recommendation: Leverage Canada's Zero-Emission Vehicle Awareness Initiative and other programs to support capacity-building.

Challenge addressed: Shortfall in ZEV-ready skilled workers

[34] Charge Ahead Partnership, "What Are PURPA Amendments?" January 12, 2023. https://www.chargeaheadpartnership.com/blog/what-are-purpa-amendments

Across the sector, there is a growing need to develop a ZEV-ready workforce. Planners, fleet managers, truck operators, engineers, mechanics, and other technical workers require training and experiential opportunities with new and emerging low-carbon and zero-emission technology and charging infrastructure.

The scale of support required must be calculated so that sufficient funding is allocated to programs offering training and skills building. In partnership with provincial governments and educational institutions, funding should be directed toward the certification, training, and upskilling of the labour force already employed in the auto industry as well as those who intend to work in the sector. Canada's Zero-Emission Vehicle Awareness Initiative, or possibly other, new, programming streams, can be a source of funding to support the development of a zero-emission ready workforce.

The State of California offers a template for how to create a pipeline of workers with the skillsets applicable to the ZEV industry. The California Energy Commission (CEC) supports training for technicians to repair and maintain alternative fuel vehicles through a dedicated funding stream for the Advanced Transportation and Logistics Sector of the California Community Colleges.[35] The CEC and the California Air Resources Board also provide grants for projects that provide training on ZEVs and infrastructure through the Inclusive, Diverse, Equitable, Accessible and Local (IDEAL) ZEV Workforce Pilot.[36]

[35] Advanced Transportation and Logistics, "The Zero Emissions Vehicle Equity Training Project." https://atleducation.org/cec/the-clean-transportation-training-project/

[36] California Energy Commission, "GFO-21-602 – IDEAL ZEV Workforce Pilot." https://www.energy.ca.gov/solicitations/2021-10/gfo-21-602-ideal-zev-workforce-pilot

4. Conclusion

Canada needs a clear and comprehensive strategy that lays out how the MHDV sector will achieve a transition to ZEVs within the timeframes set by the federal government. A successful transition includes a build-out of charging and refuelling infrastructure that is timed to meet the energy needs of an increasing number of ZE MHDVs on the road. Two federal programs — the Zero Emission Transit Fund and the Zero Emission Vehicle Infrastructure Program — have been set up to support the build-out of an infrastructure network for charging and refuelling MHDVs.

Table 2 below shows the costs associated with installing the level of infrastructure necessary to meet the needs of ZE MHDVs on the road in line with government targets. We recommend allocating $1 billion to ZETF and scaling up ZEVIP funding, while also identifying new funding opportunities and revenue streams to support this scale of infrastructure development.

Table 2. Estimated infrastructure investment needed for buses, MDVs and HDVs by 2030

MHDV Vehicle type	Total cost of infrastructure	Aligned programs
Buses	$1 billion	Zero Emission Transit Fund
MDVs and HDVs	$3.5 billion	Zero Emission Vehicle Infrastructure Program
Total amount	**$4.5 billion**	

Note: Investments in charging infrastructure deployment will need to continue past 2030. However, the suggested amounts in the table need to be addressed by 2030, by which point most ZEVs (in the buses and MDV categories) are expected to reach cost parity with diesel vehicles in terms of total cost of ownership. Once cost parity is reached, we expect mass adoption of ZE MHDVs. Once this happens, we assume private investments in charging infrastructure will increase post 2030, requiring relatively little government support.

As Canada's second largest source of greenhouse gas emissions as well as a source of air pollution and the associated negative health impacts, the case for switching from fossil-fuel-powered to clean energy MHDVs is clear. There is also a strong economic incentive. ZE MHDV manufacturing will lead to restructuring the automotive supply chain, which will create new opportunities for SMEs in the process — particularly in the build-out of an extensive infrastructure network to fuel zero-emission heavy trucks and buses.

Planning, developing, supplying, and installing infrastructure to meet the needs of ZE MHDVs opens up significant job opportunities and avenues for economic growth.

Already, many Canadians are employed in the charging and refuelling industry from coast to coast. Projections show that this is a growth sector where we can expect to see continued high employment and sustainable careers[37]. Investment in infrastructure today is essential to a successful transition, deep cuts in carbon emissions, a healthier environment, and a robust labour force.

[37] Chandan Bhardwaj, Donald Jantz and Priyanka Lloyd, *Power Boost: Electric school buses and the revitalization of small- and medium-size businesses in Ontario's auto industry*, (Pembina Institute, 2023). https://www.pembina.org/pub/power-boost