PEMBINA institute

ZeroX2040

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

Part 1: Zero-Emission Vehicles

Chandan Bhardwaj, Sarah McBain, Adam Thorn
November 2023

photo: IvanSpasic, iStock

PEMBINA institute

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

Part 1: Zero-Emission Vehicles

Chandan Bhardwaj, Sarah McBain, Adam Thorn

November 2023

Recommended citation: Bhardwaj, Chandan, Sarah McBain and Adam Thorn. *Canada's Pathway to Net-Zero for Medium- and Heavy-Duty Trucks and Buses: Part 1: Zero-Emission Vehicles*. The Pembina Institute, 2023.

ISBN 1-897390-65-3

The Pembina Institute
#802, 322 – 11 Avenue SW
Calgary, AB T2R 0C5
Phone: 403-269-3344
www.pembina.org.

About the Pembina Institute

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.

pembina.org

twitter.com/pembina facebook.com/pembina.institute

Donate to the Pembina Institute

Together, we can lead Canada's transition to clean energy. Your gift to the Pembina Institute directly supports environmental education and innovative research that advances understanding and action on critical energy and environmental issues.

pembina.org/donate

Acknowledgements

TAF

The Pembina Institute wishes to thank The Atmospheric Fund for their generous support.

Valuable insight was also provided by Electric Mobility Canada, especially the Medium- and Heavy-Duty Working Group, and by the partners of the Urban Delivery Solutions Initiative.

The Pembina Institute acknowledges that the work we steward and those we serve span across many Nations. We respectfully acknowledge the space our organization is headquartered in as the traditional and ancestral territories of the Blackfoot Confederacy, comprised of the bands Siksika, Piikani, and Kainai, the Îyârhe Nakoda Nations, including the bands of Goodstoney, Chiniki, and Bearspaw, and the Tsuut'ina

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.

Contents

List of Figures

List of Tables

Executive summary

The transport sector contributes approximately a quarter of the total greenhouse gas (GHG) emissions in Canada. Medium- and heavy-duty vehicles (MHDVs), while an essential component of Canada's economy, represent a growing share of transportation-generated emissions. Despite making up only 17% of Canada's total vehicle stock, MHDVs account for over 37% of vehicle-related GHGs. Given that emissions from MHDVs are expected to bypass those from passenger cars by 2030, it is increasingly urgent that the federal government fully address the rising levels of carbon pollution produced from this sector.

Recognizing this sector's emissions trajectory, the Government of Canada included ambitious sales targets for automakers in its 2030 Emissions Reduction Plan (ERP) in March 2022. By 2030, 35% of all new medium- and heavy-duty vehicle sales (both domestic and for export) must be zero-emission (ZE) vehicles; by 2040 (based on feasibility), 100% of sales must be ZE MHDVs. While the need to manufacture ZE MHDVs and the concurrent need for charging and refuelling infrastructure is acknowledged at the federal level, as yet there is no concrete, implementable plan in place that outlines how this transition will take place. Our research clearly shows that under the set of policies and spending announced to date, Canada will not meet those targets.

Pulling from research, analysis and stakeholder engagement, the Pembina Institute has developed the ZeroX2040 strategy. The strategy recommends a phased approach as a practical, cost-effective pathway to transition to zero-emission MHDVs where ZE MHDVs are introduced in stages that align with technological and commercial market readiness. In this scenario, MHDVs that are market-ready will be subject to the most aggressive goal-setting and timelines guiding manufacture/supply and purchase requirements. ZE MHDVs that are not yet market-ready would be subject to similar guidelines and requirements at later dates.

Our recommendations can be summarized as:

1. **Implement a strong ZE MHDV sales standard** that staggers sales requirements across the different MHDV sub-classes, such that the ones most ready to transition are targeted first.

2. **Improve on demand-side measures that stimulate uptake** and help defray large upfront capital investments in zero-emission vehicles (ZEVs) and associated technology.
3. **Invest in capacity building and skills training** to grow a workforce with experiential knowledge of the ZEV sector from production to operations to maintenance.
4. **Enact increasingly stringent emissions standards** to lower emissions generated by long-haul vehicles that are not yet close to market readiness.

Canada can take advantage of new economic opportunities during this time of transition that will help revitalize the bus and truck automotive industry, grow GDP, lower carbon emissions substantially, and contribute to better health outcomes with fewer pollutants in the air. We urge the federal government to adopt these recommendations and accelerate climate actions already underway that will support Canada's clean transportation goals.

1. Introduction

Canada has committed to reducing its greenhouse gas (GHG) emissions to net-zero levels by 2050.[1] Achieving this goal is only possible if the emissions from medium- and heavy-duty vehicles are significantly reduced. The 2030 Emissions Reduction Plan of March 2022 set out ambitious targets to reach 35% of new medium- and heavy-duty vehicle (MHDV) sales by automakers being zero emission (ZE) by 2030, and 100% MHDV sales to be ZE by 2040 (based on feasibility).[2] However, the current suite of policies and programs in Canada will not be sufficient to meet these targets (Figure 1).

