REDUCING GREENHOUSE GAS EMISSIONS FROM ONTARIO DIESEL HIGHWAY TRUCKS

ONTARIO SOCIETY OF PROFESSIONAL ENGINEERS

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Executive Summary

The effects of climate change are becoming more and more tangible as time passes. If we expect to provide a sustainable country and world for future generations, we must reduce greenhouse gas (GHG) emissions in the next years.

Canada's 2030 Emissions Reduction Plan[1] commits Canada to reach an emissions reduction target of 40 to 45 percent below 2005 levels by 2030, and to put Canada on a path to achieve net-zero emissions by 2050.These are absolute emissions, not emissions-per-person. If we intend to reach this target, our attempts to reduce GHG emissions must include a significant reduction in emissions from a critical sector: Ontario freight trucks.

This **Ontario Society of Professional Engineers ("OSPE")** White Paper makes recommendations on ways to reduce Ontario's Freight Truck GHG emissions, to meet Canada's GHG reduction targets.

The movement of goods and services by the freight trucking sector contributes to the growth and well-being of our economy. It is a key component to a robust and sustainable supply chain for businesses. Reducing the sector's emissions ticks all the climate change requirements pertaining to ESG (Environment, Social and Governance) metrics used by financial investors to rank progress towards sustainability. Reducing sector GHG emissions will be a competitive edge for Ontario.

This OSPE white paper is the result of considerable research and interviews with transportation experts in the trucking, rail and marine sectors. The recommendations of this white paper affect not only the trucking industry sector, but also energy, transportation, environment, communities and infrastructure.

Why Freight Trucks?

Greenhouse gas ("GHG") emissions from Ontario freight trucks, caused mostly by the combustion of diesel fuel, have increased at a higher rate than emissions from any other sector in Ontario's economy.

Ontario freight truck GHG emissions increased from **6,390 kilotonnes** of carbon dioxide equivalent ("kt CO_2e") **in 1990** to **12,700 kt in 2019**[2], a **99% increase**. During the same period, Ontario's population increased by 41%. GHG emissions from freight trucks in Ontario increased during the same period, from 620 tonnes per person to 872 tonnes

[1] https://www.canada.ca/en/environment-climate-change/news/2022/03/2030-emissions-reduction-plan--canadas-next-steps-for-clean-air-and-a-strong-economy.html

[2] Canada's National Greenhouse Gas Emissions Inventory https://unfccc.int/documents/271493

per person, an **increase of 41% per capita**. In contrast, during the same years, Ontario's GHG emissions from railways decreased by 12%[3], and emissions from stationary combustion sources and industrial processes also decreased.

For the trucking sector and the economy to be sustainable, GHG emissions need to be reduced significantly.

Recommendations to Reduce Emissions

We offer two key recommendations are made for Ontario to reduce emissions from freight trucking.

1. Major Policy and Program Decisions

The Need for Action

Climate change, caused by our emission of GHGs, is already causing human suffering in many parts of the world, including Ontario. Reducing GHG emissions must be a government priority, as significant as maintaining the health care system.

Canada has committed to reduce its GHG emissions by 40-45 percent below 2005 levels, by 2030. GHG emissions by heavy duty diesel vehicles are the fastest-increasing GHG emissions from Ontario sources.

In Ontario, we must and can reduce significantly our GHG emissions from heavy trucks by 2030. We have less than nine years.

> **A Call to Action to reduce highway truck emissions in these nine remaining years needs to be made by the Ontario Provincial Government.**

The Need for Unity

The Canadian Government, the Ontario and Québec Governments, municipal governments, industry associations, labour unions, and all relevant jurisdictions in the USA must work together in a coordinated fashion, to reduce GHG emissions from diesel trucks.

Many of the industry experts interviewed in this study expressed their concerns about the lack of coordination between levels of government. For example, the provincial government has jurisdiction over motor vehicles and highways, while the federal government has jurisdiction over railways and marine. Several attempts to interest provincial officials in the advantages of truck-to-marine intermodal freight shifting met with zero response.

[3] Comment from D. Bradley: "Rail carries heavy loads of bulk cargos, whereas trucks carry lighter loads of manufactured goods."

The *Metrolinx* 2016 URBAN GOODS MOVEMENT report emphasized the need for better overall planning of freight shipments in the GTA[8].

> **The freight transportation sector in Ontario, Canada, and North America needs a unifying policy and program, coordinated and transparent, emphasizing the reduction in greenhouse gas emissions.**

Such a Policy or Program requires a careful communications strategy to explain the need and the advantages.

The **Ontario Society of Professional Engineers** can provide key advice to the leadership of such a program.

2. Infrastructure and Technology

Infrastructure Needs

Ontario needs to improve its infrastructure to achieve the necessary GHG emission reductions from diesel trucks. Ontario needs efficient intermodal freight terminals, better access to these intermodal terminals,[8] and a more efficient, less fragile freight rail network.

These infrastructure improvements would cost in the hundreds of millions of dollars, but they would be cost-effective and achievable within the next ten years. Their cost per tonne of GHG emission reduction would be much less than the cost of exotic future technologies.

Practical, Achievable Actions and Technologies

Practical, achievable actions and technologies are available now. These technologies and actions can reduce significantly our GHG emissions (and emissions of other air pollutants) from large diesel trucks within the next ten years. These actions and technologies include:

- Organized planning of freight shipments
- Truck Efficiency Improvements:
    - Streamlining of Trucks and Trailers
    - Low rolling resistance tires
    - Longer Containers: from 53 feet to 60 feet
    - Long Combination Vehicles
- Driver Training
- Off-Peak Delivery of Freight
- Transportation Management Systems
- Truck-to-Rail Modal Shift and Infrastructure
- Truck-to-Marine Modal Shift and Infrastructure
- Natural Gas Fuel

This White Paper does not attempt to predict exactly how many kt/y CO2e of truck emissions could be eliminated by each of these measures, or how many dollars per annual kilotonne of reduced emissions each measure would cost. However, an effective combination of these measures could easily reduce total emissions by at least 50% within 10 years at a cost much less than the exotic future technologies that could be available in the distant future.

In the Long Term, New Technologies

In coordination with other jurisdictions, governments should continue to encourage the Research, Development and Demonstration of new technologies, that will reduce GHG emissions from Ontario freight trucks in the distant future.

These technologies include, in order of precedence:

- BioDiesel Fuel – Production and Use
- Renewable Natural Gas Fuel
- Renewable Ethanol and Methanol in Diesel Fuel
- Autonomous Trucks
- Truck Platooning
- Electric Battery Infrastructure, Charging and Propulsion
- Hydrogen Infrastructure and Propulsion

Introduction

Canada has committed to reduce greenhouse gas emissions by 40 to 45 percent below 2005 levels by 2030, and to put Canada on a path to achieve net-zero emissions by 2050.[4] If we intend to reach these targets, our attempts to reduce GHG emissions must include a significant reduction in emissions from a critical sector: Ontario freight trucks.

The movement of goods and services by the freight trucking sector contributes to the growth and well-being of our economy. It is a key component to a robust and sustainable supply chain for businesses. Reducing the sector's GHG emissions would meet all the ESG (Environment, Social and Governance) metrics used by financial investors to rank progress towards sustainability. These reductions would be a competitive edge for Ontario.

Greenhouse gas ("GHG") emissions from Ontario freight trucks, caused mostly by the combustion of diesel fuel, have increased at a higher rate than emissions from any other sector in Ontario's economy.

Ontario freight truck GHG emissions increased from 6,390 kt CO_2e in 1990 to 12,700 kt in 2019[5], a 99% increase, or 41% per capita. In contrast, during the same years, Ontario's GHG emissions from railways decreased by 13%, and emissions from stationary combustion sources and industrial processes also decreased.

For the trucking sector and economy to be sustainable, GHG emissions need to be significantly reduced. OSPE's recommendations could lead to the reduction of GHG emissions in the freight trucking sector.

This paper is the result of considerable research and interviews with transportation experts in the trucking, rail and marine sectors. These recommendations affect not only the trucking industry sector, but also energy, transportation, environment, communities and infrastructure.

Rationale for Recommendations

[4] https://www.canada.ca/en/environment-climate-change/news/2022/03/2030-emissions-reduction-plan--canadas-next-steps-for-clean-air-and-a-strong-economy.html

[5] Canada's National Greenhouse Gas Emissions Inventory https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/sources-sinks-executive-summary-2021.html#toc4

Fortunately, many Ontario, Canadian, and North American experts are vigorously promoting technologies and actions which could reduce GHG emissions from freight trucks, in a favourable policy climate.

Most of Ontario's GHG emissions from freight trucks could be eliminated by low-cost measures, within 10 years, using existing technologies.

In the long run, newer, more advanced technologies could reduce emissions even further.

An exact cost/benefit analysis of each of these technologies is beyond the scope of this paper. However, the potential emission reductions from these recommended technologies and actions are massive.

Actions and Technologies 1: Low Cost, Early Adoption, Highly Effective

Improving Efficiencies and Fuels

> **Combustion of 1 litre of diesel fuel emits 2.73 kilograms of CO_2 into the atmosphere.[6]**
>
> **Improved Fuel Efficiency = Reduced GHG Emissions**

North American Council for Freight Efficiency

An excellent guide to the opportunities to improve the fuel efficiency (and GHG emissions) from long-distance freight trucks is the 2019 Annual Fleet Fuel Study of the *North American Council for Freight Efficiency* ("NACFE")[7].

This study considers the potential for efficiency improvements from 85 currently available actions and new technologies in the North American truck fleet. These actions and technologies are in the following general groups:

- Truck Chassis Improvements
- Idle Reduction
- Operational Practices, including Telematics
- Powertrain Improvements
- Tires and Rolling Resistance
- Tractor Aerodynamics

[6] https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references
[7] North American Council for Freight Efficiency https://nacfe.org/downloads/2019-nacfe-fleet-fuel-study/

- Trailer Aerodynamics
- Trailer Improvements

These improvements are described in detail in the web site
https://www.nacfe.org/current-technology/

NACFE promotes a goal to reduce the average fuel consumption (and GHG emissions) of a standard, large, "Class 8" truck from a typical 6.3 miles per USGallon (2.67 km/L) (1022 gCO_2/km) to 10 miles per USGallon (4.23 km/L)(645 gCO_2/km).

Ontario Trucking Association ("OTA")

The *Ontario Trucking Association* ("OTA") intends to improve the fuel efficiency of truck transportation by 20% through a combination of easily-implemented technologies[8]:

- Streamlining of Trucks and Trailers:
  - Aerodynamic Truck Side-Skirts, Gap Reducers and Boat-Tails
- Low rolling resistance tires
- Longer Containers: from 53 feet to 60 feet
- Long Combination Vehicles:
  - *Canadian Tire* reports a 30% fuel savings, when replacing two trucks with one, long-combination vehicle.
  - In Ontario, 70 or 80 companies are driving long combination vehicles.
  - Concerns about safety, driver training.
  - The *Metrolinx Urban Freight Report* (2016)[8] mentions that the weight allowance in Ontario for trucks is higher than the weight allowance in neighboring states and provinces, more tolerant of longer trucks.

Professor Matthew Roorda says that truck improvements will occur over the years, as the older trucks are replaced by newer trucks[9].

OTA maintains that diesel fuel will continue to be the primary energy source for trucks, for the next 10-15 years.

OTA is working with engine manufacturers on efficiency improvements for truck diesel engines.

OTA is promoting (with success) simple, practical actions and technologies to improve the fuel efficiency of Ontario freight trucks.

