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Railway Association of Canada

Locomotive Emissions Monitoring / Report

2023

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REVIEW NOTICE

This report has been reviewed and approved by the Technical Review and Management Committees of the *2023–2030 Memorandum of Understanding between Transport Canada and the Railway Association of Canada for Reducing Locomotive Emissions*.

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Executive Summary

INTRODUCTION

The Locomotive Emissions Monitoring Program (LEM) data filing for 2023 has been completed in accordance with the terms of the 2023–2030 Memorandum of Understanding (referred hereafter as "the MOU") signed on December 5, 2023, between the Railway Association of Canada (RAC) and Transport Canada (TC) concerning the emissions of greenhouse gases (GHGs) and criteria air contaminants (CACs) from locomotives operating in Canada. This is the first report prepared under this MOU, though it is based on reporting for the LEM program governed by MOUs dating back to 1995.

2023-2030 MOU

In 2023, RAC and TC jointly announced a renewed MOU for reducing locomotive emissions. This MOU reflects a shared vision of working toward net-zero emissions by 2050 and builds upon the meaningful progress made to date by the Canadian rail sector. TC and RAC members agreed to work together to:

- advance low-carbon fuel use,
- move more goods and people by rail where possible,
- accelerate the development of advanced net-zero solutions for locomotives, and
- advance knowledge of climate risks to rail infrastructure and enhance climate resiliency of Canada's rail network.

As stated in the MOU, RAC will continue to encourage its members to reduce their GHG emissions intensity and CAC emissions from railway operations.

Reporting by RAC of CAC emissions as agreed under the MOU and included in this LEM report does not fulfil any member reporting requirements under the *Locomotive Emissions Regulations* (LER), which came into force on June 9, 2017.

The 2023 LEM Report methodology represents an improvement over previous reports, as it introduces year-specific GHG emissions factors that account for the use of biofuels in the overall fuel mix used by locomotives. In earlier LEM reports, all fuel litres were assumed to be diesel fuel. Historical emissions factors and GHG emissions have been updated accordingly.

In 2023, the GHG emissions intensity (combustion emissions) of Canada's freight railways remained relatively flat, as both traffic (measured in revenue tonne-kilometres) and fuel consumption increased by a little more than one percent year-over-year. The GHG emissions intensity of intercity passenger railways improved by 6.11% compared to 2022, as the increase in passenger-kilometres (21.9%) was much larger than the increase in fuel consumption (13.7%).

In 2023, Canadian railways continued to invest in fleet modernization, acquiring higher-tiered locomotives and retiring non- and lower-tiered locomotives. These investments enabled the industry to achieve reductions in absolute emissions of nitrogen oxides (NO_x), particulate matter (PM_{10}), and hydrocarbons (HC) despite an increase in freight traffic, passenger traffic, and fuel consumption.

Since the 2005 base year, GHG emissions intensities have been reduced by 17.54% (regional & shortline), 28.82% (Class 1 freight) and 34.25% (intercity passenger). Despite a significant growth in freight traffic since 2005, Canada's Class 1 freight railways (CN and CPKC) reduced their absolute GHG emissions by 8.87%. In the same period, absolute CAC emissions have been cut by 6.8% (carbon monoxide, CO), 48.9% (NO_x), 56.7% (HC), 62.7% (PM_{10}), and 99.0% (sulphur dioxide, SO_2).

2023 RESULTS

2023–2030 MOU Progress – GHG Emissions Intensities

Railway Operation	Productivity Units	2005 Base Year	2022	2023	Change from 2005–2023	Change from 2022–2023
Class I Freight	kg CO_2e per 1,000 RTK	17.06	12.15	12.14	-28.82%	-0.04%
Intercity Passenger	kg CO_2e per passenger-km	0.128	0.090	0.084	-34.25%	-6.11%
Regional & Shortline	kg CO_2e per 1,000 RTK	16.80	13.76	13.85	-17.54%	0.67%

Note: GHG emissions (combustion) for all years have been calculated based on IPCC Fifth Assessment Global Warming Potentials (CO_2: 1, CH_4: 28, N_2O: 265) and emissions factors that consider the mix of biofuels and diesel fuel used in locomotives. Historical values have been updated.