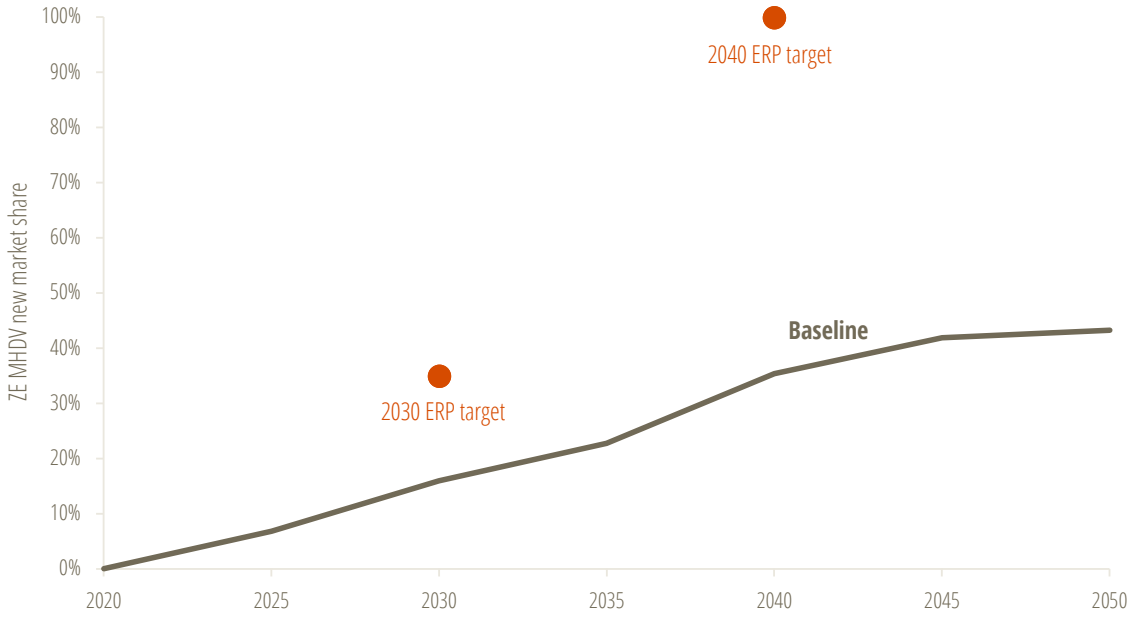

Figure 1. ZE MHDV new sales under Baseline scenario

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.

The transition of MHDVs (currently running mostly on diesel and gasoline) to zero-emission vehicles (ZEVs) entails two related but distinct requirements: the production

[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

and purchase of ZE MHDVs and the build-out of the charging and refuelling infrastructure needed to power them. Both elements are necessary to create a well-functioning ZE MHDV ecosystem where there are sufficient vehicles to incentivize investments in infrastructure and enough infrastructure to instill investment confidence in manufacturing and large-scale ZE MHDVs purchases.

The transition to ZEV manufacturing presents an opportunity for a resurgence in Canada's MHDV sector,[3] which has been in decline and even now is operating at only 60% of its pre-Covid production levels.[4] Canada produced 939,364 commercial vehicles in 2022, falling from its production of 1,568,214 commercial vehicles in 2016.[5] The market size of the truck and bus manufacturing industry in Canada has declined 8.1% per year on average between 2017 and 2022, falling faster than declines in the wider economy.[6] Economic output of the heavy-duty vehicle manufacturing sector too has declined, dropping from $690 million in 2018 to $409 million in 2022.[7] As a result, Canada's contribution to global commercial vehicle production has fallen from a high of 6.8% in 2016 to 3.5% in 2021. In contrast, the demand for ZE MHDVs is likely to grow globally.[8] Canada can take advantage of this opportunity to transition its MHDV manufacturing sector to producing more ZE MHDVs, and in turn stem the current decline.

What is missing is a credible pathway to achieve a transition to ZE MHDVs in Canada. The Pembina Institute has developed a national strategy, ZeroX2040, which provides guidance on how Canada can gradually turn over its fossil-fuelled medium- and heavy-duty vehicles to electric and hydrogen-fuelled ones by 2040. 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. In the ZeroX2040 strategy, we identify a series of key recommendations that will help develop that pathway.

---

[3] Claire Buysse, *Zero-Emission bus and truck market in the United States and Canada: A 2021 update* (International Council on Clean Transportation, 2022). https://theicct.org/wp-content/uploads/2022/09/update-ze-truck-bus-market-us-can-sept22.pdf

[4] OICA, "Production statistics" https://www.oica.net/category/production-statistics/2022-statistics/

[5] OICA, "Production statistics."

[6] IBIS World, "Truck & Bus Manufacturing in Canada - Market Size." https://www.ibisworld.com/canada/market-size/truck-bus-manufacturing/

[7] Statistics Canada, "Gross domestic product (GDP) at basic prices, by industry, provinces and territories", https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3610040201&pickMembers%5B0%5D=2.2&pickMembers%5B1%5D=3.140&cubeTimeFrame.startYear=2018&cubeTimeFrame.endYear=2022&referencePeriods=20180101%2C20220101

[8] International Energy Agency, *Net Zero by 2050*, (2021). https://www.iea.org/reports/net-zero-by-2050

In this report, we provide recommendations specific to the production and uptake of ZE MHDVs. A complementary report (*Part 2: Charging and Refuelling Infrastructure*) puts forward policies that should be prioritized to ensure that ZE MHDV charging and refuelling infrastructure is built out so that it aligns with uptake. Together, the two reports outline the roadmap to a ZE MHDV transition.

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.[9,10,11]

Positive health outcomes: Exposure to diesel exhaust from MHDVs has been linked to increases in the incidence of asthma, cancer, and other respiratory diseases.[12] 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),[13] most of which can be avoided by shifting to ZE MHDVs and substantially lowering the amount of pollutants in the air.

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

[9] 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/

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

[11] 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

[12] 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

[13] 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

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.[14, 15, 16, 17]

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.[18] 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.[19,20] 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.[21] 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

[14] 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

[15] 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

[16] 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/

[17] 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

[18] 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

[19] 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

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

[21] 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

manufacturing), a transition to ZE MHDV manufacturing could offer one way to help stem the current decline of the MHDV manufacturing sector.

2. A strategic approach to ZE MHDV transition

The ZeroX2040 strategy recognizes that different segments of the MHDV market are at different stages of market readiness for the transition to zero-emission vehicles.[22] Buses, especially transit and school buses, are currently the most ready to transition, as there are many ZE bus models available, they tend to operate on relatively short and predictable routes, and buses return to the same depot at the end of a shift with sufficient time to recharge overnight. Lighter, medium-duty vehicles (MDVs) such as urban delivery vans share similar characteristics although fewer models are currently available. However, market-ready — or near market-ready — heavy-duty vehicles (HDVs), especially long-haul trucks, are scarce. HDVs travel long distances and therefore need access to very fast recharging/refuelling options, which are still in short supply.

By utilizing the ZeroX2040 strategy, where sales goals and associated milestones are aligned with market readiness, we can adapt our recommendations to variances in commercial viability among MHDVs and identify the most efficient transition pathway. Our recommendations are most aggressive in the bus and MDV segment, while recognizing the greater uncertainty that exists in the HDV classes. The learnings, innovation, and technological development that occur in the ZE transition of buses and MDVs will likely ease the transition for HDVs.

