PEMBINA institute

Fuel savings and emissions reductions in heavy-duty trucking

A blueprint for further action in Canada

Lindsay Wiginton, Cedric Smith, Maddy Ewing, Geoffrey Battista

April 2019

photo: Roberta Franchuk Pembina Institute

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

The Pembina Institute wishes to thank the Metcalf Foundation and Echo Foundation for their generous support.

The Institute also wishes to thank the following experts and stakeholders who provided insight during the research phase: Bora Plumptre, Bob Oliver, Don Moore, Lak Shoan, Brendan McEwan and Rymal Smith. The information and recommendations presented in this report, however, are solely those of the Institute and their participation does not imply an endorsement of this report or the views presented herein.

Contents

Executive summary 1
1. Introduction 4
2. Supporting a transition in Canada's heavy-duty trucking sector 8
2.1 Heavy-duty trucking in Canada 8
2.2 A shared interest in solutions 10
2.3 Technology options for heavy-duty trucks 12
3. A blueprint for further action 21
3.1 Setting emissions standards for new vehicles 25
3.2 Improving efficiency for existing vehicles 29
3.3 Shifting from higher- to lower-emitting modes and investing in infrastructure 32
3.4 Putting more zero-emission vehicles on the road 37
3.5 A low-carbon or clean fuel standard 41
3.6 Comprehensive measures to support action in heavy-duty trucking 43
4. Conclusion 45
Appendix A. Glossary of Terms 48

List of Figures

Figure 1. Growing freight volumes and relatively few efficiency gains are driving significant growth in GHG emissions from freight trucks 5
Figure 2. Complementary action areas to reduce emissions from on-road freight 6

List of Tables

Table 1. How vehicle classes contribute to Canada's vehicle pool and VKT 9
Table 2. Greenhouse gas and criteria air pollutant emissions, financial and operational considerations of currently available alternative heavy-duty vehicle technologies relative to a diesel baseline 13
Table 3. Availability of cleaner HDV technologies and fuels suitable for application in the long haul heavy-duty trucking sector and state of relevant industries in Canada 18
Table 4. Analysis of PCF transportation commitments as they relate to heavy-duty trucking and recommended actions 22

Executive summary

Every day, the majority of goods transported by road in North America are moved by heavy-duty truck. While goods movement by truck is a backbone of the economy, it is also a major source of pollution: 10.5% of Canada's greenhouse gas (GHG) emissions come from freight transportation, and a majority of these emissions come from heavy-duty trucks. With truck activity increasing and fewer vehicle efficiency gains compared to light vehicles, emissions from freight are expected to bypass those from passenger movement by about 2030 in Canada. Supporting a shift to a cleaner on-road freight sector must be a pillar of any climate action plan, and the federal government has an important role to play.

Since the establishment of the Pan-Canadian Framework on Clean Growth and Climate Change, Canada's first truly national plan to act on climate change and enable clean growth, Canada has had a clear action plan for supporting a cleaner transportation sector. Commitments include: setting emissions standards and improving efficiency by developing new requirements for heavy-duty trucks to install fuel-saving devices, putting more zero-emission vehicles on the road, shifting from higher- to lower-emitting modes and investing in infrastructure, and using cleaner fuels. Significant progress has been made on these commitments, but further efforts are needed to accelerate fuel savings, efficiency gains, and technological shifts in the heavy-duty trucking sector specifically.

In this report, we provide a brief overview of the on-road heavy-duty freight industry and the current technology and fuel options available across the country. We also examine progress on the above commitments as they apply to heavy-duty trucking and then present a blueprint for the federal government to move the needle further on these important commitments. In this report, we do not conduct a detailed examination of progress on the regulatory development of the Clean Fuel Standard, which has yet to be passed into law. However, if implemented with a stringent fuel-intensity reduction target for the transport sector (and with a strong partition from other sectors), this policy would drive increased supply of renewable fuels, such as biodiesel and renewable diesel (HDRD), thereby increasing the availability of fuel-based solutions for decarbonizing the on-road trucking fleet.

Our recommendations reflect the following approach:

1. Maximizing short-term opportunities to reduce emissions and improve efficiency on existing and new diesel fleets as diesel is expected to continue to dominate key segments of the freight industry until approximately 2030.
2. Taking action now to accelerate the development, testing and uptake of zero-emissions heavy-duty truck technologies that offer the potential to achieve the deep emissions reductions required to meet our long-term commitments to mitigating climate change to 2050.

Our blueprint for further action by the federal government is as follows:

1. Confirm Canada's intent to maintain the already-implemented Phase II heavy-duty vehicle (HDV) rules in their entirety.
2. Establish federal financial incentives for fuel saving devices on heavy-duty trucks funded by proceeds from the fossil fuel charge.
3. Establish a target year by which fuel saving devices will be mandatory for all diesel-powered heavy-duty trucks and work with provinces to develop an implementation plan for the requirement.
4. Identify major corridors along which to invest in publicly-funded zero-emissions heavy-duty refueling/recharging stations targeted at long haul operations, and create a five-year investment plan.
5. Allocate government funding and loan programs for low- and zero-emissions HDV according to lifecycle emissions reductions anticipated from the applicant technology.
6. Work with utilities and the hydrogen industry[1] across Canada to create a national zero-emissions heavy-duty vehicle infrastructure development strategy.
7. Build modest adoption targets for medium- and heavy-duty vehicles into the Zero-Emissions Vehicle Strategy update in 2020.
8. Establish new federal financial incentives funded by proceeds from the fossil fuel charge to support Canadian transit agencies in purchasing zero-emissions buses.
9. Proceed with the swift implementation of the Clean Fuel Standard on the transportation (liquid fuel) sector according to the timelines established in the CFS Update and Regulatory Design Paper.

[1] Please see Appendix A: Glossary of Terms for definitions of 'blue' hydrogen and 'green' hydrogen.

10. Study and share information about viable short- and medium-term clean heavy-duty trucking technologies and inform government on actions needed to support the transition through aligning government infrastructure spending and industry investment.
11. Produce a National Land Freight Strategy that would include actions to support mode shift and increased efficiency for goods movement.

1. Introduction

Every day, the majority of goods transported by road in North America are moved by heavy-duty truck. In fact, trucks move approximately 90% of all consumer products and foodstuffs traded from Canada to the United States.[2]

While goods movement by truck is clearly a backbone of the economy, it is also a major source of pollution: 10.5% of Canada's greenhouse gas (GHG) emissions come from freight transportation (nearly on par with the electricity sector), and a majority of these emissions come from heavy-duty trucks.[3]

With truck activity increasing and fewer vehicle efficiency gains compared to light vehicles, emissions from freight are expected to bypass those from passenger movement by about 2030 in Canada.[4] Canada plays an important role in global emissions reductions – not only because of its high carbon footprint but also due to its potential to be a global leader. Supporting a shift to a cleaner on-road freight sector must be a pillar of climate action plans around the world if global emissions are to be cut by about 45% from 2010 levels as of 2030, thereby limiting warming to 1.5 degrees Celsius above pre-industrial levels – which, relative to 2.0 degrees of warming or more, would allow for some of the worst impacts in areas including human health, human well-being, global sea level rise and coral reef loss to be avoided. [5,6]

---

[2] Naveen Nav, "Canadian Trucking Industry in Competition with U.S. Operators." *The Trucking Network,* February 15, 2018. https://thetruckingnetwork.ca/canadian-trucking-industry-competition-u-s-operators/

[3] Environment and Climate Change Canada, *National Inventory Report 1990-2016: Greenhouse Gas Sources and Sinks in Canada* (2017) [NIR 2018] Part 3, Table A10-2. https://unfccc.int/documents/65715

[4] Bora Plumptre, Eli Angen and Dianne Zimmerman, *The State of Freight: Understanding greenhouse gas emissions from goods movement in Canada* (Pembina Institute, 2017). http://www.pembina.org/pub/state-of-freight

[5] V. Masson-Delmotte, P. Zhai, O. Portner, et al, "Summary for Policymakers," in *Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* (IPCC, 2018). https://www.ipcc.ch/2018/10/08/summary-for-policymakers-of-ipcc-special-report-on-global-warming-of-1-5c-approved-by-governments/

[6] V. Masson-Delmotte, P. Zhai, O. Portner, et al, *Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* (IPCC, 2018). https://www.ipcc.ch/sr15/

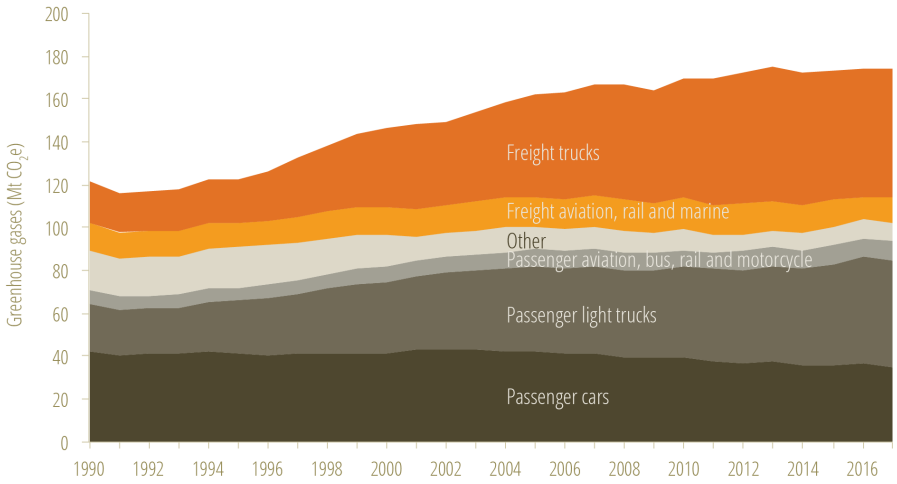

Figure 1. Growing freight volumes and relatively few efficiency gains are driving significant growth in GHG emissions from freight trucks

Source: Environment and Climate Change Canada (2019) National Inventory Report 1990-2017: Greenhouse Gas Sources and Sinks in Canada[7]

All levels of government and industry must act to bend the curve for on-road freight emissions. We need a complementary suite of actions which not only reduce the GHG-intensity of current operations, but also shift goods movement to lower-emitting vehicles and fuels, and where possible, reduce demand for goods movement in the first place. These complementary action areas are presented in Figure 2.

[7] Environment and Climate Change Canada, "Transportation sector greenhouse gas emissions, Canada, 1990 to 2017," spreadsheet, April 2009. https://www.canada.ca/content/dam/eccc/documents/csv/cesindicators/ghg-emissions/2019/GHG-emissions-sector-en.csv

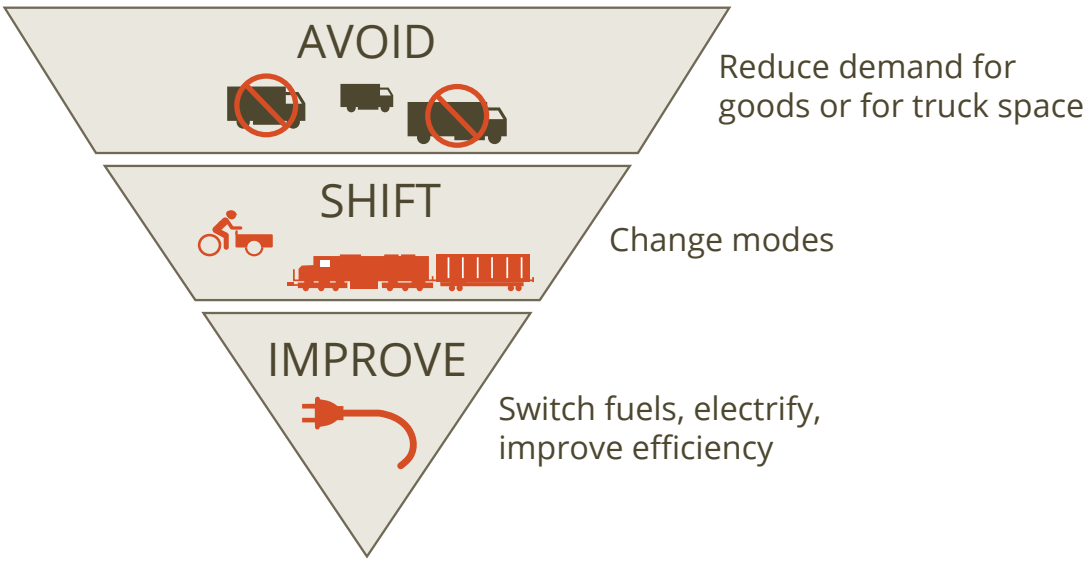

Figure 2. Complementary action areas to reduce emissions from on-road freight

Addressing GHG emissions from freight brings a host of benefits to businesses and communities, including fuel savings (with cost reductions potentially being passed on to consumers), air quality improvements, and potentially faster deliveries and reduced congestion.

