Greening Freight.

Pathways to Reducing GHG Emissions From Trucking
Preface

At 75.9 megatonnes of carbon dioxide equivalent, or 10.5 per cent of the national total, freight transportation (including trucks, aviation, rail, and marine) is one of the largest contributors to Canada’s greenhouse gas (GHG) emissions. Freight trucks account for a majority share of this figure (83 per cent). In previous research, The Conference Board of Canada concluded that even with some very aggressive assumptions concerning vehicle technology penetration and efficiency gains, GHG reduction targets (i.e., 80 per cent below 1990 levels by 2050) would not be met. This raises important questions about what more can be done to achieve further reductions from road transport, and from freight transportation in particular. Through a literature and policy document review, this report examines technology and policy options to reduce freight transportation GHG emissions in Canada. Pathways examined include reducing the need to travel by truck, increased support for existing fuel-saving devices and disruptive technologies, pricing, and regulations and standards.
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The findings and conclusions of this report are entirely those of The Conference Board of Canada. Any errors and omissions in fact or interpretation remain the sole responsibility of The Conference Board of Canada.
EXECUTIVE SUMMARY

Greening Freight: Pathways to Reducing GHG Emissions From Trucking

At a Glance

- Freight transport is one of the largest contributors to Canada’s greenhouse gas (GHG) emissions. Emissions from freight trucks have increased substantively over the last 25 years.

- Numerous pathways to reduce freight truck GHG emissions exist, including reducing truck travel, using fuel-saving devices and disruptive technologies, carbon pricing, and regulations and standards.

- No single technology, regulation, program, standard, or pricing plan will be “the pathway” to substantive emission reductions from freight transport.

- Securing GHG emission reductions from freight trucks will also involve a wider process of consumer behavioural change and managing societal expectations around the demand for goods.
Greenhouse gas (GHG) emissions from the transportation sector in Canada accounted for 173 megatonnes of CO₂ equivalent (Mt CO₂e), or 24 per cent of the national total, in 2015. This sector was responsible for nearly half of the increase in GHG emissions in Canada between 1990 and 2015, increasing by 42 per cent, or 51 Mt of CO₂ equivalent.

During this 25-year period, the share of transportation emissions from freight increased substantively (from 28 per cent in 1990 to 44 per cent in 2015). The proportional share of emissions from freight trucks compared with aviation, rail, and marine freight also increased during this time (from 61 per cent in 1990 to 83 per cent in 2015). By contrast, emissions from passenger travel declined (from 64 per cent in 1990 to 52 per cent in 2015), though they remain significant.

Achieving meaningful reductions to Canada’s emission profile and reaching Canada’s GHG reduction targets requires a focus on freight, and on trucking in particular. This report considers how advances in the technology and policy landscape could help meaningfully reduce emissions from freight transport. It examines:

- the factors influencing choice of transportation mode as possible explanations for the increase in the use of freight trucks;
- established and disruptive truck technologies to reduce fuel consumption and GHG emissions;
- the role of carbon pricing and how it will impact the economics of freight transportation;
- regulations directly affecting freight emissions.

We identified a number of pathways as part of this analysis; alongside the opportunities they present for reducing GHGs, many bring their own unique challenges.
Pathway #1 (Intermodal)

The increase in Canada’s GHG emission profile is tied in part to the rise of freight trucking. Transporting goods by truck is significantly more GHG-intensive than transporting goods by rail, yet the flexibility and convenience of the former remain unrivalled. Leveraging an intermodal system in which modes of transport with lower energy intensities are optimized is one important pathway to help secure GHG reductions. Our analysis reveals several regulatory incentives and infrastructure investments that could help support this pathway more fully—some targeting rail and some the road.

Pathway #2 (Established Fuel-Saving Technologies)

As emissions are derived from the burning of fuel, technologies that reduce fuel consumption (and increase fuel economy) are another important mechanism by which GHGs can be reduced. While numerous fuel-saving truck technologies have been available for some time, some have been taken up by industry in a significant way and others have not. This is attributed to uncertainties about device performance, technology availability, return on investment, payback period, capital costs, and split incentives. Understanding and overcoming these barriers form another pathway to securing GHG reductions from freight trucks.

Pathway #3 (Disruptive Technologies)

Disruptive technologies—such as electric and automated trucks—form an additional pathway to GHG reductions from freight. Our analysis estimates that for the period 2020 to 2050, further GHG reductions of up to 17.4 per cent could be achieved from electric zero-emission trucks and up to 5.9 per cent from driverless trucks. While these findings outline what is possible, the real challenge lies in managing the transition period in which these technologies are implemented.
Pathway #4 (Carbon Pricing)

Carbon pricing is increasingly advanced as a mechanism to reduce GHGs. Pricing has been introduced in Canada over the last decade by selected provinces, and from 2018 through the federal government’s Pan-Canadian Framework on Climate Change. Indirect increases in the cost of goods are also materializing. Conference Board foundational research demonstrates that carbon pricing can take Canada partway to its GHG emission goals, with a minimal impact on overall GDP. However, there will be distributional impacts on sectoral performance, both negative and positive. And importantly, a significant level of investment in low-carbon energy production and use will be required to cut emissions sharply—$2 trillion or more (in 2011 $) in new incremental investments would be required between now and 2050. Freight transport will be one of the sectors requiring significant low-carbon investment.

Pathway #5 (Regulations and Standards)

The trucking sector is also subject to direct regulations and standards. Environment Canada regulates tailpipe GHG emissions at the federal level, while provincial and territorial governments regulate truck dimensions, weights, and configurations within their jurisdictions. Current tailpipe emission regulations are expected to reduce CO₂ equivalent emissions by 19 Mt over the lifetime of 2014–18 model year vehicles and lead to $4.2 billion in cost savings to truck companies, derived from reduced fuel consumption. As the best way to comply with tailpipe emission regulations is through improved fuel efficiency, trucking companies can benefit from fuel-saving technologies and programs that support fuel efficiencies, such as those offered by Natural Resources Canada.

Overall, the analysis confirms that no single technology, regulation, program, standard, or pricing plan will be “the pathway” to substantive emission reductions from freight transport. Canada’s ability to reach its 2030 target depends upon strong commitment from multiple stakeholders to numerous initiatives and measures.
Additionally, reducing GHGs from freight transport will be hard to achieve without also engaging with consumer preferences and societal expectations around the demand for goods. Further research and public consultation would be required to facilitate behavioural change in ways that benefit the environment.
CHAPTER 1

Introduction

Chapter Summary

- Transportation sector emissions accounted for nearly half of the increase in greenhouse gases (GHGs) in Canada between 1990 and 2015, increasing by 42 per cent (51 Mt of CO₂ equivalent).

- The share of transportation emissions from freight has increased from 28 per cent in 1990 to 44 per cent in 2015. Meanwhile, emissions from passenger travel have declined during this period, from 64 per cent to 52 per cent.

- While emissions from freight trucks are high (61 per cent of all freight GHGs in 1990), they have increased substantively over the last 25 years (to 83 per cent of all freight GHGs in 2015) and their share relative to aviation, rail, and marine freight has also increased.

- Making meaningful reductions to Canada's emission profile requires a focus on freight, and on trucking in particular.
Canada’s GHGs

Emissions in Canada are on the rise. As Chart 1 illustrates, greenhouse gases (GHGs) in Canada (expressed in megatonnes of CO₂ equivalent [Mt CO₂e]) totalled 611 Mt in 1990.¹ By 2015, these had risen to 722 Mt, an increase of 18 per cent.²

Chart 1
GHG Emissions in Canada by Sector, 1990
(Mt CO₂e; per cent)

Over this period, the transportation sector has been a significant contributor of GHGs: it accounted for 21 per cent of emissions in 1990 (at 129.4 Mt), making it the highest emitting sector at that time. By 2015, it had risen to 24 per cent (173 Mt), where it became the second-highest emitter (behind upstream oil and gas production, at 189.5 Mt in 2015 versus 107.3 Mt in 1990).³ Other significant contributing sectors as of 2015, from highest to lowest emitter, include buildings (85.6 Mt); electricity (78.7 Mt); heavy industry (i.e., mining, smelting and refining, pulp and paper, iron and steel, etc.).

² Ibid.
³ Ibid.
cement, lime and gypsum, and chemicals and fertilizers) (74.6 Mt); agriculture (72.8 Mt); and waste and others\(^4\) (47.6 Mt).

Within the transportation sector, freight has become a significant contributor of emissions. As illustrated in Chart 2, its relative share (compared with passenger travel and other recreational, commercial, and residential uses) has been increasing over a 25-year period.\(^5\) Notably, emissions from passenger travel have declined (though they are still significant).

**Chart 2**
*Transportation Sector GHG Emissions in Canada by Subsector, 1990–2015 (per cent)*

GHG emissions in the transportation sector are affected by activity (i.e., number of freight trucks on the road); structure; energy intensity (a combination of load factor utilization and fuel economy); and fuel carbon content (i.e., the carbon released when a fuel is burned to generate energy).

Economic activity has spurred the demand for freight transport over the past few decades, leading to more trucks on Canadian roads, which in turn has resulted in increasing GHG emissions. ([https://www.pembinafoundation.org/reports/state-of-freight-report-final1.pdf](https://www.pembinafoundation.org/reports/state-of-freight-report-final1.pdf))

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\(^4\) This category refers to light manufacturing, construction, forest resources, waste, and coal production.

The energy intensity of freight transportation is a combination of vehicle fuel efficiency and how well existing infrastructure and logistical capacity are used (e.g., the amount of empty kilometres travelled and route optimization). Improvements in capacity utilization have the potential to reduce overall emissions from freight transportation.

GHG emissions from the transportation sector continue to climb, in spite of decreases observed in most other sectors. Between 1990 and 2005, for example, emissions in Canada for most sectors increased. Yet between 2005 and 2015, emissions for most sectors declined or showed marginal increases. (See Chart 3.) Transportation and the oil and gas sectors are exceptions to this overall trend, with increases of 20 per cent over the last decade (from 158 Mt CO₂e in 2005 to 189 Mt CO₂e by 2015). While GHG emissions in the transportation sector increased over this 10-year period, the increase was notably less (6 per cent, from 163 to 173 Mt of CO₂e between 2005 and 2015) than for the oil and gas sector.

Chart 3
GHG Emissions in Canada by Economic Sector, 1990–2015
(percentage change)

Chart 4 provides a breakdown of GHG emissions derived from the transportation sector, for all forms of passenger and freight transport, between 1990 and 2015. Increased emissions from freight trucking in particular are notable and have demonstrated sharp increases, especially since 2005 (with a decrease observed and associated with the 2008 recession). The upward trend in historical GHG emissions from freight trucks contrasts sharply with trends in other sectors. Despite improvements in technology making the freight truck sector more energy-efficient, these gains have been offset by increased demand for road freight transport.

**Chart 4**

*GHG Emissions for Transportation in Canada, Passenger and Freight (per cent)*

*Source: Environment and Climate Change Canada, 2017.*

**Previous Conference Board Research**

A 2015 Conference Board of Canada report (*A Long, Hard Road*) considered the opportunities and challenges Canada would face in reducing road transport GHG emissions to 80 per cent below 1990 levels by the year 2050. The report concluded that even with some very aggressive assumptions about vehicle technology penetration...
This report considers how advances in technology and policy could help reduce emissions from freight transport.

and efficiency gains, the “80 by 50” target would not be met. The report also reviewed a broad range of government initiatives, programs, and regulations that have contributed to shaping road transportation and related emissions.

Since the release of that report, however, a number of changes to the transportation and climate policy landscape have emerged. The federal government, for example, has established the *Pan-Canadian Framework on Clean Growth and Climate Change*9 (its strategic transportation plan), with GHG emission-reduction targets of 30 per cent below 2005 levels by the year 2030.10 Included in the Framework are numerous tools to help reduce emissions (such as carbon pricing and greater investments in zero-emission vehicle technologies and green infrastructure) that were not in place at the time of our previous research.

Advances have also been made around disruptive innovations as they relate to freight transport—these include driverless and electric trucks. While these technologies have been considered in other CBoC work,11 the environmental benefits associated with driverless trucks were not explicitly examined in *A Long, Hard Road*.

**Questions and Approach to the Research**

This report considers how advances in the technology and policy landscape could help meaningfully reduce emissions from freight transport. The research presented in this report seeks to answer the following questions:

- What are the technology and policy options to reduce freight transportation GHG emissions in Canada from the trucking sector?
- Which options represent the best opportunities to secure GHG reductions from freight transportation?

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8 Robins, Knowles, and Coad, *A Long, Hard Road*.
9 Transport Canada, “Transportation 2030.”
11 Gill and others, *Automated Vehicles*.
To answer these questions, we conducted a review of academic, grey, and policy literature on freight-based trucking emissions, established and emerging technologies to reduce GHGs from trucking, carbon-pricing policies, and other regulatory mechanisms.

## What We Mean By Trucking

As defined by the International Energy Agency (IEA), road freight transport comprises “all activities that are linked to the movement of goods, including everything from raw materials to foodstuffs and electronics.”\(^{12}\) While many types of vehicles are employed in this activity, the IEA broadly classifies these into three main categories:\(^{13}\)

**Heavy-freight trucks**: commercial vehicles used for long-haul goods delivery, often travelling over 100,000 kilometres per year and operating year-round;

**Medium-freight trucks**: commercial vehicles typically used in regional activities, including large vans, rigid trucks, and tractor-trailers; public vehicles (i.e., firefighting trucks); and commercial service vehicles;

**Light commercial vehicles**: typically used for smaller-scale and “last mile” deliveries, including vans and pickup-trucks, to transport building materials and goods from one work site to another, and for delivering commercial services (i.e., plumbing, carpentry).

The discussion and analysis presented in this report centres on the first category of heavy-freight (long-haul) trucks. In Canada, this IEA category aligns with heavy-duty vehicle classes 7 and 8, which are defined as vehicles with a gross weight of 11,793 kg to 14,969 kg (26,000 to 33,000 lbs.) and a gross weight over 14,969 kg (33,000 lbs.), respectively.\(^{14}\) This means that other options to reduce emissions from urban (short-haul, light commercial) freight, such as cargo bikes,\(^ {15,16}\) are not examined here.

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\(^{13}\) Categories from IEA, *The Future of Trucks*, 15–16.

\(^{14}\) Environment and Climate Change Canada, *Guidance Document*.

\(^{15}\) Spurr, “UPS to Test Cargo Bikes for Deliveries in Toronto.”

\(^{16}\) Vijayakumar, *Cyclelogistics*. 

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Find Conference Board research at www.e-library.ca.
Report Structure

This report comprises seven chapters:

• Chapter 2 examines the factors influencing choice of mode and carriers, including the growing importance of trucking relative to rail over time.

• Chapter 3 reviews established (fuel-saving) technologies and devices to reduce freight truck GHG emissions. It includes a comparative benchmark for road transport GHG emissions per tonne-kilometre carried and sets out expected GHG reductions resulting from these technologies.

• Chapter 4 explores how disruptive technologies, such as electric trucks and automated vehicles, can be leveraged to reduce emissions from freight.

• Chapter 5 considers how carbon-pricing initiatives in Canada will impact the economics of freight transportation and emissions from freight. It looks at the role of revenue recycling as a mechanism to support investments in the freight sector.

• Chapter 6 reviews regulations directly affecting freight emissions, such as tailpipe regulations and the Clean Fuel Standard, and considers the role of harmonization.

• The seventh, and final, chapter summarizes the key findings from each aspect of our analysis. It also suggests avenues for further research on reducing GHG emissions from Canada’s freight transportation sector.
CHAPTER 2

Freight and Mode Choice

Chapter Summary

- Despite rail being more environmentally friendly and cost-effective than trucking, road freight is a crucial and growing part of the transportation system due to its unrivalled flexibility and potential to move goods from the first to the last mile.

- Promoting and implementing intermodal supply chains, where road, rail, and marine work in tandem to maximize capacity utilization and reduce empty kilometres travelled, can lead to GHG reductions; these should be explored as part of Canada’s transition to a low-carbon economy.

- A more comprehensive intermodal strategy for freight would be supported through regulatory incentives and infrastructure investments—some targeting rail and some the road.
Introduction

As illustrated in the previous chapter, freight trucks have become the dominant emitter of transport-related GHGs. (See Chart 4 in Chapter 1.) This dominance reflects a gradual shift in the ways in which freight is moved. Whereas rail was a dominant mode at the beginning of the 20th century, road-based transport became increasingly used by the end of that century. Against that backdrop, this chapter examines the factors influencing the choice of mode and carriers for freight transportation in Canada. It then analyzes the emission footprint of freight, with a focus on the differences between goods delivered by truck and rail.

Freight Transport Modes: Key Characteristics

The mode choice of freight is influenced by numerous factors, including the cost and speed of transportation; the flexibility, reliability, and availability of the service provided; and the nature of goods and commodities being transported. Road, rail, marine, and air transport each have their own strengths and drawbacks when measured against these criteria (see Table 1), which leads to differing roles in the movement of goods.2

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2 Woodburn and Whiteing, ”Transferring Freight to ‘Greener’ Transport Modes,” 126.
### Table 1

<table>
<thead>
<tr>
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<th>Road</th>
<th>Rail</th>
<th>Marine</th>
<th>Air</th>
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<tr>
<td><strong>Cost per tonne-km</strong></td>
<td>More expensive than rail and marine; cheaper than air</td>
<td>Cheaper than road and air; more expensive than marine</td>
<td>Cheaper than all other modes</td>
<td>Most expensive of all modes</td>
</tr>
<tr>
<td><strong>Capital cost</strong></td>
<td>Lowest</td>
<td>Second lowest</td>
<td>Highest</td>
<td>Second highest</td>
</tr>
<tr>
<td><strong>Speed</strong></td>
<td>Faster than rail and marine; slower than air</td>
<td>Slower than road</td>
<td>Slowest of all modes</td>
<td>Fastest of all modes (depending on circumstances)</td>
</tr>
<tr>
<td><strong>Flexibility</strong></td>
<td>Most flexible of all modes</td>
<td>Less flexible than road</td>
<td>Relatively inflexible (schedules, routes)</td>
<td>Less flexible than road</td>
</tr>
<tr>
<td><strong>Availability</strong></td>
<td>Most readily available at different times, locations</td>
<td>Less available than road (due to schedules, rail infrastructure)</td>
<td>Less available than road (due to schedules, port infrastructure)</td>
<td>Less available than road (due to schedules, airport infrastructure)</td>
</tr>
<tr>
<td><strong>Goods suited</strong></td>
<td>Manufactured goods, equipment, machinery, vehicles</td>
<td>High-volume, low-value freight and commodities; auto products</td>
<td>Large-volume, heavy goods and commodities</td>
<td>High-value goods; perishable and urgent goods</td>
</tr>
<tr>
<td><strong>Distance</strong></td>
<td>Mostly national and international</td>
<td>National and international</td>
<td>Up to intercontinental</td>
<td>Regional to intercontinental</td>
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Source: The Conference Board of Canada; Roy, “By Road, Rail, Sea and Air.”