MHD vehicle categories

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

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

coupled with return-to-depot operations — make transit and school buses prime candidates for electrification.

Medium-duty vehicles (MDVs)

There are about 650,000 MDVs in Canada; urban delivery vans and short-haul and regional freight trucks typically fall under this category. Most MDVs in Canada are privately owned. Urban MDVs, with daily routes of about 200 km and overnight charging at the same depot, are also good candidates for electrification.

Heavy-duty vehicles (HDVs)

Heavy-duty vehicles refer to vehicles with a GVWR greater than 11,794 kilograms and includes GVWR classes 7 and 8.[23] 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 infrastructure if they are to convert to electric.

The main challenges in the manufacturing and purchasing options for ZE MHDVs are outlined in the table below.

[23] Statistics Canada, "Vehicle registrations, by type of vehicle and fuel type." https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2310030801

Table 1. Key challenges to manufacturing and purchasing ZE MHDVs in Canada

Challenge	Description
High purchase costs	Currently, ZE MHDVs are more costly than diesel MHDVs. While Canada's Incentives for Medium- and Heavy-Duty Zero-Emission Vehicles Program (iMHZEV) and Zero Emission Transit Fund (ZETF) help offset the purchase price, the current financial outlay of both programs is not enough to fully cover the difference between low-carbon vehicles and ones that are diesel-fuelled. Funding needs also differ among MHDV categories. **Buses:** Transit and school bus purchases are directly funded by the government, either via municipalities (for transit) or via provincial ministries of education (for school buses). **MDVs and HDVs:** Larger, well-capitalized MDV and HDV fleet owners can be expected to pay — at least partially — for ZE MHDV purchases. However, government funding that can offset some of the upfront expense will attract private investment to cover the balance and act as an incentive for ZE MHDV adoption. Less well-capitalized fleets may require additional funding support that is tailored to the circumstances.
Insufficient planning for transition	Canada does not have a clear plan that outlines how the transition to ZE MHDVs should be implemented and also allows for the variance in market readiness among MHDV sub-classes.
Shortfall in ZEV-ready skilled workers	The pool of skilled labour is too small to meet near-term demand for workers trained in the production and maintenance of ZEVs. Canada will need to support skills training for planners, fleet managers, truck operators, engineers, mechanics, and other technical workers that can be applied to emerging ZEV technology.
Lack of technological readiness in some classes	While the number of commercially available ZE MDV and bus models continues to grow, long-haul ZEVs are still a few years away from being commercially available at the scale required for deep decarbonization of the HDV sector.

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

1. **A strong ZE MHDV sales standard** that staggers the sales requirements across different MHDV subclasses (buses, MDVs, HDVs) to align with market readiness and commercial viability (Section 3.1).
2. **Demand-side measures,** such as financial support and procurement mandates, that align with the ZeroX2040 strategy and differentiate between public and private fleets (Section 3.2).

3. **Capacity building and skills training** to grow a workforce that can be employed in the ZEV supply chain and to increase the number of skilled workers needed to build and maintain ZEVs (Section 3.3).
4. **Increasingly stringent emissions regulations** for MHDVs powered by fossil fuels, which gradually push automakers to manufacture vehicles that produce fewer emissions until they fully transition to zero-emitting (Section 3.4).

3. Recommendations

3.1 A strong ZE MHDV sales standard

All vehicle classes (Buses, MDVs, HDVs)

Recommendation: Implement a ZE MHDV sales standard as the key policy for MHDV decarbonization.

Challenge addressed: Insufficient planning for transition

After extensive analysis of different policy scenarios to decarbonize the MHDV sector and achieve Canada's ZE MHDV 2030 and 2040 sales targets, the Pembina Institute determined that the most effective means of transitioning MHDVs off fossil fuels is by regulating **a ZE MHDV sales standard**. The sales standard must require truck and bus manufacturers and importers to ensure that a specified percentage of their total MHDV sales be zero- or low-emission. This percentage would increase over time to near 100% of sales.

A ZE MHDV sales standard offers several advantages over other policy measures such as offering substantial financial incentives or increasing a carbon price. Our modelling shows that a ZE MHDV sales standard will promote sales of ZE MHDVs that meet (or come close to) the 35% target by 2030 and the 100% target by 2040 (Figure 2). Other policy options, such as a carbon price increasing over time to $170/tonne and the Clean Fuel Regulations (shown as the Baseline in Figure 2), would also increase sales of ZE MHDVs but would fall short of the targets. Our modelling showed that, by 2050, these policies result in ZE MHDVs accounting for approximately 30-60% of new MDV sales and 10-50% of HDV sales.

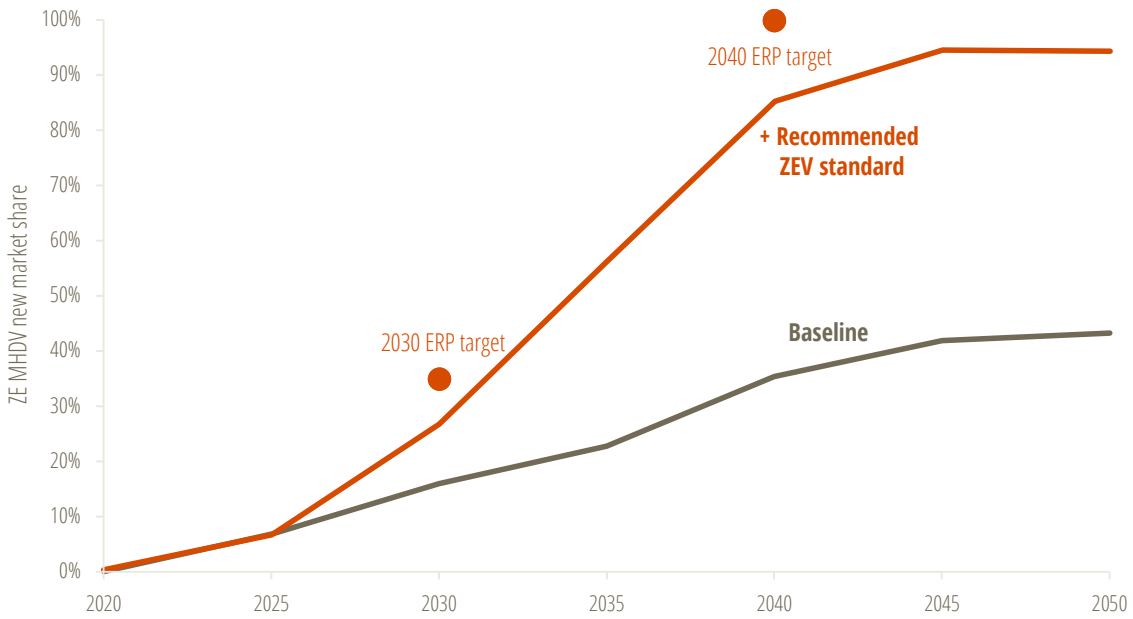

Figure 2. ZE MHDV new sales under the Baseline and Recommended ZEV sales standard scenarios