The federal government has an important role to play because of its role and mandate to ensure a safe, green, innovative and efficient transportation system; preserve Canada's environment and address climate change; manage natural resources; and help Canadian businesses grow.

By establishing the Pan-Canadian Framework on Clean Growth and Climate Change (PCF), Canada's first ministers delivered the country's first ever truly national plan to act on climate change and enable clean growth. The PCF presents a comprehensive strategy to reduce GHG emissions by 30% by 2030 from 2005 levels. It touches on every sector, including transportation, setting out several commitments that will directly or indirectly support cleaner growth in the freight industry. Specifically, the PCF proposes the following new actions for the transportation sector:

1. Setting emissions standards and improving efficiency by developing new requirements for heavy-duty trucks to install fuel-saving devices like aerodynamic add-ons.
2. Putting more zero-emission vehicles on the road by developing a nationwide strategy for zero-emission vehicles by 2018 and accelerating the demonstration and deployment of zero-emission vehicle infrastructure.

3. Shifting from higher- to lower-emitting modes and investing in infrastructure by building more efficient transportation and trade corridors, hubs, and ports and considering opportunities with the private sector to support refueling stations for alternative fuels, including natural gas, electricity, and hydrogen.
4. Using cleaner fuels by developing a clean fuel standard to reduce emissions for transportation, buildings, and industry.

In this report, we begin with a brief overview of the on-road heavy-duty freight industry and the current technology and fuel options available (Section 2). We then examine progress on the Pan-Canadian Framework commitments to a cleaner transportation sector as they apply to heavy-duty trucking and present a blueprint for the federal government to move the needle further on these important commitments. (Section 3).

2. Supporting a transition in Canada's heavy-duty trucking sector

2.1 Heavy-duty trucking in Canada

This report focuses on the heavy-duty trucking sector. In contrast to goods movement by medium-duty vehicles, heavy-duty trucking has been and will be more difficult to decarbonize due to the industry's higher energy demands that stem from heavier payloads and longer annual distance travelled.[8]

One of the most common ways to classify vehicles is by their gross vehicle weight rating (GVWR). In their Canadian Vehicle Survey, Natural Resources Canada divides vehicles into three weight classes: light vehicles weighing less than 4.5 tonnes, medium trucks weighing between 4.5 and 15 tonnes, and heavy-duty trucks weighing more than 15 tonnes.[9] It is worth noting that cut off between light-duty vehicles and medium-duty trucks is otherwise typically made at 3,856 kg (class 2a).[10]

Nearly all (97.5%) heavy-duty trucks use diesel.[11] As shown in Table 1, despite making up only 1.5% of the Canadian vehicle pool, Class 8 vehicles contribute disproportionately (6.4%) to Canada's total vehicle kilometers travelled (VKT).[12][13]

[8] National Petroleum Council, "Heavy-Duty Vehicles," In *Advancing Technology for America's Transportation* (2012). http://www.npc.org/reports/FTF-report-080112/Chapter_3-Heavy_Duty_Vehicles.pdf

[9] Natural Resources Canada, *Canadian Vehicle Survey* (2009). http://oee.nrcan.gc.ca/Publications/statistics/cvs05/pdf/cvs05.pdf

[10] Environment and Climate Change Canada. *"Guidance Document - Heavy-Duty Vehicle and Engine Greenhouse Gas Emission Regulations,"* (2017). https://ec.gc.ca/lcpe-cepa/default.asp?lang=En&n=71EF09D7-1&offset=3

[11] NRCAN, *Canadian Vehicle Survey* (2009). http://oee.nrcan.gc.ca/Publications/statistics/cvs05/pdf/cvs05.pdf

[12] Environment and Climate Change Canada. *"Guidance Document - Heavy-Duty Vehicle and Engine Greenhouse Gas Emission Regulations,"* supra note 12.

[13] Sustainable Development Technology Canada, *"Industrial Transportation in Canada"*

Within this class, it is combination trucks (class 8b vehicles, or tractor-trailers) that are responsible for the largest share of VKT.[14]

Table 1. How vehicle classes contribute to Canada's vehicle pool and VKT

Vehicle Type	Class	Gross Vehicle Weight	Applications	Share of Canadian vehicle pool	Share of Canadian VKT
Light-duty vehicle	1, 2a, 2b	<4,536 kg	Passenger car, minivan, SUV, minibus	96.3%	91.1%
Medium-duty truck	3-7	4,536 to 14,969 kg	Parcel delivery truck, school bus, city transit bus	2.1%	2.4%
Heavy-duty truck	8a, 8b	>14,969 kg	Dump truck, cement mixer, refuse truck, various configurations of tractor trailers	1.5%	6.4%

Sources: Davis et al.,[15] Natural Resources Canada,[16] U.S. Department of Energy.[17]

Combination trucks may be further categorized as short haul or long-haul. Unsurprisingly, the VKT of combination long-haul vehicles is nearly double that of short-haul vehicles in Canada.[18] Combination long-haul vehicles are distinguished by their range. They travel long distances and do not return to their base each night; instead, they may travel for several days in order to complete a single trip.[19] In the

[14] NRCAN, *Canadian Vehicle Survey* (2009). http://oee.nrcan.gc.ca/Publications/statistics/cvs05/pdf/cvs05.pdf

[15] Stacy Davis, Susan Williams, Robert Boundy, and Sheila Moore, *Vehicle Technology Market Report 2016* (2016). https://www.osti.gov/biblio/1361368-vehicle-technologies-market-report

[16] NRCAN, *Canadian Vehicle Survey* (2009). http://oee.nrcan.gc.ca/Publications/statistics/cvs05/pdf/cvs05.pdf

[17] U.S. Department of Energy, "Types of Vehicles by Weight Class," 2012. https://afdc.energy.gov/data/10381

[18] Natural Resources Canada. *Long Haul Activity Is the Majority of Activity in Both Canada and the US (Class 8b Trucks, 2014)* (SmartWay Trends and Statistics, 2018).https://www.nrcan.gc.ca/energy/efficiency/transportation/21076

[19] Hao Cai, Andrew Burnham, Michael Wang, Wen Hang and Anant Vyas, *The GREET Model Expansion for Well-to-Wheels Analysis of Heavy-Duty Vehicles* (Argonne National Laboratory, 2015). https://greet.es.anl.gov/publication-heavy-duty

United States, the average trip length for a long-haul class 8b vehicle is just over 1600 km, but these vehicles typically only travel 725 to 885 km in a day.[20,21]

The disproportionately high energy demands of class 8b vehicles coupled with the projected growth in freight truck activity makes these vehicles of particular importance in climate change policy-making in Canada.

2.2 A shared interest in solutions

Viable technologies that can save or eliminate fossil fuel use can bring immense benefit to industry, since fuel typically represents the greatest operational cost to fleets, at about 30-40% of costs per kilometre.[22] Despite advances in alternative fuel technology, most on-road freight fleets in Canada, especially long-haul operations, still rely on diesel. Diesel-fueled trucks are anticipated to dominate the heavy-duty truck market through at least 2030.[23] This means that trucking fleets are subject to a number of existing and forthcoming policies (e.g. fossil fuel charge, Clean Fuel Standard) that will apply an added cost to business-as-usual operations powered by diesel and other fossil fuels, in some cases without immediate options to fuel switch.

Options to reduce fuel use include driver training, improving the efficiency of new diesel-powered trucks and trailers, and retrofitting existing vehicles and trailers using technologies like aerodynamic add-ons. Improving the efficiency of diesel-fueled vehicles is important while the technological readiness and economics of zero-emissions vehicles improve, especially because heavy-duty trucks can be expected to

[20] *The GREET Model Expansion for Well-to-Wheels Analysis of Heavy-Duty Vehicles*.

[21] Hengbing Zhao, Wang Qian, Lewis Fulton, Miguel Jaller and Andrew Burke, *A Comparison of Zero-Emission Highway Trucking Technologies* (University of California Institute of Transportation Studies, 2018). https://doi.org/10.7922/G2FQ9TS7

[22] American Transportation Research Institute, *An Analysis of the Operational Costs of Trucking: 2017 Update* (2017). http://atri-online.org/wp-content/uploads/2017/10/ATRI-Operational-Costs-of-Trucking-2017-10-2017.pdf

[23] Marissa Moultak, Nic Lutsey, and Dale Hall, *Transitioning to Zero-Emission Heavy-Duty Freight Vehicles* (International Council on Clean Transportation, 2017). https://www.theicct.org/sites/default/files/publications/Zero-emission-freight-trucks_ICCT-white-paper_26092017_vF.pdf

remain on the road for anywhere between one and two decades, making their way from long-haul operations to regional firms during their lifetime.[24,25]

However, to make real progress on ensuring fuel savings and cleaner air, we need to shift to zero-emissions vehicles. Battery-electric and hydrogen fuel cell heavy-duty trucks (also referred to as zero-emissions trucks) are forecast to become increasingly cost-competitive with same-size diesel and natural gas trucks after 2030.[26] Zero-emissions buses (also in the heavy-duty category) are already being manufactured in Canada, and several models of battery electric and hydrogen fuel cell heavy-duty vehicles are already available on the market[2728]. Supporting a cleaner heavy-duty trucking sector – through, for example, pilot projects and infrastructure build outs – will encourage further progress and will be an opportunity for job creation in Canada if the related manufacturing and service industries are further cultivated. Private businesses and industry have expressed an interest in investing in ZEVs but have uncertainties with respect to viability of alternative technological pathways and the direction of future government investment.

Benefits of climate action in the transportation sector

The Pan-Canadian Framework anticipates that the plan's actions will yield several benefits to consumers and freight operators beyond reducing emissions. For example, fuel efficiency improvements may reduce the costs of goods and services by decreasing transportation costs. Investments in alternative fuel infrastructure can address range anxiety for zero-emissions transportation technologies, promoting their adoption. Climate action is expected to generate jobs across the transportation sector, from maintenance to manufacturing and research and development, while helping Canada's economy adapt to a decarbonizing world.

---

[24] IHS Automotive, "Class 8 Commercial Vehicles Continue to Drive Overall U.S. Commercial Vehicle Demand, IHS Says," media release, November 4, 2015. https://news.ihsmarkit.com/press-release/automotive/class-8-commercial-vehicles-continue-drive-overall-us-commercial-vehicle-de

[25] William Cassidy, "Age-old problem: Not all trucks are equal," *JOC.com,* June 5, 2014. https://www.joc.com/trucking-logistics/trucking-equipment/age-old-problem-not-all-trucks-are-equal_20140605.html

[26] *Transitioning to Zero-Emission Heavy-Duty Freight Vehicles.*

[27] New Flyer Industries Inc. "Xcelsior CHARGE," 2019. https://www.newflyer.com/buses/xcelsior-charge/.

[28] New Flyer Industries Inc. "Montréal and Laval Award Canada's Largest Ever Battery-Electric Bus Contract to New Flyer." *Cision*, August 24, 2018. https://www.newswire.ca/news-releases/montreal-and-laval-award-canadas-largest-ever-battery-electric-bus-contract-to-new-flyer-691671781.html.

2.3 Technology options for heavy-duty trucks

When deciding to invest in new technologies, fleet owners and operators must consider financial factors such as payback period and potential capital, maintenance and fuel costs/savings; as well as operational factors including cargo capacity and range, availability of charging/fueling infrastructure, reliability and others. When designing programs to support uptake of cleaner technologies, policymakers must also consider lifecycle pollution costs/benefits and opportunities to support Canadian industries. Finally, buy-in from vehicle operators (i.e. truck drivers) is important. Canada is faced with a shortage of drivers and the driver workforce is aging[29]. New vehicles can be useful incentives to keep drivers on – but drivers will be more receptive to new technologies if they're given proper training and introduction. Table 2 illustrates these considerations for cleaner heavy-duty truck technologies, in comparison to a diesel baseline. Below, we provide more detail on each technology.