Road-based freight is advantageous as a relatively economical, flexible, and fast method of transportation.³ Low barriers to entry for potential operators, lower initial capital cost, and business expansion opportunities for existing operators are cited as important economic benefits that favour trucking relative to rail.⁴ With lower capital investments (in buying a truck or fleet of trucks), shippers’ costs are relatively low and this enables market entry, expansion, and further competition (which keeps prices low for shippers).⁵

Road transport can be considerably more flexible than other modes; this has contributed to the increased use of road over rail for goods movement.⁶ This flexibility takes expression geographically, temporally, and with respect to speed, planning, and capacity.⁷ Governments provide and invest in infrastructure, which has a significant effect on the mode choice for freight. Canada’s vast network of roads and highways forms an important part of the country’s “surface transportation gateways”

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³ Engström, “The Roads’ Role in the Freight Transport System.”
⁴ Ibid., 1445.
⁵ Ibid.
⁶ Ibid.
⁷ Ibid., 1445–46.
The use of road freight for the last mile of the journey can have a significant impact on GHG emissions.

and is central to its economic performance. The extensive road and highway network in Canada contributed to the increase in trucking by facilitating flexibility and reliability for road freight transportation. Yet, the public sector has considerably reduced its presence in freight rail. While truckers pay fuel taxes and vehicle regulatory fees, rail freight carriers incur higher infrastructure costs.

Road-based freight is also invaluable at the beginning and end of the transport chain, also known as the first and last mile. Goods and commodities are often transported using several different modes of transportation from point of origin to destination (referred to as intermodal transportation). The use of road freight for the last mile of the journey, especially in urban centres, can have a significant impact on GHG emissions, since urban driving is considerably less efficient than highway driving in terms of fuel usage and emissions. Road freight is particularly useful for moving manufactured goods and products (as opposed to commodities).

Rail is particularly well suited to transporting bulk commodities that are high in volume or weight. This is in part due to its higher transport capacity (i.e., a single train can carry larger quantities of goods) and reliability, supported by the vast rail networks across Canada. Crucially, rail is also cheaper than road-based freight transportation and other modes. It is often the only economic option for certain types of commodities—especially bulk commodities (i.e., coal, potash, grain, lumber) that travel considerable distances to reach markets. However, rail is inflexible, in that shippers must follow a relatively strict schedule and some goods must still be transported from the point of origin to railcar loading stations (i.e., the first mile), and then from unloading stations to final destinations (the last mile). However, this is generally the case for consumer and finished goods where there are numerous small locations to serve and it is not feasible to have rail spurs to all

8 Canada Transportation Act Review (CTAR), Pathways, 35.
9 Iacobacci, Shared Corridors, Strange Bedfellows, 4.
10 Woodburn and Whiteing, “Transferring Freight to ‘Greener’ Transport Modes,” 126.
11 Coad and others, Building for Growth.
12 Woodburn and Whiteing, “Transferring Freight to ‘Greener’ Transport Modes,” 126.
13 Coad and others, Building for Growth, 25.
These locations. Bulk commodities, such as potash, can generally be loaded onto railcar containers from point of origin and unloaded directly to bulk vessels, depending on the port. So while rail is a well-suited and cost-effective mechanism for transporting goods over long distances between transportation hubs, it faces some logistical issues around the first and last mile of the supply chain, since the rail network is not as extensive as the road system in Canada.

Marine is the cheapest mode of transport for freight, and, not unlike rail, offers the ability to carry larger quantities of goods (in a single vessel). Yet marine freight transportation is relatively slow and inflexible, since freight vessels follow schedules and certain sea/ocean routes. Marine transportation also requires goods to first be transported to port and then transported from port to their final destination.

Compared with marine and other modes, air-based freight transport is faster, but also more expensive. It lends itself to the movement of high-value, perishable, and urgent goods. Air transport can also be relatively inflexible, as it relies on runways and related infrastructure and is subject to restrictions on the weight and volume of goods that can be carried.

Focus on the Road and Rail

Canada has an open, resource-based, export-driven economy with numerous trading partners. Although the United States has historically been Canada’s largest trading partner, significant (and a growing share of) Canadian exports are destined for other regions of the world like Europe and Asia. Given Canada’s vast land mass and distances between ports, it is important to focus on those modes and carriers well suited to efficient, long-distance transportation of goods such as trucks and rail.

14 Woodburn and Whiteing, “Transferring Freight to ‘Greener’ Transport Modes,” 126.
15 Coad and others, Building for Growth.
16 Ibid.
Volume Versus Value: Commodities and Mode Choice

With the cost-effectiveness of rail over road freight when economies of scale are realized, this mode lends itself to the transport of bulky and heavy goods that are not necessarily high in value17 (with lower "value densities," defined as “the dollar value of one kilogram or tonne of a good”18). This is because goods high in volume or weight but lower in value density, such as grain, lumber, and coal, lend themselves to low-cost, large-scale methods of transportation. In this sense, choice of mode is determined by the nature of the commodity being transported.19

Emission Intensities

The two modes not only differ with respect to usage, cost-effectiveness, and suitability by type of good and commodity, they also have notably different emission profiles. While rail freight accounts for almost one and a half times the tonne-kilometres compared to road freight, for example, it contributes less than one-quarter of transportation-related GHG emissions. As illustrated in Chart 5, GHG emissions derived from road freight transportation (freight trucks) were over four times higher in 2014 (at 54.7 Mt CO₂) than emissions from freight rail, marine, and aviation combined (13 Mt CO₂).20

This large disparity in total GHG emissions by mode can be explained by the significantly lower emissions per tonne-kilometre for rail relative to road freight. (See Chart 6.) To transport 1,000 tonnes of freight over 1,000 kilometres, road-based freight emits 48.9 tonnes of CO₂, while rail emits 16.2 tonnes of CO₂ to achieve the same result.

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17 Ibid., 17.
18 Ibid.
19 Ibid., 24.
20 Data from Environment and Climate Change Canada used in this chart aggregate figures for freight rail, marine, and aviation.
Reducing Travel by Truck

The differing emission intensities by mode suggest that one pathway to reducing GHGs from freight involves evaluating options to reduce travel by truck. Of interest, here is how an intermodal system (including greater reliance on rail) could be leveraged to reduce GHG emissions. Organizations like the Railway Association of Canada (RAC), for example, have recognized the emission reductions that could be achieved if some
A greater reliance on rail is not a likely scenario in the absence of substantive intervention by governments.

Portion of domestic road freight traffic were diverted from trucks to rail. In this organization’s estimation, a shift of 10 per cent of domestic road freight traffic to rail could lead to CO₂ savings of 3.8 Mt of CO₂e (6.9 per cent from the 2014 emissions level). A 15 per cent shift from road to rail freight traffic could lead to a reduction of 5.6 Mt of CO₂e—equivalent to removing more than 1 million cars from Canada’s roads.

In spite of these important potential GHG reductions, it is apparent that a greater reliance on rail is not a feasible or likely scenario in the absence of substantive intervention by governments. As illustrated in Table 2 and drawn from experiences within selected European Union (EU) member states, an effective and comprehensive intermodal strategy for freight would require numerous regulatory incentives and infrastructure investments—some targeting rail and some the road.

Moreover, the lessons learned from the experiences in those member states confirm that for these strategies to be successful, better coordination by various levels of government is required and measures need to be aligned with the unique circumstances in which they operate.

The regulatory and infrastructure strategies presented in this table were based on research conducted on the experiences of selected EU member states. Accordingly, some of these may be more feasible and transferable to the Canadian context than others. Further research and engagement with rail and road freight sectors across Canada would therefore be useful in identifying barriers to intermodal freight transport, as well as determining the most relevant and effective mechanisms for overcoming those barriers.

21 Gullo and Rosales, Part of the Problem or Part of the Solution? 12.
22 Railway Association of Canada, Canada’s Railways.
23 Steer Davies Gleave, Freight on Road.
24 Ibid.
### Table 2

**Initiatives to Support an Intermodal Strategy**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Regulatory incentives</th>
<th>Infrastructure investment</th>
</tr>
</thead>
</table>
| **Rail** | • Reduce costs of rail freight transport to incentivize modal shift (i.e., lower infrastructure access charges, targeted discounts)  
• Encourage strong market competition; reduce burdens to market entry  
• Provide monetary incentives for rail freight operations that are part of intermodal transport | • Improve interoperability of freight services and remove bottlenecks at borders  
• Promote construction of intermodal facilities (rail sidings, dedicated connections to ports, industrial areas to incentivize combined and integrated freight transport)  
• Expand rail network to increase density, coverage |
| **Road** | • Introduce road user charging  
• Lower charges for haulers involved in intermodal services  
• Relax regulations on maximum weight and height for heavy good vehicles carrying goods to/from rail freight terminals | • Promote construction of intermodal facilities (rail sidings, dedicated connections to ports, industrial areas to incentivize combined and integrated freight transport) |


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**The Benefits of Intermodal Transportation**

Intermodal transportation refers to goods being transported by different modes from point of origin to their final destination. Many firms have complex supply chains that employ several different modes, although as discussed earlier in this chapter, vehicle freight transport is crucial for first- and last-mile transportation.

Since different modes of transportation have different energy intensities, reductions in GHG emissions can be achieved by utilizing modes of transport with lower energy intensities, such as rail or marine. To this end, developing short-line railways and short sea shipping as part of intermodal freight transport could have an important role to play in Canada’s transition to a low-carbon economy.

Transporting 1,000 tonnes of cargo over a distance of 1,000 kilometres by rail produces approximately a third of the GHG emissions that would result from transporting the same amount of cargo by truck.
Highway H\textsubscript{2}O

Highway H\textsubscript{2}O is a program that offers direct access to the industrial hub of North America via the St. Lawrence River and along the Great Lakes. It stretches approximately 3,700 kilometres and offers access to over 40 marine ports with key intermodal connections to rail or truck freight hubs.\textsuperscript{25} The program claims to save cargo shippers approximately $3.6 billion annually compared to transporting the same goods by truck.\textsuperscript{26}

Advantages of shipping goods via seaway include better fuel economy compared to rail and truck, which translates into lower GHG emissions per tonne-kilometre.

Conclusion

In this chapter, we have examined the factors influencing the mode choice of freight. As illustrated here, the speed and cost of transportation, flexibility, reliability, availability, and the nature of the goods and commodities being transported are all contributing factors.

Rail and marine are significantly more cost-effective than road freight and are more suitable for the transportation of bulky and heavy goods over long distances. Yet road freight has a considerable flexibility advantage, which makes it crucial in intermodal supply chains. This flexibility means that road freight is relied on for first- and last-mile transport.

Despite rail accounting for almost one and a half times more tonne-kilometres of freight as road, it is responsible for less than a third of the GHG emissions from road freight transport. This is because moving goods by truck produces more than three times as many GHG emissions as shipping those same goods by rail. Thus, the promotion of intermodal supply chains that reduce the need to travel by truck can play a significant role in reducing GHG emissions from the freight trucking sector.

\textsuperscript{25} Hwy H\textsubscript{2}O, “About Hwy H\textsubscript{2}O.”
\textsuperscript{26} Ibid.
Given the relatively large advantages that rail offers in terms of GHG intensity, even minor proportional shifts from road to rail could make meaningful reductions in the emission profile associated with freight transport. Yet it is apparent that government interventions would be required to support this process, comprising a suite of infrastructure and regulatory measures targeting the road and rail.27 Where broad political support for rail freight has been applied, an increase in the share of rail is observed.28

Reducing travel by truck is one potential pathway to emission reductions. Others necessitate a focus on technologies that reduce fuel consumption and GHGs from the trucks themselves. We examine this in the next chapter.

27 Steer Davies Gleave, *Freight on Road.*
28 den Boer and others, "Potential of Modal Shift to Rail Transport."
CHAPTER 3
Reducing Emissions From Freight: Established Truck Technologies

Chapter Summary

- Fuel-saving technologies are important mechanisms for realizing GHG emission reductions from freight.

- Numerous technologies have been on the market for some time, with differential fuel economies and adoption rates. This is due to a range of factors, including uncertainties about return on investment and device performance, capital costs, split incentives, and technology availability.

- We propose fuel-efficiency standards, market approaches, and fiscal measures to overcome barriers to adoption.
Introduction

The Conference Board report *A Long, Hard Road* identified a range of heavy-duty truck technologies that are available to reduce GHG emissions from road freight. These centred on improving fuel economy for truck fleets\(^1\),\(^2\) and relate specifically to the engine, transmission, hybridization, idle reduction, vehicle body, and tires. While many of these technologies have been available for some time, they are implemented on a voluntary basis and thus far have not achieved significant market penetration. Numerous barriers contribute to low market uptake, including technology uncertainties and concerns about return on investment, capital cost constraints, split incentives, and technology availability.\(^3\)

Fuel Economy Technologies to Reduce GHGs

This chapter focuses on technologies that have the potential to increase the energy efficiency and decrease the energy intensity of the heavy-duty freight trucking sector through improving fuel economy. Improved fuel economy is a direct mechanism by which reductions in GHG per distance travelled can be realized. As emissions are derived from the burning of fuel, reduced fuel consumption leads to fewer emissions for a given number of kilometres travelled. It has been suggested, for example, that if the entire fleet of Class 8 trucks in Canada adopted a combination

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1 Fuel efficiency refers to how efficiently a vehicle can convert fuel into mechanical energy.
2 IEA, *Technology Roadmap*.
3 Sharpe, *Barriers to the Adoption of Fuel-Saving Technologies*, 4–6.
of these technologies, 4.1 billion litres of fuel could be saved annually (thereby reducing GHG emissions by 11.5 million tonnes)\(^4\) for the same total distance travelled. (See Table 3.)

**Table 3**  
**Fuel Consumption and Emissions for Heavy-Duty Trucks**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel carbon content—diesel (kg of CO(_2) per L)*</td>
<td>2.66</td>
</tr>
<tr>
<td>Fuel carbon content—B20 (kg of CO(_2) per L)</td>
<td>2.62</td>
</tr>
<tr>
<td>Average truck fuel consumption (L per 100 km)**</td>
<td>35.30</td>
</tr>
<tr>
<td>Average annual distance travelled (km)</td>
<td>69,800</td>
</tr>
<tr>
<td>Average annual fuel consumption (L)</td>
<td>24,639.4</td>
</tr>
<tr>
<td>Average annual emissions per truck (Kt of CO(_2))</td>
<td>64.5–65.5</td>
</tr>
</tbody>
</table>

\(^*\)NRCAN, “Learn the Facts.”  
\(^**\)NRCAN, 2008 Canadian Vehicle Survey.

Source: Natural Resources Canada.

There is a financial incentive from within the trucking sector to support fuel-saving initiatives. Fuel represents a large share of fleet vehicle operating costs (20 per cent of the total operating costs for local trucking carriers and 17 per cent for long-distance carriers in 2010).\(^5\)

For most trucking companies in Canada, it is now the second-largest cost component\(^6\) (after labour costs). Reducing fuel purchases through greater fuel efficiency can therefore provide one way the trucking industry can improve its profitability. As such, it is in the direct interest of the industry to explore these new technologies.\(^7\)

It is important to note that the effectiveness of technologies that ensure fuel economy varies by vehicle duty cycles\(^8,9\)—defined as how a “certain type of vehicle is used in [its] targeted application.”\(^10\) By way of example, a long-haul truck’s duty cycle reflects its operation on high-speed highways and with few stops; by contrast, a local truck’s

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\(^4\) Ogburn and Ramroth, *Truck Efficiency and Greenhouse Gas (GHG) Reduction Opportunities.*

\(^5\) Statistics Canada, CANSIM table 403-0009.

\(^6\) Ontario Trucking Association, OTA.

\(^7\) Robins, Knowles, and Coad, *A Long, Hard Road.*

\(^8\) The target application of how vehicles are used.


\(^10\) Ibid., 61.
duty cycle reflects operation in urban areas with lower-speed roads and more frequent stops.11 Trucks are purchased for specific duty cycles to minimize costs and ensure more efficient operations12: a long-haul vehicle would not be purchased for exclusive use in urban areas, nor would a local truck be used for extensive highway operations. (See Exhibit 1.)

There are several main energy loss sources for a heavy-duty freight truck. These include engine losses (due to the inherent inefficiency of internal combustion diesel engines); drivetrain losses (i.e., transmission and driveline); rolling resistance (i.e., losses due to the friction of tires on the road); and aerodynamic losses (i.e., losses due to drag).