[8] Ontario Trucking Association - Environment
https://ontruck.org/environment/
https://ontruck.org/wp-content/uploads/2019/07/CTA-2019-2020-Infrastructure-Priorities_public.pdfneed ref
[9] Interview with Professor Matthew Roorda

At the same time, OTA is wary of exotic new technologies that might not be practical during the next 10-15 years.

OTA is concerned about the looming shortage of truck drivers in Ontario. This may influence the shift from transporting freight from trucks to rail and ships.

Metrolinx Urban Freight Report

URBAN GOODS MOVEMENT: FULL REPORT[10]
Technical Paper 5 to support the Discussion Paper for the
Next GTHA Regional Transportation Plan
July 2016
David Kriger Consultants Inc. and CPCS

A large, comprehensive study of the issues and opportunities for transport of goods in the GTHA, from a perspective of efficiency of transportation, not always from the perspective of GHG emission reductions. A good summary of Ontario Reports, Regulations and Policy Statements before 2016. The Kriger Report highlights the important of intermodal freight hubs and freight transportation data sharing.

Organized Planning of Freight Shipments

The entire logistics industry in Canada and the USA could benefit from a nationally standardised technological fix, that would provide complete container management, including automated status notifications, real-time GPS tracking and document management and analytics for every container. Such a system is being discussed in the USA.[11]

Streamlining of Trucks

When a traditional, rectangular box-shaped tractor trailer is cruising on the highway at 100 km/h, approximately 52% of the engine power is used to overcome aerodynamic drag. External attachments (fairing and covering) have notable impact on aerodynamic drag, which they can reduce by up to around 26%.[12]
A 2017 study of drag reduction in Class 8 trailer trucks, using external attachments, showed that adding gap reducers and a new, streamlined top to a truck reduces the "drag coefficient" from 0,55 to 0.45.[13]

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[10] https://www.metrolinx.com/en/regionalplanning/rtp/technical/05_Urban_Goods_Movement_Report_EN.pdf

[11] https://theloadstar.com/us-logistics-industry-needs-a-unified-data-stream-to-boost-cargo-velocity/

[12] A Study on Aerodynamic Drag of a Semi-trailer Truck
Harun Chowdhury, Hazim Moria, Abdulkadir Ali, Iftekhar Khan, Firoz Alam, Simon Watkins
School of Aerospace, Mechanical and Manufacturing Engineering, RMIT University, Melbourne, VIC 3083, Australia
7 May 2013.
https://www.sciencedirect.com/science/article/pii/S1877705813004621

[13] https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1028&context=polytechsummit

Erb Transport, in Ontario, reports a 9% fuel savings on its freight trucks, by employing fuel saving devices on its trucks.[14]

Natural Gas Fuel

Already used as a fuel in many urban transit buses, natural gas emits 30% less GHG per unit fuel energy than diesel fuel.[15] Ontario's natural gas utilities are promoting compressed natural gas ("CNG") as a fuel alternative to diesel fuel for freight trucks. *Enbridge Gas*[16] claims that natural gas is up to 40% lower in cost per unit fuel energy than diesel fuel, and is more stable in price. Federal funding is provided through Natural Resources Canada's Electric Vehicle and Alternative Fuel Infrastructure Deployment (EVAFIDI), which is investing to establish natural gas refueling stations along key transportation routes[17].

Southern Ontario already has twelve public service stations where trucks can refill with compressed natural gas.[18] Some truck manufacturers (*Volvo, Kenworth, Freightliner*) already offer heavy trucks with CNG engines. OTA says that these CNG engines are limited to 12 litres in size, suitable for light loads.[19]

Energir has a plant in Montreal to make Liquid Natural Gas ("LNG") at extremely cold cryogenic temperatures. LNG is being used in marine shipping. *Fortis* uses LNG to power ferries in BC.

Le Group Desgagnes, based in Québec, has 5 dual fuel diesel-LNG vessels, mostly on Arctic resupply services.[20]

Enbridge has an LNG plant that could be expanded, or could build a new plant for Great Lakes shipping. These uses of natural gas were considered by Enbridge several years ago.

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[14] Ontario Trucking Association - Environment
https://ontruck.org/environment/
https://ontruck.org/wp-content/uploads/2019/07/CTA-2019-2020-Infrastructure-Priorities_public.pdfneed ref

[15] Calculations based on based on the published heats of combustion and specific GHG emissions for common fuels.

[16] CNG Highway Tractors: Fuel your fleets for less:
https://www.enbridgegas.com/sustainability/compressed-natural-gas/highway-tractor

[17] https://www.trucknews.com/transportation/three-cng-stations-coming-to-trans-canada-highway-in-northern-ontario/1003150144/

[18] https://www.nrcan.gc.ca/energy-efficiency/transportation-alternative-fuels/electric-charging-alternative-fuelling-stationslocator-map/20487#/find/nearest?location=Ontario&fuel=CNG&page=2

[19] Comment by Lak Shoan, Ontario Trucking Association

[20] https://desgagnes.com/en/pioneer-in-sustainable-maritime-transport-desgagnes-christens-and-inaugurates-two-polar-class-dual-fuel-lng-vessels

A Canadian manufacturer, *Westport Fuel Systems*[21], was developing a LNG fuelling system for large truck engines, but abandoned development when the price of petroleum collapsed in the mid-2010's. [22]

Driver Training

NRCan's Greening Freight Programs[23] provide training, tools and resources to help Canada's truck fleets lower their fuel consumption, operating costs and GHG emissions. These programs include:

- Smart Driver Training
- Green Freight Assessment: Helping companies to lower fuel costs and emissions, by supporting decision-making and investments in supply chain structure, fleet energy assessments, retrofits and fuel switching.
- *SmartWay Transport Partnership*: Originally developed by the USEPA, Smart Way has been promoted in Canada by NRCan since 2012. SmartWay encourages best practices in freight supply chains. It helps carriers and shippers benchmark their operations, track fuel consumption and improve their overall performance. *Musket Transport Ltd*., operating predominantly in Ontario and Quebec, adopted the NRCan Smart Driver Highway Training curriculum and administered the program at CHET academy, the company's in-house driving school. The company reports a 35% fuel savings, after driver training.

Off-peak delivery of Freight

A 2019 pilot project in the *Regional Municipality of Peel*[24] showed that deliveries by large truck to major retail stores (LCBO, Wal-Mart, Loblaws) during off-peak hours reduced greenhouse gas emissions by delivery trucks by 10.6%, compared to daytime deliveries.

The *Metrolinx* URBAN GOODS MOVEMENT study of 2016 also offered some words of encouragement for off-peak deliveries[8].

This off-peak delivery by trucks in Ontario municipalities was discouraged in the past, because of concerns about noise. Ontario's new *Main Street Recovery Act, 2020* limits municipalities from regulating noise related to the delivery of goods to retail establishments, restaurants, hotels, motels, and goods distribution centres, except as

[21] https://wfsinc.com/
[22] Comment from S.Pogorski
[23] NRCan – Commercial Vehicles
https://www.nrcan.gc.ca/energy/efficiency/transportation/commercial-vehicles/reports/7607
[24] Pilot Off-Peak Delivery Program in the Region of Peel
http://smartfreightcentre.ca/wp-content/uploads/2020/02/SFC-OPDPeelPilot-FinalReport-January30_2020.pdf

otherwise authorized by regulation. This change to the Municipal Act allows for off-peak delivery of goods by trucks inside municipalities.

Electrification of Truck Stops

Plug-in power for cabin electricity, air conditioning, refrigeration is available at some truck terminals, when the trucks are idle. Electrification can reduce idling of truck diesels.

Computer-Based Transportation Management Systems

Computer based transportation management systems optimize the scheduling and delivery of freight to retail stores[25]. A major retailer, *Canadian Tire Corporation*, controls its 147 trucks and 5000 containers from a centralized Transportation Management System, staffed by 18 operators.

Telematics[26] is an on-board GPS navigation, truck management and communication system for truck fleets. The advantages of Telematics are improved routing and scheduling, driver coaching, and more regular routine maintenance.

Auxiliary Power Units

"APUs" are small diesel engines often used to provide power for refrigeration plants in "reefer" trucks, when the main engines are shut off.[27] APUs can also provide electric power to lights, communications and computers, heating and air conditioning and engine warming during idling hours, at much better efficiency (and fewer air emissions) than idling truck engines.

Sharing of Truck Space

The rise of e-commerce has resulted in faster deliveries of goods to customers, but the need for fast delivery has meant that many trucks are only half-full when delivering.[28] Large retailers in the USA (e.g. Amazon, Walmart) are overcoming the problem of half-full trucks by sharing truck space with each other.[29]

Modal shift: Truck-to-Rail

Intermodal, truck-to-rail, refers to shipping freight in containers over long distance, by rail, and then transferring the containers to trucks, for final delivery. Since shipping by rail is much lower in GHG emissions (13.3 grams CO_2 per tonne-km) than shipping by

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[25] Interview with Gary Fast, Canadian Tire Corporation.

[26] What is telematics? Everything you should know: Keep Truckin: September 14, 2020 https://keeptruckin.com/blog/what-is-telematics#What_is_telematics

[27] What is an APU on a truck? TAFS: https://www.tafs.com/apu-powered-trucks-worth-investment/

[28] Comment by M. Roorda.

[29] https://www.cnbc.com/2021/12/04/how-amazon-beats-supply-chain-chaos-with-ships-and-long-haul-planes.html

truck (65.5 grams CO_2 per tonne-km)[30], shifting more freight from truck alone to truck-to-rail offers a significant opportunity to reduce GHG emissions.

In 2019, 37.2 million tonnes of freight were carried in containers on railway cars in Canada[31].

Canada's largest railway, *CN*, a master of intermodal shipping, owns one of Canada's largest truck fleets. In 2018, CN shipped over 2.6 million containers through its intermodal system[32].

Canada's two freight railways, *CN and CP*, operate highly efficient intermodal shipping of freight containers from the Port of Montreal, the Port of St. John, NB, and other sources to large, efficient intermodal freight container yards at Vaughan, Mississauga and Brampton, where the containers are transferred from rail cars to trucks for final delivery.[33] The (short) final delivery routes are ideal for rechargeable, short range electric vehicles. These intermodal freight yards are also used to load containers of Ontario products on trains, for delivery throughout North America.

CN is also seeking approval to build another intermodal freight yard in Milton. If built, this yard would significantly reduce GHG emissions from freight trucks in Ontario.[34]

A champion of intermodal rail-to-truck is *Canadian Tire Corporation*[35], which ships containers of retail merchandise across Canada by rail, transfers the containers to trucks at Ontario intermodal yards, and then delivers the containers by truck to retail stores.

Across North America, large e-commerce retailers (e.g. *Amazon, Walmart*) are already creating their own intermodal shipping networks.[36]
In Europe, the container *Port of Rotterdam* offers shipment inland of containers by truck or rail or barge, [37] along with a free calculation of the kg of CO_2 emitted by shipment of one container to each destination by each mode of shipment.

Canadian Tire is concerned about the fragility of the railway infrastructure, for example, the recent fire in Lytton, BC took out the *CN* and *CP* rail lines linking Vancouver and Calgary. More double tracks, more sidings, and fewer level crossings for freight rail would make the rail freight system less fragile.

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[30] CN: https://www.cn.ca/repository/popups/ghg/Carbon-Calculator-Emission-Factors
[31] Railway Association of Canada: https://www.railcan.ca/101/rail-is-green-transportation/
[32] Interview with Ben Chursinoff, Railway Association of Canada
[33] Interview with Chursinoff
[34] Interview with Ben Chursinoff
[35] Interview with Gary Fast
[36] https://www.cnbc.com/2021/12/04/how-amazon-beats-supply-chain-chaos-with-ships-and-long-haul-planes.html
[37] https://www.portofrotterdam.com/en/logistics/connections/intermodal-transportation/inland-shipping

Ben Chursinoff of the Railway Association of Canada believes that infrastructure fragility affects the entire supply chain across Canada. The bigger issue really is about supply chain / infrastructure climate resiliency, as more severe climate incidents occur throughout Canada.