[29] CPCS, *The Truck Driver Supply and Demand Gap*, prepared for the Canadian Trucking Alliance (2016). http://184.107.41.75/~drivershortage/wp-content/uploads/2017/01/Update-2016-%E2%80%93-Truck-driver-Supply-and-Demand-Gap-CPCS-Final-Report.pdf

Table 2. Greenhouse gas and criteria air pollutant emissions, financial and operational considerations of currently available alternative heavy-duty vehicle technologies relative to a diesel baseline

	Greenhouse gas and criteria air pollutant emissions		Financial		Operational	
	Benefits	Costs	Benefits	Costs	Benefits	Costs
Tractor-trailer retrofits (diesel engine)	Lower particulate matter (PM) and NO_x tailpipe emissions; lower life cycle GHG emissions due to reduced fuel consumption	None	Reduced fuel consumption leads to lower fuel costs	Retrofit costs to trucking fleets	Long range; refueling infrastructure already developed	None
Battery electric	Zero tailpipe emissions; very low life cycle GHG emissions where carbon intensity of electricity source is low	None	Reduced fuel costs in comparison to petroleum diesel, especially in provinces where cost of electricity is low; reduced maintenance costs	High vehicle purchase price; high refueling infrastructure costs; battery weight may reduce payload capacity and thus ROI; battery charging times may cut into driver time and take-home pay	Higher vehicle efficiency and improved torque (consistent across all driving profiles)	Very limited range; fast charging infrastructure for HDVs is not yet available[30]
Hydrogen fuel cell	Zero tailpipe emissions; low life cycle GHG emissions when hydrogen is produced from	Life cycle GHG emissions can exceed those of petroleum diesel when produced from fossil fuels or if	May be eligible for credits under proposed Canadian Clean Fuel Standard (CFS)	High vehicle purchase price; very high fuel costs; high refueling infrastructure costs; expected to remain	Longer range than battery electric	Limited availability of refueling infrastructure; higher vehicle curb weight[31]

[30] Approximately 480 to 720 kWh of energy is required for a 40-tonne truck travelling at an average speed of 80km/h for 360 km (see Mareev, Becker & Sauer, 2018). To charge a vehicle of this configuration at a rest stop in under 45 minutes, a charging station with a power output of 640 to 960 kW is required. Current models of fast (level 3) charging stations in Canada have a maximum power output of 120 kW. Using currently available stations, it would take between four and six hours to fully charge a vehicle with these specifications.

[31] Curb weight refers to the weight of the vehicle without passengers or cargo.

	renewable feedstocks and clean electricity (i.e. green hydrogen)	hydrogen is liquefied		expensive		
Natural gas (CNG/LNG/RNG)[32]	Lower PM, NO_x and HC tailpipe emissions; modest reductions in life cycle GHG emissions in comparison to petroleum diesel if upstream methane emissions are under control; greater reductions in life cycle GHG emissions expected for renewable natural gas	May have higher life cycle GHG emissions depending on rates of methane leakage in upstream natural gas production	Reduced fuel costs under current market conditions; renewable natural gas may be eligible for credits under proposed CFS	Cost of vehicle retrofit; refueling infrastructure costs	Long range	Limited existing refueling infrastructure; safety issues surrounding liquefied natural gas handling
Biodiesel	Lower PM, HC and CO tailpipe emissions; very low life cycle GHG emissions associated with higher blend levels	Potential increase in NOx tailpipe emissions; indirect effects of biofuel production uncertain	May be eligible for credits under proposed CFS	Higher fuel costs than petroleum diesel, on average	Improved lubricity; little to no engine or refueling infrastructure modifications required	Poor cold flow properties; blending limits in OEM warranties
Renewable Diesel	Lower NO_x and PM tailpipe emissions; low life cycle GHG emissions; tolerates very high blend levels	Indirect effects of biofuel production uncertain	May be eligible for credits under proposed CFS	Very high fuel costs	No engine or refueling infrastructure modifications required	Low lubricity of fuel, but can easily be overcome through the addition of lubricants

Sources: various[33]

[32] Please see Appendix A: Glossary of Terms for definitions of compressed natural gas (CNG), liquefied natural gas (LNG) and renewable natural gas (RNG).

[33] ICF International. *Options to Address Air Pollutant and Greenhouse Gas Emissions from In-Use Heavy Duty on-Road and off-Road Diesel Vehicles* (2016). https://www.ccme.ca/files/Resources/air/mobile_sources/Options%20to%20Address%20Air%20Pollutant%20and%20Greenhouse%20Gas%20Emissions%20from%20In-use%20Heavy%20Duty%20On-road%20and%20Off-road%20Diesel%20Vehicles%20and%20Engines_1561.pdf

Dan Meszler, Oscar Delgado, Felipe Rodriguez, and Rachel Muncrief, *European Heavy Duty Vehicles: Cost-Effectiveness of Fuel-Efficiency Technologies for Long-Haul Tractor-Trailers in the 2025–2030 Timeframe* (2018). https://www.theicct.org/sites/default/files/publications/ICCT_EU-HDV-tech-2025-30_20180116.pdf

Brianna Jackson, *Electric Trucks Facing Long Road to Unseat Diesel Engines* (Bloomberg, 2018). https://www.bloomberg.com/news/articles/2018-08-22/electric-trucks-facing-long-road-to-unseat-diesel-engines

Marissa Moultak, Nic Lutsey, and Dale Hall, *Transitioning to Zero-Emission Heavy-Duty Freight Vehicles* (The International Council on Clean Transportation, 2017). https://www.theicct.org/sites/default/files/publications/Zero-emission-freight-trucks_ICCT-white-paper_26092017_vF.pdf

British Columbia Ministry of Energy Mines and Petroleum Resources, *Renewable and Low Carbon Fuel Requirements Regulation* (2017). https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/electricity-alternative-energy/transportation/renewable-low-carbon-fuels/rlcf-007-2016.pdf

NRCAN, *Electricity Facts* (2018). https://www.nrcan.gc.ca/energy/facts/electricity/20068

NRCAN, *Electric Charging and Alternative Fuelling Stations Locator* (2018). https://www.nrcan.gc.ca/energy/transportation/personal/20487#/find/nearest?location=Canada&fuel=HY&country=CA&hy_nonretail=true

Burak Sen, Tolga Ercan, and Omer Tatari, Does a Battery-Electric Truck Make a Difference? – Life Cycle Emissions, Costs, and Externality Analysis of Alternative Fuel-Powered Class 8 Heavy-Duty Trucks in the United States," *Journal of Cleaner Production* 141 (2017), 110–21. https://doi.org/10.1016/j.jclepro.2016.09.046

Shashank Sripad and Venkatasubramanian Viswanathan, "Performance Metrics Required of Next-Generation Batteries to Make a Practical Electric Semi Truck," *ACS Energy Letters* 2, no. 7 (2017), 1669–73. https://doi.org/10.1021/acsenergylett.7b00432

Ivan Mareev, Jan Becker, and Dirk Uwe Sauer, "Battery Dimensioning and Life Cycle Costs Analysis for a Heavy-Duty Truck Considering the Requirements of Long-Haul Transportation," *Energies* 11, no. 1 (2018), 55. https://doi.org/10.3390/en11010055

California Air Resources Board, "Carbon Intensity Lookup Table for Diesel and Fuels That Substitute for Diesel." https://www.arb.ca.gov/fuels/lcfs/121409lcfs_lutables.pdf

Thomas Earl, Lucien Mathieu, Stef Cornelis, Samuel Kenny, Carlos Calvo Ambel, and James Nix, "Analysis of Long Haul Battery Electric Trucks in EU," *European Federation for Transport and Environment* (2018). https://www.transportenvironment.org/sites/te/files/publications/20180725_T%26E_Battery_Electric_Trucks_EU_FINAL.pdf

Dong Yeon Lee, Amgad Elgowainy, Andrew Kotz, Ram Vijayagopal, and Jason Marcinkoski, "Life-Cycle Implications of Hydrogen Fuel Cell Electric Vehicle Technology for Medium- and Heavy-Duty Trucks," *Journal of Power Sources* 393, April (2018), 217–29. https://doi.org/10.1016/j.jpowsour.2018.05.012

Elco den Boer, Sanne Aarnink, Florian Kleiner, and Johannes Pagenkopf, *Zero Emissions Truck: An Overview of State-of-the-Art Technologies and Their Potential*, (CE Delft, 2013). https://www.cedelft.eu/publicatie/zero_emission_trucks/1399

M Werpy, D Santini, A Burnham, and M Mintz, "Natural Gas Vehicles: Status, Barriers, and Opportunities," *Energy Systems Division, Argonne National Lab (*2010), 1–59. https://doi.org/ANL/ESD/10-4

Hengbing Zhao, Andrew Burke, and Lin Zhu. "Analysis of Class 8 Hybrid-Electric Truck Technologies Using Diesel, LNG, Electricity, and Hydrogen, as the Fuel for Various Applications," *2013 World Electric Vehicle Symposium and Exhibition, EVS 2014* (2014). https://doi.org/10.1109/EVS.2013.6914957

Ramón Alvarez, Stephen Pacala, James Winebrake, William Chameides, and Steven Hamburg, "Greater Focus Needed on Methane Leakage from Natural Gas Infrastructure," *PNAS 109*, no. 17 (2012), 6435-6440. https://doi.org/10.1073/pnas.1202407109

Patrick Meyer, Erin Green, James Corbett, Carl Mas, and James Winebrake, "Total Fuel-Cycle Analysis of Heavy-Duty Vehicles Using Biofuels and Natural Gas-Based Alternative Fuels," *Journal of the Air and Waste Management Association* 61, no. 3 (2011), 285–94. https://doi.org/10.3155/1047-3289.61.3.285

Lew Fulton and Marshall Miller, *Strategies for Transitioning to Low-Carbon Emission Trucks in the United States* (Sustainable Transportation Energy Pathways Program Institute of Transportation Studies – University of California, Davis, 2015). https://steps.ucdavis.edu/files/06-11-2015-STEPS-NCST-Low-carbon-Trucks-in-US-06-10-2015.pdf

Canadian Natural Gas Vehicle Alliance, *Payback and Performance* (2018). http://cngva.org/natural-gas-vehicles-canada/payback-and-performance/

United States Department of Energy, "How Do Liquefied Natural Gas Trucks Work?" https://afdc.energy.gov/vehicles/how-do-lng-cars-work

United States Department of Energy, "Biodiesel Fuel Basics." https://afdc.energy.gov/fuels/biodiesel_basics.html

Jennifer Littlejohns, Lars Rehmann, Rachel Murdy, Aung Oo, and Stuart Neill, "Current State and Future Prospects for Liquid Biofuels in Canada," *Biofuel Research Journal* 5, no. 1 (2018), 759–79. https://doi.org/10.18331/BRJ2018.5.1.4

Heather L. MacLean, Daniel I. Posen, Bradley A. Saville, Stu Porter, Caroline Vanderghem, Baishali Dutta, and Pei Lin Chu, *Evaluation of the Impact of Using Biodiesel and Renewable Diesel to Reduce Greenhouse Gas Emissions in City of Toronto's Fleet Vehicles* (2019). https://www.toronto.ca/legdocs/mmis/2019/ie/bgrd/backgroundfile-130965.pdf

NREL,"Biodiesel Handling and Use Guide - Fourth Edition", 2008. https://www.nrel.gov/docs/fy09osti/43672.pdf

Biobus Project Committee Members, *Biodiesel Demonstration and Assessment with the Société de Transport de Montréal (STM) Final Report* (2003). http://www.sinenomine.ca/Download/biobus_ang.pdf

Johnathon Leonard and Patrick Couch, *Renewable Diesel as a Major Heavy-Duty Transportation Fuel in California* (Gladstein, Neandross and Associates, 2017). http://learn.gladstein.org/whitepaper-renewablediesel

Canada has significant manufacturing and other economic activities around some of the cleaner freight technologies described in Table 2. Canada is the fifth largest natural gas producer in the world and has 1,225 trillion cubic feet (Tcf) of remaining resources.[34] In 2017 a survey of Canada's hydrogen and fuel cell sector reported revenues of over $207 million and 2,177 jobs.[35] There is significant job growth potential. Total upstream natural gas employment – including direct, indirect and induced employment – was 62,500 in 2017 and forecast to grow to 115,000 by 2027.[36] Surveys of Canada's hydrogen and fuel cell sector, meanwhile, recorded an increase in total employment of about 38% among repeat respondents between 2015 and 2017.[37]

A suite of alternative fuels and heavy-duty vehicle technologies are already being marketed as well. Battery electric and hydrogen fuel cell trucks exist for a variety of heavy-duty trucking applications, engines are available which are suitable for use in heavy-duty trucks running on natural gas, and a variety of biofuels are already being blended into the diesel pool in Canada. Table 3 illustrates a sample of the technologies that are available for application in just one sector of heavy-duty trucking, long haul. A variety of vehicle models exist outside of those mentioned below for application in heavy-duty trucking activities outside of long-haul.