2023–2030 MOU Progress – Class 1 Freight Railways' Locomotive GHG Emissions

		2005	2022	2023	Change from 2005-2023	Change from 2022-2023
Locomotive GHG Emissions*	Kilotonnes of CO_2e	5,788.34	5,198.66	5,274.88	-8.87%	1.47%

*Includes CN and CPKC GHG emissions from locomotive operations in Canada.

2023–2030 MOU Progress – Absolute CAC Emissions (kilotonnes, unless otherwise specified)

CAC Emission	2005 Base Year	2022	2023	Change from 2005-2023	Change from 2022-2023
NO_x	126.50	66.30	64.65	-48.9%	-2.5%
PM_{10}	3.41	1.32	1.27	-62.7%	-3.5%
CO	15.43	14.12	14.39	-6.8%	1.9%
HC	5.78	2.60	2.50	-56.7%	-3.7%
SO_2 (tonnes)	4,974.49	49.75	50.70	-99.0%	1.9%

Note: The table presents CAC emissions for total rail operations.

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Freight Railway Traffic

	2022	2023	Change from 2022–2023
GTK (billion)	822.62	824.19	0.2%
RTK (billion)	438.73	444.56	1.3%
Intermodal Tonnage (million)	41.22	37.68	-8.6%

- **Gross Tonne-Kilometres (GTK):** In 2023, Canada's freight railways handled 824.19 billion GTK compared to 822.62 billion GTK in 2022, representing a 0.2% increase. GTKs were 23.3% higher than in 2005, the reference year, having increased at an average rate of 1.2% per year. [1] In 2023, Class 1s accounted for 94.8% of total GTKs.

- **Revenue Tonne-Kilometres (RTK):** In 2023, Canada's freight railways handled 444.56 billion RTK compared to 438.73 billion RTK in 2022, representing a 1.3% increase. RTKs were up 26.0% compared to 2005, having increased at an average rate of 1.3% per year. In 2023, Class 1s accounted for 94.7% of total RTKs.

- **Intermodal Traffic:** In 2023, intermodal tonnage decreased by 8.6% to 37.68 million tonnes from 41.22 million tonnes in 2022. Several factors, including significant labour disruptions at B.C. ports in July, contributed to the reduction in intermodal volumes. Overall, intermodal tonnage comprising both container-on-flat-car and trailer- on-flat-car traffic for railways in Canada has risen 22.2% since 2005.

Passenger Railway Traffic

	Intercity Passengers (million)	Commuter Passengers (million)
2019	5.05	101.94
2020	1.15	22.75
2021	1.55	13.32
2022	3.36	27.83
2023	4.19	47.45
Change from 2022-2023	24.6%	70.5%

- **Passenger Traffic:** In 2023, passenger rail traffic continued to rebound from the low ridership levels experienced during, and following, the COVID-19 pandemic. Year-over-year, intercity rail ridership increased by 24.6% to 4.19 million passengers and the number of commuters increased by 70.5% to 47.45 million. Despite these strong gains, ridership remained below 2019 (pre-pandemic) levels.

1 Growth rates are calculated using the compound annual growth rate (CAGR) formula.

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Fuel Consumption

	Million litres		Change from 2022–2023
	2022	2023	
Total	2,018.61	2,057.07	1.9%
Total Freight Operations	1,919.98	1,946.65	1.4%
Class 1 Freight	1,750.57	1,774.22	1.4%
Regional & Shortline	113.24	113.75	0.4%
Yard Switching and Work Train	56.17	58.68	4.5%
Passenger Operations	98.63	110.41	11.9%

- Fuel consumed by railway operations in Canada increased by 1.9%, from 2,018.61 million litres in 2022 to 2,057.07 million litres in 2023.
- Of the total fuel consumed by all railway operations, Class 1 freight line-haul operations (excluding yard switching) consumed 86.3% and regional & shortlines consumed 5.5%. Yard switching and work train operations consumed 2.9%, and passenger operations accounted for 5.4%.
- Total freight operations consumed 1,946.65 million litres, a 1.4% increase from 2022 but 7.6% below 2005. In 2023, Canada's freight railways could move one tonne of freight 228.37 kilometres on just one litre of fuel.
- Total passenger operations consumed 110.41 million litres, an 11.9% increase from 2022, to service an increasing number of passengers.