What would be the other, non-GHG benefits in shifting freight from trucks to rail?

- Reduced highway congestion (which also reduces GHG emissions)
- Safer highways
- Less demand for new, bigger highways (which also offsets GHG emissions from highway construction)
- Reduced wear-and-tear on highways (reduction in maintenance and associated GHG emissions)
- Health care benefits of faster, more dependable, less overloaded highways
- Reduced shortages of truck drivers
- Health benefits of improved air quality from reduced diesel emissions[38]

Any discussion of intermodal shipping must consider the inconvenience of moving containers from train to truck, for final delivery to customers.

Ben Chursinoff, from the *Railway Association of Canada*, thinks that convincing shippers to shift more freight from trucks to rail will be difficult. The shift requires more promotion and enthusiasm from governments. The only provincial program to support modal shift is Québec's PRESTI. The USA Government, through the Section 45G Tax Credit, is more supportive of shift-to-rail than Canada's Government. USA companies and governments have more $ for demonstration off new technologies.

Modal shift: Trucks-to-Marine

Using Ships instead of Trucks to Move Freight in the St. Lawrence Seaway/Great Lakes Region. A significant fraction of the general cargo that is now transported to, from, and within Ontario by trucks or by trains could be carried by ships.

(For a detailed analysis of marine intermodal, please see Appendix 1: In the Spotlight: Trucks-to-Marine*, at the end of this document.)*

[38] Quantifying the air quality and health benefits of greening freight movements LauraMinetTufayelChowdhuryAnWangYijunGaiDanielPosenMatthewRoordaMarianneHatzopoulou Environmental Research, Volume 183, April 2020, 109193, https://www.sciencedirect.com/science/article/abs/pii/S0013935120300852 Volume 183, April 2020, 109193 https://www.sciencedirect.com/science/article/abs/pii/S0013935120300852

Actions and Technologies 2:
Longer Term, Major Technological Change

Renewable Fuels

Bio-Diesel Fuel

Bio-diesel is made from (used, recycled) animal or vegetable fats and oils, reacted with ethanol or methanol, to produce a fuel for diesel engines. HDRD bio-diesel is made by aggressive hydrogenation of animal or vegetable fats or oils, producing the same hydrocarbon molecules as petroleum-based diesel. Bio-diesel can be blended into petroleum-based diesel, to certain limits. Railway engine manufacturers specify limits for percent bio-diesel in railway diesel fuel[39]. One litre of biodiesel has 93% of the fuel energy of one litre of petroleum-based diesel. Biodiesel has a high "cetane" number, a measure of diesel fuel quality. Currently, biodiesel makes up about 2.3% of the total volume of diesel fuel in Canada, or about 700 million litres per year.[40]

On August 25th, 2021, *Imperial Oil* announced that it plans to build a new renewable diesel unit at its Strathcona Refinery, near Edmonton[64]. The proposed unit would use the HDRD process to produce 20,000 barrels per day (3.18 million litres per day) of biodiesel, to be blended with petroleum-based diesel. This addition of biodiesel would meet some of the requirements of Canada's Clean Fuel Standard.

The *Ontario Trucking Association* is wary of the use of biodiesel, citing problems with freezing and gelling of biodiesel in Northern Ontario[41]

In the USA, prices for bio-diesel are slightly higher than prices for petroleum-based diesel, when taxes and subsidies are included. In January 2021, the USA national average retail price for bio-diesel was the equivalent of $1.05 Cdn per litre, while the USA national retail price for petroleum-based diesel was the equivalent of $0.87 Cdn per litre. (Taxes may have some effect on these two quoted prices.)

In 2019, about 75% of USA biodiesel production was from agricultural crops. The remainder was from waste or recycled fats and oils.

Are agricultural resources sufficient to meet our demand for diesel fuel? Neither bio-ethanol nor bio-diesel can replace petroleum without impacting food supplies.

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[39] Chursinoff interview

[40] Biofuels in Canada https://www.naviusresearch.com/wp-content/uploads/2019/05/Biofuels-in-Canada-2019-2019-04-25-final.pdf

[41] Interview with Lak Shoan, Ontario Trucking Association

If 100% of U.S. corn and soybean production were dedicated to biofuels, the total production of biofuels would meet only 12% of USA gasoline demand and 6% of USA diesel demand.[42] Canada's situation would be worse.

Renewable Natural Gas (RNG)

Methane, CH_4, the principal component of natural gas, is produced by the anaerobic digestion of biomass in municipal solid waste landfills, anaerobic digesters, agricultural waste, wood waste piles and wastewater treatment plants. The gases emitted by these sources can be purified, to remove the non-methane components, producing a methane which is completely identical to the methane in natural gas.

Several years ago, *Enbridge* considered establishing an RNG plant in Ontario to power Great Lakes shipping.

RNG can be compressed and transported to the pipeline in tube trailers. Small (less than 6 tonnes per day) liquid natural gas plants are now available to collect, liquify and store cryogenic liquid natural gas (LNG) from these sources. [43] Compared to diesel fuel, RNG as a motor fuel emits much lower quantities of air pollutants.

In just the first half of 2020, RNG made up nearly 90% of all natural gas vehicle fuel consumed in California.[44]

Unfortunately, RNG is still expensive, costing from two to eight times as much per unit energy as geological natural gas.[45] In 2019, a study for the *American Gas Foundation* predicted that by 2040, 1570 PJ/y of RNG could be available for USA markets at a price of $24.00 Cdn/GJ. (Currently, natural gas retails for about $3.50Cdn/GJ in Ontario.[46]) Assuming that Ontario's RNG supply would be about 1/20 in size, compared to the USA supply, Ontario would have 78 PJ of renewable natural gas available, or about 36% of the current demand for diesel fuel energy for Ontario freight trucks.

A possible unexplored source of renewable natural gas is the hundreds of piles of rotting wood waste in the Canadian forest.

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[42] https://www.pnas.org/content/103/30/11206

[43] https://www.wartsila.com/marine/build/gas-solutions/liquefaction-bog-reliquefaction/lng-plants-small-scale-liquefaction-technology

[44] https://www.act-news.com/news/is-rng-a-california-only-fuel/

[45] Cost and quantities of renewable natural gas in USA https://gasfoundation.org/wp-content/uploads/2019/12/AGF-2019-RNG-Study-Full-Report-FINAL-12-18-19.pdf

[46] Ontario Energy Board: Natural Gas Rates: https://www.oeb.ca/rates-and-your-bill/natural-gas-rates

One industry expert interviewed mentioned that a key barrier to production and use of new fuels (e.g. RNG) is the NIMBY —"not in my back yard" syndrome. NIMBY views drive costs up in review processes and often prevent new plants from being built.[47]

Renewable Ethanol and Methanol in Diesel Fuel

Renewable ethanol (CH_3CH_2OH) can be produced from biomass by conversion of starches to sugars, fermentation, and distillation. Ethanol blends have already been proven as a motor fuel.

Currently, renewable ethanol is made from agricultural crops. Ethanol fuel from USA crops yields about 25% more energy than the energy consumed in its production.[48] Current research (e.g., *Iogen*, Ottawa, ON) is attempting to develop low-cost processes to produce ethanol from waste biomass such as wood waste and straw.[49] The current price of fuel ethanol is about 81¢ (Cda) per litre, or $38.20/GJ (exclusive of taxes).[50] This compares with the average diesel price of about $1.25/L (including taxes), or $32.40/GJ. The added ethanol improves air emissions from the diesel engine.[51]

Renewable methanol (CH_3OH) is made from waste cellulose or waste polymers, by partial combustion with oxygen, followed by gas cleaning of the carbon monoxide product, and reaction with hydrogen. Methanol itself can be a motor fuel or additive to diesel fuel. The produced methanol can be used to make hydrocarbon diesel fuel, although the overall energy balance and the economics are uncertain. A Canadian company, *Enerkem*[52], has built and is now operating a renewable methanol plant in Edmonton. The goal of the project is to convert 100,000 tonnes per year of post-sorted municipal solid waste into 38 million litres of biofuel. *Enerkem* claims waste-based biofuels can reduce GHG emissions by more than 60% when compared with fossil fuel production and landfill operations. *Enerkem* has announced the beginning of two more plants, in Varennes, QC, and in Spain. This technology offers some hope for meeting the demand for non-petroleum-based fuels in the future.

Ethanol or methanol can be added to diesel fuel to a maximum limit of about 15%. If the blend contains more than 15% alcohol, the fuel separates into two phases, an upper hydrocarbon layer (diesel fuel) and a lower aqueous layer (alcohol).[53]

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[47] Interview with Paul Topping, Chamber of Marine Commerce.

[48] Ethanol in Diesel: https://afdc.energy.gov/files/pdfs/barriers_ediesel.pdf

[49] https://www.iogen.ca/

Biofuels in Canada

https://www.naviusresearch.com/wp-content/uploads/2019/05/Biofuels-in-Canada-2019-2019-04-25-final.pdf[50]

[51] Biofuels in Canada

https://www.naviusresearch.com/wp-content/uploads/2019/05/Biofuels-in-Canada-2019-2019-04-25-final.pdf

[52] https://enerkem.com/company/about-us/

[53] As calculated by authors

Hydrogen Fuel

Hydrogen gas can be produced from renewable electric energy, by electrolysis of water, H_2O.[54] A valuable byproduct of the electrolysis process is oxygen gas. The hydrogen gas can be compressed to extremely high pressure and stored in high-pressure tanks on board a vehicle. The hydrogen can then provide electric power, through a fuel cell, to drive the vehicle. The only exhaust gas is water vapour.

The $15 million*, Alberta Zero-Emissions Truck Electrification Collaboration* (AZETEC) project, led by the *Alberta Motor Transport Association*, is testing hydrogen powered heavy trucks for freight transport.[55] The three-year AZETEC project, scheduled to run until mid-2022, involves the design and manufacture of two heavy-duty, extended-range, hydrogen fuel cell electric hybrid trucks that will move freight year-round between Edmonton and Calgary.

A Canadian company, *Ballard Power Systems Inc.,* supplied the fuel cells for 500 delivery trucks, in Shanghai, in 2017.[56] So far, Shanghai has three hydrogen refuelling stations. The refuelling operation for a fuel cell truck takes about 10 minutes. The maximum reported distance travelled by a fuel cell vehicle, without refuelling, is 400 km.[57]

The energy density of stored hydrogen, even at high pressure, is much lower than the energy density of stored diesel fuel. This problem of energy density limits the range of hydrogen-fuelled trucks.

Hydrogen fuel cell trucks are a possible future option for Ontario freight operations, provided that the refuelling infrastructure can be developed, and new, non-emitting sources of electric power can be brought on-line to power the electrolytic production of hydrogen.

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[54] Ibid.

[55] Alberta Zero-Emissions Truck Electrification Collaboration (AZETEC) Fueling Station: https://www.nrcan.gc.ca/science-and-data/funding-partnerships/funding-opportunities/current-investments/alberta-zero-emissions-truck-electrification-collaboration-azetec-fueling-station/23620

[56] Ballard Announces Planned Deployment of 500 Fuel Cell Commercial Trucks in Shanghai: https://www.ballard.com/about-ballard/newsroom/news-releases/2018/02/14/ballard-announces-planned-deployment-of-500-fuel-cell-commercial-trucks-in-shanghai

[57] Retail Insider – Autonomous Trucks – Canadian Tire https://retail-insider.com/retail-insider/2021/03/canadian-tire-testing-first-of-its-kind-in-the-world-autonomous-trucking-technology/; Truck News – Autonomous Trucks https://www.trucknews.com/technology/canadian-tire-deploying-two-nuport-automated-trucks/1003149535/

Autonomous Trucks

Autonomous (self-driving) trucks are already being tested in Ontario. With their computer-driven routing, acceleration and braking, autonomous trucks have better fuel efficiency than human-driven trucks.