We also expect to see a decline in costs associated with technological advances. The ZE MHDV sales standard will accelerate investment in ZEV-related research and development. Investors and automakers will be motivated to innovate more and achieve economies of scale rapidly, which will drive a reduction in expenses.

Meeting the ZE MHDV sales goals will have a cascading effect resulting in the following outcomes, according to our analysis:

- A substantial reduction in greenhouse gases by 2050 (as much as an 80% decline in GHGs relative to business-as-usual). Emissions from MHDVs are anticipated to drop from 60 Mt in 2015 to 10 Mt or less in 2050 as energy generated by fossil fuels (mainly diesel) is displaced with clean electricity and hydrogen (Figure 3).
- A reduction of more than 25% in overall energy consumption from the MHDV sector: from 500 petajoules (PJ) in 2015 to 400 PJ in 2050. ZE MHDVs, on average, use less energy than diesel/gasoline vehicles. For example, an electric truck consumes about 30% less energy than a diesel truck.[24] Note that while overall electricity consumption will rise with the increased number of ZEVs on the road, total energy consumption will decline due to greater energy

[24] Dong-Yeon Lee, Valerie M. Thomas, and Marilyn A. Brown, "Electric urban delivery trucks: Energy use, greenhouse gas emissions, and cost-effectiveness." *Environmental Science & Technology* 47 (2013), 14. https://pubs.acs.org/doi/abs/10.1021/es400179w

efficiencies. Moreover, the combination of using renewable energy sources and more energy efficient technologies translates into much greater energy security and independence from the volatility of oil prices.

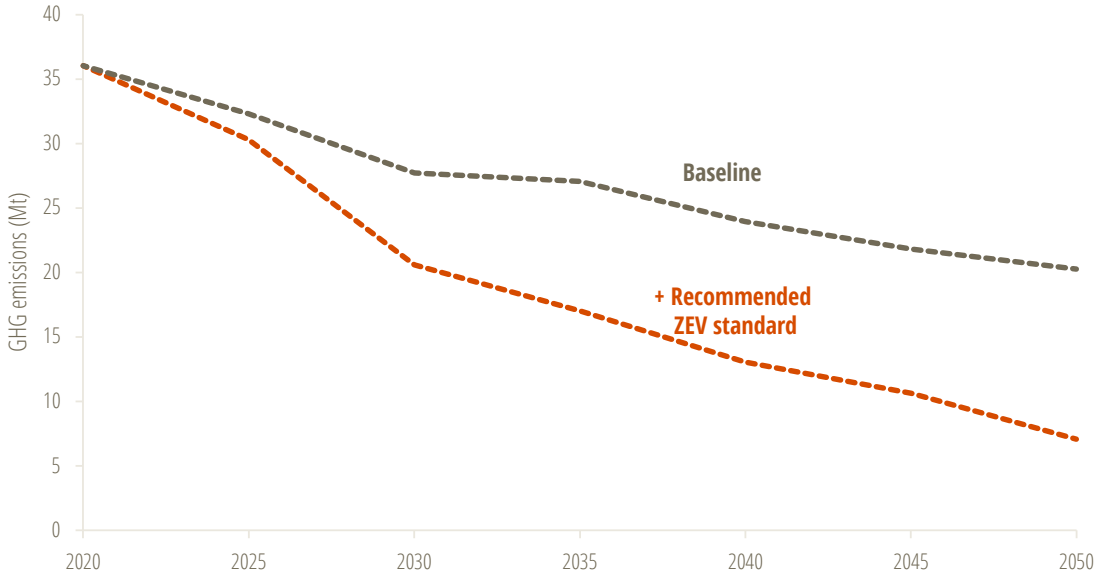

Figure 3. Greenhouse gas emissions from the MHDV sector under the Baseline and Recommended ZEV sales standard scenarios

Alternative policies, most notably the establishment of a more stringent Heavy Duty Vehicle and Emission regulation, can be designed to achieve similar outcomes as the ZE MHDV sales standard in terms of ZE MHDV sales and GHG emissions reductions. More stringent GHG standards that cannot be met through improvements to existing diesel vehicle technologies will likely spur ZE MHDV sales.

The significant drawback to employing this alternative, however, is that it would require roughly tripling the stringency of the current emissions standards to achieve the same results as that of a sales standard: from the current regulation requiring a 30% reduction in grams/mile of emissions per vehicle relative to 2010 levels by 2030, to a 90% reduction per vehicle by 2040.[25]

Historically, Canada's emission standards have closely aligned with those of the U.S. to ensure policy uniformity within an integrated North American auto market. Since the stringency of the current GHG standards in the U.S. and Canada is well short of that

[25] Authors' calculations based on Canada's average vehicle stock retirement rate, current average emissions per vehicle, expected stock of vehicles over time, and projected improvement in fuel economy of vehicles over time.

needed to achieve Canada's ambitious GHG reduction and ZE MHDV sales goals — and the U.S. is unlikely to change the stringency of its GHG standards to meet a 90% reduction per vehicle by 2040 — a ZE MHDV sales standard is needed.