Locomotive Fleet

	2022	2023	Change from 2022-2023
Total Locomotives	3,715	4,249	14.4%
Line Haul Freight	2,861	3,417	19.4%
Class 1	2,555	3,138	22.8%
Regional	162	150	-7.4%
Shortline	144	129	-10.4%
Freight Yard Switching and Work Train	602	567	-5.8%
Passenger	252	265	5.2%
Intercity	79	86	8.9%
Commuter	155	157	1.3%
Tourist/Excursion	18	22	22.2%

The reported number of diesel-powered locomotives and diesel multiple units (DMUs) in active service in Canada operated by MOU signatory railways totaled 4,249 in 2023 versus 3,715 in 2022, an increase of 14.4%. The active fleet is reported as it existed on December 31st of each year. As the data represents the fleet on one particular day in the calendar year, significant year-over-year fluctuations are possible.

For line haul freight operations in 2023, 3,138 locomotives were operated by Class 1s, 150 by regional railways, and 129 by shortlines. A further 567 locomotives were used in freight yard switching and work train operations. A total of 265 locomotives and DMUs were used in 2023 to support passenger railway operations in Canada, of which 86 were for intercity passenger services, 157 for commuter railway services, and 22 for tourist and excursion services.

LOCOMOTIVES MEETING EMISSION STANDARDS

In 2023, 88.7% of the active fleet met emission standards (as set out under the LER),[2] a notable improvement from 84.4% in 2022 and 29.7% in 2005.

As per the locomotive inventory on December 31st, 2023, the active fleet increased by more than 500 locomotives through the acquisition of new and remanufactured locomotives, bringing locomotives out of storage and into active service, as well as the combination of CP and KCS which expanded the number of locomotives available to operate in Canada. Overall, the total number of locomotives moved out of active service and into storage or retirement was surpassed by the fleet increases.

The number of active Tier-4s increased by 112 (+36.8%), from 304 in 2022 (8.2% of the active fleet) to 416 (9.8% of the active fleet) in 2023. 63 of these additions were remanufactured locomotives.

In 2023, across the active fleet, 32 new locomotives were added, 312 locomotives were remanufactured, and 123 were retired. 30 of the 32 added locomotives, and all 312 remanufactured locomotives, were tier-leveled. Most of the 123 retired locomotives were non-tier-level and lower-tier-level locomotives.

LOCOMOTIVES EQUIPPED WITH ANTI-IDLING DEVICES

The number of active locomotives in 2023 equipped with a device to minimize unnecessary idling, such as an automatic engine stop-start (AESS) system or auxiliary power unit (APU), was 3,960, which represents 93.2% of the fleet, compared to 3,355 in 2022 (90.3% of the 2022 fleet).[3]

Tropospheric Ozone Management Areas (TOMA)

TOMAs are geographically defined areas in which governments, stakeholders, and other interested parties work together to improve local air quality and manage air pollutant concentrations. Of the total GHGs emitted by the railway sector in 2023, an estimated 2.8% were emitted in the Lower Fraser Valley of British Columbia, 13.7% in the Québec City-Windsor Corridor, and 0.3% in the Saint John area of New Brunswick. Estimated CAC emissions for each TOMA were at the same ratios as GHGs.

2 The active fleet is reported as it existed on December 31st of each year, and reflects all locomotives classified as active on that date, not just those in operation. As the data represents the fleet on one particular day in the calendar year, significant year-over-year fluctuations are possible, and changes may reflect fleet acquisitions.
3 Ibid.

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1. Introduction

This report contains the Locomotive Emissions Monitoring (LEM) data filing for 2023 in accordance with the terms of the Memorandum of Understanding (MOU) signed on December 5, 2023, between the Railway Association of Canada (RAC) and Transport Canada (TC) concerning the emissions of greenhouse gases (GHGs) and criteria air contaminants (CACs) from locomotives operating in Canada.

In 2023, RAC and TC jointly announced a renewed MOU for reducing locomotive emissions. This MOU reflects a shared vision of working toward net-zero emissions by 2050 and builds upon the meaningful progress made to date by the Canadian rail sector. TC and RAC members agreed to work together to:

- advance low-carbon fuel use,
- move more goods and people by rail where possible,
- accelerate the development of advanced net-zero solutions for locomotives, and
- advance knowledge of climate risks to rail infrastructure and enhance climate resiliency of Canada's rail network.

As stated in the MOU, RAC will continue to encourage its members to reduce their GHG emissions intensity and criteria air contaminant emissions (CAC) from railway operations.