[34] Canadian Association of Petroleum Producers (CAPP), *Canada's Natural Gas Fact Book* (2018), 3. https://www.capp.ca/publications-and-statistics/publications/315990

[35] Canadian Hydrogen and Fuel Cell Association (CHFCA) and MNP LLP, *Canadian Hydrogen and Fuel Cell Sector Profile: November 2018,* Sector Profile 2018 (2018), 3, http://www.chfca.ca/media/CHFC%20Sector%20Profile%202018%20-%20Final%20Report.pdf

[36] Canadian Association of Petroleum Producers (CAPP), *Canada's Natural Gas Fact Book* (2018), 31. https://www.capp.ca/publications-and-statistics/publications/315990

[37] Canadian Hydrogen and Fuel Cell Association (CHFCA) and MNP LLP, *Canadian Hydrogen and Fuel Cell Sector Profile: November 2018,* Sector Profile 2018 (2018), 2, 17, http://www.chfca.ca/media/CHFC%20Sector%20Profile%202018%20-%20Final%20Report.pdf

Table 3. Availability of cleaner HDV technologies and fuels suitable for application in the long haul heavy-duty trucking sector and state of relevant industries in Canada

	Long haul tractor trailer models currently available	State of industry in Canada
Battery electric	Tesla has announced production of a class 8 "semi". The company cites a range of 800 km and an efficiency of less than 2 kWh/km. Los Angeles-based start-up Thor Trucks has also announced production of a class 8 tractor with a range of 480 km. BYD markets a class 8 tractor with a range of 200 km however this model only features a day cab. [38]	Quebec-based Lion Electric Company has designed a class 8 HDV for urban applications that will be available Fall 2019. Bathium Canada and Electrovaya and both involved in battery manufacturing for electric vehicles. Canada's first commercial charging station manufacturing plant opened in 2018 in Markham, Ontario.
Hydrogen fuel cell	Nikola Motor Company manufactures a class 8 fuel cell electric vehicle, the Nikola One. The vehicle is powered by a 300 kWh fuel cell and a 240-320 kWh battery. It has a range of up to 1600 km and a fuel consumption as low as 125 kWh/100 km. Toyota has also developed two class 8 hydrogen fuel cell electric vehicles for drayage (short distance ground freight transport) applications. Their second model, "Beta", has a 12 kWh battery and two-114 kWh fuel cell stacks with a range of approximately 500 km.	Canada is host to notable hydrogen and fuel cell industries. The west coast of Canada, in particular, is a hub for these industries. Some notable companies include Ballard, Loop, Palcan and Hydrogenics, who are involved in the development of fuel cells; Powertech Labs, Hydrogen Technology and Energy Corporation (HTEC) and Air Liquide are involved in hydrogen fuel production for transportation applications and the development of hydrogen refueling infrastructure.
Natural gas (CNG/LNG)	Existing HDVs can be retrofit to accommodate natural gas. Vancouver-based Cummins Westport manufactures a natural gas spark-ignition engine for application in HDVs. The engine accommodates both CNG and LNG and can power loads up to 36.3 tonnes.	Canada is the world's fifth largest producer of natural gas and is host to over a dozen companies advocating for the deployment of natural gas vehicles. As of 2015, there were 12,745 natural gas vehicles on the road in Canada, 2% of which were HDVs. Approximately 40% of new medium- and heavy-duty natural gas vehicle purchases are highway tractor trailers (class 8b vehicles).
Renewable natural gas (RNG)	RNG is also applicable for use in Cummins Westport spark-ignition engines.	The Canadian Gas Association has set a target of 10% RNG in Canada's natural gas stream by 2030. Certain provinces have also adopted their own targets, such as Québec (1% in 2020, 2% in 2023, 5% in 2025) and British Columbia (15% by 2030). The adoption of similar targets in other jurisdictions, as well as future CFS regulations are expected to promote the availability and use of RNG across

[38] Please see Appendix A: Glossary of Terms for the definition of day cab.

		Canada in the short term. As of 2017, there were eleven RNG production facilities in Canada.
Biodiesel	Biodiesel blends can be used in existing HDVs equipped with a compression ignition (CI) engine. Blend levels, however, may be limited under the engine manufacturers' (OEM) warranty.	Federal Renewable Fuel Regulations currently require a minimum 2% renewable fuel content for diesel fuel. Biodiesel is currently the only fuel being used to satisfy Canada's renewable fuel requirements that is produced domestically. There are eleven commercial biodiesel plants in operation in Canada, the largest of which has a capacity of 265 million litres per year. Approximately 376 million litres of biodiesel were consumed in Canada in 2017.
Renewable Diesel	HDRD is suitable for use in an HDV equipped with a standard CI engine.	There are currently no commercial HDRD fuel producers in Canada. Up until now, the country has relied exclusively on imports of HDRD. Approximately 326 million litres of HDRD were consumed in Canada in 2017. Forge Hydrocarbons has plans to open an HDRD production plant in Sombra, Ontario that will have a capacity of 19 million litres per year.

Sources: various[39]

[39] Tesla, "Tesla Semi," 2018. https://www.tesla.com/en_CA/semi?redirect=no

Thor Trucks, "ET-One." https://www.thortrucks.com/et-one/

BYD, "Electric Tough Long-Range 100% Battery Electric Class 8 - 105,000 Lbs GCWR." https://en.byd.com/wp-content/uploads/2018/07/8tt_redesign6-23-18.pdf

The Lion Electric Co.,"Urban Class 8 Truck." https://thelionelectric.com/en/products/electric_truck_class8

Nikola Motor Company, "Nikola One," 2018. https://nikolamotor.com/one

Toyota, "Toyota Doubles down on Zero-Emission Heavy-Duty Trucks," 2018. https://media.toyota.ca/releases/toyota-doubles-down-on-zero-emissions-heavy-duty-trucks

Cummins Westport Inc., "ISX12G: Heavy-Duty Natural Gas Truck Engine," 2015. https://www.cumminswestport.com/content/506/ISX12%20G%204971500_0315.pdf

Canadian Association of Petroleum Producers (CAPP), *Canada's Natural Gas Fact Book* (2018), 3. https://www.capp.ca/publications-and-statistics/publications/315990

Natural Gas Use in Transportation Roundtable, *Natural Gas Use in the Canadian Transportation Sector: Deployment Roadmap* (2010). https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/oee/pdf/transportation/alternative-fuels/resources/pdf/roadmap.pdf

Canadian Natural Gas Vehicle Alliance, *Study on Natural Gas Research and Development Priority Setting for Transportation in Canada* (2015). http://cngva.org/wp-content/uploads/2018/01/Natural-Gas-RD-Priority-Setting-for-Transportation-in-Canada-External-V....pdf

Energie et Resources Naturelles Quebec, "Québec Encadre La Quantité Minimale de Gaz Naturel Renouvelable et Met En Place Un Comité de Suivi," 2019. https://mern.gouv.qc.ca/quebec-encadre-quantite-gaz-naturel-2019-03-26/

Paul Cheliak, R*enewable Natural Gas: Providing Affordable, Renewable Energy for Canada CGA Membership & Canadian Energy Demand* (Canadian Gas Association, 2016). http://www.biocleantech.ca/presentations/cheliak.pdf

Canadian Gas Association, *Renewable Natural Gas Technology Roadmap for Canada* (2014). https://biogasassociation.ca/images/uploads/documents/2017/rng/The_Renewable_Natural_Gas_Technology_Roadmap.pdf

NREL, *Biodiesel Handling and Use Guide - Fourth Edition* (2008). https://www.nrel.gov/docs/fy09osti/43672.pdf

Heather L. MacLean, Daniel I. Posen, Bradley A. Saville, Stu Porter, Caroline Vanderghem, Baishali Dutta, and Pei Lin Chu, *Evaluation of the Impact of Using Biodiesel and Renewable Diesel to Reduce Greenhouse Gas Emissions in City of Toronto's Fleet Vehicles* (2019). https://www.toronto.ca/legdocs/mmis/2019/ie/bgrd/backgroundfile-130965.pdf

Environment and Climate Change Canada, "Federal Renewable Fuels Regulations: Overview," 2017. https://ec.gc.ca/energie-energy/default.asp?lang=En&n=828C9342-1

Jennifer Littlejohns, Lars Rehmann, Rachel Murdy, Aung Oo, and Stuart Neill, "Current State and Future Prospects for Liquid Biofuels in Canada," *Biofuel Research Journal* 5, no. 1 (2018), 759–79. https://doi.org/10.18331/BRJ2018.5.1.4

Michael Wolinetz, Mikela Hein, and Barbar Moawad, *Biofuels in Canada 2019* (Navius, 2019). https://www.naviusresearch.com/wp-content/uploads/2019/04/Biofuels-in-Canada-2019-2019-04-25-final.pdf

NRCAN, *Study of Hydrogenation Derived Renewable Diesel as a Renewable Fuel Option in North America* (2012), 1–78. https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/oee/files/pdf/transportation/alternative-fuels/resources/pdf/HDRD_Final_Report_eng.pdf

Lockheed Martin, "Lockheed Martin Invests $4 Million in Forge Hydrocarbons," *Biodiesel Magazine*, December 4, 2018. http://www.biodieselmagazine.com/articles/2516525/lockheed-martin-invests-4-million-in-forge-hydrocarbons

3. A blueprint for further action

In this section, we examine the progress made to date on the PCF transportation commitments as they relate to heavy-duty trucking. We provide recommended actions to accelerate progress and generate new opportunities for fuel savings and emissions reductions.

Our recommendations reflect the following approach:

1. Maximizing short-term opportunities to reduce emissions and improve efficiency on existing and new diesel fleets as diesel is expected to continue to dominate key segments of the freight industry until about 2030.[40]
2. Taking action now to accelerate the development, testing and uptake of zero-emissions heavy-duty truck technologies that offer the potential to achieve the deep emissions reductions required to meet our long-term commitments to mitigating climate change to 2050.

Our analysis and blueprint for further progress is summarized in Table 4 and explored further in the sections below.

[40] *Transitioning to Zero-Emission Heavy-Duty Freight Vehicles.*

Table 4. Analysis of PCF transportation commitments as they relate to heavy-duty trucking and recommended actions

PCF Transportation Commitment	Progress to date		Recommended actions to support clean heavy-duty trucking
	Ranking	Discussion	
Setting emissions standards. *Applies to new vehicles and trailers.*		In May 2018 Canada released its Phase II heavy-duty vehicle and engine emissions regulations for model years 2021-27. Canada's regulations are closely aligned with those in the U.S., but the U.S. EPA has announced its intention to revisit the provisions pertaining specifically to trailers.	Confirm Canada's intent to maintain the already-implemented Phase II HDV rules in their entirety. Study the Canadian trailer and retrofit market; determine and mitigate any cost premiums that may apply to domestic fleets should the Canadian and U.S. rules diverge.
Improving efficiency by developing new requirements for heavy-duty trucks to install fuel-saving devices like aerodynamic add-ons. *Applies to existing vehicles and trailers.*		No regulatory progress has been made; however, some educational and assessment programs are provided by the Canadian government.	Establish federal financial incentives for fuel saving devices on heavy-duty trucks funded by proceeds from the fossil fuel charge. Establish a target year by which fuel saving devices will be mandatory for all diesel-powered heavy-duty trucks and work with provinces to develop an implementation plan for the requirement.
Shifting from higher- to lower-emitting modes and investing in infrastructure by considering opportunities with the private sector to support refueling stations for alternative fuels, including natural gas, electricity, and hydrogen.		Natural Resources Canada recently released a request for proposals under Phase 2 of the Electric Vehicle and Alternative Fuel Infrastructure Deployment Initiative (EVAFIDI). The government has also committed funding to support the demonstration of next-generation charging technologies.	Identify major corridors along which to invest in publicly-funded zero-emissions heavy-duty refuelling/recharging stations targeted at long haul operations, and create a five-year investment plan. Allocate government funding and loan programs for low- and zero-emissions HDV according to lifecycle emissions reductions anticipated from the applicant technology. Work with utilities and the hydrogen industry across Canada to create a national zero-emissions heavy-duty vehicle infrastructure development strategy.

Putting more zero-emission vehicles on the road by developing a nationwide strategy for zero-emission vehicles and by accelerating the demonstration and deployment of zero-emission vehicle infrastructure.		Canada has made progress on the zero-emission vehicle strategy for passenger cars. Canada's Minister of Transportation has announced a non-binding goal of increasing the number of zero-emission cars sold in Canada to 100% in 2040 and several financial measures were announced in Budget 2019 to support passenger zero-emission vehicle uptake. One measure that supports heavy-duty zero-emissions vehicles is a measure in Budget 2019 to make zero-emissions light-, medium- and heavy-duty vehicles eligible for a full tax write-off in the year they are put in use, supporting business uptake. Significant federal transit funding is available but no programs specifically support transit agencies in shifting to low- and zero-emissions transit vehicles.	Build modest adoption targets for medium- and heavy-duty vehicles into the Zero-Emissions Vehicle Strategy update in 2020. Establish new federal financial incentives funded by proceeds from the fossil fuel charge to support Canadian transit agencies in purchasing zero-emissions buses.
Using cleaner fuels *Develop a clean fuel standard (CFS) to reduce emissions from fuels used in transport (and other sectors)*		The Clean Fuel Standard Update (released July 2018)[41] and subsequent Regulatory Design Paper (published December 2018)[42] together confirmed Canada's commitment to this policy, elaborated various design details, and at the same time officially "split" the envisioned regulation into two parts. The first part would apply a declining carbon intensity requirement to liquid fuels (80% of which are used for transportation) and would deliver 23 Mt of incremental emissions reductions in 2030,	Proceed with the swift implementation of the Clean Fuel Standard on the transportation (liquid fuel) sector according to the timelines established in the CFS Update and Regulatory Design Paper.