The Pembina Institute's ZeroX2040 strategy recommends that the government institute ZE MHDV sales requirements based on feasibility instead of a uniform sales target across all MHDV classes (as proposed in the Emissions Reduction Plan 2022). The most easily electrifiable truck operations currently and in the near term are within the MDV and bus subsector. In contrast, HDVs, especially long-haul trucks, will take longer to transition due to cost and technological challenges. Within this context, the Pembina Institute's proposed ZEV sales standard (Figure 4) would require that:

- Most **buses** reach 100% ZEV sales by 2030
- Most **urban MDVs** reach 50% ZEV sales by 2030, and near 100% by 2040
- **HDVs** reach up to 10% ZEV sales by 2032 and near 100% by 2045.

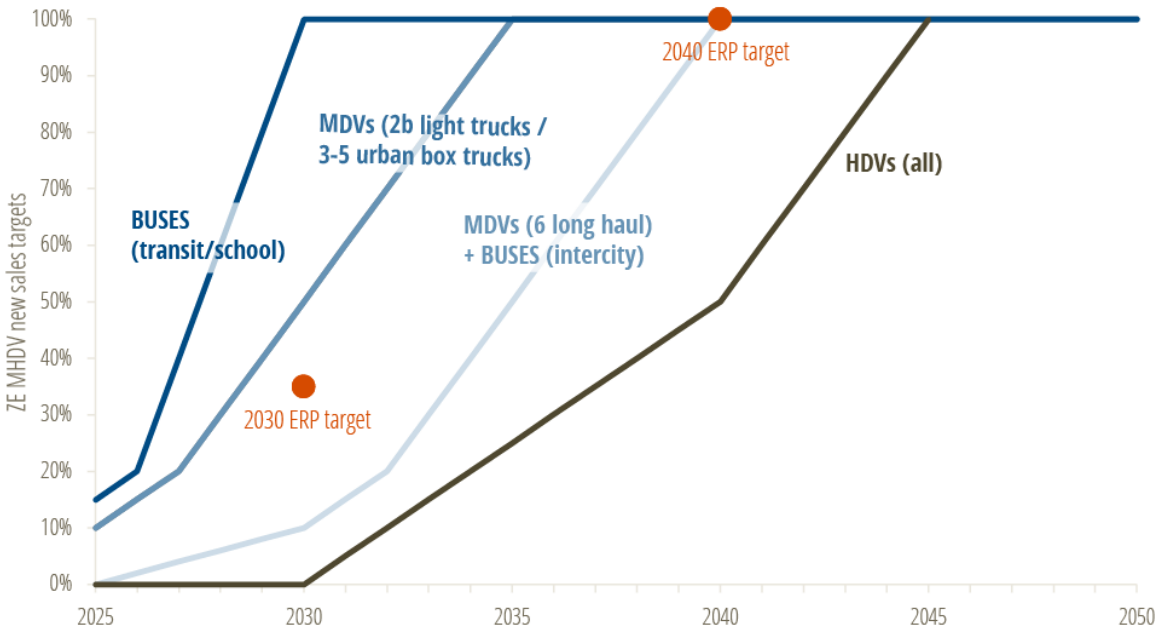

Figure 4. Recommended ZE MHDV new sales targets across different MHDV classes

Most buses and MDVs see an accelerated ZEV uptake (i.e. exceed the ERP target), while HDVs and some difficult-to-electrify buses and MDVs see slower ZEV uptake.

Note, these targets are for sales of new vehicles and not total stock. For example, of the approximately 5,000 new school buses purchased annually in Canada, a 15% new sales target means that a total of 750 ZE buses should be sold by original equipment manufacturers. Already, fleet owners, provincial agencies and others in Canada have

collectively announced the purchase of 2,000 new ZE buses over the next two to three years[26,27]. If these announced orders come through, Canada will come close to achieving or exceeding the 15% new ZE bus sales target by 2025.

3.2 Demand-side measures to stimulate uptake

Although the ZE MHDV sales standard is an effective supply-side regulation, manufacturers will likely find it difficult to comply with the regulation without sufficient demand for ZE MHDVs. The sales standard will need to be complemented by a combination of financial incentives and public procurement mandates to incentivize demand. As already noted, there will also need to be concurrent planning and financing to advance charging and refuelling infrastructure. We discuss infrastructure policies in greater depth in *Part 2: Charging and Refuelling Infrastructure*.

We offer the following recommendations to help eliminate barriers to ZE MHDV uptake. We start with the category of vehicles easiest to transition to ZE MHDVs (i.e. school buses and urban transit), followed by MDVs and HDVs. For many use cases (school buses, urban transit, urban delivery trucks), electrification is the most successful technology to transition to ZE MHDVs.

Buses

> Recommendation: Encourage provincial governments to enact a requirement that by 2030 all new school and transit bus purchases are zero–emission vehicles.

Challenge addressed: Insufficient planning for transition

The federal government will need to coordinate with provincial governments and their respective ministries of education to make it mandatory that all schools progressively buy an increasing number of zero-emission buses. By 2030, this requirement must be

[26] Mehanaz Yakub, "Student Transportation of Canada places conditional order for 1,000 electric school buses," *Electric Autonomy Canada,* 2021, https://electricautonomy.ca/2021/10/28/student-transportation-electric-buses/

[27] CBC news, "Quebec to get 1,229 electric buses in $2.1B deal with Nova Bus," May 8, 2023. https://www.cbc.ca/news/canada/montreal/nova-bus-quebec-canada-electric-buses-1.6836326

100% of new buses purchased. Quebec has already set a target of electrifying 65% of its total (not just new purchases) school bus fleet by 2030.[28]

Similarly, all public transit agencies must be required to gradually transition to a 100% ZE fleet by 2030. By 2026, 50% of new bus purchases by large transit agencies must be ZE; 25% of new bus purchases made by small transit agencies must be ZE.[29] By 2030, 100% of both large and small transit agencies' new bus purchases must be ZE.

These procurement requirements and targets are already in place in several jurisdictions, including in California which requires transit agencies to purchase only ZE buses by 2029 under the Innovative Clean Transit regulation.[30]

Recommendation: Extend financial support beyond 2026 to directly fund deployment of transit and school buses.

Challenge addressed: High purchase costs

Through the Zero Emission Transit Fund (ZETF), the Government of Canada is investing $2.75 billion over five years, starting in 2021, to a) support public transit and school bus operators in planning for electrification; b) support the purchase of 5,000 ZE buses; and c) build charging infrastructure and facility upgrades.[31] This is an important funding source and is likely to encourage the electrification of approximately 6.25% of the total school and transit bus fleet by 2026 (for a near 80,000 transit and school bus stock nationally).