As of March 2021, *Canadian Tire*[58] is operating two autonomous heavy trucks, transporting freight between a Canadian Tire distribution centre and nearby rail terminals. The project is a partnership including the Province of Ontario's *Autonomous Vehicle Innovation Network* and Toronto-based autonomous trucking startup *NuPort Robotics*. Human truck drivers are riding in the vehicles, for safety.

International mining giant Vale is now operating a fleet of large, autonomous mining trucks at an open-pit iron ore mine in Brazil.[59]

Loblaws already has five, level-4 autonomous delivery trucks making deliveries in the GTA.

It is hoped that the efficiency gains by autonomous trucks can reduce fuel consumption and GHG emissions per tonne-km.

Truck Platooning

According to the *USA Office of Energy Efficiency and Renewable Energy*[60]*,* "Platooning involves the use of vehicle-to-vehicle communications and sensors, such as cameras and radar, to virtually connect two or more trucks together in a convoy. The virtual link enables all of the vehicles in the platoon to communicate with each other, allowing them to automatically accelerate together, brake together, and enables them to follow each other at a closer distance than is typically possible with unlinked trucks.

"The technology detects and reacts to stopped or slow vehicles ahead of the platoon and adjusts as needed when a vehicle cuts in between the trucks in the platoon. With current platooning technology, each truck in the platoon has a human driver responsible for steering and taking over the speed and braking as needed. The driver of the first truck leads the platoon and navigates the route. As the technology improves, there may only be the need for a lead driver, or no human drivers at all.

"Early studies have shown that 65% of current long-haul truck miles could potentially be platooned, reducing total truck fuel consumption by 4%."

OTA is wary of the prospects for truck platooning in Ontario's winter weather.[61]

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[58] Ibid.

[59] https://www.mining-technology.com/news/vale-autonomous-trucks-brazilian-complex/

[60] Potentials for Platooning in U.S. Highway Freight Transport: https://www.nrel.gov/docs/fy17osti/67618.pdf

[61] Interview with Lak Shoan, Ontario Trucking Association

Photovoltaic Assist

One reviewer mentioned the opportunities to use photovoltaic (solar electric) panels to provide auxiliary power to shipping containers for refrigeration.[62]

Electric Battery Energy

Major improvements in battery technology have led to the commercialization of battery-driven automobiles, buses and trucks, with zero greenhouse gas emissions from the vehicle, and with performance comparable to fossil fuel-powered vehicles.[63] A wave of enthusiasm is propelling electric battery vehicles, mostly automobiles, into the market. Many cities, including Toronto, are equipping their public transit fleets with battery-powered buses. The Ontario and Canadian Governments have assisted major motor vehicle manufacturers to establish manufacturing facilities for battery-powered automobiles and light trucks in Ontario.[64]

Nikola, a USA electric-truck startup, has delivered its first two vehicles to a customer operating at the ports of Los Angeles and Long Beach. The *Tre BEV* is an electric semi with a claimed 350 miles of range via a 753.0-kWh battery.
If the pilot program goes well, Nikola plans to deliver 30 Tre BEVs and 70 Tre hydrogen fuel-cell trucks to the same company in the next two years.[65]

On Transportation Day, at Paris 2021, Canada and 14 other nations committed to accelerating the shift towards zero emission medium- and heavy-duty vehicles, targeting 30 per cent new Zero Emission Vehicle ("ZEV") sales by 2030 and 100 per cent new ZEV sales by 2040. [66]

On October 21st, 2021, the Government of Canada announced the Zero Emission Vehicle Infrastructure Program, providing financial subsidies for the establishment of electric vehicle charging stations across Canada [67]

As announced on March 29th[68], the Government of Canada will aim to achieve 35 percent of total MHDV (Medium-and-Heavy Duty Vehicle) sales being ZEVs (Zero Energy Vehicles) by 2030. In addition, the Government will develop a MHDV ZEV regulation to require 100 percent MHDV sales to be ZEVs by 2040 for a subset of

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[62] Ismail Barakat, P.Eng.
[63] Electric vehicles, Setting a course for 2030-https://www2.deloitte.com/us/en/insights/focus/future-of-mobility/electric-vehicle-trends-2030.html
[64] Governments unveil details of $590M investment to help Ford Oakville plant make electric cars – https://www.cbc.ca/news/business/ford-oakville-government-1.5754974
[65]https://www.msn.com/en-ca/autos/news/ev-startup-nikola-delivers-its-first-electric-semi-trucks-to-l-a-customer/ar-AARZEjm?ocid=msedgdhp&pc=U531
[66] https://electricautonomy.ca/2021/11/09/cop26-zero-emission-truck-bus-canada/
[67] https://www.nrcan.gc.ca/energy-efficiency/transportation-alternative-fuels/zero-emission-vehicle-infrastructure-program/21876
[68] https://www.canada.ca/en/environment-climate-change/news/2022/03/2030-emissions-reduction-plan--canadas-next-steps-for-clean-air-and-a-strong-economy.html

vehicle types based on feasibility, with interim 2030 regulated sales requirements that would vary for different vehicle categories based on feasibility, and explore interim targets for the mid-2020s.

Electric vehicles have lower operating costs than fossil fuel-driven vehicles. According to Canadian electric truck manufacturer *Lion Electric*, an electric truck saves 80% on energy costs, and 60% on repair costs, compared to a diesel truck.[69] The world's biggest truck manufacturer, *Daimler Truck AG*, plans to ramp down internal combustion engine (ICE) powertrain spending and redirect research and development to zero-emission vehicle (ZEV) technologies by 2025.[70]

A weakness of current battery-driven vehicles is that the batteries must be recharged after several hours of operation. Recharging requires anywhere from fifteen minutes to ten hours, before the vehicle battery is fully charged.

Electric freight and delivery vehicles are more suited to urban, stop-and-go transportation than to long-distance highway deliveries. Within an urban environment, the electric vehicles are never far from their home charging stations.[71]

An example of effective use of electric vehicles within a confined area is the electric shuttle buses for passengers in the Calgary Airport. These electric shuttle buses were designed, built and supplied by a consortium of Québec companies.[72]

On April 4th, General Motors announced that it will spend $1 billion in Ontario, mostly to convert existing motor vehicle assembly plants at Ingersoll and Oshawa to manufacture electric commercial vehicles. Canada and Ontario area each contributing $259 million to this project.[73]

Transformation from Diesel to Electric Batteries or Hydrogen

If Ontario's 135,000 large, diesel engine vehicles[74] were replaced by battery-powered or hydrogen-powered vehicles, how much electrical energy would be

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[69] Lion Electric: EVs save transport firms 80% on energy, 60% on repair costs compared to diesel https://www.transportdive.com/news/Lion-Electric-trucking-total-cost-of-ownership-diesel/596640/

[70] Stand-alone Daimler Trucks to focus on zero-emission future - https://www.trucknews.com/transportation/standalone-daimler-trucks-to-focus-on-zero-emission-future/1003151271/

[71] Interview with Professor Matthew Roorda.

[72] http://medias.mtq.fabrique3.net.s3.amazonaws.com/wp-content/uploads/2015/10/CIAO-047_-_MTQ_-_LGS_-_Rapport_FR_v5_V.pdf

[73] https://www.chathamdailynews.ca/news/local-news/500m-government-funding-super-charges-gms-push-on-electric-vehicles-2

[74] Statistics Canada – Vehicle Registrations - https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2310006701&pickMembers%5B0%5D=1.7&cubeTimeFrame.startYear=2015&cubeTimeFrame.endYear=2019&referencePeriods=20150101%2C20190101

required to charge or fuel the new vehicles? How could we generate this new electrical energy?

For a complete calculation, see :
Appendix 2:
Pathways to Supply Electrical Energy for Electric and Hydrogen Trucks

To convert all of Ontario's 135,000 highway trucks from diesel to electric battery or hydrogen power, Ontario would need to generate **23 terawatt-hours** of additional electrical energy per year.

Ontario's **existing non-fossil fuel generation system** would be able to provide a small fraction of this additional 23 terawatt-hours, on windy nights.

Ontario's **natural gas-fired generators** have enough unused capacity to generate the additional 23 terawatt-hours that would be required to charge the trucks, provided that the trucks were not charging during times of peak electricity demand.

In the absence of major changes in the electricity generation fleet, this natural gas-fired capacity would become the major source of electrical energy to charge electric vehicles in Ontario. The promoters of electric vehicles should realize that most of the electrical energy to charge these vehicles would come from natural gas-fired generators.

The use of Ontario's existing gas-fired generators to charge electric vehicle batteries would be attacked by non-government organizations and by some municipal governments that have pledged to end fossil-fuel energy.

If we chose to generate all 23 terawatt-hours from new **wind turbines**, we would need to install **9323 new, 1-megawatt wind turbines**. These new wind turbines would cover **6,060 square kilometres** of land area, in windy areas of Ontario.

If we chose to generate all 23 terawatt-hours from new **photovoltaic** (solar electric) modules, we would need to install **79.3 million square metres of new photovoltaic modules, covering a land area 13 kilometres by 13 kilometres.**

If we chose to generate all 23 terawatt-hours from new Candu **nuclear** reactors, we would need **three new, Bruce-size Candu nuclear units**.

These calculations do not account for inefficiencies of electrolysis, energy storage, battery charging, hydrogen compression, or electricity transmission.

An even greater challenge would be the installation of thousands of vehicle battery chargers. One of the most recent battery-powered heavy freight trucks, the *Volvo* FH Electric, can be fully charged over 9.5 hours at 43 kW AC or over 2.5 hours at 250 kW

DC.[75] Can Ontario install thousands of chargers, to provide these kilowatts at thousands of locations, to charge thousands of electric freight trucks, rapidly? (Ontario has 135,000 large diesel highway trucks.) Each charger would require a massive distribution line, transformer, and rectifier, to deliver the power from the high voltage AC transmission line to the low voltage DC charger.

The purpose of this calculation is to show that a complete conversion of Ontario's freight vehicle fleet from diesel to electric would require an enormous increase in Ontario's electrical generation, transmission and distribution capacity. Conversion of private motor vehicles from gasoline to electric would require even more new capacity.

In its 2020 Annual Planning Outlook, Ontario's *Independent Electricity Systems Operator ("IESO"*[76] reminds us that the federal government has set a long-term sales target of 100 percent zero-emission vehicles by 2040, with interim sales goals of 10 per cent by 2025 and 30 percent by 2030. Here is IESO's forecast of total electrical energy consumption by electric vehicles in Ontario:

> "Overall, electric vehicle electricity demand is forecast to grow in Scenario 1, from 0.4 TWh in 2022 to 4.1 TWh in 2040, an average annual growth rate of 15.2 per cent, and in Scenario 2, from 0.3 TWh in 2022 to 3.1 TWh in 2040, an average annual growth rate of 14.5 per cent."

IESO's forecast of total electrical energy consumption by all Ontario electric vehicles, cars and trucks, is much smaller than the total energy that would be required by the freight truck fleet, if all diesel freight trucks were replaced by electric.