[41] Environment and Climate Change Canada, "Clean Fuel Standard Update: timelines, approach and next steps," July 2018. https://www.canada.ca/en/environment-climate-change/services/managing-pollution/energy-production/fuel-regulations/clean-fuel-standard/timelines-approach-next-steps.html

[42] Environment and Climate Change Canada, "Clean Fuel Standard Regulatory Design Paper," December 2018. https://www.canada.ca/en/environment-climate-change/services/managing-pollution/energy-production/fuel-regulations/clean-fuel-standard/regulatory-design.html

		thus accounting for more than three-quarters of the overall GHG reductions anticipated from the CFS when including non-transport sectors (30 Mt). Canada intends to publish draft rules for the "liquids" portion of the CFS by summer 2019 and final rules in 2020; the rules would enter into force in 2022. Regulations on gaseous and solid fuels (in the buildings and industry sectors) would follow over the 2020-2023 period.	
Comprehensive measures to support all commitments across heavy-duty trucking.	N/A	Reliable information on the most viable and cost-effective clean Heavy-duty truck solutions is lacking, which prevents fleet managers from making informed decisions and managing the risk associated with these choices. Canada has not articulated a comprehensive strategy to decarbonize freight, and many government departments share responsibility.	Study and share information about viable short- and medium-term clean heavy-duty trucking technologies and inform government on actions needed to support the transition through aligning government infrastructure spending and industry investment. Produce a National Land Freight Strategy that would include actions to support mode shift and increased efficiency for goods movement.

Key

- Significant progress made.
- Progress made
- Little progress made
- ! Warning – potential for backslide

3.1 Setting emissions standards for new vehicles

Emissions standards for internal combustion engine vehicles are a crucial tool for decarbonizing the transportation sector in the near term, as the sector shifts to low- and zero-emissions fleets. Early action to decarbonize HDVs is especially important given global expectations of growth in on-road freight transport (threefold 2010 levels by 2050) and the long-term challenge of reducing emissions from mobile point sources.[43] Improving the efficiency of diesel-powered vehicles is especially important because as noted earlier, heavy-duty trucks can be expected to remain on the road for ten to twenty years, making their way from long-haul operations to regional firms during their lifetime.

3.1.1 Progress to date

The PCF committed to setting new emissions standards, including for heavy-duty vehicles. In May 2018 Canada released its Phase II heavy-duty vehicle and engine emissions regulations[44] so as to reduce emissions from new on-road HDVs, engines, and trailers, representing significant progress made on a core commitment within the PCF. The regulations apply for model years 2021-27 with increasing stringency over time, and they are closely aligned with those in the U.S. As in the U.S., the new Canadian regulations apply, for the first time, to manufacturers and importers of on-road heavy-duty trailers.

The already-implemented regulations will drive significant economic, climate and health benefits for Canadians and industry. Environment and Climate Change Canada estimates the in-year GHG reduction potential of the fully phased-in standards in 2030 at approximately 6 Mt CO_2e.[45] This is equivalent to 3% of Canada's current Nationally Determined Contribution to mitigation efforts under the Paris Agreement.[46] It has

[43] Climate Action Tracker, *The Highway to Paris: Safeguarding the Climate by Decarbonising Freight Transport* (2018), 1. https://climateactiontracker.org/publications/highway-paris-safeguarding-climate-decarbonising-freight-transport/

[44] Environment and Climate Change Canada, Regulatory Impact Analysis Statement for *Regulations Amending the Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations and Other Regulations Made Under the Canadian Environmental Protection Act, 1999*, Canada Gazette, Part II, Volume 152, Number 11. http://gazette.gc.ca/rp-pr/p2/2018/2018-05-30/html/sor-dors98-eng.html

[45] Government of Canada, "2018 Amendments to HDV Regulations," RIAS Table 10, supra note 52.

[46] Total national GHG emissions in Canada in 2016 were 704 Mt. Using figures from NIR 2018, on an absolute basis, the 2030 target is equivalent to ~ 512 Mt—implying a total mitigation objective of about 192 Mt.

estimated the monetized benefits of 2030 in-year reductions at about $2 billion – with benefits due to fuel savings, greater travel opportunities and GHG emissions reductions.[47]

The contribution of the trailers provisions to this in-year reduction from the regulation is estimated to be approximately 16% in 2030, or 0.91 Mt CO_2e.[48] Furthermore, the model year 2020 GHG benefits of the regulations are entirely attributable to the model year 2020 trailer provisions.[49]

3.1.2 Recommendations

1. Confirm Canada's intent to maintain the already-implemented Phase II HDV rules in their entirety in order to provide certainty to industry.

The U.S. EPA has announced its intention to revisit the provisions in their standards pertaining specifically to trailers. To maintain the integrity of PCF commitments that have already been implemented, drive much-needed decarbonization in the transportation sector, and support industry in saving fuel, Canada should commit to maintaining the Phase II heavy-duty vehicle emissions standards in their entirety, including the provisions that apply to trailers. Providing this certainty now will reduce the risk for industry actors in taking the steps required today to comply in 2020. In so doing, Canada should continue to share information and best practices with the State of California which has virtually identical trailer provisions in its own state-level regulation.

For trailers, aerodynamics and low-resistance tires offer some of the most significant GHG reduction potential and cost-effectiveness.[50,51] There are some concerns that

---

[47] Government of Canada, *Regulations Amending the Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations and Other Regulations Made Under the Canadian Environmental Protection Act, 1999* SOR/2018-*98* Canada Gazette Part II 152, no. 11 (2018), Table 10. http://gazette.gc.ca/rp-pr/p2/2018/2018-05-30/html/sor-dors98-eng.html

[48] The absolute percentage of the reductions from the regulation attributable to the trailers provisions is adopted from calculations conducted by the International Council on Clean Transportation for the U.S. regulations, which are functionally equivalent to the Canadian standards. Calculations available upon request.

[49] *Regulations Amending the Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations.*

[50] Ben Sharpe, Mehul Garg, and Oscar Delgado, *Compliance pathways in the U.S. Phase 2 heavy-duty vehicle efficiency regulation* (International Council on Clean Transportation, 2017). https ://www.theicct.org/publications/compliance-pathways-US-phase-2-HDV

maintaining the existing trailer standards in Canada, in the case where there are changes to the U.S. rules, would increase capital costs for fleet owners and owner-operators. In fact, many existing commercial trailer technologies have payback periods of 1-2 years (e.g., side skirts, boat tails, tire pressure monitoring and auto-inflate systems)[52] and many trucking fleets are already using these technologies: a 2015 study estimated that nearly 50% of new box trailers sold in Canada had at least one type of aerodynamic feature; [53] that share is likely more than half today. Although weight reduction via material substitution is available to trailer manufacturers as a technology option, it is not typically a cost-effective strategy for compliance for the majority of trucking fleets, particularly in the earlier years of compliance.

Examples in other jurisdictions

The United States implemented regulations related to carbon emissions and fuel consumption in 2014 — covering on-road vehicles with gross vehicle weight ratings above 3,850 kilograms.[54] Phase 1 of the regulations covered model years 2014 to 2018 while Phase 2, finalized by the Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA) in August 2016, is for model years through to 2027.[55] Phase 1 regulations provided standards for vehicles and engines.[56] Phase 2 introduces additional regulations respecting trailers.[57] U.S.

---

[51] Dan Meszler, Nic Lutsey, and Oscar Delgado, *Cost effectiveness of advanced efficiency technologies for long-haul tractor-trailers in the 2020–2030 timeframe* (International Council on Clean Transportation, 2015). https://www.theicct.org/publications/cost-effectiveness-advanced-efficiency-technologies-long-haul-tractor-trailers-2020

[52] North American Council for Freight Efficiency, *Confidence Report: Trailer Aerodynamic Devices* (February 2016), 8. https://nacfe.org/downloads/confidence-report-trailer-aerodynamics/

[53] Ben Sharpe, Derek May, Bob Oliver, and Husam Mansour, *Costs and Adoption Rates of Fuel-Saving Technologies for Trailers in the Canadian On-Road Sector* (International Council on Clean Transportation and Pollution Probe, 2015). https://www.theicct.org/sites/default/files/publications/ICCT_Canada-trailers_20150209.pdf

[54] Ben White, Felix Kirsch, Samuel Levin, Ian Skinner, John Norris and Luke Jones, *Analysis of fuel economy and GHG emission reduction measures from Heavy Duty Vehicles in other countries and of options for the EU,* prepared by Ricardo Energy & Environment for the European Commission – DG Climate Action (2017), 4. https://ec.europa.eu/clima/sites/clima/files/transport/vehicles/heavy/docs/analysis_fuel_economy_hdv_en.pdf

[55] Environmental Protection Agency (EPA), "Regulations for Greenhouse Gas Emissions from Commercial Trucks and Buses." https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-greenhouse-gas-emissions-commercial-trucks

[56] *Analysis of fuel economy and GHG emission reduction measures from Heavy Duty Vehicles in other countries and of options for the EU.*

[57] Ibid., 5.

regulations are similar to those in Canada[58]. However, unlike light duty vehicle standards, Canadian HDV standards do not incorporate the US rules by reference.[59]

The European Union (EU) has lagged behind somewhat. As of early April 2019 neither the EU nor its member states regulated CO_2 emissions from heavy-duty vehicles.[60] In May 2018 the European Commission proposed new carbon dioxide emission standards for new EU HDVs as part of its third 'mobility package'.[61] These standards[62] set targets for average CO_2 emissions for new trucks – 15% lower in 2025 relative to 2019 and 30% (indicative target) lower in 2030. The proposal applied to certain categories of large trucks which account for the majority of HDV CO_2 emissions. The European Commission proposed a review of the legislation in 2022 – both to create a binding 2030 target and to extend the legislation to areas including trailers.

Trilogue negotiations began in January 2019 with an informal agreement reached in February 2019. The agreement set a slightly later reference period (1 July 2019 to 30 June 2020) than the European Commission proposal did. It also set a 30% average fleet emission reduction target for new trucks by 2030 which was legally binding. The European Parliament is expected to vote on the agreement in its April II plenary session.[63]

1.1 Study the Canadian trailer and retrofit market; determine and mitigate any cost premiums that may apply to domestic fleets should the Canadian and U.S. rules diverge.

It will be important to study the market to examine share of trailers in Canadian fleets that are domestic vs. imported and determine any cost premiums that may apply should the Canadian and U.S. standards diverge. The federal government could propose incentives or tradeoffs to defray the financial impact on Canadian fleets in the short term, should any such premiums be found to legitimately apply.

---

[58] Ibid., 4.

[59] Government of Canada, "2018 Amendments to HDV Regulations," RIAS Table 10, supra note 52.

[60] Gregor Erbach, *Briefing: EU Legislation in Progress: CO_2 emission standards for heavy-duty vehicles* (European Parliament, 2019), 1,3. http://www.europarl.europa.eu/RegData/etudes/BRIE/2018/628268/EPRS_BRI(2018)628268_EN.pdf

[61] Ibid., 1,2

[62] Ibid., 1.

[63] Ibid., 8.

3.2 Improving efficiency for existing vehicles

While emissions standards ensure more efficient new vehicles, retrofits address trucks that are already on the road. Retrofits are important because, despite advances in alternative fuel technology, diesel-fueled trucks are anticipated to dominate the heavy-duty truck market through at least 2030.[64] Truck retrofits provide short-term environmental advantages that can be integrated into existing fleets of any fuel type, generating modest air pollution and GHG benefits.[65] Policymakers can catalyze the adoption of these technologies using regulations and incentives.

There are several retrofit technologies available today. Low-resistance tires leverage materials and geometries to improve fuel efficiency by 5% or more, particularly for heavily-loaded vehicles, while real-time pressure monitoring technology ensures tires perform optimally in variable conditions.[66] Aerodynamic modifications to tractors and trailers, such as fairings, side skirts, and gap reducers, altogether reduce aerodynamic drag as much as 30%.[67] Aerodynamic retrofits provide greater fuel savings in colder climates with denser air, yielding 20% larger reductions to aerodynamic drag and 10% larger increases to fuel efficiency than in warmer regions.[68]

The federal government also offers programs to support driver education, fleet data collection, and the identification of alternatives for emissions reduction such as FleetSmart[69], SmartWay[70] and the Green Freight Assessment Program[71].