Transportation is Canada's second largest source of GHG emissions. In 2023, the transportation sector emitted 195 Mt of CO_2e, accounting for 28.1% of Canada's total GHG emissions.[4] The majority of transportation GHGs are attributed to on-road vehicles. Canadian railways accounted for 0.9% of Canada's total GHG emissions and 3.0% of transportation GHGs, which is less than light-duty on-road vehicles (41.2% of transportation GHGs), heavy-duty on-road vehicles (20.6%), pipelines (5.0%), aviation (4.3%), and several other transportation categories.[5] To meet Canada's commitment to reduce GHGs by 40-45 percent below 2005 levels by 2030 and reach net-zero by 2050, the transport sector must make a significant contribution.

Railways have played and will continue to play a key role in contributing to Canada's climate targets. Since 2005, freight railways have reduced their GHG intensity by 28.6%. During the same timeframe, railways have experienced a 26.0% increase in revenue traffic. Canada's Class 1 freight railways (CN and CPKC) have reduced their Canadian, absolute locomotive GHG emissions by 8.87%.

Passenger railways continue to invest in training, technology and equipment to reduce emissions, while contributing to emissions reductions by providing a sustainable transportation option for commuters and intercommunity travelers. Since 2005, intercity passenger railways have reduced their GHG intensity by 34.2%. Canada's railways will continue to contribute to national emissions reductions through investments in innovative solutions to increase efficiency and sustainability.

The 2023-2030 MOU between RAC and TC is the fifth MOU signed by RAC and the federal government since 1995. The MOU established a

4 Source: Canada's National Inventory Report, 1990–2023: Greenhouse Gas Sources and Sinks in Canada, Environment and Climate Change Canada, 2025, Table ES-1 and Table 2-3.
5 Ibid.

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framework through which RAC, its MOU signatory member companies (as listed in Appendix A), and TC committed to address GHG and CAC emissions produced by locomotives in Canada. The MOU, which can be found on RAC's Website and the Government of Canada's website, includes several collaborative objectives. Areas of collaboration include research, development and demonstration of advanced technologies, policy research, modelling, reporting, and driving actions that will achieve further GHG and CAC emissions reductions from rail operations in Canada.

Continued emissions reductions will help protect the environment, the health of Canadians, and address climate change. This is the first report prepared under the 2023-2030 MOU.

Data for this report were collected via a survey sent to each RAC member. Based on these data, the GHG and CAC emissions produced by in-service locomotives in Canada were calculated. The GHG emissions in this report are expressed as carbon dioxide equivalent (CO_2e), the key constituents of which are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). CAC emissions include nitrogen oxides (NO_x), particulate matter (PM_{10}), carbon monoxide (CO), hydrocarbons (HC), and sulphur oxides (SO_x). The SO_x emitted is a function of the sulphur content of diesel fuel and is expressed as SO_2. The survey and calculation methodology are available upon request to RAC.

1.1 OVERVIEW OF REPORT

This report provides an overview of 2023 rail performance including traffic, fuel consumption, the locomotive fleet inventory, and GHG and CAC emissions. Also included are sections on partnerships and initiatives being undertaken or examined by the sector to reduce fuel consumption and emissions.

1.2 GHG COMMITMENTS

As stated in the MOU (Section 4.0 Reducing Greenhouse Gas Emissions), RAC encourages its members to improve their GHG emissions (combustion emissions) intensity from railway operations. The 2005 baseline, 2022, and 2023 data on annual emissions (expressed as kilograms of CO_2e per productivity unit) are outlined in Table 1.

For historical comparison purposes and alignment with the Government of Canada's 2030 Emissions Reduction Plan (ERP), the year 2005[6] has been set as the reference year. The 2023 LEM Report methodology introduces year-specific GHG emissions factors that account for the use of biofuels in the overall fuel mix used by locomotives. In earlier LEM reports, all fuel litres were assumed to be diesel fuel. Historical emissions factors and GHG emissions have been updated accordingly. The revised data in this report supersede data in earlier versions of the report. Unless otherwise specified, metric units are used and quantities are expressed to two significant figures, while percentages are expressed to the number of significant digits reflected in the tables. Data in imperial units are available upon request to RAC.