Government Programs and Policies

2030 Emissions Reduction Plan: Canada's Next Steps for Clean Air and a Strong Economy

March 29, 2022

"Making it easier for Canadians to switch to electric vehicles through additional funding of $400 million for zero-emission vehicles (ZEVs) charging stations, in support of the Government's objective of adding 50,000 ZEV chargers to Canada's network. In

[75] Electric trucks. Ready to deliver - https://www.volvotrucks.com/en-en/trucks/alternative-fuels/electric-trucks.html

[76] https://www.ieso.ca/en/Sector-Participants/Planning-and-Forecasting/Annual-Planning-Outlook

addition, the Canada Infrastructure Bank will also invest $500 million in ZEV charging and refueling infrastructure.

The Government of Canada will provide $1.7 billion to extend the Incentives for Zero-Emission Vehicles (iZEV) program will make it more affordable and easier for Canadians to buy and drive new electric light-duty vehicles. The Government will also put in place a sales mandate to ensure at least 20 percent of new light-duty vehicle sales will be zero-emission vehicles by 2026, at least 60 percent by 2030 and 100 percent by 2035.

To reduce emissions from medium- and heavy-duty vehicles (MHDVs), the Government of Canada will aim to achieve 35 percent of total MHDV sales being ZEVs by 2030. In addition, the Government will develop a MHDV ZEV regulation to require 100 percent MHDV sales to be ZEVs by 2040 for a subset of vehicle types based on feasibility, with interim 2030 regulated sales requirements that would vary for different vehicle categories based on feasibility, and explore interim targets for the mid-2020s."[77]

Canada's National Budget, April 6, 2022

"To help build more resilient and efficient supply chains, Budget 2022 proposes to provide $603.2 million over five years, starting in 2022-23, to Transport Canada, including:

$450 million over five years, starting in 2022-23, to support supply chain projects through the National Trade Corridors Fund, which will help ease the movement of goods across Canada's transportation networks. This is in addition to the $4.2 billion that has been allocated to the fund since 2017. The Minister of Transport will rename the fund to reflect the government's focus on supply chains;

$136.3 million over five years, starting in 2022-23, to develop industry- driven solutions to use data to make our supply chains more efficient, building on the success of initiatives like the West Coast Supply Chain Visibility Program. Of this amount, $19 million will be sourced from existing resources; and

$16.9 million over five years, starting in 2022-23, to continue making Canada's supply chains more competitive by cutting needless red tape, including working to ensure that regulations across various modes of cargo transportation (e.g., ship, rail) work effectively together.

"Building a National Network of Electric Vehicle Charging Stations
Since 2015, the federal government has helped build almost 1,500 charging stations across the country. As more and more Canadians adopt zero-emission vehicles, we

[77] https://www.canada.ca/en/environment-climate-change/news/2022/03/2030-emissions-reduction-plan--canadas-next-steps-for-clean-air-and-a-strong-economy.html

need to build the charging infrastructure that drivers can rely on, no matter where they're going.

"Budget 2022 announces that the Canada Infrastructure Bank will invest $500 million in large-scale urban and commercial ZEV (Zero Emission Vehicle) charging and refuelling infrastructure. Funding will be sourced from the Canada Infrastructure Bank's existing resources under its green infrastructure investment priority area.

"Budget 2022 proposes to provide $400 million over five years, starting in 2022-23, to Natural Resources Canada to fund the deployment of ZEV charging infrastructure in sub-urban and remote communities through the Zero-Emission Vehicle Infrastructure Program (ZEVIP).

"Budget 2022 proposes to provide $2.2 million over five years, starting in 2022-23, to Natural Resources Canada to renew the Greening Government Operations Fleet Program, which will continue to conduct readiness assessments of federal buildings required to facilitate the transition of the federal vehicle fleet to ZEVs.
Helping Businesses Switch to Medium- and Heavy-Duty Zero-Emission Vehicles
Businesses across Canada want to upgrade their fleets to be part of the solution to climate change. However, those upgrades can be expensive, and businesses need to be confident that ZEVs can reliably transport their goods to market.

"Budget 2022 proposes to provide $547.5 million over four years, starting in 2022-23, to Transport Canada to launch a new purchase incentive program for medium- and heavy-duty ZEVs.

"Budget 2022 proposes to provide $33.8 million over five years, starting in 2022-23, with $42.1 million in remaining amortization, to Transport Canada to work with provinces and territories to develop and harmonize regulations and to conduct safety testing for long-haul zero-emission trucks.

"With these investments, the government is taking a significant step towards reducing pollution on our roads, and is on track to meet its commitment to add 50,000 new ZEV chargers and hydrogen stations across Canada."[78]

Carbon pricing

Under Canada's *Greenhouse Gas Pollution Pricing Act* (2018)[79], Ontario's long-distance truckers pay a carbon tax for each litre of diesel fuel that they purchase. In 2021, the

[78] https://budget.gc.ca/2022/report-rapport/chap2-en.html
[79]Carbon pollution pricing systems across Canada
https://www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work.html

carbon tax is 10.73 ¢/L. This carbon tax is part of the overall price of diesel fuel, averaging about $1.30/L in Ontario.

A typical long-distance truck, travelling 200,000 km/y in Ontario, at a fuel economy of 3.0 km/L, pays about $86,700/y for diesel fuel, the most expensive component in operating costs.

By 2030, the carbon tax will increase to 45.56 ¢/L. The annual fuel cost for the truck described above will increase to $110,000/y. This cost will be passed on to customers and consumers. Trucking is not eligible for rebates. None of the revenues from the carbon tax are being used to improve truck efficiency.

This massive increase in fuel cost will certainly motivate truckers to increase their fuel efficiency, by various methods. The 2030 carbon tax may also motivate shippers to ship their goods through the USA instead of Canada.

Canada Clean Fuel Standard

At time of writing, the *Canada Clean Fuel Standard* is still under discussion.[80]
The proposed Canada Clean Fuel Standard would require fuel suppliers to report the carbon intensity of their product, well-to-wheel, and, in 2022, to reduce this carbon intensity in delivered fuel by 2.4 grams CO_2 per megajoule of fuel energy, compared to 2016. This reduction would increase, year-over-year, to 12.0 grams CO_2 per MJ of fuel energy, by 2030. Reductions in emissions intensity can come from improvements in efficiency of production and delivery, switching to a lower-intensity feedstock, or blending biofuels into the final product.

The federal government claims that adoption of the Canada Clean Fuel Standard would reduce the carbon intensity of liquid fuels by 13% by 2030. This proposed federal government program is similar to programs in other states and provinces.

> How would this work for diesel truck fuel? In 2016, one litre of diesel fuel contained 38.3 [81] MJ of fuel energy, and emitted 2700 grams of CO_2 [82] , when burned in the engine. CO_2 emissions were therefore 70.4 grams of CO_2 per MJ of fuel energy. This calculation does not include the GHG emissions from production, refining and delivery of the diesel fuel to the service station, which add about 30% to the total

[80] Canadian Clean Fuel Standard https://www.canada.ca/en/environment-climate-change/services/managing-pollution/energy-production/fuel-regulations/clean-fuel-standard.html
[81] US Energy Information Agency: https://www.eia.gov/energyexplained/units-and-calculators/energy-conversion-calculators.php
[82] https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/oee/pdf/transportation/fuel-efficient-technologies/autosmart_factsheet_9_e.pdf

"well-to-wheel" emissions.[83] Diesel from Canadian Oil Sands is from 8% to 18% higher in well-to-wheel emissions than diesel from conventional petroleum.[84]

On August 25th, 2021, Imperial Oil announced that it plans to build a new renewable diesel unit at its Strathcona Refinery, near Edmonton[85]. The proposed unit would use the HDRD process to produce 20,000 barrels per day (3.18 million litres per day) of biodiesel, to be blended with petroleum-based diesel. This addition of biodiesel would meet some of the requirements of Canada's Clean Fuel Standard.

NRCan's Greening Freight Programs

NRCan's Greening Freight Programs[86] provide training, tools and resources to help Canada's truck fleets lower their fuel consumption, operating costs and GHG emissions.

These programs include:

- Smart Driver Training.
- Green Freight Assessment: Helping companies to lower fuel costs and emissions, by supporting decision-making and investments in fleet energy assessments, retrofits and fuel switching.
- SmartWay Transport Partnership: Originally developed by the USEPA, Smart Way has been promoted in Canada by NRCan since 2012. SmartWay encourages best practices in freight supply chains. It helps carriers and shippers benchmark their operations, track fuel consumption and improve their overall performance.

Canada Emission Standards

In 2018, Canada passed a regulation, specifying the phased, year-by-year standards for GHG emissions from freight trucks.[87] The regulation is harmonized with the corresponding *USEPA* regulation.

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[83] Canada Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations guidance document https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/publications/vehicle-emission-regulations-guidance-document.html

[84] Oil Sands – GHG Emissions - https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/eneene/pubpub/pdf/12-0614-OS-GHG%20Emissions_eu-eng.pdf

[85] Imperial to produce renewable diesel at Strathcona refinery https://news.imperialoil.ca/news-releases/news-releases/2021/Imperial-to-produce-renewable-diesel-at-Strathcona-refinery/default.aspx

[86] NRCan Greening Freight Programs - https://www.nrcan.gc.ca/energy-efficiency/transportation-alternative-fuels/greening-freight-programs/21044

[87] Ibid., 59.

These maximum emission standards for large trucks range from 72 grams CO_2 per ton-mile (49 g/t-km) to 124 grams per ton-mile (85 g/t-km), depending on the body style and age of the truck.

OTA maintains that the phased emission standards were implemented without the consent of the trucking industry.[88]

National Trade Corridors Fund

The $4.2 billion National Trade Corridors Fund (NTCF) helps fund infrastructure projects in Canada. Infrastructure projects could include work to airports, ports, railways, transportation facilities, and access roads.[89]

Ontario's Autonomous Vehicle Innovation Network

Through the *Autonomous Vehicle Innovation Network* (AVIN)[90], the Ontario Government supports the development of new technologies, to transform our road vehicle system. AVIN capitalizes on the economic potential of automotive and truck technologies and smart mobility solutions such as connected and autonomous vehicles (C/AVs). It enables the province's transportation and infrastructure networks to plan for and adapt to this evolution.

Each AVIN program supports the development and demonstration of motor vehicle technologies and mobility solutions such as connected and autonomous vehicles (C/AVs), in areas such as:

- Heavy duty vehicles (commercial vehicles, trucks, buses, recreational vehicles, and others used for goods movement)
- Transportation infrastructure
- Intelligent transportation systems (ITS)
- Transit-supportive systems and vehicles

Successful applicants can have up to one-third of their project funding covered by AVIN.

Lessons from Other Jurisdictions

Here are some good examples of government activities in other jurisdictions to reduce GHG emissions from freight transport:

Québec

[88] Interview with Lak Shoan, Ontario Trucking Association
[89] https://tc.canada.ca/en/programs/funding-programs/national-trade-corridors-fund
[90] Ontario's Autonomous Vehicle Innovation Network https://www.avinhub.ca/about/

In Québec, the *Action Plan on Climate Change* (PACC) 2006-2012[91] targeted two measures to reduce GHG emissions from freight transport: Measure 8 was intended to foster the implementation of intermodal projects, while Measure 9 aimed to improve energy efficiency in freight transport.

These measures have resulted in two government programs: *PAREGES* (Assistance Program Aiming to Reduce or Avoid Greenhouse Gas Emissions through the implementation of intermodal Rail and Marine Transport projects) and *PEET* (Assistance Program for Improving Energy Efficiency in Road, Rail and Marine Transportation), both closed in March 2013.

The Québec Government has established *Propulsion Québec*[92], an organization to rally the electric vehicle sector around joint projects, aimed at positioning Québec as a global leader in developing and implementing smart and electric modes of ground transportation.