To meet the proposed target of 100% new ZE transit and school bus sales by 2030, financial support will need to continue beyond 2026. Our analysis shows that approximately $10 billion will be required between 2027 and 2030 (~$1.4 billion in 2027; ~2 billion in 2028; ~3.2 billion in 2029; and ~4 billion in 2030), by which point ZE buses are expected to reach cost parity with diesel vehicles in terms of total cost of ownership.

[28] Olivia O'Malley, "Quebec unveils detailed plan to electrify most school buses by 2030," *Global News*, April 23, 2021. https://globalnews.ca/news/7784257/quebec-electric-school-buses-2030/

[29] Following the definition as used by California Air Resources Board, we assume large transit agencies to be those with a fleet of 100 vehicles or more.

[30] California Air Resources Board, *Innovative Clean Transit Regulation Factsheet* (2019). https://ww2.arb.ca.gov/resources/fact-sheets/innovative-clean-transit-ict-regulation-fact-sheet

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

In anticipation of the total cost to transition to ZE buses, the federal government can collaborate with provincial governments and initiate plans prior to 2026 to identify opportunities to generate funding sources and financial mechanisms that will support a clean energy transportation system in the MHDV sector. Collective efforts will be required to source necessary funding across all levels of government and the private sector. We further recommend that increased funding allocations to ZETF be included in the sources of revenue needed going forward.

Medium-duty vehicles

> Recommendation: Partner with provincial governments to ensure that 50% of new purchases of federal, provincial, and municipal-owned urban MDV fleets, and fleets owned by large entities, be ZE by 2030.

Challenge addressed: Insufficient planning for transition

The federal government, in collaboration with provincial and municipal governments, should require that 50% of new purchases of municipal, provincial, and federal government MDV fleets must be ZE by 2030. This requirement must also apply to Crown corporations with $50 million or more in gross annual revenue and that own at least one MDV vehicle, or public entities that own and operate 50 or more MDVs.

California has proposed the Advanced Clean Fleet regulation requiring state-, local- and federal-owned fleets, as well as large entities, to transition their vehicle procurement to ZEVs.[32] The European Union's Clean Vehicle Directive similarly requires a minimum percentage of clean (with emissions lower than a specified amount) vehicles in the aggregate public procurement for each Member State, and at least half of the procurement target for clean buses should be met through the procurement of ZE

[32] State of California, *Advance Clean Fleets Regulation Summary* (2022). https://ww2.arb.ca.gov/resources/fact-sheets/advanced-clean-fleets-regulation-summary

buses.[33] In 2016, China implemented a nationwide mandate that requires at least 30% of new vehicle purchases by government agencies and public institutions be ZEVs.[34]

Recommendation: Explore financing mechanisms to increase support for greater uptake of ZE MDVs in the private sector.

Challenge addressed: High purchase costs

Through the Incentives for Medium- and Heavy-Duty Zero-Emission Vehicles (iMHZEV) Program, the Government of Canada provides financial support that helps defray the upfront cost of purchasing ZE MHDVs.[35] Budget 2022 announced $547.5 million over four years for the iMHZEV program, which covers up to $200,000 or 50% of the purchase costs of a ZE MHDV. To achieve our recommended target of 50% sales of ZE MDVs by 2030, approximately $4 billion between 2026 and 2030 will be needed. However, post-2030, ZE MDVs should reach parity with diesel vehicles in total cost of ownership.

Our recommendation is that funding allocated to the iMHZEV program be increased and that the federal government, in collaboration with provincial governments and the private sector, explore new revenue opportunities and partnerships to help facilitate uptake and grow the domestic market for ZE MDVs.

Heavy-duty vehicles

Recommendation: Allocate at least $1 billion to the Green Freight program directed to retrofitting existing stock of long-haul trucks.

Challenge addressed: High purchase costs and insufficient planning for transition

[33] European Commission, *Clean Vehicles Directive* (2019). https://transport.ec.europa.eu/transport-themes/clean-transport-urban-transport/clean-and-energy-efficient-vehicles/clean-vehicles-directive_en

[34] Government of China, "The Implementation Plan for the Purchase of New Energy Vehicles by Government Agencies and Public Institutions was issued," July 13, 2014. .http://www.gov.cn/xinwen/2014-07/13/content_2716565.htm

[35] Government of Canada, "Incentives for Medium- and Heavy-Duty Zero-Emission Vehicles." https://tc.canada.ca/en/road-transportation/innovative-technologies/zero-emission-vehicles/medium-heavy-duty-zero-emission-vehicles/program-statistics

Natural Resources Canada is launching Stream 2 of the Green Freight Program in 2023.[36] The program provides 50% cost-share contributions up to a maximum of $5 million to truck owners who retrofit their diesel exhaust systems with cleaner technologies. Retrofitting, in general, entails replacing the main mechanical components of a vehicle (engine, transmission, etc.) with cleaner systems such as a compressed natural gas engine,[37] or an electric drive train/propulsion system, and, in some cases, with a hydrogen range extender (hydrogen tanks).[38]

We support this initiative, and further support that the current scope of the program includes electric engine retrofits. Retrofitting a diesel truck with an electric engine costs one-third less than buying a new electric truck — the average sticker price of a new electric truck is $300,000 compared to a retrofit which will likely cost approximately $200,000.[39] Our recommendation is that at least $1 billion be allocated to the Green Freight program over the next 10 years. The cost of a typical renewable gas engine (as opposed to an electric one) retrofit varies[40,41,42] and can often run to approximately

[36] Government of Canada, "Green Freight Program Stream 2." https://natural-resources.canada.ca/energy-efficiency/transportation-alternative-fuels/greening-freight-programs/green-freight-program/green-freight-program-stream-1/24810

[37] Robert Giorgis, *Gas Technology Institute: Medium- and Heavy-Duty Vehicle Technologies: Thirteen-Liter Dual-Fuel Natural-Gas Engine Demonstration* (California Energy Commission, 2019). https://www.energy.ca.gov/sites/default/files/2021-05/CEC-600-2019-026.pdf