11 Transportation Research Board and National Research Council, Technologies and Approaches to Reducing Fuel Consumption.
12 National Petroleum Council, "Heavy-Duty Engines & Vehicles."
Engine Losses

Diesel remains the top fuel of choice for the trucking industry in Canada, and for heavy-duty trucks in particular.13,14 While diesel engines are more efficient than gasoline engines, they are still only approximately 45 per cent efficient.15 The remaining energy is lost as waste heat, and technologies that reduce waste heat or capture and convert it into power (bottoming cycles, thermal insulation, turbo compounding) can improve fuel efficiency.16

A bottoming cycle is a secondary engine that is powered by waste heat sources such as exhaust energy from the main engine. The power gained from the bottoming cycle can be used to power electric motors supplementing engine output, power electrified accessories, or charge batteries in a hybrid system.17 Employing a bottoming cycle can reduce fuel consumption by as much as 10 per cent.18

Mechanical turbo compounding refers to a power turbine being added to the exhaust stream of a truck to extract additional energy from the exhaust and then apply it to the crankshaft for additional power.19 These systems reach optimal performance at full load and are significantly less effective at light loads.20 Mechanical turbo compounding can reduce fuel consumption by 2.5 to 5 per cent. (See Table 4)

Electric turbo compounding also employs a power turbine added to the exhaust stream, but in this instance the turbine powers an electrical generator that can then be used to supplement engine output, power electrified accessories, or charge a hybrid system battery.21 Electric turbo compounding is more efficient than mechanical turbo compounding and can reduce fuel consumption by 3 to 10 per cent.

13 Canadian Fuels Association, Petroleum.
14 Robins, Knowles, and Coad, A Long, Hard Road.
16 Ibid.
17 Transportation Research Board and National Research Council, Technologies and Approaches to Reducing the Fuel Consumption.
18 Ibid.
19 Ibid.
20 Ibid.
21 Ibid.
Table 4
Technologies to Reduce Engine Losses

<table>
<thead>
<tr>
<th>Engine</th>
<th>Fuel savings (per cent)</th>
<th>CO₂ savings* (tonnes per truck per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottoming cycle system</td>
<td>Up to 10</td>
<td>Up to 6.5</td>
</tr>
<tr>
<td>Mechanical turbo compound system</td>
<td>2.5–5</td>
<td>1.6–3.3</td>
</tr>
<tr>
<td>Electric turbo compound system</td>
<td>3–10</td>
<td>2.0–6.5</td>
</tr>
<tr>
<td>Low-viscosity engine oil</td>
<td>3</td>
<td>4.93**</td>
</tr>
<tr>
<td>Real-time combustion control system</td>
<td>1–4</td>
<td>0.7–2.6</td>
</tr>
<tr>
<td>Improved fuel injection system</td>
<td>1–4</td>
<td>0.7–2.6</td>
</tr>
<tr>
<td>Accessory electrification</td>
<td>2–5</td>
<td>1.3–3.3</td>
</tr>
</tbody>
</table>

*Unless otherwise cited, CO₂ reductions were calculated using an estimate based on the assumption that a 1 per cent fuel savings generates 1.6433 tonnes-reduction in emissions.

**EPA, *Low-Viscosity Lubricants*.


Improved fuel efficiency can be realized through reduced engine friction, and the use of lower-viscosity oil (i.e., 10W-30 instead of 15W-40) can contribute to friction reduction. While higher-viscosity oils have historically been perceived to be better for engine protection, this perception is changing with improvements in low-viscosity blends.22

The Environmental Protection Agency (EPA) confirms that fuel economy can be improved by 3 per cent from the use of synthetic low-viscosity engine oil and drivetrain lubricants. This translates into reductions of 4.93 metric tonnes of CO₂e per year per truck.23

Real-time combustion control systems refer to improvements in combustion chamber design, materials, and structural design that enable higher cylinder pressures, higher combustion temperature, and more precise control of the timing and rate of combustion of engines.24 These improvements are estimated to reduce fuel consumption by 1 to 4 per cent.25

22 Park and others, *Confidence Report*.
23 United States Environmental Protection Agency (EPA), *Low-Viscosity Lubricants*.
24 Transportation Research Board and National Research Council, *Technologies and Approaches to Reducing the Fuel Consumption*.
25 Ibid.
Improved fuel injection systems refer to high-pressure fuel injectors that allow for more control of combustion. Improvements in fuel injection are estimated to reduce fuel consumption by 1 to 4 per cent. 26

Using a truck’s engine to power its accessories (such as the truck’s air conditioning system and the engine water pump, air compressor, and power-steering pump) is inefficient, since these accessories create a constant load on the engine and thus increase fuel consumption. By contrast, electrically powered accessories operate only when needed and can lead to a 2 to 5 per cent reduction in fuel consumption. 27

**Drivetrain and Transmission Losses**

Transmission and driveline refer to the transmission, final drive, and axle, which are used to connect a truck’s engine to the wheels. Improved driveline efficiency refers to increasing the efficiency of power transfer from the engine to the wheels, while improved system integration enables the engine to operate at higher average drive-cycle efficiency. 28

Freight trucks generally use manual transmissions, but switching to automatic transmissions can reduce fuel consumption by up to 3 per cent. 29 Low-friction lubricants for the transmission, axle, and wheel bearings can also reduce fuel consumption by 1 per cent or more. 30

Finally, axle types and ratios affect fuel consumption. A higher number of drive axles provides improved traction but increases fuel consumption due to increased weight and friction to the driveline. However, provinces regulate maximum axle loads, since more axles also reduce road wear. The rear axle ratio determines engine rpm at cruising speed, which can have a significant effect on fuel consumption. Taller axle ratios result in lower engine rpm at speed but have an adverse impact on vehicle performance and acceleration. Overall, transmission and driveline improvements can yield fuel savings of 5 to 7 per cent for heavy-duty freight trucks.

26 Ibid.
27 Ibid.
28 Ibid.
29 Ibid.
30 Ibid.
Hybridization refers to vehicles with two or more means of propulsion, such as a diesel engine working in tandem with electric motors. Hybrid vehicle advantages include the use of regenerative braking (converts energy from braking into electricity and stores it for future use); higher energy efficiency (electric motors are more efficient than internal combustion engines); improved torque (electric motors provide high torque at low speeds); reduced emissions (eliminates engine idling); engine shutoff; smaller engines (allows use of smaller and lighter combustion engines since electric motors make up some of the power difference); accessory electrification; and improved drivability (electric engines are more responsive). However, hybrid vehicles have the disadvantages of increased complexity, increased weight and cost, and possibly lower system reliability, since there are more systems that can fail. Although hybridization can cover a wide range of systems and power train combinations, it has been estimated that fuel savings of 5 to 10 per cent can be achieved for tractor trailers through reductions in total load, some idle reduction, and some electrification of accessories (See Table 5).

Table 5
Technologies to Reduce Drivetrain and Transmission Losses

<table>
<thead>
<tr>
<th>Technology</th>
<th>Fuel savings (per cent)</th>
<th>CO₂ savings* (tonnes per truck per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybridization</td>
<td>5–10**</td>
<td>3.3–6.5</td>
</tr>
<tr>
<td>Transmission and driveline</td>
<td>5–7**</td>
<td>3.3–4.6</td>
</tr>
</tbody>
</table>

*Unless otherwise cited, CO₂ reductions were calculated using an estimate based on the assumption that a 1 per cent fuel savings generates 1.6433 tonnes-reduction in emissions.
**Transportation Research Board and National Research Council, Technologies and Approaches to Reducing the Fuel Consumption.
Sources: Environmental Protection Agency; Transportation Research Board and National Research Council; Rodriguez and others, Market Penetration of Fuel Efficiency Technologies; The Conference Board of Canada, A Long, Hard Road, 46–47.

Idle Reduction Technologies
While the Conference Board report A Long, Hard Road reflected on the contribution that idling makes to GHGs and considered the
need for anti-idling policies, the discussion was largely framed within
the context of motorists and passenger vehicles. (See pages 40–41
of that report.) Yet idling is also common within long-haul trucking
and is often practised by drivers during rest periods.\footnote{EPA, \textit{Idle Reduction}.} Idling helps
to ensure that the sleeping compartment is sufficiently cooled or
heated for drivers; it can avoid cold weather engine trouble through
heat generation; and it serves as an electrical power source for other
appliances.\footnote{Ibid.} When considering the contribution that freight makes to
the emission profile associated with the road network, it is important
to not overlook the role of idle-reduction technologies\footnote{Behavioural change is another way to reduce idling (through driver/operator training and financial incentives from fleets).} for the trucking
sector. (See Table 6.) The EPA suggests that a typical long-haul
truck would save approximately 3,400 to 5,300 litres of fuel each year
(900 to 1,400 gallons) if unnecessary idling were eliminated\footnote{EPA, \textit{Idle Reduction}.} (based
on an average 1,600 to 2,400 hours of idling per year for a typical
long-haul truck). The EPA has verified five types of idle-reduction
technologies as part of its SmartWay program. These include:

- \textbf{auxiliary power units (APUs):} a device mounted externally on the
  truck’s cab (a combination generator and small combustible engine)
  that can provide power when the truck is shut off\footnote{Ibid.} and supply electrical
  power, heating, and cooling to the truck;

- \textbf{fuel-operated heaters (FOHs), also known as direct fired heaters (DFHs):} which burn fuel from either a fuel reserve or from the engine’s
  main fuel supply (they can be used with cooling systems but provide
  only heat);

- \textbf{battery air conditioning (BAC) systems:} battery-powered and
  independent cooling systems (they can be integrated with fuel-operated
  heaters but provide only cooling);

- \textbf{thermal storage systems (TSS):} which collect heat energy generated
  by a truck in motion and use this energy for air conditioning;

\textit{Find Conference Board research at www.e-library.ca.}
• truck stop electrification (TSE), also known as electric parking spaces (EPS): whereby electric power from external sources are provided for trucks while parked so they don’t need to idle to power various components (i.e., heating and cooling systems).  

Table 6

Idle Reduction Technologies

<table>
<thead>
<tr>
<th>Idle reduction</th>
<th>Fuel savings (per cent)</th>
<th>CO₂ savings* (tonnes per truck per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auxiliary power units</td>
<td>8**</td>
<td>9–14***</td>
</tr>
<tr>
<td>Battery air conditioning systems</td>
<td>Up to 8†</td>
<td></td>
</tr>
<tr>
<td>Thermal storage systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel-operated heaters</td>
<td></td>
<td>3.6–14.6††</td>
</tr>
<tr>
<td>Truck stop electrification</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Unless cited otherwise, CO₂ reductions were calculated using an estimate based on the assumption that a 1 per cent fuel savings generates 1.6433 tonnes-reduction in emissions.
**Ogburn and Ramroth, Truck Efficiency and Greenhouse Gas (GHG) Reduction Opportunities.
***APUs use only 25 per cent of the fuel of an idling engine; fuel-operated heaters use 5 per cent of the fuel of an idling engine.
†Transportation Research Board and National Research Council, Technologies and Approaches to Reducing the Fuel Consumption.
††EPA, Idle Reduction.

Sources: Environmental Protection Agency; Transportation Research Board and National Research Council; Rodriguez and others, Market Penetration of Fuel Efficiency Technologies; The Conference Board of Canada, A Long, Hard Road, 46–47.

Aerodynamic Losses

One of the forces that heavy-duty trucks are exposed to is known as aerodynamic drag. Technologies to reduce drag focus on improving the aerodynamics of trucks and trailers (see Table 7); these in turn can realize fuel economies. The International Council on Clean Transportation (ICCT) recognizes that at constant highway speeds (104.6 km/hour) and no grade, a 1 per cent reduction in drag results in a 0.5 per cent reduction in fuel consumption.  

Key technologies that improve aerodynamics relate to the vehicle body and include side skirts, underbody devices, boat tails, and gap reducers.

Side skirts are the most widely used technology to reduce aerodynamic drag in trailers and have the longest commercial history (relative to other

39 EPA, Learn About Idling Reduction Technologies.
40 Sharpe and Roeth, Costs and Adoption Rates of Fuel-Saving Technologies for Trailers, 5.
aerodynamic devices). An ICCT study confirmed average fuel savings of between 3 and 5 per cent for side skirts; similar average fuel savings (4.5 per cent) were observed in a 2009 Canadian study. According to the Canadian study, and assuming average fuel savings of 4 per cent, the GHG savings per truck per year have been estimated at 4.98 tonnes of CO₂ equivalent.

### Table 7

<table>
<thead>
<tr>
<th>Vehicle body</th>
<th>Fuel savings (per cent)</th>
<th>CO₂ savings* (tonnes per truck per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Side skirt</td>
<td>3–5</td>
<td>4.98**</td>
</tr>
<tr>
<td>Underbody device</td>
<td>2–5</td>
<td>6.225***</td>
</tr>
<tr>
<td>Boat tail</td>
<td>3–6</td>
<td>7.47</td>
</tr>
<tr>
<td>Gap reducer</td>
<td>1–2</td>
<td>2.49</td>
</tr>
</tbody>
</table>

*Unless cited otherwise, CO₂ reductions were calculated using an estimate based on the assumption that a 1 per cent fuel savings generates 1.6433 tonnes-reduction in emissions.

**This figure is based on fuel savings of 4 per cent.

***This figure is based on fuel savings of 5 per cent and is extrapolated based on Rocky Mountain Institute’s outputs for 4 per cent.

Sources: Environmental Protection Agency; National Research Council; Rodriguez and others, Market Penetration of Fuel Efficiency Technologies; Rocky Mountain Institute; The Conference Board of Canada, A Long, Hard Road, 46–47.

Underbody devices (also known as undertrays) are also used to reduce aerodynamic drag, often as an alternative to side skirts as they don’t affect access to the underbody and side of a trailer and are more durable. Despite these advantages, uptake has been more limited as they have not been on the market for as long as side skirts. According to the ICCT study, average fuel savings for underbody devices range between 2 and 5 per cent. Assuming fuel savings at the upper end of this range (5 per cent), the expected GHG savings per truck per year are 6.225 tonnes of CO₂e.
Boat tails (also known as rear-end fairings or base flaps) are aerodynamic devices located at the rear of the trailer to help decelerate air passing at the trailer sides and over the roof.\footnote{Sharpe and Roeth, Costs and Adoption Rates of Fuel-Saving Technologies for Trailers, 9.} An ICCT study confirms fuel savings of between 3 and 5 per cent,\footnote{Ibid.} whereas an earlier Canadian study places these savings higher, at 6 per cent.\footnote{Ogburn and Ramroth, Truck Efficiency and Greenhouse Gas (GHG) Reduction Opportunities.} Assuming the upper end of this range (6 per cent) the GHG savings per truck per year are estimated at 7.47 tonnes of CO$_2$e.\footnote{Ibid., 10.} However, some aerodynamic devices such as boat tails faced regulatory barriers to their adoption. For instance, boat tails required an exemption since they add to the maximum length of the vehicle. A more in-depth discussion of regulatory barriers to the adoption of fuel-saving technologies follows at the end of this chapter.

Gap reducers are devices that are attached to the front of a trailer to minimize the gap (and air turbulence) between it and the truck tractor.\footnote{EPA, Improved Aerodynamics.} An ICCT study confirms that this technology has had “negligible” uptake in Canada, and fuel savings are the lowest of aerodynamic vehicle technologies (between 1 and 2 per cent).\footnote{Sharpe and Roeth, Costs and Adoption Rates of Fuel-Saving Technologies for Trailers, 11.} Assuming the upper end of this range (2 per cent), gap reducers are estimated to generate GHG savings per truck per year of 2.49 tonnes of CO$_2$e.\footnote{Ogburn and Ramroth, Truck Efficiency and Greenhouse Gas (GHG) Reduction Opportunities, 11.}

**Rolling Resistance Losses**

Another important mechanism to achieve fuel economy relates to tires. (See Table 8.) One option is wide-base single (WBS) tires. Used in place of a traditional (dual tire) set, WBS tires contribute to efficiencies through reduced weight and inertia. Low rolling resistance tires are another option; these are a dual-tire configuration but narrower than a traditional set. A drawback associated with low rolling resistance tires is that they can result in reduced traction during winter weather conditions.
According to a 2015 study, the adoption of low rolling resistance tires is more widely accepted and widespread than for WBS tires.\textsuperscript{56} However, their fuel savings are lower (starting at 3 per cent\textsuperscript{57}).

<table>
<thead>
<tr>
<th>Tires</th>
<th>Fuel savings (per cent)</th>
<th>CO$_2$ savings$^*$ (tonnes per truck per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low rolling resistance tires</td>
<td>3</td>
<td>5.08</td>
</tr>
<tr>
<td>Wide-base single tires</td>
<td>2–5</td>
<td>8.30\textsuperscript{**}</td>
</tr>
<tr>
<td>Automatic tire inflation systems</td>
<td>0.604</td>
<td>1.12</td>
</tr>
</tbody>
</table>

$^*$Unless cited otherwise, CO$_2$ reductions were calculated using an estimate based on the assumption that a 1 per cent fuel savings generates 1.6433 tonnes-reduction in emissions.

$^{**}$This figure assumes fuel savings of 5 per cent (Rocky Mountain Institute study).

Sources: Environmental Protection Agency; National Research Council; Rodriguez and others, Market Penetration of Fuel Efficiency Technologies; Rocky Mountain Institute; The Conference Board of Canada, A Long, Hard Road, 46–47.

Automatic tire inflation (ATI) systems are another technology that can help save fuel and reduce GHG emissions. When under load, tires flex more if not inflated properly (i.e., under-inflated). This increases rolling resistance, generates heat, and reduces fuel efficiencies.\textsuperscript{58} By continually monitoring and adjusting tire pressure—even while the vehicle is travelling—ATI systems relieve drivers from manually monitoring air pressure. The EPA confirms that ATI systems can achieve fuel savings of 0.604 per cent, resulting in CO$_2$ emission reductions of 1.12 metric tonnes per truck per year.\textsuperscript{59}

What Are the Costs of GHG Reduction (Abatement)?

Although the technologies and equipment presented in Table 9 all have potential impacts on the GHG emissions of trucks, some are more cost-effective than others. An abatement cost curve refers to the cost outlays necessary to reduce

\textsuperscript{56} Sharpe and Roeth, Costs and Adoption Rates of Fuel-Saving Technologies for Trailers.

\textsuperscript{57} EPA, Low Rolling Resistance Tires.

\textsuperscript{58} EPA, Automatic Tire Inflation Systems.

\textsuperscript{59} Ibid.
GHG emissions by a certain amount. For example, a technology that costs $100 and reduces GHG by 1 tonne is clearly more cost-efficient than a technology that costs $1,000 and reduces GHG by 1 tonne within the same time period.