The Écocamionnage Program, which was re-started in December,2021, provides support to activities and equipment, including electric vehicles, to reduce the emissions of GHGs by highway transport trucks. [93]

British Columbia

In 2020, as part of the Clean BC Program, A sum of $5 million will be dedicated to purchasing incentives for zero-emission buses and heavy-duty vehicles such as trucks, marine vessels and airport ground equipment. Funding for new public fast-charging and hydrogen stations for zero-emission vehicles will also be supplied to the tune of $2 million.[94]

The web magazine Electric Autonomy reports that BC is offering up to $100,000 rebates for medium- and heavy-duty electric trucks.The rebates are part of B.C.'s Go Electric Specialty Use Vehicle Incentive (SUVI) program..[95]

BC has established a hub of information and incentive programs for consumers and fleets to go electric, through *Plug In BC*.[96]

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[91] Quebec - 2013-2020 Climate Change Action plan -Phase 1 - https://www.environnement.gouv.qc.ca/changements/plan_action/pacc2020-en.pdf

[92] Gouvernement du Québec https://propulsionquebec.com/wp-content/uploads/2020/12/PropulsionQc_Rapport_E_lectrification_des_parcs_de_ve_hicules_EN_v2-1.pdf

[93] https://www.transports.gouv.qc.ca/fr/aide-finan/entreprises-camionnage/aide-ecocamionnage/Pages/aide-ecocamionnage.aspx

[94] https://electricautonomy.ca/2020/02/20/b-c-government-announces-419-million-additional-funding-for-cleanbc-plan-in-2020/

[95] https://electricautonomy.ca/2021/05/20/incentives-electric-heavy-duty-trucks/

[96] https://pluginbc.ca/

California

In June, 2020, the *California Air Resources Board* adopted a rule requiring truck manufacturers to transition from diesel trucks and vans to electric zero-emission trucks, beginning in 2024.[97] By 2045, every new truck sold in California will be zero-emission.

California's *Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project* (HVIP) provides incentives to purchase the cleanest medium- and heavy-duty trucks.[98]

Since 2014, California has supported *Low Carbon Transportation Heavy-duty Pilot and Demonstration Projects*.[99]

In just the first half of 2020, RNG made up nearly 90% of all natural gas vehicle fuel consumed in California.[100]

Since 2014, heavy duty freight trucks in California must use *Smartway* technologies to reduce their fuel consumption and GHG emissions.[101]

European Union

Europe's steps towards reducing CO_2 emissions from freight trucks, as published by the *European Commission* (EC, 2014).[102] include a strategy for reducing Heavy Duty Vehicle fuel consumption and CO_2 emissions. A number of the actions foreseen in the strategy have since been initiated, including:

- Development of a computer simulation tool — the *Vehicle Energy Consumption Calculation Tool (VECTO)* — to estimate fuel consumption and CO_2 emissions from heavy duty vehicles.[103]

[97] https://www.gov.ca.gov/2020/09/23/governor-newsom-announces-california-will-phase-out-gasoline-powered-cars-drastically-reduce-demand-for-fossil-fuel-in-californias-fight-against-climate-change/

[98] Hybrid And Zero-Emission Truck And Bus Voucher Incentive Project - https://californiahvip.org/

[99] California clean trucks websites https://ww2.arb.ca.gov/search/site?keys=trucks

[100] https://www.act-news.com/news/is-rng-a-california-only-fuel/

[101] Facts AboutTractor-Trailer Greenhouse Gas Regulation - https://ww2.arb.ca.gov/sites/default/files/classic/cc/hdghg/fact_sheets/hdghg_genl_fact_sheet.pdf

[102] https://www.eea.europa.eu/themes/transport/heavy-duty-vehicles/carbon-dioxide-emissions-europe

[103] https://ec.europa.eu/clima/policies/transport/vehicles/vecto_en

- New legislation to specify and limit CO_2 emissions and fuel consumption from new heavy duty vehicles.[104]

- Analytical work in view of setting potential future heavy duty CO_2 emission standards.

Summary of Recommendations

In the big picture, what should we do to reduce GHG emissions from freight trucks in Ontario?

There is a need for action. Climate change, caused by our emission of GHGs is already causing human suffering in many parts of the world, including Ontario. Reducing GHG emissions must be a government priority, as significant as maintaining the health care system. Canada has committed to reduce its GHG emissions by 40-45 percent below 2005 levels, by 2030. GHG emissions by heavy duty diesel vehicles are the fastest-increasing GHG emissions from Ontario sources. In Ontario, we must and can reduce significantly our GHG emissions from heavy trucks by 2030.

There is a need for unity. The Canadian Government, the Ontario Government, the Québec Government, municipal governments, industry associations, labour unions, the USA Federal Government, and US state governments must work together in a coordinated fashion, to reduce GHG emissions from diesel trucks. Many of the industry experts interviewed in this study expressed their concerns about the lack of coordination between levels of government, e.g. the provincial government has jurisdiction over motor vehicles and highways, while the federal government has jurisdiction over railways and marine. During the 1950s, Canada's government delegated the authority over inter-provincial trucking to the provinces, reducing the opportunity for national coordination.[105] Several attempts to interest provincial officials in the advantages of truck-to-marine intermodal freight shifting met with zero response.

One encouraging development was the National Supply Chain Summit, on January 31st, which brought together business and industry leaders and associations to discuss the challenges facing Canada's supply chain and to identify potential solutions. To further advance this work, a new Supply Chain Task Force will be created. The Task Force will consult with industry experts to make recommendations regarding short and long-term actions pertaining to Canada's supply chain. In addition, Transport Canada will make available an online portal for stakeholders and businesses to be able to provide opinions and suggestions.[106]

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[104] https://www.transportenvironment.org/newsroom/blog/what-co2-emissions-deal-means-trucks
[105] Comment from D. Bradley.
[106] https://www.newswire.ca/news-releases/ministers-alghabra-bibeau-champagne-ng-o-regan-and-qualtrough-hosted-a-national-summit-to-strengthen-canada-s-supply-chain-898255705.html

Ontario needs to improve its infrastructure, to achieve the necessary GHG emission reductions from diesel trucks. Ontario needs efficient marine-to-truck intermodal ports and a more efficient, less fragile freight rail network. These infrastructure improvements would cost in the hundreds of millions of dollars, but they would be cost-effective and achievable within the next ten years. Their cost per tonne of GHG emission reduction would be much less than the cost of exotic future technologies.

Practical, achievable actions and technologies are available now. These technologies and actions can reduce significantly our GHG emissions from large diesel trucks within the next ten years. These actions and technologies include:

- Truck Efficiency Improvements:
  - Streamlining of Trucks and Trailers
  - Low rolling resistance tires
  - Longer Containers: from 53 feet to 60 feet
  - Long Combination Vehicles
- Driver Training
- Off-Peak Delivery of Freight
- Transportation Management Systems
- Truck-to-Rail Modal Shift
- Truck-to-Marine Modal Shift
- Natural Gas Fuel

In the **long term** the adoption of **new technologies** is needed. In coordination with other jurisdictions, governments should continue to encourage the Research, Development and Demonstration of new technologies, that will reduce GHG emissions from Ontario freight trucks in the distant future. These technologies include:

- Autonomous Trucks
- Truck Platooning
- BioDiesel Fuel – Production and Use
- Renewable Natural Gas Fuel
- Renewable Ethanol and Methanol in Diesel Fuel
- Electric Battery Infrastructure, Charging and Propulsion
- Hydrogen Infrastructure and Propulsion

Appendix 1. In the Spotlight: Trucks-to-Marine

Using Ships instead of Trucks to Move Freight in the St. Lawrence Seaway/Great Lakes Region.

A significant fraction of the general cargo that is now transported to, from, and within Ontario by trucks or by trains could be carried by ships.

This option has been studied extensively, and promoted by Canada's Government, in the past. The marine option has some enthusiastic promoters, and some skeptic critics.

How would trucks to marine reduce emissions?

According to Canada's *Centre for Marine Commerce*, ships emit much less CO_2 per tonne-km than trucks, and slightly less than rail freight., per tonne-km of freight transportation,

Mode of Transport	GHG Emissions, gCO_2/t-km
Marine	8.1
Rail	13.3
Truck	65.6

(Data from Canada's Centre for Marine Commerce)

Other organizations report different figures for average GHG emissions per tonne-km.

CN recently updated its figures: 12.1 g/t-km for rail, 63.4 g/t-km for trucks.[107]

Major, ocean-going container ships carry up to 26,000 TEUs. (A TEU is a Twenty foot Equivalent Unit, half the size of a typical container.) A container ship that can navigate the St. Lawrence Seaway can carry only 800 TEUs. The Seaway-size container ship would probably have a higher gCO_2/t-km than the Marine figure quoted above.

Peter Hirthe, International Trade Specialist at *The Great Lakes St. Lawrence Seaway Development Corporation*, reports in the Autumn, 2021 edition of *Dry Bulk Magazine* that Great Lakes Seaway commercial navigation, carrying one tonne of cargo for one km, emits 19% fewer GHGs than rail, and 533% fewer GHGs than trucks.[108]

[107] Correspondence with B. Chursinoff, Canadian Railway Association

[108] https://www.drybulkmagazine.com/magazine/

In the EU, the *Port of Rotterdam* offers truck, rail, or barge shipment of cargos to inland European destinations. Rotterdam's GHG figures for transport of one container from The Port of Rotterdam to Dusseldorf, upstream on the Rhine River, are as follows:
by rail: 50 kg CO_2
by barge: 75 kg CO_2
by truck: 185 kg CO_2

Notice that the GHG total for shipment by small barge from Rotterdam, upstream, to Dusseldorf is larger than the GHG total for shipment by rail.[109]

What current actions can guide us to implementing trucks-to-marine?

The *Saint Lawrence Seaway*, opened in 1959, was originally planned as a maritime highway for bulk commodities (e.g. coal, grain, iron ore) and for general cargo (e.g. manufactured items).

Over the years, total shipments of bulk cargo have increased, while shipments of general cargo have decreased. The Seaway is now operating at 40% of design capacity[110]. About 50 percent of total cargo travels to and from overseas ports, especially Europe, the Middle East, and Africa. The remainder is U.S. and Canadian coastal trade..[111]

Marine organizations, notably the *Chamber of Marine Commerce*, the *St. Lawrence Seaway Management Corporation,* the *Port of Hamilton*, and the *Hamilton-Oshawa Ports Authority ("HOPA")*, are enthusiastic about the potential to shift freight from road and rail to ships in the Great Lakes and St. Lawrence Seaway.[112]

In the opinion of Ken Carey at the *St. Lawrence Seaway Management Corporation*, "We need only 5 or 10 shippers to establish a viable, permanent service."

[109] https://rotterdam.navigate-connections.com/voyages
[110] Interview with Jean Aubry-Morin
[111] https://greatlakes-seaway.com/wp-content/uploads/2019/10/overview_brochure-1.pdf
[112] Interviews with St.Lawrence Seaway Management Corporation, Hamilton-Oshawa Ports Authority, and Canada's Centre for Marine Commerce

"Every journey begins with one small step."
In 2009, the *Hamilton-Oshawa Ports Authority* ("HOPA") operated a trial shipment of containers on barges to Montreal.[113]
HOPA ran another container feeder trial this year (2021) between Montreal and Hamilton, three, round-trip voyages. The service will be expanded to 22 voyages in 2022.HOPA's other container feeder trial was with Desgagnes who have general cargo ships that can readily handle containers.
A European shipping line, *Spliethoff Lines*, operates a twice-monthly general cargo and container service through the Seaway, between Antwerp and Cleveland, with occasional stops at Valleyfield, QC and Ramey's Bend, ON.[114]
One Ontario company, *Doornekamp Lines*, has announced that it is beginning a bi-weekly marine container service between Halifax and Picton, Ontario, using a single, 869 TEU container ship. This service could be expanded to other Ontario and USA Great Lakes ports.[115]
In 2020, the *St. Lawrence Seaway Management Corporation* (Canada) and the *St. Lawrence Seaway Development Corporation* (USA) launched The *Highway H_2O* marketing program, to promote the marine mode's ability to deliver cargo reliably and efficiently, while complementing existing road and rail intermodal network.[116]
The *Port of Hamilton* is planning to increase its container marine traffic to 60,000 TEUs per season, shipping containers from Montreal and from Newark, NJ. Sanjeev Saraf of the Port of Hamilton believes that increased marine shipment of containers is essential, because highways and rail intermodal are overloaded, and truck drivers will be scarce.