[38] Hydrogen Central, "New System Retrofits Diesel Engines to Run on 90 Per Cent Hydrogen." https://hydrogen-central.com/new-system-retrofits-diesel-engines-run-90-per-cent-hydrogen/

[39] John Hitch, "Diesel trucks may get new life in electrified world," *Fleet Owner*, July 15, 2021. https://www.fleetowner.com/emissions-efficiency/electric-vehicles/article/21169611/diesel-trucks-may-get-new-life-in-electrified-world

[40] Tom Jackson, "Does it pay for contractors to run a truck or fleet on natural gas?" *Equipment World*, April 23, 2013. https://www.equipmentworld.com/business/article/14951770/does-it-pay-for-contractors-to-run-a-truck-or-fleet-on-natural-gas

[41] Global News Wire, "Aemetis Biogas and APG Demonstrate Low-Cost Conversion of Diesel Trucks to Utilize up to 65% Renewable Natural Gas," September 28, 2022. https://www.globenewswire.com/en/news-release/2022/09/28/2524246/0/en/Aemetis-Biogas-and-APG-Demonstrate-Low-Cost-Conversion-of-Diesel-Trucks-to-Utilize-up-to-65-Renewable-Natural-Gas.html

[42] Joseph Kubsh, *Diesel Retrofit Technologies and Experience for On-road and Off-road Vehicles,* prepared for the International Council on Clean Transportation (2017). https://theicct.org/sites/default/files/publications/Diesel-Retrofits_ICCT_Consultant-Report_13062017_vF.pdf

$50,000.[43] Our recommendation assumes that 25% of the nearly 600,000 HDVs in Canada will be retrofitted by 2030, and that the federal government will continue to offer funds that will cover 50% of the retrofit costs.

3.3 Capacity building and skills training

The production and uptake of ZE MHDVs will rely on a skilled, specialized labour force. Capacity building measures need to be put in place as well as direct investments in innovation and production incentives.

All vehicle classes (Buses, MDVs, HDVs)

> Recommendation: Collaborate with Canada-based ZEV manufacturers to train 10,000 technicians by 2030.

Challenge addressed: Shortfall in ZEV-ready skilled workers

Across the sector, the need for increased skills training to create a ZEV-ready workforce is becoming increasingly urgent. Planners, fleet managers, truck operators, engineers, mechanics and other technical workers will need training and experience with new and emerging near- and zero-emission technology, and charging/refuelling infrastructure. Recent estimates anticipate that more than 2,500 skilled workers will be needed by 2025.[44]

Extrapolating from these initial estimates, we can infer that demand for a skilled workforce is likely to rise significantly by the end of the decade to meet the federal ZE MHDV targets. Demand for ZEV-trained technicians will likely exceed 10,000 by 2030.

Federal and provincial governments can work with local ZE MHDV manufacturers to develop programs offering access to training and experiential opportunities. Ontario recently launched a program with the Canadian Vehicle Manufacturers' Association to train 500 individuals on new automotive technologies for a project cost of $5 million.

---

[43] U.S. Department of Transportation, *Congestion Mitigation and Air Quality Improvement (CMAQ) Program-Diesel Retrofits.* https://www.fhwa.dot.gov/ENVIRonment/air_quality/cmaq/reference/cmaq_diesel_retrofits/cmaqdiesel.pdf

[44] Matthew Fortier, "The transition to net-zero requires rapidly upskilling Canada's workforce," *Electric Autonomy*, February 14, 2023. https://electricautonomy.ca/2023/02/14/upskilling-canada-net-zero-workforce/

The federal and provincial governments can do likewise by partnering with Canadian ZEV manufacturers to create programs that offer training for a minimum of 10,000 technicians by 2030, with an allocated budget of $100 million.

Heavy-duty vehicles

> Recommendation: Support R&D and innovation in hydrogen fuel cell vehicles to ensure market readiness by 2030.

Challenge addressed: Lack of technological readiness in some classes and insufficient planning for transition

Numerous studies, including our own analysis, indicate that hydrogen fuel cell vehicles will likely be a dominant ZE technology for heavy-duty long-haul trucks post-2030. Yet technological advances have been slow and have yet to demonstrate market/commercial readiness at scale.[45] Hydrogen fuel cell technology will need to be market-ready for long-haul trucks by the early 2030s for Canada to achieve the goal of 100% ZEV sales in the HDV sector by 2040. We recommend that the federal government adopt a multi-pronged approach that includes:

- Continuing federal support that incentivizes small and medium enterprises (SMEs) to undertake innovative initiatives within the hydrogen supply chain; the Hydrogen Tax Credit in Budget 2023 is one such financial tool.
- Making strategic investments in hydrogen-related R&D so that Canada continues to attract international cooperation in sharing knowledge and research, and co-developing hydrogen supply chains. A commendable first step is the Canada-Germany Hydrogen Alliance in which the two countries signed an agreement to collaborate on the export of Canadian clean hydrogen to Germany by 2025.[46]
- Initiating support for pilot projects that test/demonstrate the commercial-scale viability of hydrogen fuel cell electric vehicles. One of the rare Canadian

[45] Jennifer Henderson, "Hydrogen and electric vehicles are future of transportation: expert," Rocky Mountain Outlook, May 15, 2022. https://www.rmoutlook.com/beyond-local/hydrogen-and-electric-vehicles-are-future-of-transportation-expert-5370142

[46] Government of Canada, "Canada and Germany Sign Agreement to Enhance German Energy Security with Clean Canadian Hydrogen," August 23, 2022. https://www.canada.ca/en/natural-resources-canada/news/2022/08/canada-and-germany-sign-agreement-to-enhance-german-energy-security-with-clean-canadian-hydrogen.html

examples of hydrogen-related pilots is the City of Mississauga Hydrogen Fuel Cell Electric Bus project.[47] Phase 1 of the project examined the available possibilities in developing a local hydrogen supply chain, explored implementation challenges, and analyzed the economic viability of hydrogen fuel cell electric vehicle uptake in Mississauga. Phase 2 of the project is currently seeking funding. The federal government needs to support more such projects across Canada, with greater focus on long-haul heavy-duty vehicles, particularly those whose duty cycle does not include returning to a designated home base at the end of the day.