Table 9 presents the cost per tonne of GHG abated for select technologies presented in previous sections of this chapter. Unfortunately, it was not feasible to obtain cost measures for all technologies. The cost of some of the technologies, such as the specific engine technologies, tends to be incorporated into the overall cost of a truck and no individual breakdown is available.

### Table 9

<table>
<thead>
<tr>
<th>Technology</th>
<th>Payout period</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ENGINE AND DRIVETRAIN</strong></td>
<td></td>
</tr>
<tr>
<td>Bottoming cycle</td>
<td>5–6</td>
</tr>
<tr>
<td>Turbo compounding</td>
<td>2–3.5</td>
</tr>
<tr>
<td><strong>TRANSMISSION AND DRIVETRAIN</strong></td>
<td></td>
</tr>
<tr>
<td>Automated manual transmission</td>
<td>3–5</td>
</tr>
<tr>
<td>Hybridization</td>
<td>6–8</td>
</tr>
<tr>
<td><strong>IDLE REDUCTION</strong></td>
<td></td>
</tr>
<tr>
<td>Auxiliary power units</td>
<td>2–4</td>
</tr>
<tr>
<td>Battery air conditioning systems</td>
<td>2–4</td>
</tr>
<tr>
<td>Fuel-operated heaters</td>
<td>2–4</td>
</tr>
<tr>
<td><strong>AERODYNAMIC LOSSES</strong></td>
<td></td>
</tr>
<tr>
<td>Side skirts</td>
<td>2–5</td>
</tr>
<tr>
<td>Underbody devices</td>
<td>1.5–5.5</td>
</tr>
<tr>
<td>Boat tail</td>
<td>3</td>
</tr>
<tr>
<td>Gap reducer</td>
<td>1–2</td>
</tr>
<tr>
<td><strong>ROLLING RESISTANCE LOSSES</strong></td>
<td></td>
</tr>
<tr>
<td>Low rolling resistance tires</td>
<td>2–4</td>
</tr>
<tr>
<td>Wide base single tires</td>
<td>2–4</td>
</tr>
<tr>
<td>Automatic tire inflation system</td>
<td>2</td>
</tr>
</tbody>
</table>


Clearly, some technologies are more cost-effective than others in terms of dollars spent per tonne of GHG reduced. Low-viscosity engine oil costs only about $70 more per year than regular engine oil, yet can yield fuel savings up to 3 per cent and GHG reductions up to 4.93 tonnes annually. Other technologies, however, may cost significantly more and provide fewer benefits in terms of fuel
savings and GHG abatement. The high cost can also be a market barrier, since truckers would be hesitant to invest in something they see no clear payback from (i.e., reduced fuel consumption).

Market Penetration Rates and Barriers

While many of these technologies have been on the market for some time, they have variable uptake throughout the sector. An ICC study relying on interviews with trucking stakeholders in Canada, for example, demonstrated vastly different adoption rates for fuel-saving devices in new box trailer sales. (See Table 10 for selected technologies.) For example, while widespread utilization of low rolling resistance tires was observed (70 to 90 per cent adoption in new box trailers), wide-base single tires exhibited low utilization rates. Similarly, side skirts were the most widely adopted of all vehicle body devices (40 to 50 per cent adoption in new box trailers), with all others exhibiting nominal adoption rates.

**Table 10**

Market Penetration Rates
(per cent)

<table>
<thead>
<tr>
<th>Fuel-saving technology</th>
<th>Estimated adoption in new box trailer sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>VEHICLE BODY</td>
<td></td>
</tr>
<tr>
<td>Side skirt</td>
<td>40–50</td>
</tr>
<tr>
<td>Underbody devices</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Boat tail</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Gap reducer</td>
<td>&lt;1</td>
</tr>
<tr>
<td>TIREs</td>
<td></td>
</tr>
<tr>
<td>Low rolling resistance tires</td>
<td>70–90</td>
</tr>
<tr>
<td>Wide-base single tires</td>
<td>5–10</td>
</tr>
<tr>
<td>Tire pressure monitoring systems</td>
<td>5–15</td>
</tr>
<tr>
<td>Automatic tire inflation systems</td>
<td>20–30</td>
</tr>
</tbody>
</table>

Source: Sharpe and others, Costs and Adoption Rates of Fuel-Saving Technologies, 24.

As detailed in this section, variable costs and payback times are some of the barriers to market penetration of these fuel-saving technologies. (See “Payback Time.”)
Payback Time

“Payback time”—or the amount of time before the initial monetary investment in a fuel-saving device is recouped (or pays itself back) through savings in fuel expenditures—is one of the most important factors in determining technology adoption rates within trucking. As the ICCT demonstrated, the “real world” payback period for most technologies is one to two years (12 to 18 months).60 If the actual payback period for a technology is longer than anticipated, this can have a negative impact on market adoption.

Uncertainties About Return on Investment and Technology Performance

Recent ICCT studies have noted that uncertainty about and lack of credible information on technology performance and other variables (i.e., operational impacts, payback period, effectiveness, driver acceptance61) are important barriers to adoption, with many fleets reporting that they only “trust” technology that they themselves have tested.62 This mistrust can be especially strong in the early stages of the development of a technology, when information is typically in scarce supply.63 While some fleets are “early adopters” and able to invest in a technology (including testing and research), lack of information-sharing was another contributing barrier to wider uptake.64 A lack of tools available for sharing information and to support learning throughout industry was also cited as contributing to low uptake.65 Inconsistencies in the reliability of new technologies were cited as reasons for low adoption rates. Given the demands that the trucking sector places on equipment—with little room for error—any gaps between expectations and results can affect the reputation of a fuel-saving technology, with long-term impacts on implementation.66

60 Sharpe and others, Costs and Adoption Rates of Fuel-Saving Technologies for Trailers.
61 Sharpe, Barriers to the Adoption of Fuel-Saving Technologies, 4.
62 Roeth and others, Barriers to the Increased Adoption of Fuel Efficiency Technologies, 33.
63 Ibid.
64 Ibid., 35.
65 Ibid., 40.
66 Ibid., 44.
Capital Costs

A second key barrier to greater uptake of fuel-saving technologies relates to their initial capital costs. Truck technologies that are effective in reducing GHGs form an additional expense—this is in addition to the high cost associated with new trucks generally.\(^67\) For these technologies to be attractive to truck owners, the fuel savings generated must be larger than the costs of installation.\(^68\) These fuel savings occur over time, whereas the upfront costs of investment are borne immediately. Moreover, there may be additional operating and maintenance expenses presented by the technology. A recent ICCT study confirmed that payback time is the most important economic consideration in determining whether or not to invest in fuel-saving technologies.\(^69\) For fleets, payback time must be shorter than ownership cycles (approximately half)—this allows a return on investment as well as an offset of the initial capital investment in a technology.\(^70\) ICCT research confirmed that ideal payback periods are between 12 and 24 months.\(^71\)

In addition, other technologies that support safety or offer features that are appealing to drivers can often compete for priority against fuel-saving devices.\(^72\) This is particularly the case in the for-hire trucking market, which exhibits high driver turnover rates and thus is focused on those technologies that help to retain drivers.\(^73\)

Split Incentives

A related barrier to greater fuel-saving technology adoption in the trucking sector emerges in the form of split incentives. This has an influence when the organization or individual purchasing the fuel-saving technology is not the same as the one paying for fuel,\(^74\) as in the case of differential truck and trailer ownership and contractual provisions.

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\(^{67}\) Sharpe, *Barriers to the Adoption of Fuel-Saving Technologies*, 5.

\(^{68}\) Roeth and others, *Barriers to the Increased Adoption of Fuel Efficiency Technologies*, 50.

\(^{69}\) Ibid.

\(^{70}\) Ibid.

\(^{71}\) Ibid., 26.

\(^{72}\) Sharpe, *Barriers to the Adoption of Fuel-Saving Technologies*, 5.

\(^{73}\) Ibid.

\(^{74}\) Ibid.
When fuel expenses are paid for by a different entity, there is no incentive to invest in fuel-saving devices.

in which fleets specify that fuel costs be borne by a shipper (also known as “open book contracts”). When fuel expenses are paid for by a different entity, there is no incentive to invest in fuel-saving devices (as the benefits associated with reduced fuel consumption and cost savings are passed on). While this barrier was not determined to be the most significant of the four (an ICCT study confirmed that open-book provisions are prevalent in approximately 20 per cent of contracts), it does have an impact on priorities for fuel efficiency.

**Technology Availability**

When a technology is unavailable for purchase in a given region or market, cannot be made available through a preferred manufacturer, or is available only through a limited number of original equipment manufacturers (OEMs), this forms a fourth barrier to adoption. Variability in OEM supply of fuel-saving devices has also been observed. Issues include technologies being delivered as options but not part of standard packages for vehicles, or sold as retrofit devices on used vehicles but not on new trucks. As a recent ICCT study noted, lack of technology is more of an issue for trailers, as these devices are rarely offered unless a client specifically requests them.

**Long Combination Vehicles**

A long combination vehicle (LCV) refers to one tractor pulling two or more semi-trailers. This combination offers economic benefits, since it enables one tractor to transport double the goods of a traditional tractor–semi-trailer combination without doubling fuel consumption (or the capital cost of a second tractor).

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75 Ibid., 7.
76 Ibid.
77 Ibid., 6.
78 Ibid., 7.
79 Ibid.
LCVs also have the potential to reduce emissions from the freight transportation sector, since the same amount of goods can be transported by fewer trailers. Currently, the vehicles have been operating in Western Canada and Ontario has issued a limited number of permits for LCV operation.

## Conclusion: Overcoming Barriers

As a response to these barriers to more widespread adoption of technology, the ICCT has advanced three main policy measures. These comprise fuel-efficiency standards, market-based programs, and fiscal measures. As Table 11 illustrates, these policy measures help support the deployment of fuel-saving technologies in different ways.

### Table 11

<table>
<thead>
<tr>
<th>Policy Measures to Improve Fuel-Saving Technology Adoption</th>
<th>Notes/examples</th>
<th>Impacts addressed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel-efficiency standards (mandatory regulations)</td>
<td>• Regulations for fuel efficiency and/or GHGs for new vehicles • Countries with these demonstrate reductions in fuel consumption of 2–4 per cent per annum (compared with 1 per cent per year without)</td>
<td>• Direct: uncertain ROI, lack of technology availability • Indirect: capital cost constraints, split incentives</td>
</tr>
<tr>
<td>Market-based programs</td>
<td>• Voluntary programs that provide shippers and fleets with information to support decision-making (re. technologies, strategies, testing) • Examples include SmartWay, FleetSmart</td>
<td>• Direct: uncertain ROI, lack of technology availability</td>
</tr>
<tr>
<td>Fiscal measures</td>
<td>• Taxes levied on vehicles and fuels to accelerate fuel-efficient options and alternatives • Financial incentives for fuel-efficient technologies</td>
<td>• Direct: capital cost constraints, split incentives • Indirect: uncertain ROI</td>
</tr>
</tbody>
</table>


As subsequent chapters of this report detail (see chapters 5 and 6), Canada has implemented many of these measures as they relate to existing technologies. This suggests opportunities for leveraging disruptive truck technologies.
CHAPTER 4

Reducing Emissions From Freight: Disruptive Truck Technologies

Chapter Summary

- For the period 2020 to 2050, we estimate that further GHG reductions of up to 17.4 per cent could be achieved from electric zero-emission trucks and up to 5.9 per cent from driverless trucks.

- While these findings outline what is possible, the real challenge lies in managing the transition period.

- To successfully navigate the transition to a transportation sector that includes these disruptive technologies, Canada’s climate, transportation, innovation, and workforce transition portfolios need to be aligned.
Disruptive Technologies to Reduce GHGs

The previously cited attempts to help reduce emissions from trucking reflect those fuel-saving technologies that are established and have been on the market for some time. Looking ahead, disruptive technologies in transport are poised to have important impacts on the emission profile associated with goods movement. Two examples discussed in this section include electric and automated (driverless) trucks.

**Battery Electric Trucks**

While electric grid vehicles are in development in other countries, such as Sweden (see “Electric Highways”), battery-operated trucks have been in development for the North American market. Tesla recently announced a battery-powered semi-truck, claiming a range of 475 or 800 kilometres (depending on the model), autonomous driving capabilities, and an initial price that is approximately 50 per cent higher than a traditional diesel-powered truck. Despite these claims, the battery-powered truck remains untested in real-world situations.

**Electric Trucks and Impacts on GHGs**

There are several types of electric trucks: hybrids (powered by a diesel engine in combination with an electric motor); fuel cell vehicles (powered by fuel cells); and overhead catenary grid integrated vehicles (powered by an electric motor with electricity supplied by an overhead catenary grid). (See Table 12.)

A previous Conference Board of Canada report, *A Long, Hard Road,* estimated a continuous-improvement scenario in which emissions from heavy-duty trucks would decrease from 59.6 Mt of CO₂ equivalent
in 2020 to 25.9 Mt by 2050. This analysis considers that scenario, but with the addition of either driverless or electric zero-emission trucks.

Table 12
Electric Truck Technologies Uptake and Fuel Savings
(per cent)

<table>
<thead>
<tr>
<th>Technology and scenario</th>
<th>Uptake</th>
<th>Fuel savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>HYBRID</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early adoption 3 (by 2030)*</td>
<td>3</td>
<td>20**</td>
</tr>
<tr>
<td>Late adoption 1 (by 2030)</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>FUEL CELL VEHICLES</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business as usual 0 (by 2050)</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Favourable 50 (by 2050)</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>Ambitious*** 50 (by 2050)†</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>OVERHEAD Catenary Grid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business as usual 0 (by 2050)</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Favourable 0 (by 2050)</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Ambitious 40 (by 2050)</td>
<td>40</td>
<td>100</td>
</tr>
<tr>
<td>BATTERY ELECTRIC</td>
<td>Speculative</td>
<td>100</td>
</tr>
</tbody>
</table>

*Heid and others, “What’s Sparking Electric-Vehicle Adoption in the Truck Industry?”
**Union of Concerned Scientists, Truck Electrification.
***den Boer and others, Zero Emissions Trucks.
†Enter market earlier than favourable scenario

Sources: Heid and others; Union of Concerned Scientists; den Boer and others.

The fuel cell hybrid electric vehicle (FCHEV) and the overhead catenary grid integrated vehicle (OC-GIV) are considered mutually exclusive technologies—i.e., the industry adopts either FCHEV trucks or OC-GIV trucks, but not both, given the significant costs of developing both technologies simultaneously. (See Table 13.)

For the FCHEV, battery-electric, and OC-GIV technologies, the emission savings are the same percentage as the market penetration, since both these technologies are zero emission. For example, a zero-emission technology with a 40 per cent market share would remove 40 per cent of emissions.

The uptake of hybrid truck powertrains has the potential to reduce GHG emissions by up to 4.2 Mt, or 0.35 per cent of total emissions, between 2020 and 2050. The introduction of FCHEVs can save up to 210 Mt of
GHG emissions under the ambitious scenario. Meanwhile, OC-GIVs, if the technology is developed, could reduce GHG emissions by 174 Mt under the ambitious scenario. Battery electric trucks have the potential to be truly disruptive in the North American market, but the viability of the technology has not yet been tested. However, the adoption of fully electric heavy-duty trucks would lead to a GHG reduction of the same percentage as the market penetration.

### Table 13

<table>
<thead>
<tr>
<th>Technology and scenario</th>
<th>Mt of GHG emissions saved (2020–50 total)</th>
<th>Percentage of emissions saved (2020–50 total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybrid—early adoption</td>
<td>4.2</td>
<td>0.35</td>
</tr>
<tr>
<td>Hybrid—late adoption</td>
<td>1.4</td>
<td>0.12</td>
</tr>
<tr>
<td>FCHEV—business as usual</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>FCHEV—favourable</td>
<td>85</td>
<td>7</td>
</tr>
<tr>
<td>FCHEV—ambitious</td>
<td>210</td>
<td>17.4</td>
</tr>
<tr>
<td>OC-GIV—business as usual</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>OC—favourable</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>OC-GIV—ambitious</td>
<td>174</td>
<td>14.4</td>
</tr>
</tbody>
</table>

Source: The Conference Board of Canada.

### Electric Highways: Infrastructure to Support Greening Freight

In June 2016, the world's first electric highway (eHighway) was launched in Gävle, Sweden. It is 2 kilometres in length and part of the E16 motorway, a public highway north of Stockholm.³ An electrically powered, diesel-hybrid truck developed by Scania (the G 360 4x2 model already on the market) made the opening journey.⁴ The launch of the eHighway signalled the beginning of a two-year trial of the technology. Two diesel-hybrid trucks are participating in this pilot, to help the Transport Administration of Sweden (Trafikverket) and the Region of Gävleborg determine the effectiveness and feasibility of the highway

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³ Siemens, “World’s First eHighway Opens in Sweden.”
⁴ Scania, “World’s First Electric Road Opens in Sweden.”
for wider commercial deployment. The pilot program reflects the strength of national climate policy in Sweden. A fossil fuel-free transportation sector by 2030 is a key commitment in the country’s climate protection strategy.\(^5\)

The potential environmental benefits from the electrification of trucking are considerable. The transition from diesel-fueled to electric-powered trucks can reduce energy consumption by at least 50 per cent and GHG emissions by 80 to 90 per cent.\(^6\) Moreover, operating costs are also lower, since electric engines are more efficient than internal combustion engines.\(^7\)

### Automated Trucks for Greening Freight

Automated vehicle (AV) technology has been in development for some years now.\(^8\),\(^9\) While the popular term for an automated vehicle is a driverless car, suggesting an emphasis on the movement of people, the technology also applies to goods movement generally and the trucking sector in particular. Indeed, this sector has been identified as one of the earliest adopters (relative to passenger systems and networks).\(^10\) “AVs in Practice,” for example, provides an indication of the extent of development and testing in selected EU countries.

While there are a number of anticipated benefits associated with AV technology, including road safety and reductions in the number of injuries and fatalities on the road network,\(^11\) a key benefit relevant to this report is environmental in nature. Fuel efficiencies and reduced emissions are two key defining features associated with AV technology as applied to the trucking sector.