---

[64] *Transitioning to Zero-Emission Heavy-Duty Freight Vehicles.*

[65] Dan Meszler, Oscar Delgado, Felipe Rodriguez, and Rachel Muncrief, *European Heavy Duty Vehicles: Cost-Effectiveness of Fuel-Efficiency Technologies for Long-Haul Tractor-Trailers in the 2025–2030 Timeframe,* (International Council on Clean Transportation, 2018). https://www.theicct.org/sites/default/files/publications/ICCT_EU-HDV-tech-2025-30_20180116.pdf

[66] Thomas Curry, Isaac Liberman, Lily Hoffman-Andrews, and Dana Lowell, *Reducing Aerodynamic Drag & Rolling Resistance from Heavy-Duty Trucks: Summary of Available Technologies & Applicability to Chinese Trucks* (International Council on Clean Transportation, 2012). https://www.theicct.org/sites/default/files/publications/AERO_RR_Technologies_Whitepaper_FINAL_Oct2012.pdf

[67] Jeff Patten, Brian McAuliffe, William Mayda, and Bernard Tanguay, *Review of Aerodynamic Drag Reduction Devices for Heavy Trucks and Buses* (National Research Council Canada, 2012). https://www.tc.gc.ca/en/programs-policies/programs/documents/AERODYNAMICS_REPORT-MAY_2012.pdf

[68] Ibid.

[69] Natural Resources Canada, "Commercial driver fuel efficiency training." https://www.nrcan.gc.ca/energy/efficiency/transportation/21048

3.2.1 Progress to date

While the PCF committed to establishing new requirements for heavy-duty trucks to install fuel-saving devices like aerodynamic add-ons, no regulatory progress has been made on this file at the federal level. Crucially, the development of new requirements for Canada will require close collaboration with provincial transportation ministries, who are responsible for intra-provincial transportation.[72]

3.2.2 Recommendations

2. Establish federal financial incentives for fuel saving devices on heavy-duty trucks funded by proceeds from the fossil fuel charge

To build support and best practice toward an efficiency requirement, Canada should immediately establish federal financial incentives for fuel saving devices on heavy-duty trucks funded by proceeds from the fossil fuel charge. Trucking companies are already often more interested in fuel saving devices than in alternative fuel technologies as means to reducing emissions as they are less likely to affect day-to-day operations. This program could include any incentives for trailer efficiency on new trucks as discussed in the previous section as the same fuel-saving technologies would be used.

A Canada-wide program could use provincial programs as a starting point and build from the knowledge generated at the provincial level. The incentive program should be designed to provide greater support in initial years and less support in later years as technologies become mainstream.

Examples in other jurisdictions

Some provinces offer examples of incentive programs to support truck retrofits.

Quebec's Ecocamionnage Program provides financial support for firms which decrease GHG emissions through the use of equipment and technology, with a focus on goods transportation. The program will end on December 31st, 2020. Additionally, the program has a budget of $81.35 million. Should all of these funds be administered before the

[70] Natural Resources Canada, "About SmartWay." https://www.nrcan.gc.ca/energy/efficiency/transportation/21052

[71] Natural Resources Canada, "Green Freight Assessment Program." https://www.nrcan.gc.ca/energy/efficiency/transportation/20893#S1

[72] Government of Canada, "Governance of the Canadian Transportation System." https://www.tc.gc.ca/eng/policy/acf-acfi-menu-2962.htm

program's end date, the program will end early. The program aims to support five primary initiatives: acquisition of an emission-reducing technology, approval of an emission-reducing technology, demonstration of a new emission-reducing technology, projects aimed at logistical improvements that will promote emissions reductions, and acquisition of low emissions vehicles.[7374]

From late 2017 until mid-2018, Ontario offered financial incentives for retrofits and the purchase of new lower-emissions vehicles through the Modernized Ontario Green Commercial Vehicle Program. Alternative vehicle subsidies applied to electric (50% of cost difference with same-size diesel models), natural gas (30%), and diesel-natural gas hybrids (15%). The modernized program also subsidized the purchase and installation costs of fuel-saving aerodynamic and air conditioning technologies by 30% for most device classes. This program, designed in collaboration with the trucking industry, was funded via the revenue generated by the cap-and-trade program and involved up to $270 million in funding.

3. Establish a target year by which fuel saving devices will be mandatory for all diesel-powered heavy-duty trucks and work with provinces to develop an implementation plan for the requirement.

The government should work now to establish a target year by which fuel saving devices will be mandatory for all diesel-powered heavy-duty trucks and announce this future date as part of the initial incentive program. Canada should work with provinces to develop an implementation plan for this requirement.

One avenue to explore could be to gradually make participation in SmartWay, a voluntary program encouraging freight supply chain best practices through means including fuel consumption tracking and operational benchmarking[75], mandatory for certain types of fleets over time.

---

[73] Transports Quebec, "Programme visant la reduction ou l'evitement des emissions de gaz a effet de serre par le developpement due transport intermodal." https://www.transports.gouv.qc.ca/fr/aide-finan/programmes-aide/Pages/Programme-reduction-evitement-ges.aspx

[74] Transports Québec, "Programme d'Aide Écocamionnage", 2019. https://www.transports.gouv.qc.ca/fr/aide-finan/entreprises-camionnage/aide-ecocamionnage/Pages/aide-ecocamionnage.aspx

[75] "About SmartWay."

Examples in other jurisdictions

California offers an example of a retrofit requirement for in-use trucks. California's Tractor-Trailer Greenhouse Gas Regulation requires retrofits to older, in-service trucks to bring their energy efficiency in line with newer models.[76] It mandates retrofits to pre-2010 tractors and trailers, bringing the vehicles in sync with requirements for newer models. Retrofit requirements are based on the percentage of fuel savings for each device, with targeted vehicles required to improve cumulative fuel efficiency by at least 5%.

An indirect regulatory approach to drive lower-emissions trucks is to use spatial restrictions. Many local governments in Europe have designated Low-Emission Zones in urban areas which restrict access for heavy-duty trucks unless vehicles conform to more stringent emission standards (original or retrofitted equipment).[77] These policies are, however, the responsibility of local governments.

3.3 Shifting from higher- to lower-emitting modes and investing in infrastructure

The measures described above are essential to ensuring that new and existing diesel heavy-duty truck fleets are incrementally cleaner and more fuel-efficient. To achieve required deep GHG emissions reductions, however, it is also necessary to plan for and invest in alternative engine technologies and fuels in order to switch to low- and especially zero-emitting fleets in the medium to long term.

A clear technology pathway to decarbonization in the heavy-duty trucking sector has not yet emerged, particularly for long-haul operations.[78] There is no one-size-fits all technology pathway to replace conventional diesel fleets. When deciding to invest in new technologies, fleet owners and operators must consider a wide range of factors including:

---

[76] California Air Resources Board, *Facts about Tractor-Trailer Greenhouse Gas Regulation* (2014). https://www.arb.ca.gov/cc/hdghg/fact_sheets/HDGHG_Genl_Fact_Sheet.pdf

[77] Transport & Environment, *How to get rid of dirty diesels on city roads: Analysis of diesel restriction measures in European cities to date* (2018). https://www.transportenvironment.org/sites/te/files/publications/TE%20Air%20Quality%20Report_FINAL_12032018%20NEW.pdf

[78] *Transitioning to Zero-Emission Heavy-Duty Freight Vehicles.*

- Financial factors such as payback period and potential capital, maintenance and fuel costs or savings
- Operational factors including cargo capacity, range and reliability
- Availability of refueling/recharging infrastructure
- Availability of skilled maintenance workers
- Driver training requirements
- Potential risks around large investments resulting in a lock-in to technology that does not end up becoming standard

For example, return-to-base operations (many retailers) typically travel shorter distances and return daily to a central distribution centre where refuelling/recharging can take place in the same location. Such operations are candidates for technology applications that have shorter ranges and will be more amenable to private refueling/recharging sites. Conversely, long-haul operations (many for-hire companies) require vehicles with longer range capabilities and will need to rely on public refueling/recharging infrastructure to support their journeys.

To support investment by first-mover fleets in new technologies, it will be important not only to provide financial incentives, but also to de-risk investments. When designing programs to support uptake of cleaner technologies, policymakers must also consider:

- Lifecycle pollution costs or benefits, including the emissions intensity of the local electricity grid,
- Opportunities to support Canadian manufacturing and fuel industries.

3.3.1 Progress to date

Natural Resources Canada recently released a request for proposals under Phase 2 of the Electric Vehicle and Alternative Fuel Infrastructure Deployment Initiative (EVAFIDI). EVAFIDI is a six-year program allocating $96.4M towards supporting the establishment of a coast-to-coast charging network for electric vehicles, natural gas stations along key freight corridors and stations for hydrogen fuel cell electric vehicles in metropolitan centres.[79] The program does not support biofuels infrastructure. It would have been useful to keep the option for biofuel infrastructure in EVAFIDI open. Biofuels, when produced sustainably, and especially at higher blend levels, can produce significant

[79] Natural Resources Canada, "Electric Vehicle and Alternative Fuel Infrastructure Deployment Initiative." https://www.nrcan.gc.ca/energy/alternative-fuels/fuel-facts/ecoenergy/18352

GHG emission reductions, and should be one of the technological options considered for the de-carbonization of transportation.

Through Phase 1 investments the program deployed 102 electric vehicle fast-chargers, seven natural gas stations and three hydrogen stations. Of the $14.469 million in signed agreements presented on the program website,[80] 34% of funding was allocated to EV chargers (mostly fast chargers), 45% to natural gas, and 21% to hydrogen stations. Phase 2, with an anticipated $80 million in funding, has notional targets of 900 electric vehicle fast-chargers, 15 natural gas stations and 12 hydrogen fuel cell stations. At the maximum contribution rates, this would result in a distribution of funds as follows: 63% to EV fast chargers, 21% to natural gas, and 17% to hydrogen. Notably, the program does not differentiate between infrastructure for light and heavy-duty vehicles, but the natural gas and hydrogen stations likely serve medium- and heavy-duty vehicles. It should be noted again that heavy-duty vehicles sometimes require unique refueling or charging infrastructure – such as fast fill refueling and high power charging infrastructure.[81,82,83]

The EVAFIDI program provides repayable contributions and participants must produce a business case demonstrating ability to pay back the contribution from anticipated profits over time. However, if conditions change, the repayment can be waived. This mechanism is a way to de-risk business investments in these new technologies. Stations must offer public access to qualify.

The Government of Canada has also committed $76.1 million to support the demonstration of next-generation charging technologies and $10 million for the development of binational (Canada and the U.S.) codes and standards for low-carbon vehicles and infrastructure.[84] The Electric Vehicle Infrastructure Demonstrations (EVID) program launched a call for expressions of interest which closed in February 2018. As of

[80] Natural Resources Canada, "Electric Vehicle and Alternative Fuel Infrastructure Deployment Initiative – Successful Applicants – Phase 1." https://www.nrcan.gc.ca/energy/alternative-fuels/fuel-facts/ecoenergy/19464

[81] Ivan Mareev, Jan Becker and Dirk Uwe Sauer, "Battery Dimensioning and Life Cycle Costs Analysis for a Heavy-Duty Truck Considering the Requirements of Long-Haul Transportation." *Energies* 11, no. 1 (2018). https://doi.org/10.3390/en11010055.

[82] Jennifer Littlejohns, Lars Rehmann, Rachel Murdy, Aung Oo and Stuart Neill, "Current State and Future Prospects for Liquid Biofuels in Canada." *Biofuel Research Journal* 5, no. 1 (2018). https://doi.org/10.18331/BRJ2018.5.1.4.

[83] *Transitioning to Zero-Emission Heavy-Duty Freight Vehicles.*

[84] "Electric Vehicle and Alternative Fuel Infrastructure Deployment Initiative."

April 1, the government has allocated $30 million to selected projects. This is one of several programs under Natural Resources Canada's Energy Innovation Program.

3.3.2 Recommendations

4. Identify major corridors along which to invest in publicly-funded zero-emissions heavy-duty refuelling/recharging stations targeted at long haul operations, and create a five-year investment plan.

Existing funding programs are making headway into the challenge of building out alternative refueling/recharging infrastructure. Because the program doesn't differentiate between LDV and HDV infrastructure, however, there may be ways to build on the approach to ensure that heavy-duty trucking – especially long-haul operations – is supported.

To optimize public investment in public infrastructure for heavy-duty trucking, it would be beneficial to identify and focus on key goods movement corridors to ensure viable operations along highly-travelled routes in order to get the initial uptake required for these technologies to take off.

5. Allocate government funding and loan programs for low- and zero-emissions HDV according to lifecycle emissions reductions anticipated from the applicant technology.

Uptake under EVAFIDI for natural gas refueling stations has been high, but a more systematic approach may be needed to plan and build out zero-emissions heavy-duty trucking (hydrogen fuel cell and battery electric). Since there are more barriers to deploying these technologies, and since they have more significant emissions reduction potential in the near future compared to natural gas,[85] it would be appropriate to ensure that committed program dollars are allocated proportionally to anticipated GHG emissions reductions. Ensuring accountability would be useful as well – reporting could be required using metrics such as emissions displaced.

[85] *Transitioning to Zero-Emission Heavy-Duty Freight Vehicles.*

6. Work with utilities and the hydrogen industry across Canada to create a national zero-emissions heavy-duty vehicle infrastructure development strategy.