In addition, this report contains data on fuel consumed and emissions produced by railways operating in three designated Tropospheric Ozone Management Areas (TOMA): the Lower Fraser Valley in British Columbia, the Québec City-Windsor Corridor, and the Saint John area in New Brunswick.

6 Starting with the 2020 LEM Report, 2005 has been set as the reference year, as it aligns with the Government of Canada's climate targets, among other merits. In previous reports, 1990 was set as the reference year.

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Table 1 2023–2030 MOU Progress - GHG Emissions Intensities

Railway Operation	Productivity Units	2005 Base Year	2022	2023	Change from 2005–2023	Change from 2022–2023
Class I Freight	kg CO_2e per 1,000 RTK	17.06	12.15	12.14	-28.82%	-0.04%
Intercity Passenger	kg CO_2e per passenger-km	0.128	0.090	0.084	-34.25%	-6.11%
Regional & Shortline	kg CO_2e per 1,000 RTK	16.80	13.76	13.85	-17.54%	0.67%

Note: GHG emissions (combustion) for all years have been calculated based on IPCC Fifth Assessment Global Warming Potentials (CO_2: 1, CH_4: 28, N_2O: 265) and emissions factors that consider the mix of biofuels and diesel fuel used in locomotives. Historical values have been updated.

1.3 CAC COMMITMENTS

As stated in the MOU, Transport Canada has developed regulations to control CAC emissions under the *Railway Safety Act*. The *Locomotive Emissions Regulations* (LER) came into force on June 9, 2017, and apply to federally regulated railways.[7] The Canadian regulations are aligned with the United States Environmental Protection Agency (US EPA) emissions regulations (*Title 40 of the Code of Federal Regulations of the United States, Part 1033*).

Prior to the implementation of the Canadian regulations, RAC encouraged all members to conform to the US EPA emission standards and to adopt operating practices aimed at reducing CAC emissions. Under the MOU, RAC continues to encourage its members (Section 5.0 Reducing Criteria Air Contaminant Emissions), including those not covered by the LER, to improve their CAC emissions performance. Through this MOU, RAC continues to report on annual CAC emissions, in a manner and format that is agreeable to all parties. It should be noted that CAC reporting under the MOU does not fulfill reporting requirements under the LER.

7 Baseline and some historical CAC performance reflected in this report predates the *Locomotive Emissions Regulations* for CACs. The *Locomotive Emissions Regulations* came into force on June 9, 2017. https://laws-lois.justice.gc.ca/PDF/SOR-2017-121.pdf

Table 2 2023–2030 MOU Progress - Absolute CAC Emissions (kilotonnes, unless otherwise specified)

CAC Emission	2005 Base Year	2022	2023	Change from 2005-2023	Change from 2022-2023
NO_x	126.50	66.30	64.65	-48.9%	-2.5%
PM_{10}	3.41	1.32	1.27	-62.7%	-3.5%
CO	15.43	14.12	14.39	-6.8%	1.9%
HC	5.78	2.60	2.50	-56.7%	-3.7%
SO_2 (tonnes)	4,974.49	49.75	50.70	-99.0%	1.9%

Note: The table presents CAC emissions for total rail operations (including line haul freight, yard switching and work train, and total passenger train operations).

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2. Emissions Reduction Initiatives

In 2023, Canadian railways continued to invest in new technologies and improve operational practices to reduce locomotive emissions. In 2023, railways invested $2.9 billion in their Canadian networks, bringing the total to more than $22.7 billion over the past ten years. This section of the report highlights how Canadian railways continue to drive emissions reductions through investments in fleet renewal/modernization, fuel saving technologies, operational efficiencies, and use of low-carbon fuels. In addition, pilot projects and various partnerships that reduce emissions and advance low- and zero-emission technologies are discussed.

Continued investments in key areas outlined above support the decoupling of emissions from traffic growth. However, the Canadian rail industry's decarbonization pathway may not be linear. Collaboration among railways, equipment manufacturers, fuel producers, government, and others is critical to developing and deploying deep decarbonization solutions.

2.1 FLEET RENEWAL/ MODERNIZATION

Fleet renewal/modernization is a key driver of locomotive emissions reductions.

In 2023, CN continued to purchase the most fuel-efficient high-horsepower locomotives currently available, acquiring 10 new units and receiving delivery of 40 modernized units out of a multiyear modernization program, where existing locomotives from the CN fleet are upgraded with the latest technology, extending their life and enhancing fuel efficiency. All new and modernized locomotives are equipped with energy management systems, data telemetry systems as well as distributed power functionality to help maximize locomotive operating effectiveness and fuel efficiency.