These efficiencies and reductions are achieved through a practice known as platooning, whereby two or more trucks are driven in very close

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5 Siemens, “World’s First eHighway Opens in Sweden.”
6 Scania, “Electrification.”
8 Gill and others, Automated Vehicles.
9 Within the context of logistics and freight transport, Flämig traces the development of AVs to at least the 1950s in the United States. See Flämig, “Autonomous Vehicles and Autonomous Driving.”
10 Crandall and Formby, “Is That a Driverless Truck Alongside You?”
11 Gill and others, Automated Vehicles.
succession (with less than one second headway\textsuperscript{12,13}) in a “column”\textsuperscript{14} or “road train.”\textsuperscript{15} As all trucks in the platoon are connected electronically (through wireless vehicle-to-vehicle [V2V] technology), the leading vehicle is able to control functions of the following vehicles, such as braking, steering, and acceleration.\textsuperscript{16}

Although automated trucks have the potential to reduce overall emissions, they could also lead to an increased demand for road freight and act as a disincentive to the promotion of intermodal supply chains. Load factor (the combination of capacity utilization and empty kilometres travelled) could be adversely affected by driverless vehicles if their adoption leads to more empty kilometres travelled. Additionally, the cost reduction associated with automated trucks could also act as a disincentive for intermodal supply chains, since it would be more beneficial to transport freight via driverless truck than by rail or marine.

**AVs in Practice: The European Truck Platooning Challenge**

On April 7, 2016, six convoys of semi-automated trucks, connected by wireless technology, arrived in Rotterdam’s harbour area. The arrival of these trucks signalled the successful completion of a multi-national trial of early (semi-) automated vehicle technology. The convoys were part of the European Truck Platooning Challenge, travelling to Rotterdam from selected European cities (which included cities in Sweden, Denmark, Belgium, Germany, and the Netherlands) on public roads.\textsuperscript{17} They represented six of the largest trucking companies in Europe, including Daimler Trucks, Volvo Group, Scania, DAF Trucks, MAN Truck and Bus, and IVECO.\textsuperscript{18} As these trucks were only semi-automated, drivers were still required to be present during the trial.

\textsuperscript{12} Janssen and others, *Truck Platooning*.
\textsuperscript{13} As Janssen describes, distances between trucks in a platoon can be as low as 0.3 seconds. Assuming a travelling speed of 80 km/h, vehicles would be approximately 6.7 metres apart.
\textsuperscript{14} European Truck Platooning, “European Truck Platooning Challenge 2016.”
\textsuperscript{15} Janssen and others, *Truck Platooning*.
\textsuperscript{16} Ibid.
\textsuperscript{17} European Truck Platooning, “European Truck Platooning Challenge 2016.”
\textsuperscript{18} Agence France-Presse, “Convoy of Self-Driving Trucks.”
Initiated by the Netherlands as part of its 2016 Presidency of the European Union, the trial was the first cross-national exercise of its kind for semi-automated vehicles. As a multi-national exercise, it involved extensive cooperation from various authorities, including EU nation states, road and vehicle approval authorities, and the private sector. The trial was meant to incentivize further tests, with a series of real-live test cases to be made before the end of 2017. The emphasis on multi-national cooperation was an important foundational principle, to help achieve regulatory harmonization among participating countries and their road authorities.

The practice of platooning leads to fuel efficiencies, both for leading and following vehicles. Findings from the Safe Automated Road Trains for the Environment (SARTRE) project, for example, reveal fuel reductions ranging from 8 to 13 per cent for following vehicles and 2 to 8 per cent for the leading vehicle. Assuming average truck mileage of 0.353L/km, fuel reductions could range from 0.706 to 2.82 litres per 100 km for the leading vehicle and from 2.82 to 4.589 litres per 100 km for following vehicles. Given that one litre of diesel fuel generates 2.66 kg of CO₂ when burned, these fuel efficiencies would lead to CO₂ reductions per truck per year of between 5.24 and 8.52 tonnes for following vehicles and between 1.31 and 5.25 tonnes for the leading vehicle.

Indirect environmental benefits can also be derived from automated truck platooning. The shorter lead times between vehicles could reduce congestion on the road, optimize road capacity, and improve traffic flows throughout the road network. Janssen, for example, compares a typical scenario involving two trucks (each 18.75 metres long) driving at speeds of 80 km/h and two seconds apart, claiming 82 metres of

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19 European Truck Platooning, “European Truck Platooning Challenge 2016.”
20 European Truck Platooning, “European Truck Platooning’s Pitch.”
21 European Truck Platooning, “Corridors to Drive.”
22 Variance exists in the documentation of fuel-saving benefits derived from platooning. A recent Natural Resources Canada study revealed net fuel savings of between 5.2 per cent and 7.8 per cent for a full vehicle platoon. Assuming an average truck mileage of 0.353L/km, this would result in fuel savings of between 1.84 and 2.75 litres per 100 kilometres. See McAuliffe and others, Fuel-Economy Testing.
23 Natural Resources Canada (NRCAN), 2008 Canadian Vehicle Survey.
24 NRCAN, “Learn the Facts.”
road access (not including gaps required in front of the leading vehicle and behind the following vehicle), with a platoon involving a 0.3-second gap between vehicles. In the latter scenario, the length of road space required for those two trucks would be 44 metres (a 46 per cent reduction). The improved road capacity and traffic flows for other vehicles derived from platooning similarly improve fuel efficiencies and lead to further GHG emission reductions.

The expectation within industry (and in relation to selected EU countries) is that truck platooning will be commercially available and legally permitted by 2020. In the United States, where considerable testing has also been taking place (particularly with the states of Nevada and Texas), commercially available platooning is expected as early as 2017.

Automated Trucks and the Impact on GHGs

The impact of automated trucks on total GHG emissions depends largely on market penetration and adoption rates. Assuming the midpoint fuel reduction from the OECD SARTRE study of 5 per cent for the leading vehicle and 10 per cent for following vehicles, and truck platoons with one lead and two trailing trucks, the convoy would reduce fuel consumption by 8.33 per cent. This analysis also assumes the total heavy-duty truck fleet grows from 484,615 in 2020 to 903,122 in 2050.

There were four scenarios considered for the market penetration of automated trucks. (See Table 14.) The baseline scenario assumes no expansion of automated trucks over the medium term. The conservative adoption scenario assumes a gradual adoption of automated trucks on public roads starting in 2030, achieving 15 per cent market share by 2032, 20 per cent by 2036, and 25 per cent by 2040. The disruptive adoption scenario assumes that industry adopts the technology before governments have resolved regulatory issues. Automated trucks would be introduced in 2020, with 40 per cent market share by 2022, 70 per cent by 2027, and 80 per cent by 2030. Finally, the regulated scenario assumes the entire road freight industry adopts automated trucks

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25 Janssen and others, Truck Platooning, 24.
26 Driverless Transportation, “Truck Platooning Barreling Ahead.”
quickly to avoid being undercut by the competition and legislative issues are resolved quickly. Under this scenario, automated trucks would be introduced in 2027, with 20 per cent market share by 2028, 80 per cent by 2030, and 95 per cent by 2032.

Table 14
Automated Trucks and Impact on GHG

<table>
<thead>
<tr>
<th>OECD scenario</th>
<th>Mt of GHG emissions saved (2020–50 total)</th>
<th>Percentage of emissions saved (2020–50 total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Conservative adoption</td>
<td>11.9</td>
<td>1.0</td>
</tr>
<tr>
<td>Disruptive adoption</td>
<td>72.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Regulated scenario</td>
<td>58.6</td>
<td>4.9</td>
</tr>
</tbody>
</table>

Source: The Conference Board of Canada.

Market Penetration Rates and Barriers
There remains considerable uncertainty around the timeline for market penetration of these technologies. Based on statements from industry, the commercial rollout of AVs could happen in a matter of years. Companies like Daimler Trucks, for example, which is leading the testing and development of automated trucks in America, has indicated that commercial deployment could be as early as 2025.27 However, some leading researchers have suggested that governments are nowhere near ready to authorize AVs on public roads and highways, and that effective deployment could be decades away.28

It is apparent from these debates that the key barriers to market penetration of AVs will not be technological in nature. As this report demonstrates, the technology is already here and being tested in numerous contexts and conditions. Similarly, there do not appear to be the same behavioural or attitudinal barriers on the part of industry

27 Roberts, “Daimler Debuts Driverless Truck.”
28 Associated Press, The, “Startup Aims to Take Over Highways.”
as identified in relation to the more established (fuel economy) technologies. The major trucking companies, for example, are leading the charge when it comes to developing and testing automated vehicles. These companies are also making increasingly bold predictions as to when these vehicles will be on the market and readily available for use.

One important barrier to the market update of automated vehicles—for both land and air vehicles—is the policy and regulatory framework. While the Province of Ontario has positioned itself as a leader on AVs within Canada, and remains the only province to date (at the time of writing) to have revised its highway traffic act to allow for the testing of automated vehicles on public roads, Canada as a whole ranks last relative to all other G7 countries when it comes to testing and research support for the technology. Revisions to provincial highway traffic acts are significant, because automated vehicles are illegal otherwise. (Central to all highway traffic acts is the presence of a human driver.) So, while industry and the technology are progressing swiftly, they cannot have any significant impact on goods movement in Canada until the policy and regulatory framework catches up.

The backdrop to the rise of automated truck technology is a well-documented truck driver shortage, something noted in Canada and the United States. The introduction of AV technology, therefore, raises some interesting questions as to its role in potentially alleviating the effects of this shortage. At a 2016 conference on automated vehicles, hosted by The Conference Board of Canada, the overwhelming view from within industry was that the technology would not offset the current shortage. Over time, however, that view could change.

30 Gill and others, Automated Vehicles.
31 Gill and Macdonald, Understanding the Truck Driver Supply and Demand Gap.
32 Costello and Suarez, Truck Driver Shortage Analysis 2015.
33 Schulz, “While No Panacea.”
Conclusion

In this chapter, we reviewed disruptive truck technologies that achieve fuel savings and GHG reductions from the trucking sector. While these could help secure reductions in the emission profile associated with road-based freight, the regulatory, policy, and monetary support for research and development of these technologies within Canada is not as advanced as in other G7 nations. This presents opportunities within Canada for the climate file and the innovation file to be better aligned, so that these technologies can be leveraged to reduce emissions.

This discussion around technologies raises important questions about what more government can do to help further GHG emission reductions from the trucking sector. Recognizing that carbon pricing has become to reduce emissions from transport, this is the subject of the next chapter.
CHAPTER 5

Carbon Pricing and Freight Economics

Chapter Summary

- Carbon pricing has been introduced in Canada over the last decade by selected provinces, and from 2018 through the federal government’s Pan-Canadian Framework on Clean Growth and Climate Change.

- Research on the impacts of carbon pricing suggests that increased costs are being passed on directly to consumers in the form of surcharges. Indirect increases in the cost of goods have also been observed.

- Previous Conference Board research confirms that a significant level of investment in low-carbon energy production and use will be required to cut emissions sharply. Freight transport will be one of the sectors requiring investment.

- Revenue recycling from pricing to freight transport could help support these investments.
Pricing Carbon

This chapter explores two carbon-pricing tools used to reduce emissions: carbon taxes and cap-and-trade systems. Both measures are applications of the “polluter pays” principle, but vary by approach and introduce different levels of uncertainty around reducing GHGs (relating to either the price or quantity of emissions). While their foundational goals are similar, their implementation is almost the opposite, and the public perception around these approaches can vary widely. Furthermore, there are different strategies around using or “recycling” the revenue generated from these pricing measures.

In a carbon tax, government sets a price per tonne of GHGs emitted. As a price signal, the amount charged per tonne encourages behavioural change over time (especially as the cost per tonne tends to increase with time) to reduce emissions throughout the economy. In this approach, the net reductions in GHGs are unclear (as these depend upon the willingness to pay within the economy), but the price that people will pay for carbon is certain.

By contrast, a cap-and-trade system involves establishing a concrete limit (or cap) on the quantity (tonnes) of allowable GHG emissions released. Each year, the cap is reduced in order to further behavioural change throughout the economy and reduce emissions. In this system, permits or credits can be issued or sold by government to those organizations that exceed the cap, and organizations can trade these credits (i.e., buy and sell them) to other companies operating in the same system to ensure compliance. So while the net reductions in GHGs are clear, the price that people will pay for carbon is determined by the market and thus uncertain.
Provincially Led Carbon-Pricing Initiatives

Since 2007, various approaches to carbon pricing have been introduced in Canada at the provincial level. These are summarized in Table 15 below and detailed in Appendix A.

Table 15
Carbon Pricing in Canada

<table>
<thead>
<tr>
<th>Type</th>
<th>Year initiated</th>
<th>Province</th>
<th>Name of initiative</th>
<th>Key characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon tax</td>
<td>2008</td>
<td>British Columbia</td>
<td>Carbon tax</td>
<td>• Tax on use and purchase of fuels*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Revenue-neutral: The tax raised revenue of $1.73 billion in 2015–16, with 33 per</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>cent of the amount being returned to individuals and 67 per cent to businesses</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>through income tax reductions and various tax credits.**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• $10/tonne of CO₂ equivalent emissions in 2008; increased to $30/tonne by 2012***</td>
</tr>
<tr>
<td></td>
<td>2017</td>
<td>Alberta</td>
<td>Carbon levy</td>
<td>• Tax on use and purchase of fuels†</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Partial revenue-recycling: approximately 65 per cent of Alberta households to</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>receive a consumer rebate and income tax rates for small businesses to be reduced</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>by 2 per cent</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• $20 per tonne of CO₂ equivalent, set to increase to $30 per tonne in 2018</td>
</tr>
<tr>
<td></td>
<td>2007</td>
<td>Quebec</td>
<td>Green Fund levy</td>
<td>• Tax of $3 per tonne of CO₂ equivalent levied on petroleum companies</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Tax revenue used to support energy-saving projects and initiatives in Quebec’s</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>climate change action plan</td>
</tr>
<tr>
<td>Cap and trade</td>
<td>2008</td>
<td>Quebec</td>
<td>The Québec Cap-and-Trade System for Greenhouse Gas</td>
<td>• Regulated facilities require permits to emit GHG; mining and manufacturing are</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Emission Allowances</td>
<td>exempt due to international competition.††</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Allowance permits cost $40–$50 per tonne of GHG from the government.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Facilities can then buy/sell permits between one another according to their GHG</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>emissions requirements.†††</td>
</tr>
<tr>
<td></td>
<td>2017</td>
<td>Ontario</td>
<td>Cap and trade</td>
<td>• Expected revenues of $1.9 billion per year, increasing to $8 billion by 2020; must</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>be re-invested to reduce GHG</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Fuel suppliers selling more than 200 litres per year and facilities emitting over</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25,000 tonnes of GHG per year are mandatory participants.†</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Facilities emitting 10,000 to 25,000 tonnes of GHG per year are voluntary</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>participants.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Companies that do not emit GHG and individuals are market participants.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Several large facilities with significant economic output have been granted</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>exemptions for the first four years of the program.</td>
</tr>
</tbody>
</table>

* B.C. Ministry of Finance, “Carbon Tax.”
† Alberta Treasury Board and Finance, Budget 2016.
†† Houle, Obstacles to Carbon Pricing in Canadian Provinces.
‡ Government of Ontario, “Cap and Trade: Program Overview.”

Sources: Alberta Treasury Board and Finance; B.C. Ministry of Finance; Houle; Government of Ontario; Government of Quebec; United Nations Framework Convention on Climate Change.
The development of individual provincial systems implemented in isolation from other jurisdictions (with, perhaps, the exception of Ontario’s entry into the cap-and-trade system employed by Quebec and California) led to critiques of a weak (historical) federal role in this area, to the extent that the previous federal government was seen as having “abandon[ed] its responsibility on climate change” and undermined progress being made around the world. When Quebec launched the country’s first carbon tax in 2007, for example, it did so following the previous government’s decision to opt out of establishing carbon pricing at the national level.

The Federal Role in Pricing

The current federal government has included carbon pricing as part of its plans to reduce GHG emissions. In late 2016, Prime Minister Trudeau announced that provinces had until 2018 to introduce their own pricing plans, and that failure to do so would result in a price being imposed by the federal government. The suggested price was $10 per tonne starting in 2018, rising by $10 per year to $50 per tonne by 2022. This national “floor price” on carbon is designed to ensure that all provinces and territories in Canada have carbon pricing in some form.

In December 2016, the Pan-Canadian Framework on Clean Growth and Climate Change was announced, with the majority of the provinces having signed on to this agreement. Carbon pricing is an important part of this new framework, the development of which is informed by an eightfold benchmark. (See Table 16.)

As illustrated here (Item 3), jurisdictions can choose between a carbon tax (price-based) or cap-and-trade system.