Direct efforts will be required to overcome barriers to expansion of zero-emissions heavy-duty refueling/recharging infrastructure and the federal government can take a leadership role. In the case of hydrogen fuel cells, support is needed to develop markets and distribution infrastructure at the national scale. In the case of battery electric trucking, more engagement with utilities is required to overcome barriers related to electricity rates and extension policies (length of time and cost charged to upgrade the local grid).[86]

Examples in other jurisdictions

California's first ZEV Action Plan, intended to support a target of 1.5 million on-the-road zero-emission vehicles by 2025, was released in 2013. It was updated in 2016 with the "2016 ZEV Action Plan", which included medium- and heavy- duty sectors for the first time. These plans were intended to 'organize state agency actions' to grow the market for ZEVs. The 2016 plan was further updated in 2018, alongside new targets for on-the-road ZEVs — 5 million by 2030 — and alternative fuel infrastructure.[87]

The 2018 update to the 2016 ZEV Action Plan, for example, had a goal of ensuring "convenient charging and fueling infrastructure" for ZEVs, in support of which it called for a number of actions related to the medium- and heavy- duty sector, including the use of "state-owned land to provide no-cost leasing options for public transit agencies or fleets to build charging or fueling infrastructure" and identifying "opportunities to utilize additional renewable electricity generation and daytime over-generation for the fueling of zero-emission vehicles and equipment in the freight sector".[88]

---

[86] It should be noted that the Canadian Urban Transit Research & Innovation Consortium (CUTRIC) has called for "engagement of provincial utilities across Ontario (and other provinces) in a national EV-readiness and low-carbon mobility innovation consultation process…". For more information, see: CUTRIC, *Light-weight, electrified, automated, and cybersecure transportation innovation in Ontario: Consultation outputs from industry, academia and transit organizations in Ontario* (2016), 35. https://static1.squarespace.com/static/56171092e4b0d626a870edec/t/5ac92039758d46742a362f74/1523130425304/MEDG+Integrated+%26+Advanced+Mobility+Innovation+Consultation+Sessions+2016+-+Final+Version.pdf

[87] California Governor's Office of Business and Economic Development, "2018 ZEV Action Plan Priorities Update." http://www.business.ca.gov/ZEV-Action-Plan

[88] Office of Governor Edmund G. Brown Jr. Governor's Interagency Working Group on Zero-Emission Vehicles, *2018 ZEV Action Plan Priorities Update* (2018), 38. http://business.ca.gov/Portals/0/ZEV/2018-ZEV-Action-Plan-Priorities-Update.pdf

3.4 Putting more zero-emission vehicles on the road

Rapid advances in technology are presenting opportunities to electrify the heavy-duty fleet. As discussed in Table 2, hydrogen and battery electric technologies offer the potential to decarbonize the on-road freight sector more significantly than other fossil-fuel based options, but there remain greater barriers to their deployment and questions about their technical and financial viability for various freight applications.

It is crucial that initial pilots of zero-emissions heavy-duty vehicles are well-planned and well-documented, so that all stakeholders are able to learn from these trials. Failed pilots risk sending a message to industry that the technology is not viable, even when shortcomings may be project-specific. Furthermore, it is important to begin deployment in market segments where the technology is most ready.[89]

One of these important market segments is transit buses. Canadian cities are beginning to purchase and deploy different propulsion technologies, including hybrid electric and fully electric buses. For example, the City of Edmonton's Transit Service (ETS) has purchased up to 50 electric buses, based on a combination of funding from the Public Transit Infrastructure Fund (PTIF) and Alberta Community Transit funding. The City of Toronto's Toronto Transit Commission (TTC) has laid out a Green Bus Technology Plan in 2017, which aims to achieve a 50% zero emission fleet by 2028-2032, and 100% zero emission by 2038-2042. The TTC has 55 hybrid buses by the end of 2018 and another 200 by the end of 2019, and 60 electric buses by 2019.[90,91]

A second market segment is the subset of on-road freight that conducts more urban operations and may use medium- and heavy-duty vehicles. For example, California's Zero-Emission Truck Strategy targets operations that have the following characteristics: "urban, stop-and-go driving, return to base, centrally-fueled, pickup and delivery, short haul operations, vocational." In other words, long-haul operations are expected to be the last to electrify – but progress in other market segments will bring about that future more quickly.

---

[89] Taking this approach, CALSTART's clean heavy-duty vehicle commercialization strategy has identified the commercial vehicle market segments where "zero-emission and near-zero technology is most likely to succeed in the near term, and the pathways into other segments where the technology can move next as vehicle volumes and supply chains grow." For more information, see: http://globaldrive2zero.org/strategy/

[90] Toronto Transit Commission, "TTC Green Initiatives." http://ttc.ca/Riding_the_TTC/green_initiatives.jsp

[91] City of Edmonton, "Electric Buses." https://www.edmonton.ca/projects_plans/transit/electric-buses.aspx

3.4.1 Progress to date

Canada has advanced elements of the Zero-Emissions Vehicle Strategy committed to within the PCF. In January 2019, Canada's Minister of Transport announced a target of increasing the number of zero-emission vehicles sold in Canada to 10% in 2025, 30% in 2030 and 100% in 2040.[92,93] In line with this new objective, several new measures were announced in Budget 2019 to support uptake of zero-emissions vehicles: $130 million over five years (2019-2024) to deploy charging and refueling stations under the Zero-Emission Vehicle Infrastructure Program (ZEVIP)[94]; $5 million over five years to work with auto manufacturers to secure ZEV sales targets to make sure sufficient inventory are available to Canadians; and $300 million over three years for purchase incentives of up to $5,000.

These measures, however, target passenger vehicles. One exception is a new mechanism in the 2019 federal budget that will make zero-emission vehicles eligible for a full tax write-off for the year they are put into use. Vehicles that qualify will include hydrogen fuel cell vehicles, electric battery vehicles and plug-in hybrid vehicles (with a minimum 15 kWh battery capacity). This includes light-, medium- and heavy- duty vehicles. This is designed to allow businesses to more quickly recoup their investments in zero-emission vehicles.

The mechanism will be applicable to eligible vehicles purchased between March 19, 2019 and January 1, 2024. The limit for deductible capital costs for eligible zero-emission passenger vehicles will increase from $30,000 plus sales tax to $55,000 plus sales tax. The higher limit reflects the higher cost of zero-emission vehicles and will be annually reviewed to ensure it adequately reflects evolving market prices.[95]

Similarly, in the 2018 Federal Fall Economic Statement, a temporary mechanism was introduced for full expensing of eligible property in Classes 43.1 and 43.2. This would include electric vehicle charging stations. Eligible property must be purchased after

[92] Clean Energy Canada, "Canada targets 100% zero-emission vehicle sales by 2040," media release, January 22, 2019. http://cleanenergycanada.org/canada-targets-100-zero-emission-vehicle-sales-by-2040/

[93] Gene Laverty, "Canadian feds seek provincial buy-in for plan to boost electric vehicle use," *S&P Global Market Intelligence,* January 23, 2019. https://www.spglobal.com/marketintelligence/en/news-insights/trending/F8Pn8dHpuWXdxGiDaBChzw2

[94] Natural Resources Canada, "Zero-Emission Vehicle Infrastructure Program (ZEVIP)." https://www.nrcan.gc.ca/energy/alternative-fuels/fuel-facts/ecoenergy/21876

[95] Government of Canada, *Investing in the Middle Class: Budget 2019* (2019), 82. https://www.budget.gc.ca/2019/docs/plan/budget-2019-en.pdf

November 20, 2018 and must become available for use before 2028. Property that comes into use in 2023 or beforehand will receive a 100 per-cent deduction, after which the deduction is phased out over time.[96]

With respect to other market segments, supporting provinces and municipalities in investing in public transit has been a priority of the federal government, particularly since Budget 2016 announced federal investments of up to $3.4 billion over three years in public transit, through a new Public Transit Infrastructure Fund (PTIF). In Budget 2017, the federal government also announced that it will invest $25.3 billion over the next 10 years (the Investing in Canada Infrastructure Program), including $5 billion invested by the Canada Infrastructure Bank.[97]

While PTIF has supported much-needed transit expansions and state of good repair interventions, it has not facilitated a shift to cleaner transit buses due to the prohibitive up-front capital costs for vehicles and refueling/recharging infrastructure. This barrier is preventing Canadian systems from evolving to cleaner fuels; indeed, 45% of U.S. transit fleets run on alternate propulsion, while this is the case for only 1.8% of Canadian fleets.[98]

3.4.2 Recommendations

7. Build modest adoption targets for medium- and heavy-duty vehicles into the Zero-Emissions Vehicle Strategy update in 2020.

So far, neither the Government of Canada nor any of its provinces has announced a sales target for low- and zero-emissions heavy-duty vehicles. While such a target would need to initially be less ambitious than Canada's passenger vehicle target of 100% zero-emissions sales by 2040, it would play the important role of sending a market signal to industry and other levels of government. Initial targets could be articulated in a future update of the Zero-Emissions Vehicle Strategy update. Sales targets for low- and zero-emissions heavy-duty vehicles would need to be differentiated across vehicle type (GVWR class) and nature of operations (courier, return-to-base, long-haul, etc.).

---

[96] Government of Canada, *Investing in Middle Class Jobs: Fall Economic Statement 2018* (2018), 156. https://www.budget.gc.ca/fes-eea/2018/docs/statement-enonce/fes-eea-2018-eng.pdf

[97] Infrastructure Canada, "Public Transit Infrastructure." https://www.infrastructure.gc.ca/plan/pti-itc-eng.html

[98] Canadian Urban Transit Association, *Driving Communities: Transit investment that goes the extra mile* (2018), 6. https://cutaactu.ca/sites/default/files/cuta_prebudget_2018.pdf

The State of California has contemplated a sales mandate for medium- and heavy-duty vehicles and has been monitoring the status of commercialization of these vehicles to determine appropriateness. The California Air Resources Board has explored possible sales targets according to market segment.99 For example, more ambitious rules would be set for transit vehicles and airport shuttle buses, drayage[100], and state agency fleets.

California is often a leader in environmental policy and harmonization would be desirable. In the long-term, targets could be converted to sales mandates as technologies become more readily available and applicable. One challenge in this case would be the number of regulated entities in the medium- and heavy-duty markets compared to passenger vehicle original equipment manufacturers. In the short term a sales mandate could be investigated and information could begin to be collected to allow for informed decision making.

8. Establish new federal financial incentives funded by proceeds from the fossil fuel charge to support Canadian transit agencies in purchasing zero-emissions buses.

As mentioned above, battery-electric and hydrogen fuel cell heavy-duty trucks are forecast to become increasingly cost-competitive with same-size diesel and natural gas trucks after 2030. [101] In the meantime, industry stakeholders have noted an interest in investment into low- and zero-emission vehicles but are uncertain as to the most viable technological pathway. The government has a significant role to play here in supporting and funding pilot projects in low- and zero- emission heavy-duty vehicles and fleets.

The government should consider a separate incentive program to support a portion of the additional upfront capital costs for zero-emission transit fleets. Accelerating the commercialization of clean transit fleets in Canada will have knock-on benefits for the development and commercialization of cleaner trucking technologies. It will also provide business and job growth opportunities for existing Canadian clean bus

[99] California Air Resources Board, *Assessment of a Zero Emission Vehicle Requirement for Light and Heavy-Duty Vehicle Fleets: Public Workshop,* August 30, 2018, https://www.arb.ca.gov/msprog/zev_fleet_workshop_presentation_083018.pdf

[100] Please see Appendix A: Glossary of Terms for the definition of drayage.

[101] *Transitioning to Zero-Emission Heavy-Duty Freight Vehicles.*

manufacturers, improve local air quality in cities, and help transit agencies reduce operating costs.[102]

Examples in other jurisdictions

In the United States, the Federal Transit Administration (FTA) Low or No Emission Vehicle Program provides funding for local and state governments to buy or lease low or zero emission buses and to purchase, lease or construct supporting facilities.[103]

In California, the Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) seeks to increase the affordability of clean buses and trucks through the provision of point-of-sale incentives with approved dealers and vendors.[104]

3.5 A low-carbon or clean fuel standard

3.5.1 Progress to date

The Clean Fuel Standard (CFS) was originally proposed as a federal mitigation policy targeting 30 megatonnes of emissions reductions under the Pan-Canadian Framework on Clean Growth and Climate Change. This ambitious target would result from reductions to the average carbon intensity of fuels supplied in Canada for use in the transportation, buildings, and industry sectors over the period to 2030. Unlike the current federal *Renewable Fuel Regulations*, which establish minimum blending levels for renewable content in gasoline and diesel (4% and 2%, respectively), the CFS represents a market-based and technology-neutral approach to incentivizing greater uptake of low-carbon and clean fuel alternatives to conventional fossil fuels. In general, regulated parties ("fossil fuel primary suppliers") under the standard would incur debits based on the carbon intensity of the fuels they supply and in proportion to their reduction requirement for a given compliance period, while clean fuel suppliers may generate credits based on the volume of clean fuels they supply and the superior lifecycle GHG performance of their products relative to conventional fuels.