Since 1993 CN has reduced its rail locomotive GHG intensity by 45%, avoiding over 54 million tonnes of CO_2e, and remains a leader in the North American rail industry, consuming approximately 15% less locomotive fuel per GTM than the industry average.

SINCE 1993 CN HAS REDUCED ITS RAIL LOCOMOTIVE GHG INTENSITY BY

45%

AVOIDING OVER

54 MILLION

TONNES OF CO_2e

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In 2023, CN spent approximately $3.2 billion in its capital program, of which $663 million was on rolling stock, including the acquisition of 500 new grain hopper cars. Through this multiyear initiative, CN has acquired a total of 3,500 new high-capacity grain hopper cars, which save fuel as the cars enable more volume per train.

CPKC implements strategic investments in its rail network, equipment and locomotive fleet through its annual capital program to improve the fuel efficiency of operations. Locomotives upgraded or replaced through this program have a direct and positive impact on CPKC's fuel efficiency and corresponding GHG and air pollutant emissions. Supported by these investments, CPKC recorded a 2023 fuel efficiency of 1.026 U.S. gallons of locomotive fuel per 1,000 GTM. CPKC continues to advance climate-related initiatives, including efforts to reduce locomotive fuel consumption and enhance operational performance.

In 2023, CPKC invested $273M to renew depleted assets, encompassing $186M in locomotive upgrades and $87M in rail car improvements, including the acquisition of new freight cars and remanufacturing of 145 tiered locomotives in its Canadian fleet.

Following a multiyear procurement project that completed in 2022, 5,900 new high-capacity grain hopper cars are in operation across CPKC's network. CPKC's 8,500-foot HEP train model, which pairs with its higher-capacity grain hopper cars, enables 40 percent more grain per train, reducing the required total number of train starts, fuel consumption and GHG emissions versus conventional grain shipments. Based on the successful implementation of the model in Canada, CPKC is expanding it to the U.S. In 2023, CPKC launched and landed the first 8,500-foot HEP train in the U.S.

In 2023, VIA Rail advanced the deployment of its new state-of-the-art fleet in the Québec City–Windsor corridor, introducing eight additional Tier 4-compliant locomotives. This new generation of trains delivers a fully accessible, barrier-free travel experience and represents one of the most environmentally responsible fleets in North America. By meeting Tier 4 emissions standards, these locomotives reduce particulate matter and nitrogen oxide emissions by up to 95%, contributing meaningfully to improved air quality.

VIA Rail is also preparing for the renewal of its Long-Distance, Regional, and Remote fleets. A comprehensive business case was submitted to the Government of Canada in July 2022 and revised in September 2023 at the request of Cabinet Ministers. In parallel, VIA Rail launched a Request for Information (RFI) to engage with manufacturers on technical, commercial, and legal considerations.

In 2023, Genesee & Wyoming Inc. continued to purchase APUs and fuel additives to reduce locomotive GHG emissions.

West Coast Express (WCE) continued to progress on upgrading its locomotives from Tier 0 engines to Tier 2+ (Tier 3 equivalent). WCE received its first two upgraded locomotives in 2023 (one of which was purchased and one refurbished), with all six locomotives expected to be completed by late 2027/early 2028. Once these refurbishments are complete, CAC emissions should be reduced by 48 per cent, based on US EPA standards.

2.2 FUEL SAVING TECHNOLOGIES

Fuel saving technologies, often powered by big data and AI, reduce fuel consumption for a given movement. These technologies drive fuel efficiencies by optimizing things like train settings, horsepower-to-tonnage ratios, distributed power, train speeds, train pacing, braking, and anti-idling.

By the end of 2023, CPKC had installed Wabtec's Trip Optimizer™ technology on more than 800 high-horsepower locomotives, equipping 56% of its high-horsepower fleet

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Trip Optimizer™ is a sophisticated locomotive cruise control optimized for fuel economy, taking into account factors such as train length, weight and track grade to determine the optimal speed profile for a given segment of track. CPKC enhanced its use of Trip Optimizer systems in 2019 to include pacing technology to drive deeper fuel efficiency and system fluidity improvements. Pacing technology accounts for a specific train's location in relation to other trains operating within the same area of the network. The system detects opportunities to reduce train speed in certain areas along the right-of-way to minimize wait times at stations, thus facilitating continued progression at the optimum speed to deliver on time, in the most fuel-efficient manner possible.