1 Holmes and others, All Over the Map 2012, 6.
2 Ibid.
3 Houle, Obstacles to Carbon Pricing in Canadian Provinces.
4 Harris, “Justin Trudeau Gives Provinces Until 2018.”
5 Canadian Press, “5 Things to Know.”
Table 16
Canada’s Federal Carbon-Pricing Benchmark

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timely</td>
<td>• Pricing in place by 2018 in all jurisdictions</td>
</tr>
<tr>
<td>Common scope</td>
<td>• Based on GHGs</td>
</tr>
<tr>
<td></td>
<td>• Common source application (more effective, reduce interprovincial competitive impacts)</td>
</tr>
<tr>
<td></td>
<td>• Minimally, B.C.’s carbon tax as a guide for same-source application</td>
</tr>
<tr>
<td>Choice of system</td>
<td>• Jurisdictions to implement either a price-based (i.e., carbon tax, carbon levy, or performance-based system) or a cap-and-trade system</td>
</tr>
<tr>
<td>Legislated increases</td>
<td>• To support national target, market certainty</td>
</tr>
<tr>
<td></td>
<td>• Price-based (i.e., tax): start at $10 per tonne in 2018, increasing by $10 per year to $50 per tonne in 2022</td>
</tr>
<tr>
<td></td>
<td>• Cap-and-trade: 2030 emissions target equivalent to or greater than the 30 per cent national reduction target, declining annual caps to 2022</td>
</tr>
<tr>
<td>Revenues</td>
<td>• Remain within jurisdiction</td>
</tr>
<tr>
<td></td>
<td>• Used according to jurisdictional needs (i.e., to help vulnerable populations, support clean-growth objectives, address impacts in certain sectors)</td>
</tr>
<tr>
<td>Federal backstop</td>
<td>• Carbon-pricing system will be introduced by the federal government for those jurisdictions that do not meet the carbon-pricing benchmark</td>
</tr>
<tr>
<td></td>
<td>• Revenues returned to jurisdiction</td>
</tr>
<tr>
<td>Review</td>
<td>• By 2022, approach to be reviewed</td>
</tr>
<tr>
<td></td>
<td>• Document progress, determine next steps</td>
</tr>
<tr>
<td>Reporting</td>
<td>• Reports to be provided by jurisdictions on pricing impacts and outcomes</td>
</tr>
<tr>
<td></td>
<td>• Reports to be verifiable, transparent, and regularly provided</td>
</tr>
</tbody>
</table>


Conference Board Research on Carbon Pricing and Economic Impacts

The Conference Board of Canada has undertaken research on carbon pricing, the ability to reach GHG emission targets, and economic impacts, based on the Trottier Energy Futures Project (TEFP). Its 2017 report *The Cost of a Cleaner Future: Examining the Economic Impacts of Reducing GHG Emissions*7 provides a number of foundational scenarios.

In this research, the economic impacts of three carbon-pricing scenarios are assessed. Scenario A sees carbon taxes increasing from $10 per tonne in 2018 to $80 per tonne by 2025. Scenarios B and C incorporate heavier increases to carbon taxes. By 2025, the tax...

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7 Coad and others, *The Cost of a Cleaner Future.*
Our analysis suggests the economy will shrink only marginally in response to the carbon tax and the shift to higher cost electric power generation.

is at $150 per tonne in Scenario B and $200 per tonne in Scenario C. In addition to carbon pricing, this analysis incorporates changes in the electric power generation sector to reflect a move away from fossil fuels. For each scenario, we assume that carbon tax revenues are reinjected into the economy in the form of corporate and personal income tax cuts and additional public spending (mostly on infrastructure).

Compared with the status quo scenario, our analysis suggests the economy will shrink only marginally in response to the carbon tax and the shift to higher cost electric power generation. The negative impact is small due to two main factors—carbon revenue recycling measures and Canada’s flexible exchange rate, which acts as an important automatic stabilizer that cushions negative effects on the economy.

Even if the negative impact of the carbon tax on real GDP is minimal, the headline number masks important distributional differences across expenditure categories. Higher prices weaken real household income and spending, and business investment and trade volumes are lower. Public sector spending and infrastructure are bolstered throughout the forecast, partly offsetting those declines. Moreover, the carbon tax leaves some industries worse off, as the increased domestic cost of their production is not fully offset by the depreciation of the loonie. At the same time, other industries with smaller production cost increases benefit from the decline in the loonie and end up better off after carbon pricing is introduced.

The analysis also examines the economic impact of the investments required to achieve 30 and 60 per cent reductions in emissions from 1990 levels by 2050. While the 30 per cent reduction is consistent with Canada’s emission trajectory based on announced policies, a 60 per cent reduction by 2050 would put Canada on a path that closely matches the 2030 emission reductions required to achieve our commitment under the Paris Accord. The Trottier analysis outlines several scenarios or pathways that are capable of achieving 30 and 60 per cent reductions in GHG emissions based on state-of-the-art energy models that assess the lowest cost pathway to meet an assumed level of emission reductions. We chose three of the pathways developed in that report and assessed the economic impact of the required investments.
Based on one of the pathways in the Trottier analysis, to achieve just a 30 per cent reduction in emissions below 1990 levels will require some $2 trillion (in 2011 $) in new incremental investments between now and 2050. Of this, $1.7 trillion will need to be invested in national electric power generation, while an additional $360 billion will need to be invested in other sectors, such as biofuels, agriculture, and industrial and commercial operations.

Using another pathway from the TEFP analysis, which achieves a 60 per cent reduction in emissions below 1990 levels, requires a total of $3.4 trillion in new investments. About half of this comes from higher investments in low-emission transportation—new cars, trucks, subways, and so on. The rest of the additional investment is split almost equally among biofuels production, the commercial sector, and new power plants.

This foundational research creates a baseline for additional analysis on policies and practices that will shape alternative pathways to lower Canadian GHG emissions, but without sacrificing economic growth and wealth creation.

**Impacts of Pricing on Freight Economics**

The introduction of these different approaches to carbon pricing across Canada raises important questions about the impacts they are having on freight economics and behavioural change within and related to the trucking sector. In the case of carbon taxes in Canada, a commonly observed outcome has been that the direct increased costs for fuel have been passed on to the consumer. In Alberta, for example, an early impact of the 2017 carbon levy has been for carriers to introduce additional fees for customers in the form of carbon tax surcharges.8 Surcharges of up to 1 per cent of all freight charges were implemented by select trucking companies from January 1, 2017.9,10

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8 Anderson, “Alberta Trucking Companies Add.”
9 Grimshaw Trucking, Province of Alberta.
10 Anderson, “Alberta Trucking Companies Add.”
In a cap-and-trade system, such as the case of Quebec or Ontario, gasoline isn’t directly taxed in the same way as in a carbon levy.\(^{11}\) Yet as Tombe and Rivers illustrate, that doesn’t mean the price of fuel does not increase. Instead, higher wholesale prices—incurred by retail stations—lead to higher fuel prices overall.\(^{12}\) Using data on Quebec gasoline prices, these authors demonstrate an increase in the price of fuel of two to three cents per litre as of January 2015 (when the cap-and-trade system was introduced).\(^{13}\)

Increases in the price of diesel fuel following the introduction of Ontario’s cap-and-trade system have also been documented, with the Ontario Trucking Association confirming an increase for suppliers of between 5.25 and 5.50 cents per litre.\(^{14}\) The OTA also reported that these increased prices are being reflected in the invoices issued by suppliers to fuel carriers,\(^{15}\) suggesting that an early response to a cap-and-trade system is to similarly pass on the costs directly to consumers.

Yet the costs associated with carbon pricing are not only being directly borne by customers; Tombe and Rivers demonstrate that indirect costs are also being absorbed by consumers in sectors where trucking is an input and thus also affected by the increased costs for fuel.\(^{16}\) An example they provide in relation to food illustrates this relationship between direct and indirect costs. Approximately four cents of every dollar spent on food goes to transportation. Should these transportation costs increase by 1 per cent, food costs would directly increase by approximately .04 per cent. Yet the costs associated with trucking also intersect throughout the economy, leading to further increases in the cost of food. Tombe and Rivers argue that for each 1 per cent increase in the cost of transportation, food costs will rise almost 0.1 per cent.\(^{17}\)

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12 Ibid.  
13 Ibid.  
15 Ibid.  
17 Ibid.
The fact that both carbon taxes and cap-and-trade systems as implemented in Canada to date have involved costs being passed on to consumers is instructive, as this expectation is central to the success of carbon pricing generally. This is because changes in consumer behaviour are viewed as generating the most substantive reductions in GHG emissions throughout an economy. As relative prices change (increase) from carbon pricing, consumers are expected to purchase less carbon-intensive goods or to favour companies that are the most efficient at absorbing those costs (i.e., those that are able to effectively invest in emission-reducing equipment that now provides them a competitive advantage in the market). Given that consumer behavioural change is central to reducing emissions, the direct and indirect cost increases noted above suggest that carbon pricing in Canada is having its intended impacts on the costs of fuel and goods.

Carbon pricing could lead to a reduction in tonne-kilometres travelled by modes that are more GHG-intensive (e.g., trucks) and act as an incentive for an intermodal shift to less GHG-intensive modes (e.g., rail or marine). This is also beneficial, since the objective of carbon pricing is not to stifle economic activity, but rather to promote Canada’s transition to a low-carbon economy.

**Revenue Recycling to Accelerate Fuel-Saving Technology Adoption Rates**

A recent ICCt study recognized fiscal responses as one of three main types of policy measures to increase the adoption of fuel-saving technologies. This response is valued for directly addressing two main barriers to technology adoption: capital cost constraints (i.e., upfront capital costs associated with technology purchase and the imperative within industry to secure a short payback period) and split incentives (i.e., different equipment owners and operators,

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18 Sharpe, *Barriers to the Adoption of Fuel-Saving Technologies*. 
resulting in one potentially making a technology purchase but another paying for the cost of fuel). The ICCT study emphasized two broad types of fiscal measures:

- fees or taxes levied against fuels, vehicles, and less fuel-efficient technologies;
- financial incentives for greater fuel-efficient technologies and alternative fuel vehicles. Examples of this latter type of measure include grants and vouchers, rebates, and no- or low-interest loans.

Carbon pricing and more long-standing measures, such as the excise tax on diesel that has been in place since 1987 at a flat rate of $0.04/litre, are important examples of this first type of fiscal measure. As noted above, a common outcome of carbon pricing in Canada (whether a carbon tax or levy or a cap-and-trade system) is higher fuel prices. A fuller suite of responses is required to address the multiple barriers to the uptake of the fuel-efficient technologies documented in the previous chapter. Leveraging revenue-recycling opportunities from carbon pricing could lead to financial incentives for more fuel-efficient technologies. Organizations such as the Ontario Trucking Association have supported the use of revenue recycling to accelerate the shift to these technologies.

However, there are already numerous provincially led initiatives in Canada to support the uptake of fuel-efficient technologies. (See “MTO’s Green Commercial Vehicle Program” for an Ontario example). Some of these have emerged as pilot projects, with variable success rates.

19 Ibid.
20 Ibid.
21 Ibid.
22 NRCan, “Fuel Consumption Taxes in Canada.”
24 Bradley, “OTA.”
26 Viafara and Larson, A Comparison of Five Green Trucking Programs.
MTO’s Green Commercial Vehicle Program

The Green Commercial Vehicle Program (GCVP), delivered by the Ministry of Transportation for Ontario (MTO), is a rebate-based program to help offset the purchase of alternative fuel vehicles (i.e., electric, natural gas) and technologies to reduce emissions (such as aerodynamic and anti-idling devices). Building on an earlier pilot program (2008–10), the modernized program is one of the measures set out in the Ministry of the Environment’s Climate Change Action Plan for green trucking initiatives and commits $170 million to these technologies and vehicles. The draft (August 2017) program includes the following provisions:

- 50 per cent rebate for battery electric vehicles and plug-in hybrid electric vehicles (used typically for short-haul and urban routes, classes 3–5), up to a cap of $75,000;
- 30 per cent rebate on new natural gas trucks (classes 6–8) up to a cap of $30,000;
- 30 per cent rebate on natural gas conversion vehicles (classes 6–8, for engine, fuel system, and installation), up to a cap of $30,000;
- 15 per cent rebate for dual fuel system (natural gas/diesel) conversions (Class 8), up to a cap of $7,500;
- 30 per cent rebate on boat tails and side skirts (provided testing confirms fuel savings of 4 per cent fuel savings), up to caps of $4,000 or $2,000, respectively (a 30 per cent rebate with a cap of up to $4,000 is given for combinations that provide at least 9 per cent fuel savings and are certified by SmartWay as an “elite combination”);
- 30 per cent rebate for auxiliary power units, up to a cap of $4,000;
- 30 per cent rebate for other anti-idling technologies (battery air condition systems, fuel-operated heaters, thermal storage systems), up to a cap of $2,000;
- 30 per cent rebate for electric and diesel-electric refrigeration units (and electric add-ons), up to caps of $5,000 (diesel-electric) and $7,500 (fully electric).

In addition, the Climate Change Action Plan commits $100 million to create a network of low- or zero-carbon fuelling stations for trucks (to start in 2017–18).

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27 See, for example, Ontario Ministry of Transportation (MTO), Green Commercial Vehicle Program.
28 Today’s Trucking Staff, “Ontario to Invest in Green Trucks.”
29 MTO, Green Commercial Vehicle Program.
Conclusion

In this chapter, we have reviewed two main approaches to carbon pricing: carbon taxes and cap-and-trade systems. Variations of these pricing mechanisms have been in place in selected provinces since 2007, with the federal government having released a pan-Canadian framework that mandates all provinces and territories to have pricing plans in place from 2018. Conference Board research demonstrates that carbon pricing will help to encourage transformation in Canada’s energy production and use, but $2 trillion or more in investment (in 2011 $) will also be required to cut emissions sharply.

The development of this framework is significant as an important component in encouraging change within the trucking sector. A common (and direct) outcome of carbon pricing recognized to date is an increase in the cost of diesel fuel. Indirect increases in the cost of goods have also been observed. While these outcomes have important implications for freight economics, opportunities also exist to use revenue generated by carbon pricing to accelerate the adoption of the fuel-efficiency technologies described in the previous chapter. This could be one additional pathway to help overcome the barriers to adoption within the trucking sector noted previously.

Complementary programs already in place in several provinces across Canada are useful as mechanisms through which to recycle revenue from pricing. Further research and stakeholder engagement to understand how successful these programs are and how they could be improved are important next steps.

The trucking sector is subject not only to pricing measures, but also to other forms of direct government regulation and standards. These form the basis of the discussion in the next chapter.
CHAPTER 6

Direct Regulations and Standards

Chapter Summary

- Federal and provincial regulations and standards are additional pathways by which GHG reductions from trucking can be secured.

- Current tailpipe emission regulations in Canada mirror those in the U.S. and are estimated to reduce CO₂ equivalent emissions by 19 Mt over the lifetime of 2014–18 model year vehicles and lead to $4.2 billion in cost savings to truck companies from reduced fuel consumption.

- As disparities in regulations over fuel standards, vehicle dimensions, and weights can discourage the use of fuel-saving technologies for trucking, harmonization of regulations across jurisdictions is one important measure to ensure the movement of goods across provincial and territorial borders.
Introduction

This chapter examines direct regulations in Canada that aim to reduce GHG emissions from freight transportation. Heavy-duty freight trucking accounted for approximately 32 per cent of the GHG emissions from the transportation sector in 2014. Tailpipe regulations for control of GHG emissions and criteria air contaminants are considered, as well as government programs aimed at improving the fuel efficiency of trucks.

While developed for public safety and to preserve highway infrastructure, provincial regulations for vehicle weights and dimensions also have a role to play in securing GHG reductions. As the fuel-saving technologies identified in Chapter 3 can extend vehicle dimensions and modify weights, differing regulations from one province to another can prove to be a barrier to technology adoption and uptake. Harmonizing these regulations has been cited as an important first step to reducing barriers to adopting fuel-saving technologies and securing GHG reductions from freight.

Tailpipe Regulations

Tailpipe emission regulations for heavy-duty vehicles and engines are the responsibility of Environment Canada, as set out under the Canadian Environmental Protection Act, 1999 (CEPA 1999). The Act passed on the authority for regulating emissions from cars and trucks from Transport Canada to Environment Canada. However, Transport Canada is still responsible for regulating emissions from rail locomotives, aircraft, and marine transport vessels. There are currently regulations to control emissions of GHGs and criteria air contaminants (CACs), such as nitrogen and sulfur oxides.

2 Now Environment and Climate Change Canada.
3 Canadian Environmental Protection Act, 1999.
The current set of GHG emission regulations for 2014–18 model year trucks was passed in 2013 and applies to 2014 and later model year vehicles. They aim to reduce GHG emissions through mandatory GHG emission standards for new vehicles and to align with U.S. national emission standards set by the Environmental Protection Agency. The regulations were meant to mirror the EPA Phase I emission regulations for medium- and heavy-duty vehicles. This harmonization of emission regulations greatly benefits the freight trucking sector, since cross-border trade is a significant part of the overall goods transported by road. Avoiding multiple or competing emission regulations also lowers the administrative and operational costs for truck fleets and encourages the use of more efficient technologies across both the Canadian and American markets.

The current set of GHG emission regulations for 2014–18 model year trucks are estimated to lead to a reduction of 19 Mt of CO₂ equivalent over the lifetime of the vehicles, with a reduction of 5.3 Mt of CO₂e from model year 2018 vehicles. This will also lead to an estimated $4.2 billion in cost savings to truck carriers, mostly due to reduced fuel consumption.

**CO₂ Emission Regulations**

CO₂ emission standards for Class 7 (vehicles with a gross weight between 11,793 kg and 14,969 kg) and Class 8 (vehicles with a gross weight more than 14,969 kg) heavy-duty freight vehicles are outlined in Table 17. The standards were set at 81 to 92 grams of CO₂ per tonne-mile (55 to 63 g/tonne-km) for Class 8 day cabs with varying roof configurations produced as 2014 to 2016 model year vehicles. The standards are set to become marginally more stringent for 2017 and subsequent model year vehicles, with limits of 80 to 89 grams of CO₂ per tonne-mile (55 to 61 g/tonne-km) for Class 8 day cabs. Trucks with sleeper cabs have even more stringent CO₂ emission regulations, set at 68 to 76 grams of CO₂ per tonne-mile (47 to 53 g/tonne-km) for 2014–16 model year vehicles, and set at 66 to 73 grams of CO₂ per tonne-mile.

---

5 Lew, “Heavy-Duty Vehicle GHG Reduction and Fuel Efficiency Technologies.”
6 Ibid.
(45 to 50 g/tonne-km) for 2017 and subsequent model year Class 8 vehicles. Again, the CO₂ emission regulations vary depending on a truck’s roof configuration.

### Table 17

**CO₂ Emission Standards for Freight Trucks**  
(grams per tonne-mile)

<table>
<thead>
<tr>
<th>Class 7 day-cab</th>
<th>Class 8 day-cab</th>
<th>Class 8 sleeper-cab</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model year</td>
<td>2014–16</td>
<td>2017 and later</td>
</tr>
<tr>
<td></td>
<td>2017 and later</td>
<td></td>
</tr>
<tr>
<td>Low roof</td>
<td>107</td>
<td>104</td>
</tr>
<tr>
<td>Mid roof</td>
<td>119</td>
<td>115</td>
</tr>
<tr>
<td>High roof</td>
<td>124</td>
<td>120</td>
</tr>
</tbody>
</table>

Source: Adapted from Environment and Climate Change Canada.