[113] Interview with Hamilton-Oshawa Ports Authority
[114] https://www.spliethoff.com/contact/north-america-department/
[115] https://doornekamplines.ca/
[116] https://hwyh2o.com/home/

What is the potential GHG emissions reduction from modal shift: trucks to marine?

One calculation can illustrate the potential for GHG emission reductions in shifting general cargo from rail and truck to ships in the Great Lakes and St. Lawrence Seaway.

According to the *MTO Commercial Vehicle Survey*[117], on an average day in 2020 the freight truck traffic between the County of Stormont, Dundas and Glengarry (near the QC border, near Montreal) and the Regional Municipality of Peel was 326,221 tonnes/day, eastbound plus westbound.

Applying the recognized truck emission factor of 65.6 grams of CO_2 per tonne-km, and multiply by 365, and by the distance between Montreal and Peel of 485 km, the total annual GHG emissions from these truck freight shipments were 3.79 megatonnes of CO_2.

If one-half of the freight were shifted from these trucks to marine, at the recognized marine emission factor of 8.1 grams CO_2/tonne-km, the total annual GHG emissions from the ships would be 0.23 Mt/y CO_2. However, the total annual emissions from trucks would be only 1.89 Mt.

The net reduction in Annual GHG emissions would be 1.66 Mt CO_2.

This calculation represents only one of many freight routes in Ontario that could shift some freight from trucks to marine. (e.g. data from 2006 [118] indicated that from GTHA to Illinois, 3121 t/day; Illinois to GTHA, 3124 t/day).

What would be other environmental impacts and benefits of this change from trucks to marine?

The operation of a new fleet of Great Lakes vessels would have some environmental impacts (e.g., NOx and SO_2 from engine exhaust, ballast water contamination of lakes, impairment of marine life). The Chamber of Marine Commerce is working to reduce these environmental impacts from Canadian ships.[119] The industry's Green Marine

[117] Ontario Ministry of Transport Commercial Vehicle Survey https://www.arcgis.com/apps/MapSeries/index.html?appid=a0cc97d7ca8643998033b5ba7183e838

[118] Data provided by Maddy Ewing, Pembina Institute

[119] Canada's Chamber of Marine Commerce https://www.marinedelivers.com/media_release/great-lakes-ships-are-most-carbon-friendly-and-efficient-transport-mode-new-study/

organization is well positioned to make environmental improvements within the fleet and ports.[120]

The net environmental benefit from the shift would be positive. The environmental impacts of the new ships and port facilities would be less than the eliminated environmental impacts from trucks and highway congestion.

What are the economic opportunities or barriers to the adoption of increased marine freight?

The combined labour and fuel cost for ships would be much lower than the cost for the equivalent number of trucks. Approximately 30,000 tonnes of cargo can be moved by one single, Seaway-sized ship, or by 800 trucks. However, existing regulations add to the cost of marine shipping.

Any major container traffic between ocean commerce and the Great Lakes would probably require transfer of containers at Montreal or Halifax, between large, ocean-going container ships and 800-TEU, Seaway-size ships. This transfer of containers from large, maximum-size container ships to smaller, Seaway-size ships would be similar to what is already done in the Port of Rotterdam[121] and in the Pearl River Delta, China.[122]

Canada intends to apply a carbon tax to the consumption of hydrocarbon fuels by Canadians. The carbon tax will increase to $170.00/t$CO_2$ in 2030.[123] At this rate of carbon tax, the above net reduction of 3.7 Mt/year between Montreal and Region of Peel would result in carbon tax savings of $629 million/year.

An economic barrier to marine freight is the short-distance truck delivery that would be required at the origin and destination. The convenience factor of delivery-to-your-door favours trucks over other modes of transportation. Highway infrastructure improvements near ports could reduce this disadvantage to ships.

A few words of caution: The 2015 study entitled Short Sea Shipping and Extending the Seaway Season, by *Marinova Consultants*, describes a situation where government regulations make marine shipment of general cargo from (e.g.) Montreal to Hamilton much more expensive than rail shipment.[124] However, this situation could change if marine regulations were reformed.

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[120] https://green-marine.org/about-us/

[121] https://www.portofrotterdam.com/en/logistics/connections/intermodal-transportation/inland-shipping

[122] How Ocean Shipping Works (And Why It's Broken
https://www.youtube.com/watch?v=8d5d_HXGeMA

[123] Carbon pollution pricing systems across Canada
https://www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work.html

[124] http://www.marinova.com/portfolio/short-sea-shipping-and-extending-st-lawrence-seaway-season

Even if marine freight becomes less costly than truck freight, some shippers will continue to use trucks for “time-sensitive” shipments, while less time-sensitive shipments can arrive by the slower but less costly marine route.

One possible concern is that shipments eastbound and shipments westbound should be approximately equal in value, to create positive revenue for shippers in both directions.

Dave Cardin, of *Gateway Consultants*, former President of *Maersk Canada*, reminds us that the Canadian Government in the past did promote marine transport of general cargo on the Great Lakes.[125]

What changes in infrastructure would be needed to take advantage this shift from trucks to marine?

A major disadvantage to shifting freight from truck and rail to marine in the Seaway is the annual winter shutdown of the Seaway, December 31 – March 31. (In 2020-2021, the Seaway was open until January 8th.)[126] Opportunities to reduce this winter shutdown are under study. *HOPA*[127] suggests that shipping could continue in the Seaway during the winter, operating smaller barges than in summer. Shipping could continue during the winter in the Great Lakes, even with the winter Seaway shutdown. Global warming is already increasing the number of ice-free days per year in the Great Lakes and the Seaway.

Several interviewed experts noted that an efficient marine system requires efficient cranes, access roads, and port facilities. As a recent Youtube video remainds us, an efficient container ship port needs labour, transportation, and infrastructure.[128] At present, in the Canadian ports on the Great Lakes, ships use their own cranes to load and unload containers. In contrast, efficient container ports use modern container cranes. Sanjeev Saraf, of the *Port of Hamilton*, reports that each *Port of Hamilton* crane completes less than 10 lifts per hour, while each container crane in the international port of Dubai completes 35 lifts per hour[129]. Another option for loading and unloading is “roll on, roll off”, where the trucks themselves drive into the ships.

Any major changes in infrastructure and work force would require agreement between the marine industry and labour organizations.

[125] Interview with D. Cardin, November 25, 2021
[126] Conversation with Sanjeev Saraf, Port of Hamilton
[127] Interview with Hamilton-Oshawa Ports Authority
[128] https://www.youtube.com/watch?v=8d5d_HXGeMA
[129] Interview with Sanjeev Saraf, Port of Hamilton

What institutional or regulatory barriers should be reduced to take advantage of this shift from trucks to marine?

One person interviewed mentioned the Harbor Maintenance Tax in USA ports as a barrier.

The *Chamber of Marine Commerce* is concerned about the expense imposed by the requirements for harbour pilots and Seaway pilots.[130] Several persons interviewed mentioned the expense involved in paying pilots to take ships through the St. Lawrence River and the Seaway. It was suggested that Canadian ships, following a set, repetitive route, might not require pilots.

The Harbour Maintenance Tax, which applies to each visit by a foreign vessel, is a key concern for international ferries that could move back and forth multiple times a day and is one reason there is no such service.

Other concerns of the *Chamber of Marine Commerce*:[131]

Canada's Marine Services Fee system — a complex set of fees that has yielded mixed results (it underperforms; collecting about $30M on a required $40M.).

Links between fees paid and support to actual services from various charging institutions has been a sore point for the industry, with some seen as a basic revenue grab.

Cabotage Regulations require Canadian crews on Canadian built ships, when delivering cargos from one Canadian port to another Canadian port. The result: complications in scheduling, and added expense.[132]

A significant regulatory barrier is the lack of coordination between governments in changing the way freight is shipped in the Great Lakes. In Canada, the federal government is responsible for ports and marine traffic, but the provincial governments are responsible for highway traffic. The federal government would provide the incentives and resources for a freight-by-ship program, but the provincial government would be the beneficiary.

Two persons interviewed mentioned a lack of awareness in the *Ontario Ministry of Transport* of the advantages of marine freight traffic.

[130] https://marinedelivers.wpengine.com/pilotage-reform/

[131] Correspondence with Paul Topping

[132] Interview with Dave Cardin.

Paul Topping of the Canada's *Chamber of Marine Commerce* reports that some parts of the Seaway cut through First Nations territory. The First Nations along the route are concerned about shipping, and demanding more say in management decisions of the Seaway.[133]

Many organizations are at the table
A successful shift of freight from trucks to ships would require the coordination of the marine organizations, Canadian and USA, the two federal governments, the Ontario and Québec Governments, the Great Lakes Premiers/Governors Council, and the labour organizations responsible for longshoring, marine transport and truck transport.

What would be the other, non-GHG benefits in shifting freight from trucks to marine?

These benefits would include:

- Reduced highway congestion
- Safer highways
- Less demand for new, bigger highways
- Reduced wear-and-tear on highways
- Health care benefits of faster, more dependable, less overloaded highways
- Reduced shortages of truck drivers
- Improved air quality and health benefits from reduced diesel atmospheric emissions[134]

[133] Correspondence with Paul Topping

[134] Quantifying the air quality and health benefits of greening freight movements LauraMinetTufayelChowdhuryAnWangYijunGail. DanielPosenMatthewRoordaMarianneHatzopoulou Environmental Research ,Volume 183, April 2020, 109193, https://doi.org/10.1016/j.envres.2020.109193

What have other states, countries done to shift from trucks to marine?

As part of its 2013-2020 *Action Plan on Climate Change*[135], the *Government of Quebec* established a program to reduce GHG emissions through the development of intermodal transport.

One example of a grant under the *PREGTI* program[136] is a 2015 grant of $3.2 million to Termont Montreal Inc., representing 17% of the cost of replacing two diesel port cranes with electric cranes. Quebec also released the *PETMAF* program for financial aid to projects that improve the efficiency of maritime, air and railway. One PETMAF project was a 2016 grant of $766,000 to Montreal Gateway Terminal, representing 50% of the cost of two container cranes for refrigerated containers.