[102] The Canadian Urban Transit Association suggested in its 2018-19 pre-budget submission a separate incentive program on the order of $75 million annually. See: https://cutaactu.ca/sites/default/files/cuta_prebudget_2018.pdf

[103] Federal Transit Administration, "Low or No Emission Vehicle Program – 5339(c)." https://www.transit.dot.gov/funding/grants/lowno

[104] California Air Resources Board, "Frequently Asked Questions." https://www.californiahvip.org/about/#frequently-asked-questions

In its policy consultations to date, Environment and Climate Change Canada has indicated its intent to "partition" the transportation sector from reductions achieved in other sectors (e.g. stationary combustion in buildings and industrial facilities).[105] This crucial regulatory design measure will ensure that reductions in emissions from the transportation sector—one of the primary objectives of the policy—do, in fact, occur.[106] As of this writing, the bulk of emissions reductions under the policy (approximately 23 Mt) are expected to derive from a requirement for an 11% reduction in the average carbon intensity of this sector.[107]

The implementation of the Clean Fuel Standard has slipped relative to ECCC's original timeline, which envisaged final publication of a regulation covering all fuel types (liquid, gaseous, and solid) and sectors (transport, buildings, industry) by the end of 2019. Given the complexity of the regulation and the unprecedented nature of its eventual application to non-transportation sectors,[108] government decided in 2018 to "split" the CFS into two phases, the first applying to liquid fuels (approx. 80% of which are used for transport) and the second to both gaseous and solids.[109] The requirements for liquid fuels would enter into force in 2022 (allowing for a year of data collection after publication of the final rule in 2020), with the entry-into-force of the rule for the other fuel streams following a year later.

3.5.2 Recommendations

9. Proceed with the swift implementation of the Clean Fuel Standard on the transportation (liquid fuel) sector according to the timelines established in the CFS Update and Regulatory Design Paper.

While not directly targeting emissions from heavy-duty transport, the CFS can play a key role in helping to broaden the market and supply of available non-fossil or lower-carbon fuel types (and thus eventually in lowering costs). For example, over the long term, cost reductions from increased supply could help support trucking fleets'

[105] ECCC, "Clean fuel standard regulatory framework," in *Canada Gazette, Part* I, Vol. 151, No. 51, December 23, 2017. http://gazette.gc.ca/rp-pr/p1/2017/2017-12-23/html/notice-avis-eng.html#ne1

[106] Navius Research and EnviroEconomics, *Analysis of the Proposed Canadian Clean Fuel Standard: Final Technical Report*, November 2017, ii. http://cleanenergycanada.org/wp-content/uploads/2017/11/CFS-technical-report.pdf

[107] ECCC, "Clean Fuel Standard Regulatory Design Paper," *supra* note 50.

[108] Other jurisdictions, notably British Columbia, California, and Oregon, have all instituted similar low-carbon fuel standards, but which apply only to transportation.

[109] ECCC, "Clean fuel standard regulatory framework," *supra* note 117.

adoption of higher blends of biodiesel and renewable diesel, which would in turn achieve significant GHG savings owing to the immediate displacement of the use of petroleum diesel. Given the importance of this policy both in terms of Canada's ability to meet its 2030 climate target and in terms of laying a foundation for the longer-term decarbonization of transport, we recommend that the government proceed swiftly with the implementation of the CFS across all fuel streams, but targeting liquid fuels in transportation as an accelerated priority according to ECCC's revised regulatory schedule.

3.6 Comprehensive measures to support action in heavy-duty trucking

We propose two final measures to support action for fuel savings and emissions reductions across the trucking sector.

3.6.1 Recommendations

10. Study and share information about viable short- and medium-term clean heavy-duty trucking technologies and inform government on actions needed to support the transition through aligning government infrastructure spending and industry investment.

Reliable information on the most viable and cost-effective clean heavy-duty truck solutions is lacking, which prevents fleet managers from making informed decisions and managing the risk associated with these choices. Furthermore, there is an information gap on the possible long-term technology and infrastructure pathways to support deep emissions reductions and their interaction with climate policy. A joint working group comprised of industry representatives and third sector experts, with participation from government, could have the mandate to study long-term technology pathways to clean on-road freight fleets across specific sub-segments of the industry, producing recommended technology packages for fleets, and providing recommendations on further recommended federal and provincial government policy and programs proposals to support these specific technology pathways.

Recommended technology packages could take into account the perspective of truck drivers. As mentioned previously, Canada is faced with a shortage of drivers and the

driver workforce is aging[110]. In a report prepared for the Canadian Trucking Alliance (CTA), the Canadian Pacific Consulting Services (CPCS) forecast a gap between truck driver demand and truck driver supply of 34,000 in 2024 and noted an increasing age profile between 2006 and 2011 – with the share in the 55 to 64 year cohort rising five percentage points.[111] The majority in this cohort will retire within 10 years.[112] New vehicles can be useful incentives to keep drivers on – but drivers will generally not wish to use new technologies they are uncomfortable with. Technology packages produced by the joint working group could provide recommendations on increasing driver buy-in. Of particular use may be the sharing of best practices in this regard by larger trucking companies with smaller ones.

11. Produce a National Land Freight Strategy that would include actions to support mode shift and increased efficiency for goods movement.

Canada has not articulated a unified national vision on the future of goods movement. One challenge for industry and other stakeholders is that the mandate for supporting viable, clean freight is shared among government departments. Although the future is uncertain, a National Land Freight Strategy would allow the government to set forth long-term objectives and signal these to industry. A National Freight Strategy could encompass many of the recommendations included in this blueprint, including corridor planning for refueling/recharging infrastructure, commercialization strategies, and sales targets. Furthermore, a strategy would include measures to shift to lower-emitting modes (rail, and even bicycle) and avoid unnecessary trips.

Many other jurisdictions have adopted comprehensive national freight strategies. Natural Resources Canada recently commissioned a report from Pollution Probe summarizing national freight strategies in other jurisdictions.[113] To properly address demand, cities and regions will need a seat at the table. Some leading innovations on sustainable goods movement are emerging from regional governments like the Region of Peel in Ontario and Metro Vancouver who are working closely with freight companies to find efficiencies. The cities of Calgary and Edmonton also have freight strategies and the City of Toronto will be launching a Freight and Goods Movement Strategy in 2019 with expected completion in 2020.

---

[110] *The Truck Driver Supply and Demand Gap.*

[111] Ibid. 13, 15.

[112] Ibid. 15.

[113] Pollution Probe, "International Case Studies on Goods Movement Strategies." http://www.pollutionprobe.org/publications/international-case-studies-goods-movement-strategies/

4. Conclusion

While goods movement by truck is a backbone of the economy, it is also a major source of pollution – freight transportation GHG emissions make up 10.5% of Canada's total and are expected to bypass those of passenger movement by about 2030. If we are to avoid the worst effects of climate change, the federal government must support a shift to cleaner freight.

The establishment of the Pan-Canadian Framework on Clean Growth and Climate Change is promising. It has made clear commitments related to the transition to cleaner transport, on which significant progress has been made. Further efforts are required, however, for continued progress in the heavy-duty trucking sector.

This report has examined commitments made under the Pan-Canadian Framework that relate to heavy-duty trucking and given options for further progress. It has also provided an overview of the on-road heavy-duty freight industry as it stands today – including currently available technology and fuel options.

This report has provided a blueprint for further actions in the form of eleven recommendations. These have reflected the following approach:

1. Maximizing short-term opportunities to reduce emissions and improve efficiency on existing and new diesel fleets as diesel is expected to continue to dominate key segments of the freight industry until about 2030.[114]
2. Taking action now to accelerate the development, testing and uptake of zero-emissions heavy-duty truck technologies that offer the potential to achieve the deep emissions reductions required to meet our long-term commitments to mitigating climate change to 2050.

The eleven recommendations are the following:

1. Confirm Canada's intent to maintain the already-implemented Phase II heavy-duty vehicle (HDV) rules in their entirety.
2. Establish federal financial incentives for fuel saving devices on heavy-duty trucks funded by proceeds from the fossil fuel charge.

[114] *Transitioning to Zero-Emission Heavy-Duty Freight Vehicles.*

3. Establish a target year by which fuel saving devices will be mandatory for all diesel-powered heavy-duty trucks and work with provinces to develop an implementation plan for the requirement.
4. Identify major corridors along which to invest in publicly-funded zero-emissions heavy-duty refueling/recharging stations targeted at long haul operations, and create a five-year investment plan.
5. Allocate government funding and loan programs for low- and zero-emissions HDV according to lifecycle emissions reductions anticipated from the applicant technology.
6. Work with utilities and the hydrogen (note – blue hydrogen is produced from fossil fuels and typically incorporates carbon capture and storage, green hydrogen is produced from renewable resources) industry across Canada to create a national zero-emissions heavy-duty vehicle infrastructure development strategy.
7. Build modest adoption targets for medium- and heavy-duty vehicles into the Zero-Emissions Vehicle Strategy update in 2020.
8. Establish new federal financial incentives funded by proceeds from the fossil fuel charge to support Canadian transit agencies in purchasing zero-emissions buses.
9. Proceed with the swift implementation of the Clean Fuel Standard on the transportation (liquid fuel) sector according to the timelines established in the CFS Update and Regulatory Design Paper.
10. Study and share information about viable short- and medium-term clean heavy-duty trucking technologies and inform government on actions needed to support the transition through aligning government infrastructure spending and industry investment.
11. Produce a National Land Freight Strategy that would include actions to support mode shift and increased efficiency for goods movement.

It is important that we take action now to develop the technologies and approaches that will allow for deep emission cuts in the future. Immediately actionable elements of the recommendations include the following:

1. Undertake a project to identify major corridors along which to invest in publicly-funded zero- emissions heavy-duty refuelling/recharging stations targeted at long haul operations.
2. Undertake a project for the creation of a system by which life-cycle emissions of low- and zero- emission HDV technologies can be assessed.

3. Undertake a project for the creation of a national zero-emissions heavy-duty vehicle infrastructure development strategy, in concert with utilities and the hydrogen industry.
4. Study and share information about viable short- and medium- term clean heavy-duty trucking technologies and inform government on actions needed to support the transition.

Appendix A. Glossary of Terms

Day cab: Day cabs are generally semi-trucks designed to do 'day trips' and thus do not include sleeping features that would accommodate overnight travel.[115]

Drayage: The transport over a short distance of goods through the use of ground freight[116].

Heavy-duty vehicles: Though definitions differ, the term heavy-duty vehicle typically encompasses all on-road vehicles belonging to Classes 2b through 8 with a gross vehicle weight rating of more than 3856 kg. This includes vehicles ranging from utility vans and minibuses to vocational vehicles and combination tractor trailers.

Low-emissions heavy-duty vehicle: Includes heavy-duty vehicles that have demonstrated lower life-cycle greenhouse gas (GHG) emissions. Low-emission heavy duty vehicles may contrast with conventional petroleum diesel heavy-duty vehicles.

Zero-emissions heavy-duty vehicle: Heavy duty vehicles that produce no tailpipe emissions. Includes battery electric vehicles and fuel cell vehicles.

Heavy-duty trucks: Class 8 vehicles with a gross vehicle weight rating of at least 15 tonnes are typically considered a heavy-duty truck. This includes city and coach buses, vocational vehicles, refuse trucks, combination tractor trailers and others.

Refueling/recharging station: Publicly or privately owned infrastructure that supports refueling of a vehicle in the form of a liquid or gaseous fuel, or supports EV charging in the form of electrical grid connectivity.

Compressed natural gas (CNG): Natural gas in a gaseous state stored in a specialized container at high pressure and temperature (approximately 250 bar and 27 degrees Celsius).

---

[115] Commercial Truck Trader, "Conventional – Day Cab Trucks for Sale." https://www.commercialtrucktrader.com/Conventional--Day-Cabs-Trucks-For-Sale/search-results?category=Conventional%20-%20Day%20Cab%7C2000601

[116] Dedola Global Logistics, "What is Drayage?" https://dedola.com/2012/01/what-is-drayage/

Liquefied natural gas (LNG): Natural gas in a liquid state stored in a cryogenic container at low pressure and temperature (approximately 7 to 16 bar and -162 degrees Celsius).

Renewable natural gas (RNG): Identical in chemical composition to conventional natural gas (mostly methane or CH_4), but is instead derived from renewable feedstocks such municipal solid waste or forest residues. The fuel has GHG emission reduction benefits as it captures methane that would otherwise be released into the atmosphere. RNG is produced through gasification or anaerobic digestion. It can be converted into CNG or LNG.

Blue hydrogen: Hydrogen produced from fossil fuels, typically natural gas. Production incorporates carbon capture and storage (CCS) technology.

Green hydrogen: Hydrogen produced from renewable resources.