In addition to overall emissions per tonne-mile, there are also regulations set on CO₂ emissions for heavy-duty engines used in trucks. These range from 502 grams per brake-horsepower per hour (BHP-hr) to 487 g/BHP-hr for medium heavy-duty vehicles and 475 to 460 g/BHP-hr for heavy heavy-duty vehicles. (See Table 18.)

### Table 18

**CO₂ Emission Limits From Heavy-Duty Engines**  
(grams per BHP-hr)

<table>
<thead>
<tr>
<th>Class</th>
<th>2014–16</th>
<th>2017 and later</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium heavy-duty (Class 7)</td>
<td>502</td>
<td>487</td>
</tr>
<tr>
<td>Heavy heavy-duty (Class 8)</td>
<td>475</td>
<td>460</td>
</tr>
</tbody>
</table>

Source: Adapted from Environment and Climate Change Canada.

In addition to CO₂ standards, Environment and Climate Change Canada also places engine emission restrictions for nitrous oxide and methane, to prevent an increase in the emission of these gases as vehicle technologies advance. Both nitrous oxide and methane emissions are limited to 0.1 g/BHP-hr for all 2014 and subsequent model year engines.⁷

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⁷ Environment and Climate Change Canada, “Consultation Document for Discussion of the Main Elements.”
The Role of Harmonization

The emission standard regulations discussed so far are similar to those set by the EPA in the United States (under previous administrations). Consequently, manufacturers and importers of heavy-duty trucks in Canada need to evaluate their emissions using the same program testing procedures as used by the EPA. This includes the use of a simulation model that accounts for a number of real-world variables, such as aerodynamics and tire rolling resistance.8

Harmonizing GHG emission regulations can be beneficial, since it recognizes the international nature of the freight truck market in North America. This can provide one large, consistent market between the U.S. and Canada for truck manufacturers to sell their products to and leads to lower production costs, since trucks do not have to be designed specifically for the (smaller) Canadian market. This can result in a wider variety of trucks available to Canadian truck fleets. Additionally, increased economies of scale from a single North American market can be realized, improving cost-effectiveness and leading to lower prices for freight trucks and encouraging more rapid fleet turnover with more benefits to the environment.9

In the North American market, however, there are at least three factors complicating the potential benefits associated with harmonization. The first is that there are some considerations specific to the Canadian freight trucking market that do not apply to the U.S. trucking market. There are differences between the domestic heavy-duty freight fleets in the US and Canada that include tractor-trailer combinations and cold weather safety as two examples. Canadian regulations, however, are based on the EPA’s regulations, so current changes in the United States require careful consideration. In addition to the Phase 1 regulations setting limits on engine and overall GHG emissions, Phase II regulations introduced by the EPA in 2016 came into effect for model year 2018 for trailers and model year 2021 for vehicles. The stringency of the regulations is to be phased in over 10 years. The Phase II regulations examine the

8 Ibid.
entire tractor-trailer combination and set regulations for the aerodynamic efficiency of trailers in addition to more stringent GHG regulations for the tractor. This will incentivize producers to sell new technologies that apply to the trailer to make the overall tractor-trailer combination more fuel-efficient. Overall, it has been estimated the Phase II regulations have the potential to achieve a 33 per cent improvement in fuel economy by 2040.

There are also considerable differences between the U.S. and Canadian truck fleets. For instance, the U.S. fleet tends to be standardized around the 80,000-pound tractor–semi-trailer combination (one tractor hauling one container on a trailer), whereas the Canadian fleet has a wider variety of truck configurations, many of which the EPA will not examine. Regulation of vehicle dimensions and weight in Canada rests with the provinces and territories, which led to some truck configurations designed to be effective for local, provincial, or regional supply chains. Additional considerations are required when applying emission regulations in the Canadian context because Canadian winter conditions are different than those in significant portions of the United States. For instance, low rolling resistance tires improve the fuel economy of a truck, but at the cost of lower traction. This lower traction could be a significant safety concern when trucks operate on ice- and snow-covered roadways. Thus, the EPA regulations for vehicles of model year 2019 and beyond would need to be adapted for Canadian needs and considerations.

Finally, Canadian regulators are taking note of the current changes concerning the EPA. The Agency’s budget was significantly reduced in 2018, with major repercussions for the number and quality of the programs it offers. Canadian and U.S. policy regarding emissions and climate change is diverging due to the current U.S. administration’s policies on climate change. However, if Canada continues forward with emission regulations while the U.S. does not, the Canadian trucking industry could be put at a competitive cost disadvantage, since Canadian truck companies would incur higher costs compared to their U.S.

12 Ibid.
13 Meyer, “Scott Pruitt Delivers Another Trump-Era Shock.”
counters. So while harmonization of regulations can confer benefits, a number of factors can complicate these from being realized.

Fuel Efficiency Programs

The primary way of complying with tailpipe emission regulations is by improving fuel efficiency. To this end, Natural Resources Canada offers two programs aimed at improving the fuel efficiency of freight truck fleets—FleetSmart and SmartWay.

While these programs are voluntary and not mandatory, there is an increasing body of evidence that documents successful reductions in fuel consumption, and hence GHG emissions for participants. For this reason, they are included in this chapter as complementary to direct (mandatory) regulations.

FleetSmart

FleetSmart is a federal program available to all commercial and institutional truck fleets. The program offers information, tools, and training to drivers, fleet owners, and managers on improving the energy-efficiency of their vehicles, with the ultimate goal of lowering GHG emissions from transportation. It focuses and encourages the use of technologies that reduce fuel use, improve engine efficiency, and improve the aerodynamics of freight vehicles, as well as best driving practices such as reduced idling to improve fuel efficiency. In addition to reducing harmful GHG emissions, the tools and information offered by FleetSmart also claim to reduce fleet operating costs, improve productivity, and increase competitiveness by reducing the amount, and thus cost, of fuel consumed.

SmartWay

Similar to FleetSmart, which focuses on freight carriers and their best practices, SmartWay is another federal program administered by Natural Resources Canada that focuses on freight shippers and

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14 NRCAN, “Commercial Vehicles.”
15 NRCAN, “SmartWay Trends and Statistics.”
16 Ibid.
businesses to help them reduce fuel costs and transport goods in the most efficient way possible. The SmartWay program is also administered in the U.S. by the EPA. Trends and statistics for participating Canadian companies show that despite increases in total fleet size of almost 40 per cent, CO₂ emissions were reduced by an average of 12.1 per cent and particulate matter emissions were reduced by an average of 59.5 per cent over the first five years of participating in SmartWay. This was achieved through greater continuous average capacity utilization, from an average of 82.4 per cent when the companies first joined SmartWay to 86.4 per cent during the fifth year in the program. Greater capacity utilization means the same amount of goods can be transported with fewer trips, which results in overall reductions in fuel consumption and lower GHG emissions.

Additionally, companies in SmartWay managed to achieve a 6.7 per cent reduction in average idling hours by their fifth year in the program (from 765.3 to 714.4 hours per year). Moreover, the largest reduction usually occurs in the first year of the program, highlighting the potential of SmartWay to promote technologies that reduce idling as well as driver behaviour improvements. Fleets taking part in the SmartWay program have reduced their emissions from approximately 71 grams of CO₂ per tonne-kilometre before joining the program to 62 grams of CO₂ per tonne-kilometre by their fifth year in the program, which amounts to a 12 per cent decrease.

Overall, it is estimated the SmartWay program has led to a reduction of 16.5 Mt of CO₂, 235,000 tonnes of nitrogen oxides, and approximately 9,000 tons of particulate matter over the course of the program.

Renewable Fuels Regulations

The purpose of the Renewable Fuels Regulations set out at the federal level is to help reduce GHGs from gasoline and diesel fuels used in Canada, both of which are principally used in transportation.
The regulations achieve this by setting out requirements for average renewable fuel content (i.e., biodiesel, ethanol). For diesel, the regulations require that producers and imports have an average renewable content of at least 2 per cent\(^{22,23}\) (based on volume of fuel). For gasoline, the average renewable content required is 5 per cent. The regulations are set out under the *Canadian Environmental Protection Act, 1999*, were published in 2010, and commenced July 1, 2011.\(^{24}\) In concert with provincial renewable fuels policies, the federal regulations are thought to have contributed to an estimated emission reduction of 4 Mt per annum.\(^{25}\)

**Provincial Mandates**

In addition to these regulations, five provinces have renewable fuel requirements that either meet or exceed the federal targets. Their requirements for diesel fuel are summarized in Table 19.

<table>
<thead>
<tr>
<th>Province</th>
<th>Regulations</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>British Columbia</td>
<td>Renewable and Low Carbon Fuel Requirements Regulation</td>
<td>Fuel supplier to ensure that the volume of diesel fuel contains at least 4 per cent renewable fuel content*</td>
</tr>
<tr>
<td>Alberta</td>
<td>Renewable Fuels Standard Regulation</td>
<td>Fuel suppliers to ensure that diesel fuel available on the market has no less than 2 per cent renewable diesel content**</td>
</tr>
<tr>
<td>Saskatchewan</td>
<td><em>The Renewable Diesel Act</em></td>
<td>Average volume of diesel fuel sold or provided to consumers to contain at least 2 per cent renewable fuel***</td>
</tr>
<tr>
<td>Manitoba</td>
<td>Biodiesel Mandate for Diesel Fuel Regulation</td>
<td>Fuel suppliers to sell minimum of 2 per cent of the total volume of diesel fuel as biodiesel†</td>
</tr>
<tr>
<td>Ontario</td>
<td>Greener Diesel Regulation</td>
<td>Requirements phased in from 2014–17: 2 per cent to be bio-based in 2014–15; 3 per cent to be bio-based in 2015–16; 4 per cent to be bio-based in 2017††</td>
</tr>
</tbody>
</table>

**Alberta Regulation 29/2010.*  
***Statutes of Saskatchewan, ch. R-19.001.*  
†Reg. 147/2009 (Manitoba).  
††Government of Ontario, “Greener Diesel Regulation.”

Sources: Province of British Columbia; Province of Alberta; Province of Saskatchewan; Province of Manitoba; Government of Ontario.

\(^{22}\) Government of Canada, “Renewable Fuel Regulations.”  
\(^{23}\) This figure also applies to heating distillate oil, used in space heaters.  
\(^{24}\) Government of Canada, “Renewable Fuel Regulations.”  
As detailed here, provinces have introduced different minimum requirements for volumes of diesel fuel sold or provided to consumers. While many have set a minimum requirement of 2 per cent, higher percentages are noted for British Columbia (4 per cent) and Ontario (4 per cent as of 2017). The lack of requirements established beyond these five provinces, and the variation within this group of five, suggests opportunities for harmonization across Canada.

Provincial Clean Fuel Standards

At the time of writing, British Columbia was the only province to have introduced a clean fuel standard. This was adopted in 2008 as part of its Renewable and Low Carbon Fuels Requirements Regulation. The standard applies to all transportation fuels used in B.C., except aircraft fuel and that used in military operations.\(^2^6\) Using 2010 as a baseline, the standard sets out a requirement for a 10 per cent reduction in the carbon intensity of fuels by 2020. The carbon intensity target was increased to 15 per cent as part of the Province’s Climate Leadership Plan (2016).\(^2^7\)

Toward a National Clean Fuel Standard

Over the course of 2017, Environment and Climate Change Canada held a series of workshops, roundtables, and webinars to engage with government and other stakeholders to develop new regulatory requirements for a Clean Fuel Standard.\(^2^8\) The Standard would incentivize alternative energy sources and lower carbon fuels (i.e., electricity, hydrogen, renewable fuels, and natural gas) and would apply to transportation fuels as well as those used in other sectors (i.e., homes and buildings, industry). It would build on existing regulations set out at the federal level, notably the Renewable Fuels Regulations. The objective of the Clean Fuel Standard is to secure annual GHG reductions of 30 megatonnes by 2030.

\(^{26}\) Ibid., 4.
\(^{27}\) Government of British Columbia, *Climate Leadership Plan*.
Provincial Regulations for Weights and Dimensions

While not explicitly designed in relation to GHG emissions, provincial regulations for vehicle weights and dimensions have an important impact on the ability to secure GHG reductions through fuel-saving technologies. Provincial governments are responsible for setting out dimension and weight limits of vehicles to ensure public safety and to prolong the life of highway infrastructure—these are set out in provincial highway traffic acts. The dimension and weight limits set out in these acts can prove to be barriers to the uptake of the fuel efficiency technologies described in Chapter 3.

For example, the installation of some aerodynamic devices such as boat tails could mean that trucks surpass the maximum allowable length of tractor-trailer combinations in some jurisdictions, while still being legal in others. Since truckers would like to ensure their vehicles are compliant in the largest number of jurisdictions, they would ensure their trucks comply with the most stringent set of regulations so they can cross provincial and territorial borders.

A national committee of officials from the federal, provincial, and territorial governments aims to harmonize policies and regulations on vehicle weight and dimensions for heavy-duty vehicles in Canada. A memorandum of understanding (MOU) established in 1988 (which has since been amended several times over) provides a harmonized set of weight and dimension regulations for heavy-duty vehicles across all provinces and territories. This ensures that any vehicle can cross provincial and territorial borders, as long as it adheres to the guidelines set out in the MOU. However, individual provinces and territories are still able to set their own regulations, which could be less stringent than the guidelines highlighted in the MOU.

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29 See Task Force on Vehicle Weights and Dimensions Policy, Heavy Truck Weight and Dimension Limits.
In spite of these initiatives, gaps between market availability and regulatory “catch-up” are still evident. For example, while single wide-based (SWB) tires have been on the market in North America since 2000, only three provinces—Ontario, Manitoba, and Quebec—have removed regulatory weight penalties (as of 2016) to allow for them; these changes were made following extensive consultations with the trucking industry.

Conclusion

This chapter examined direct regulations aimed at reducing GHG emissions and criteria air contaminants from the heavy-duty freight transportation sector. Environment and Climate Change Canada is responsible for setting emission standards for both heavy- and light-duty road vehicles, while emission regulation responsibilities for rail and marine lie with Transport Canada.

The current set of regulations for freight trucks mirrors those set out by the EPA for model year 2014 and subsequent vehicles. The regulations are estimated to result in a reduction of 19 Mt of CO₂e over the lifetime of the vehicles, along with $4.2 billion in cost savings to truck carriers, mostly due to reduced fuel consumption.

Harmonizing (strong) GHG emission regulations in a large, consistent market like North America can confer benefits. These include: the potential to minimize administrative and fleet costs associated with meeting competing regulations; increased economies of scale, lower prices, and a wider variety of trucks available in Canada; and more rapid fleet turnover. Yet a number of complicating factors can prevent these benefits from being realized, with the changing political climate being chief among them.

30 Michelin Canada, “Encouraging Sustainable Mobility for Canada’s Trucking Industry.”
31 Ontario Trucking Association, “CTA Urges Western Ministers.”
Harmonization within Canada—having consistent regulations across provinces and territories—has also been demonstrated to support the adoption of fuel-saving technologies for those vehicles undertaking interprovincial or inter-jurisdictional travel. Yet as documented in this chapter, there are opportunities to improve this effort further to avoid “regulatory catch-up” around certain fuel-saving devices.

Although Canada currently has fuel efficiency regulations for light-duty vehicles, there are no such regulations for heavy-duty vehicles. Instead, Canada’s approach has been to implement tailpipe regulations for heavy-duty vehicles, and the main way to comply with these regulations is by increasing fuel efficiency. In addition, several programs aim to improve fuel efficiency in the heavy-duty freight transportation sector. FleetSmart is a program offered by Natural Resources Canada that provides driver training to improve driving efficiency, resulting in lower operating costs for fleets and improved productivity. SmartWay is another Natural Resources Canada program that provides firms data so they can optimize supply chain efficiency. This leads to greater capacity utilization, better fuel efficiency, and lower costs for truck fleets.
CHAPTER 7

Pathways Forward and Next Steps for Research

Chapter Summary

• Freight is a significant contributor of emissions today and is expected to outpace those associated with passenger movement in the future. Meeting Canada's climate targets necessitates a focus on freight.

• There is no one single technology, policy, regulation, standard, or program that can be relied upon to achieve substantive GHG reductions from road-based freight. Substantive reductions from freight require a strong commitment to numerous pathways.

• Reducing GHGs from freight trucks will be hard to achieve without engaging a wider process of behavioural change and managing societal expectations. Further research and public consultation would be required to facilitate change in ways that benefit the environment.
Freight Matters

A clear message revealed in this report is the significant contribution that freight makes to Canada’s emission profile generally (10.5 per cent of the national total), and trucking’s share of this contribution (83 per cent of freight transport GHG emissions). Not only is freight transport a significant contributor to emissions today, its emissions are predicted to eclipse those of passenger transportation in the coming years. Road-based freight is a key part of those emissions. While this does not mean that initiatives to reduce GHGs from passenger travel can be relaxed, it does necessitate a focus on freight to secure meaningful reductions in GHGs from transport. As we have documented here, technologies, policies, regulations, standards, and other programs can work in concert with one another, across all levels of government and all jurisdictions, if substantive GHG reductions are to be secured.

Intermodal

As Chapter 2 illustrates, one pathway to reducing emissions from freight transport involves reducing travel by truck. On a per truck basis, even a 3 per cent shift from road to rail (equivalent to 30 million metric tonnes being transported by rail instead of truck) could generate a reduction in CO₂ equivalent to 2.0 Mt.¹ Yet as this chapter also revealed, the advantages associated with trucking relative to rail make these shifts

¹ Gullo and Rosales, Part of the Problem or Part of the Solution?
less likely in the absence of additional regulatory incentives (such as road user charging) and infrastructure investments (such as promoting construction of intermodal facilities).