The *European Union's Marco Polo Programs* ((2003-2013)[137] aimed to relieve congestion on road networks and improve the environmental performance of Europe's freight transport system. It provided financial assistance to use alternative methods of transport with lower environmental impacts, in particular railways, inland waterways and short sea shipping. The first and second Marco Polo programs in total provided EU support in the order of €173 million, which led to a modal shift of 63,8 billion t-km/y, representing a GHG emission reduction of 3.7 Mt/y of CO_2. The container Port of Rotterdam now offers container shipment inland by rail, by truck, or by barge.[138]

On November 15, 2021, *USA President Joe Biden* signed a $1.2 trillion bill to improve USA infrastructure, including $17 billion for ports, and $66 billion for freight and passenger rail improvements, over the next five years. On October 13th, he revealed plans for 24/7 operations of the *Ports of Los Angeles and Long Beach*.[139]

The trade magazine The Loadstar reported on December 8th, 2021 that the USA east coast ports of Elizabeth, NJ and Baltimore, MD are making multi-hundred million dollar expansions in marine-to-rail facilities, to expedite intermodal freight, including freight for Canada.[140]

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[135] QC Air Programs
https://www.transports.gouv.qc.ca/fr/aide-finan/programmes-aide/Pages/Programme-aide-amelioration-efficacite-maritime-aerien-ferroviaire.aspx

[136] QC Air Programs
https://www.transports.gouv.qc.ca/fr/aide-finan/programmes-aide/Pages/Programme-aide-amelioration-efficacite-maritime-aerien-ferroviaire.aspx

[137] Final Report, Marco Polo Programme:
https://ec.europa.eu/inea/sites/default/files/cefpub/mp_ii_report_superfinal2020_metadone_0.pdf

[138] https://www.portofrotterdam.com/en/logistics/connections/intermodal-transportation/inland-shipping

[139] https://www.cnbc.com/2021/12/04/how-amazon-beats-supply-chain-chaos-with-ships-and-long-haul-planes.html

[140] https://theloadstar.com/us-east-coast-ports-make-major-plays-to-become-intermodal-gateways/

Considering these USA efficiency improvements, in the future, Canadian importers may choose to import general cargo through the USA instead of Canadian ports.

What would be the net cost or savings, if we shift freight from trucks to marine?

The 2015 Marinova Report, Short Sea Shipping and Extending the St. Lawrence Seaway Season,[141] presented a less-than-encouraging possibility of expanding general cargo shipping in the St. Lawrence Seaway and Great Lakes. According to the Marinova Report, the superior energy efficiency of ships, compared to rail or trucks, is not enough to overcome serious regulatory barriers and expensive longshoring labour costs. The winter shutdown of the St. Lawrence Seaway also adds complications to marine shipping.

The cost picture is somewhat distorted by the fact that truck shippers do not pay for highways, but marine shippers do pay for the Seaway pilots and facilities.

However, the marine situation may be changing rapidly. Climate change is increasing the length of the St. Lawrence Seaway season. In 2020-2021, the Seaway season was extended from December 31st to January 8th.[142]

The increasing cost of fuel and increasing carbon taxes could make the cost of freight by ship lower than the cost of freight by truck. The increasing congestion on highways and the increasing shortage of truck drivers could necessitate the shift of freight from trucks to ships.

A marine freight system with obviously lower costs for labour, energy and GHG would probably be lower in cost per tonne than truck shipments, if the marine regulatory barriers were removed.

Trucks to Marine: Time to Commercialize

According to Peter Hirthe, *Great Lakes St. Lawrence Seaway Development Corporation*, the Great Lakes-St. Lawrence Seaway System includes over 100 ports of varying capacity, of which over 40 ports offer intermodal connectivity. Since 2009, the USA and Canada have invested over $1 billion (US) in rebuilding lock and channel infrastructure. Public and private capital investments since 2009, including new ships, total almost $7 billion (US)[143]

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[141] http://www.marinova.com/portfolio/short-sea-shipping-and-extending-st-lawrence-seaway-season

[142] Interview with Sanjeev Saraf, Port of Hamilton

[143] "Can't Stop the Cargo", Peter Hirthe, International Trade Specialist, The Great Lakes St. Lawrence Seaway Development Corporation, Dry Bulk Magazine, Autumn 2021, pp 37-39 https://www.drybulkmagazine.com/magazine/

At the same time, Canadian Great Lakes ports do not have efficient infrastructure. Two persons interviewed said that loading and unloading containers at Canadian Great Lakes ports, and transferring containers to trucks or trains, is slow and awkward.[144]

The St. Lawrence Seaway facilities are already available. Development of efficient port facilities would require 5 – 10 years.

What should governments and industry do to implement trucks-to-marine?
Coordination between Governments and Organizations A significant regulatory barrier is the lack of coordination between governments in changing the way freight is shipped in the Great Lakes. In Canada, the federal government is responsible for ports and marine traffic, but the provincial governments are responsible for highway traffic. The federal government would provide the incentives and resources for a freight-by-ship program, but the provincial government would be the beneficiary.
Recognition of Maritime Commerce Marine freight would benefit from a dedicated, high profile government support program, similar to the successful Marco Polo program in Europe. The ports must also show commitment to the new marine freight shipments. There is a lack of awareness in the Ontario Ministry of Transport of the advantages of marine freight traffic.

[144] Interviews with Sanjeev Saraf, Port of Hamilton, and Ben Doornekamp, Doornekamp Lines

Reducing Regulatory Barriers

The 25 % duty required by the federal government on purchase of foreign-built ships is an obstacle to re-establishing a Seaway-Great Lakes fleet.

There is significant cost in paying Pilots to take ships through the St. Lawrence River and the Seaway. If Canadian ships followed a set repetitive route there would not be a need for Pilots.

The Harbor Maintenance Tax in USA ports is a barrier.

Better Data

Marine commerce would greatly benefit from more extensive and accurate data, concerning freight shipments, flow of goods, capacity, bottlenecks. Currently, Transport Canada, HOPA and McMaster University are establishing a data hub to assist in marine freight transport.

Infrastructure

With climate change increasing the length of ice-free operation in the Seaway and Great Lakes, Canada and the USA should consider with renewed enthusiasm the possibility of operating the St. Lawrence Seaway for 12 months of the year.

The Great Lakes ports themselves would greatly benefit from improved infrastructure, cranes, road and rail access, and port facilities.

Seed Capital

Short-sea shipping in the Saint Lawrence Seaway and the Great Lakes could certainly benefit from federal government support for seed capital to reduce the risk in start-up of new endeavours.

Appendix 2.
Pathways to Supply Electrical Energy – Calculations

If all the highway diesel trucks in Ontario were replaced by battery-powered or hydrogen-powered, how much new electrical energy would we need to generate?

Total diesel fuel consumed in Ontario in 2019: 5.57×10^9 Litres[145]

Fuel energy per litre: 38.3×10^6 Joules [146]

Total fuel energy in all the diesel fuel consumed:

$5.57 \times 10^9 \times 38.3 \times 10^6 = 213 \times 10^{15}$ Joules

Efficiency of a highway diesel truck engine: 39% [147]

Total mechanical energy generated by truck engines in Ontario in 2019:

$0.39 \times 213 \times 10^{15} = 84 \times 10^{15}$ Joules = **84 Petajoules**

Electrical energy equivalent of 84 Petajoules:

$84 \times 10^{15} / 3.6 \times 10^3 = 23 \times 10^{12}$ Watt-hours = **23 Terawatt-hours**

How could Ontario generate 23 Terawatt-hours of new electrical energy, to charge all the batteries or all the electrical energy for its entire highway truck fleet?

(1)
Existing Generating Capacity, Non-Fossil Fuels:
In 2020, Ontario's grid-connected electricity system exported 20.4 TWh of electrical energy to neighbouring states and provinces, and imported 5.2 TWh from these same states and provinces. Ontario's 15.2 TWh of net surplus energy was generated mostly on windy nights, when the wind power fleet, the nuclear fleet, and the large-scale hydro-electric fleet were all generating at full capacity. During these fortunate circumstances, **Ontario's existing non-fossil fuel electricity system would be able to provide enough power to charge a small fraction of 135,000 battery-driven trucks, if the trucks were charging on windy nights.**

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(2)
Existing Natural Gas-Fired Capacity:

According to IESO data, in 2019, 10,515 megawatts of natural gas-fired generators were supplying power to the grid. If these natural gas generators had been operating continuously, 100% of the time, they would have supplied 92 terawatt-hours of electrical energy to the grid. However, in 2019, these gas-fired generators supplied only 9.5 terawatt-hours of energy, about 10.5% of their potential. **The unused potential of the gas-fired fleet could provide the additional 23 terawatt-hours that would be required to charge 135,000 electric, highway trucks, provided that the trucks were not charging during times of peak electricity demand.**

How much GHG would this additional gas-fired generation emit? A comparison of the IESO generation data with Canada's Greenhouse Gas Inventory for 2019 shows that the average GHG emission rate for fossil-fuel electricity generation in Ontario was 408 tonnes of CO_2e per megawatt-hour of generation. Applying this emission factor, we can predict that if the gas-fired fleet provided the electrical energy to charge the trucks, the generators would emit 9.4 megatonnes per year of new CO_2e. However, the 12.7 megatonnes per year emitted by the diesel truck fleet would be eliminated.
Net savings: 3.3 megatonnes per year of CO_2e.

Proponents of electric highway trucks should realize that most of the electrical energy to charge new electric highway trucks would be generated by natural gas-fired generators, unless the Ontario generation mix changes massively.

The use of Ontario's existing gas-fired generators to charge a large number of electric vehicle batteries would be attacked by non-government organizations and by some municipal governments that have pledged to end fossil-fuel energy.

(3)
Wind Energy:

To generate 23 Terawatt-hours per year from
new wind turbines:

Total capacity of grid-connected wind turbines in Ontario in 2020: 4783 x 10^6 Watts

Total energy generated by grid-connected wind turbines in 2020: 11.8 Terawatt-hours
To generate 23 moreTerawatt-hours from new wind turbines, we would need:

(23/11.8) x 4783 = 9323 more megawatts of wind-powered capacity.

We would need 9323 new, 1-megawatt wind turbines.

Each 1 MW wind turbine would require 65 hectares of land , in a windy area of Ontario.
Total land required: 9323 x 65 = 606,000 hectares = **6,060 Square kilometres**.

(4)

Photovoltaic (Solar Electric) Energy:

To generate 23 Terawatt-hours per year from new photovoltaic (solar electric) panels:

478×10^6 Watts of grid-connected solar electric capacity were operating in Ontario in 2020 . This 478 megawatts of solar panels generated a total of 0.749×10^{12} Watt-hours of electrical energy in 2020 .

Each 1-megawatt array of solar panels generated, on average:
$(0.749 \times 10^{12})/(478 \times 10^6) = 1.57 \times 10^9 = 1.57$ GWh/y = 1570 megawatt-hours per year

Therefore, on average, each grid-connected1-kilowatt array of Ontario solar panels generated 1570 kilowatt-hours of electrical energy in 2020.

How many square metres of solar panels would we need to generate this 1670 kilowatt-hours per year?

A typical, high-quality, commercially-available solar panel has an efficiency of about 22%. This figure is defined to mean that when the sun is shining directly on the solar panel, with an intensity of 1,000 watts (1 kilowatt) per square metre, the 1 square metre solar panel will generate 220 watts (0.22 kilowatts) of electric power.

How many kilowatt-hours will a 1 square metre solar panel generate during one year in Ontario?

(22/100) x 1570 = 345 kWh/m2-y

If we replaced all the diesel-powered vehicles in Ontario with battery-powered and hydrogen-powered vehicles, how many square metres of solar panels would we need to generate all the electrical energy to charge the batteries and produce the hydrogen?

$(23 \times 10^{12}) / (345 \times 10^3) = 79.3 \times 10^6$ = **79.3 million square metres**

How much land area would this array of 79.3 million square metres of solar panels cover? Assuming each 1 square metre of solar panel requires 2 square metres of land area, this array of solar panels would cover an area of

$2 \times 79.3 \times 10^6 = 158$ million square metres of land.

This land would cover a square, 13 kilometres by 13 kilometres in area.

(5)
Nuclear Energy:

If the 23 TWh of new electrical energy were generated by new Candu nuclear units, we would need **three new, Bruce-size Candu units**.

These calculations do not account for inefficiencies of electrolysis, energy storage, battery charging, hydrogen compression, or electricity transmission.

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