3.4 Increasingly stringent emissions regulations

All vehicle classes (Buses, MDVs, HDVs)

Recommendation: Increase the stringency of the vehicle emissions standard as an interim policy for new non-ZE MHDVs (until all vehicles transition to ZE MHDVs)

Challenge addressed: Insufficient planning for transition

Our modelling demonstrates that the vehicle emission standards in Canada are too low and will not achieve deep GHG reductions in the MHDV sector, as required to reach net-zero by 2050. While the ZE MHDV sales standard will ensure uptake of ZEVs as an increasing percentage of total new sales (say, 10% of all new HDV sales by 2032), the remaining new sales (90% of HDV sales by 2032) will still be non-ZE MHDVs (primarily diesel-run internal combustion engine vehicles).

Over time, likely by 2030 in some vehicle categories and by mid-2030s for most, manufacturing costs for ZE MHDVs will reach cost parity with conventional MHDVs. When manufacturing costs of ZE MHDVs are lower than non-ZE MHDVs, automakers will find it cheaper to sell more ZEVs than non-ZEVs, and the emission standard will become redundant (in other words, will overlap with the ZE MHDV sales standard). Until this happens, regulations will be required to encourage automakers to make efficiency improvements in new non-ZE MHDVs. To complement the proposed ZE

[47] City of Mississauga, "Hydrogen Fuel Cell Electric Bus Pilot Project."https://www.mississauga.ca/projects-and-strategies/city-projects/hydrogen-fuel-cell-electric-bus-pilot-project/

MHDV sales standard, Canada must implement more stringent emission standards that progressively push automakers to improve existing technology and gradually spur the development of new ZE technologies. This approach is particularly useful for HDVs, where the commercial/technological readiness of battery electric vehicles and hydrogen fuel cell vehicles is a few years away. As noted above, we assume that Canada will continue to align with the U.S. emission standards and is therefore unable to unilaterally increase its stringency levels. Our recommendation is that Canada work with the U.S. to incrementally increase the stringency requirements until they reach a level that will result in deep emission cuts.

4. Conclusion

As the second-largest source of carbon emissions in Canada, it is increasingly urgent that efforts to decarbonize the transportation sector are accelerated. The pivot to zero-emission cars is underway and the switch to low- and zero-emission medium- and heavy-duty vehicles has begun, although there are considerable differences among the classes of trucks in market readiness.

Canada's success in meeting its 2030 emission reduction goals followed by net-zero emissions in 2050 hinges in no small part on making deep cuts to transportation-generated GHGs. Transitioning from fossil-fuelled vehicles in the MHDV sector to low- and zero-emission vehicles will require a clearly designed strategy and plan to achieve the federal target requiring 35% of new MHDV sales to be ZE by 2030, and 100% ZE by 2040. Without a national plan in place, the supply of ZE MHDVs is at risk of being too low and the pace of market transformation too sluggish. Ultimately, this puts Canada at risk of failing to meet its climate targets.

Based on our research to date, the transition to ZE MHDVs can be completed most cost-effectively through a ZE MHDV sales standard where the sales requirements vary according to vehicle type. The Pembina Institute's recommended ZE MHDV sales standard would require that:

- Most buses reach 100% ZEV sales by 2030
- Most MDVs reach 50% ZEV sales by 2030 and near 100% by 2040
- Most HDVs reach 10% ZEV sales by 2032 and near 100% by 2040.

The sales standard, on its own, will not be sufficient to drive uptake of ZE MHDVs to the levels needed. Complementary policies and regulations must be in place as well. Key measures that will need to be implemented include demand-side measures that incentivize uptake and capacity building efforts to upskill a labour force to enter a ZEV-dominated auto market.

Table 2 below summarizes the financing required by 2030 under our recommendations for the production and uptake of ZE MHDVs.

Table 2. Estimated investment needed by 2030 for the production and uptake of ZE MHDVs

MHDV type	Total amount	Aligned programs
Buses	$10 billion (~$1.4 billion in 2027; ~$2 billion in 2028; ~$3.2 billion in 2029; and ~$4 billion in 2030)	Zero Emission Transit Fund
MDVs	$4 billion (~$0.25 billion in 2027; ~$0.75 billion in 2028; ~$1.25 billion in 2029; and ~$1.75 billion in 2030)	Incentives for Medium- and Heavy-Duty Zero-Emission Vehicles (iMHZEV)
HDVs	$1 billion (spread equally across all years up to 2030)	Green Freight Program
Buses, MDVs and HDVs	$0.2 billion (spread equally across all years up to 2030)	Zero-Emission Vehicle Awareness Initiative
Total	**~$16 billion**	

Note: Bulk of the funding suggested in the table will be needed by 2030 when most ZEVs (in the buses and MDV categories) are expected to reach cost parity with diesel vehicles in terms of total cost over the lifetime of the vehicle. However, certain HDV use cases, e.g., off-road vehicles, may continue to need financial support post-2030.

The climate and human health case for ZE MHDVs is clear. But there is a strong economic case for the adoption of ZE MHDVs as well. 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. 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. ZE MHDV production, from extraction to final product, is a windfall opportunity for Canada's mining and minerals sector.

The surge in demand for ZEVs also creates a new market for Canada's MHDV manufacturing industry, which has been in decline and even now is operating at only 60% of its pre-Covid production levels. Canada's contribution to global commercial

vehicle production has fallen from a high of 6.8% in 2016 to 3.5% in 2021. Transition to ZEV manufacturing presents an opportunity for a resurgence in Canada's MHDV sector.

A growing market benefits not only manufacturers, but also the Canadian SMEs that supply the parts to these local manufacturers. Investing in production and sales within Canada of different sub-classes of ZE MHDVs would contribute to the revival of Canada's commercial vehicle manufacturing industry with economic benefits accruing to SMEs.[48] This is especially significant as SMEs constitute approximately 90% of the MHDV manufacturing sector.

Canada is in the initial stages of advancing meaningful climate action in the transportation sector and has the chance to do so in ways that promote a prosperous economy through growth in employment and specialized and in-demand skills while simultaneously advancing positive health outcomes and decarbonizing the MHDV sector.

[48] See, for example, *Power Boost: Electric school buses and the revitalization of small- and medium-size businesses in Ontario's auto industry*.