Established Fuel-Saving Technologies and Devices

As detailed in Chapter 3, there are numerous technologies and devices available to help reduce fuel consumption and GHG emissions from road freight. While many of these have been available commercially for some time, several key barriers (uncertainties about performance and return on investment, capital costs, split incentives, availability) have prevented their widespread adoption. To support greater uptake of these technologies and devices, regulations for GHGs and/or fuel efficiency, market-based programs, and fiscal measures are recommended. While Canada has variations of these measures in place, key fiscal measures, such as carbon pricing for every province and territory, are still in the early stages of implementation. Opportunities exist to leverage revenue from pricing to help address the barriers to adoption cited earlier.

Disruptive Technologies in Freight Transport

Chapter 4 revealed that disruptive technologies are poised to alter the movement of goods and the emission profile associated with heavy-duty trucks. While the commercial deployment for these technologies continues to be debated, they are already being trialled in other contexts. Unfortunately, Canada lags other G7 countries when it comes to supporting the research and testing of these technologies.\(^2\) This relative lack of investment is significant for the future of securing the 2030 target, as there appears to be great interest in these innovations from within industry. Leveraging these technologies to their full environmental benefit suggests there are opportunities to align climate change, transportation, and innovation portfolios within government.

\(^2\) Gill and others, *Automated Vehicles*. 

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Carbon Pricing and Freight

Numerous approaches to pricing carbon have been advanced in Canada over the last decade. (See Chapter 5.) These vary according to mechanism (i.e., cap-and-trade systems versus carbon taxes) and approach to recycling revenue. While carbon-pricing plans were developed initially by a few provinces (owing in large part to a lack of initiative exhibited by the previous federal government), the Pan-Canadian Framework on Clean Growth and Climate Change, implemented by the current federal government, is furthering this important effort. To address some of the barriers to widespread adoption of fuel-saving technologies and devices, opportunities exist to use revenue generated from carbon pricing to support market uptake.

Conference Board foundational research demonstrates that carbon pricing can take Canada partway to its GHG emission goals, with a minimal impact on overall GDP. However, there will be distributional impacts on sectoral performance, both negative and positive. And importantly, a significant level of investment in low-carbon energy production and use will be required to cut emissions sharply—$2 trillion or more (in 2011 $) in new incremental investments would be required between now and 2050. Freight transport will be one of the sectors requiring significant low-carbon investment.

Direct Regulations and Standards

Chapter 6 of this report highlights the role of regulations and standards as an important pathway to securing GHG reductions from freight transport. These typically operate at the federal (CO₂ regulations, fuel efficiency programs) and provincial (renewable fuels regulations, dimension and weight regulations) levels. Within Canada, the federal government’s efforts around introducing a national Clean Fuel Standard are an important addition to this pathway.
Next Steps for Research

This report builds on previous research conducted by The Conference Board of Canada on reducing the emission profile associated with transportation. In so doing, it has focused much of its discussion and analysis on long-haul, heavy-duty vehicles. As mentioned previously, these vehicles warrant attention due to their contributing share of goods moved and emissions generated. However, a number of complementary issues also merit further consideration. These include the following:

- **Automated vehicles for moving goods**: Given the enthusiasm from within industry for disruptive innovations in transport, and their application to moving goods (for land and air vehicles), further research would benefit from documenting the emission-reduction potential of these technologies. This could be an important step in overcoming some of the barriers associated with traditional fuel-efficient technologies.

- **Additive manufacturing (3D printing)**: Related to the above research area is the rise of 3D printing, a disruptive technology that could have a substantive impact on the need for moving some goods altogether. Further research could explore the applications of additive manufacturing within Canada and opportunities to leverage this technology for environmental benefit.

- **The contribution of warehouses and trans-shipment processes to emissions**: This report has focused much of its discussion on a particular component of the supply chain, namely that covered by long-haul trucks. The reality is that this is only one aspect of freight’s contribution to emissions, and further research should consider where freight is picked up and where it is delivered, notably warehouses and distribution centres.

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3 Robins, Knowles, and Coad, *A Long, Hard Road*.
4 Rüdiger, Schön and Dobers, “Managing Greenhouse Gas Emissions.”
• **Intra-city (short-haul) trucking:** Related to this is the need to consider the role of short-haul trucking within cities. As detailed elsewhere, the nature of the issues differs for short-haul trucks, as do the potential pathways to reducing emissions.\(^5\)

• **Focus on rail:** While rail has a far lower emission profile than road-based freight, it is not without its contributions to GHGs. As a complement to this research effort, further research would benefit from an examination of the technologies, regulations, and policy measures to help reduce emissions from rail-based freight.

• **Driving habits:** Underpinning some of the discussion in this report is driving habits. This is particularly the case concerning issues such as idling and driving speeds. Programs like FleetSmart include fuel-saving driving techniques as part of its portfolio,\(^6\) but further research could examine the uptake of these measures and consider opportunities for more widespread training within fleets.

## Conclusion

As this report has documented, Canada’s ability to reach its 2030 target depends upon strong commitment from multiple stakeholders to a series of initiatives and policy measures; no single technology, regulation, program, standard, or pricing plan will be the pathway to substantive emission reductions from freight transport. Commitment to a full suite of initiatives will be required from within industry and all levels of government if our targets are to be secured. As with our previous work on transportation and emissions,\(^7\) the backdrop to the issues raised in this report is a wider process of (consumer) behavioural change and managing societal expectations. Given that trucking’s popularity rests on its flexibility and speed of delivery relative to other modes, it is not

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5 Grond and Angen, *Greening the Goods.*

6 NRCAN, “Training.”

7 Robins, Knowles, and Coad, *A Long, Hard Road.*
yet clear whether members of the Canadian public would be willing to change their expectations about access to goods. This, ultimately, would be the subject of a substantive research project and sustained public engagement exercises.

Tell us how we’re doing—rate this publication.
APPENDIX A

Carbon-Pricing Plans by Province

Revenue-Neutral Carbon Tax on Fuels: British Columbia

On July 1, 2008, the Province of British Columbia implemented a revenue-neutral carbon tax, applied to the use and purchase of fuels.¹ This was the first such tax introduced in North America.² The original tax rates were set at $10 per tonne of CO₂ emissions equivalent; these increased by $5 per tonne per year until 2012, where they reached $30 per tonne (a rate that will be maintained until 2018).³ Table 1 illustrates tax rates for selected fuels, as of current (2012) CO₂ equivalents.

Table 1
Selected Carbon Tax Rates by Fuel

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>2012 tax rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>6.67 cents/litre</td>
</tr>
<tr>
<td>Diesel (light fuel oil)</td>
<td>7.67 cents/litre</td>
</tr>
<tr>
<td>Jet fuel</td>
<td>7.83 cents/litre</td>
</tr>
<tr>
<td>Natural gas</td>
<td>5.70 cents/cubic metre</td>
</tr>
<tr>
<td>Propane</td>
<td>4.62 cents/litre</td>
</tr>
<tr>
<td>Coal—high heat value</td>
<td>62.31 dollars/tonne</td>
</tr>
<tr>
<td>Coal—low heat value</td>
<td>53.31 dollars/tonne</td>
</tr>
</tbody>
</table>


¹ B.C. Ministry of Finance, “Carbon Tax.”
³ Ibid.
The variable rates set out in this table account for the fact that different fuels contribute different levels of GHG emissions as they are burned. As diesel has a higher carbon content than, for example, gasoline or propane, its tax rate is necessarily higher than the rates for those other fuels.4

What Is Revenue Neutrality?

A revenue-neutral carbon tax is one in which all tax revenues generated each fiscal year are recycled—returned to taxpayers—in the form of tax deductions.5 As part of this measure, government is required by law (through an annual plan tabled in the Legislature) to demonstrate how all revenues are returned as tax deductions.6 By way of example, a revenue-neutral carbon tax report with details on tax reductions is provided as part of the Province of British Columbia’s Budget and Fiscal Plan.7

Personal tax measures include a personal income tax credit of $115.50 per adult and $34.40 per child; reductions of 5 percentage points in the two lower income tax rates; a home renovation credit for seniors; a homeowner benefit of $200 for northern and remote residents; fitness and arts credits for children; a capital tax credit for small business ventures; and a tax credit for training.8

For businesses, tax measures include reductions in general and small business corporate income tax rates; an increase in the small business income tax threshold (from $400,000 to $500,000); credits for interactive digital media and business training; a credit for scientific research and development; credits for industrial properties (at 60 per cent of school property taxes); 50 per cent reductions in school property tax credits (for lands classified as “farm”); and credits for the film industry and production services.9

5 B.C. Ministry of Finance, “Tax Cuts Funded by the Carbon Tax.”
8 Ibid., 56.
9 Ibid.
Of the total designated revenue measures ($1.73 billion, based on the Province’s forecast for 2015/16)—those that return carbon tax revenues to residents—33 per cent ($579 million) is allocated to individuals, with the remaining 67 per cent ($1.15 billion) allocated to businesses.

Carbon Tax With Partial Revenue Recycling: Alberta

On January 1, 2017, the Province of Alberta introduced a carbon tax (referred to officially as a “carbon levy”) on the purchase and use of heating and transportation fuels. Effective this date, a carbon price of $20 per tonne was set, due to increase to $30 per tonne as of January 1, 2018. Table 2 illustrates the tax rates for major fuels, based on the carbon prices set for 2017 and 2018, respectively.

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>2017 tax rate</th>
<th>2018 tax rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td>5.35 cents/litre</td>
<td>8.03 cents/litre</td>
</tr>
<tr>
<td>Gasoline</td>
<td>4.49 cents/litre</td>
<td>6.73 cents/litre</td>
</tr>
<tr>
<td>Natural gas</td>
<td>1.011 dollars/GJ</td>
<td>1.517 dollars/GJ</td>
</tr>
<tr>
<td>Propane</td>
<td>3.08 cents/litre</td>
<td>4.62 cents/litre</td>
</tr>
</tbody>
</table>

Source: Alberta Treasury Board and Finance, Budget 2016, 5.

The revenue-recycling component to the levy takes several forms. First, lower and middle-income residents will receive a consumer rebate, details of which are summarized in Table 3 below.

<table>
<thead>
<tr>
<th>Consumer type</th>
<th>2017 rebate</th>
<th>2018 rebate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single person</td>
<td>200</td>
<td>300</td>
</tr>
<tr>
<td>Couple</td>
<td>300</td>
<td>450</td>
</tr>
<tr>
<td>Couple with two children</td>
<td>360</td>
<td>540</td>
</tr>
</tbody>
</table>

Source: Alberta Treasury Board and Finance, Budget 2016, 5.
Since the emphasis is on lower and middle-income groups, not all residents will benefit from the consumer rebate program. The Province estimates that 60 per cent of households in Alberta will be eligible for a full rebate and an additional 6 per cent will be eligible for a partial rebate. Total rebates will amount to $95 million in the 2016–17 period and $590 million in 2018–19.

A second revenue-recycling component to the carbon levy relates to small businesses. As of January 1, 2017, income tax rates for small businesses will be reduced by 2 per cent. A total of $865 million over five years will be available for these reductions.10

Revenue Recycling Into Initiatives: Alberta and Quebec

Alberta’s Specified Gas Emitter Regulation

A third revenue-recycling component, also in Alberta, relates to the Specified Gas Emitters Regulation (SGER). The SGER was introduced in 2007, and is notable within North America for being the first carbon price for large emitters.11 It applies to all facilities with direct emissions of 100,000 or more tonnes in 2003 or subsequent years, notably the larger and industrial emitters.

For any facility operating prior to 1999, the reduction target is 12 per cent below average intensities for the years 2003 to 2005 inclusive.13 While facilities established more recently have a three-year exemption period, they then are subject to targets that gradually increase until the 12 per cent target is met (by the ninth operating year). For any facilities that emit higher than the established target, a compliance payment of $15 per tonne CO₂e is made and directed to the Climate Change and Emissions Management fund (CCEMF).14 Offset credits for projects in Alberta (such as wind farms or low-till agricultural projects) can also be

10 Ibid., 6.
11 Bramley and others, Responsible Action? 5.
12 Climate Change and Emissions Management Act: Specified Gas Emitters Regulation.
13 Bramley and others, Responsible Action? 7.
14 Ibid.
purchased. As these are used “in lieu of on-site emissions reductions or payments into the CCEMF,” they do not directly contribute to meeting SGER targets.\(^{15}\)

Revenue generated by the SGER compliance payments, along with that generated by the newer carbon levy, is being reinvested in priority projects. Notable examples include green infrastructure ($2.2 billion over five years, including public transit projects); energy efficiency projects ($645 million over five years, delivered through a new provincial agency known as Energy Efficiency Alberta); larger-scale, renewable energy and bioenergy initiatives; and related technologies and innovations ($3.4 billion over five years).\(^{17}\)

**Quebec’s Green Fund Levy**

While Quebec is arguably better known for having implemented a cap-and-trade system (see “Cap-and-Trade Systems, Province of Quebec”), its first attempt at carbon pricing was a tax introduced in 2007, also known as the Green Fund levy.\(^{18}\) This was the first such tax in Canada, predating British Columbia’s by one year. The carbon price was set at $3 per tonne of CO\(_2\) equivalent and applied to petroleum companies; this resulted in less than 1.0 cent per litre on the price of fuel (0.8 cents per litre on gas and 0.9 cents per litre on diesel).\(^{19,20}\) When it was implemented, the levy affected approximately 50 companies (paying approximately $69 million per year for gasoline, $36 million per year for diesel, and $43 million per year for heating oil) and natural gas distributors (paying approximate $39 million per year).\(^{21}\)

The tax generates approximately $200 million in per year, and this revenue goes to a green fund to support energy-savings projects, including public transit, and other initiatives in the Province’s Climate

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\(^{15}\) Ibid., 13.
\(^{16}\) Ibid., 10.
\(^{17}\) Ibid., 6.
\(^{18}\) Houle, *Obstacles to Carbon Pricing In Canadian Provinces*.
\(^{19}\) CBC News, “Quebec to Collect Nation’s 1st Carbon Tax.”
\(^{20}\) Holmes and others, *All Over the Map 2012*.
\(^{21}\) CBC News, “Quebec to Collect Nation’s 1st Carbon Tax.”
Change Action Plan. However, with a relatively low carbon price (compare $3 per tonne of CO₂e with the $30 price now in place in B.C.), the tax has been criticized for not being high enough to further behavioural change. While emissions from the province as a whole have declined by 30 per cent from 1990 levels, these are attributed to changes outside the transportation sector (including a magnesium plant closure and industrial process changes in relation to the manufacturing of aluminum).

Cap-and-Trade Systems
(Québec, Ontario)

Province of Québec

Five years after introducing its carbon tax, the Province of Québec entered into a partnership with the State of California to initiate an emissions-trading (cap-and-trade) system. This was developed under the Western Climate Initiative (WCI) framework, a collaboration involving selected Canadian provinces and American states. Under the WCI framework, regulated facilities must acquire emission allowances for all emissions, but sectors such as manufacturing and mining, which are subject to international competition, receive free allowances (tied to past activity).

To ensure compliance with the system, exhibitors have six main options. (See “Options for Québec Industries to Ensure Cap-and-Trade Compliance.”).

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22 Houle, Obstacles to Carbon Pricing in Canadian Provinces.
23 Ibid.
24 The WCI was founded in 2007, when a number of American states signed agreements for a regional emission-reduction target. California, Arizona, Washington, New Mexico, and Oregon were the original member states. Four Canadian provinces (B.C., Manitoba, Ontario, and Québec) and two states (Utah and Montana) joined the five original states in 2007 and 2008 to tackle climate change. See Western Climate Initiative, “History.”
25 Western Climate Initiative, Design for the WCI Regional Program.
26 Houle, Obstacles to Carbon Pricing in Canadian Provinces.
Options for Quebec Industries to Ensure Cap-and-Trade Compliance

- Purchase allowances directly from the Quebec government—these start at $40 per tonne of CO₂ equivalent and increase to $50 per tonne).
- Purchase allowances from other emitters—those that will not reach the cap and are willing to sell their outstanding allowances.
- Purchase allowances during an allowance auction—available for registered and approved participants.
- Reduce emissions, thus ensuring compliance without the need for further allowances.
- Purchase carbon offset credits, defined as “a quantity of GHG emissions that was never emitted or that was permanently and irreversibly removed from the atmosphere by a project voluntarily implemented by an individual, organization or business, above and beyond usual practices.”27 The use of offset credits is restricted to 8 per cent.
- Secure an early reduction credit (ERC), issued to emitters for GHG reductions achieved during the eligibility period (January 1, 2008 to December 31, 2011).28

Province of Ontario

On January 1, 2017, the Province of Ontario initiated its cap-and-trade system (to be joined up with Quebec and the State of California in 2018). Fuel suppliers selling more than 200 litres per year of fuel are mandatory participants, as are electricity importers, natural gas distributors, and facilities that emit 25,000 or more tonnes per year of GHGs.29 Facilities that generate between 10,000 and 25,000 tonnes of GHGs per year qualify as voluntary participants. Should they choose to participate, they are subject to the same rules as mandatory participants.30 A third category is the market participant. This applies to individuals,

29 Province of Ontario, “Cap and Trade.”
30 Ibid.
non-profit organizations, and companies without compliance obligations (do not have emissions to report).  

For the first four years of the scheme, a number of exemptions have been allocated to industries. Included among these are Petro-Canada Lubricants (Mississauga), the chemical plant for Imperial Oil (Sarnia), Essar Steel Algoma Inc. (Sault Ste. Marie), and Vale Canada’s nickel refinery (Sudbury). These companies will receive free allocations during the four-year period.

Despite the exemptions, Ontario’s cap-and-trade system is expected to generate revenues of $1.9 billion per year—rising to approximately $8 billion by the year 2020. By law, revenues must be invested in projects that reduce GHGs, including public transit, social housing, and electric vehicles. Given the Province’s commitment to reduce emissions by 15 per cent from 1990 levels by the year 2020, the cap-and-trade system is central to achieving that goal.

31 Ibid.
33 Province of Ontario, “Cap and Trade in Ontario.”
APPENDIX B

Bibliography


Green Freight
Pathways to Reducing GHG Emissions from Trucking


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