By the end of 2023, CPKC had installed Wabtec's Trip Optimizer™ technology on more than 800 high-horsepower locomotives, equipping 56% of its high-horsepower fleet with this fuel-saving technology.

CN continues to explore and invest in innovative technologies to maximize locomotive operating effectiveness and efficiency. This includes collecting big data and installing new locomotive technologies such as Energy Management System (EMS), locomotive telemetry systems, and anti-idling devices. CN's locomotives receive real-time information on train characteristics, performance and terrain through an EMS, which helps to compute the most fuel-efficient train settings and regulate speed. CN's in-house-built Horsepower Tonnage Analyzer (HPTA) also instructs crews on how to optimize a locomotive's horsepower-to-tonnage ratio to minimize fuel consumption. Distributed Power is used to remotely control locomotives and improve braking performance, train handling and fuel efficiency.

Through the Innovative Solutions Canada Testing Stream, VIA Rail expanded its pilot of EcoRail—an AI-powered software that supports locomotive engineers with real-time driving recommendations to reduce fuel consumption and greenhouse gas emissions. Following promising simulator results indicating up to 15% fuel savings, the technology was deployed in live operations on two of the busiest routes in the Québec City–Windsor corridor.

VIA Rail deployed EcoRail fuel saving technology in live operations in the Québec City–Windsor corridor.

2.3 OPERATIONAL EFFICIENCIES

In 2023, CN continued to leverage real-time information on train operations, enabling on-the-job guidance on practices that reduce fuel consumption. Capacity upgrades, including lengthening sidings and doubling sections of mainline track, allow CN to drive fluidity in its busiest corridors, improving fuel and carbon efficiency.

In 2023, CN's recommitment to a disciplined scheduled operating plan, with a focus on velocity, helped to increase network fluidity, reducing unplanned train stops across the network and driving related gains in fuel efficiency.

CPKC has implemented a precision scheduled railroading (PSR) operating approach. PSR focuses on operational efficiency and fuel efficiency metrics to drive performance improvements.

VIA Rail continues to pursue operational excellence as a cornerstone of its climate resilience strategy. Enhancing efficiency not only reduces emissions but also strengthens service reliability and cost-effectiveness. Key initiatives include:

- **Maintenance Optimization:** Leveraging predictive maintenance to extend asset life and reduce disruptions.

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- **Energy Management:** Implementing energy-saving upgrades at stations and maintenance centres.
- **Digitalisation:** Using data analytics to optimise scheduling, reduce idling, and improve network performance.

These efforts are integral to VIA Rail's commitment to a low-carbon, resilient transportation system.

2.4 LOW-CARBON FUELS

Throughout the 2023-2030 MOU period, low-carbon fuels will be a key driver of GHG emissions reductions. The MOU commits the parties to explore the feasibility of achieving 10 to 20% of low-carbon fuels use within the rail sector by 2030. However, this is dependent on fuel availability at competitive costs.

Railways make use of renewable fuels such as biodiesel blends up to 5% (B5) and hydrogenation-derived renewable diesel (HDRD) blends up to 30%. The majority of North American engine manufacturers endorse up to a B5 biodiesel blend. Some important caveats to note include:

- The energy density of biodiesel and renewable diesel varies depending on feedstocks used, and is slightly lower than that of diesel fuel;
- railways do not always have visibility on blend levels since fuel providers are not required to disclose exact blend levels; and
- locomotive performance may be adversely impacted with higher renewable fuel content and manufacturer warranties may be voided.

Canadian railways continue to work collaboratively with a variety of partners to explore the opportunities and challenges of increasing the use of low-carbon fuels in locomotives. See Section 2.6 Partnerships for more details.

CN and CPKC collaborated with their partners, including locomotive manufacturers, fuel producers, and other Class 1 railways, to advance testing of renewable fuels in railway operations. These trials will allow railways and industry to better understand the operational impacts of advanced blends of renewable fuels, including long-term durability, especially in cold weather, and any modifications, if necessary, to increase their usage over the next decade. In 2023, trials and qualifications on CN's existing locomotive fleet of up to 100% renewable fuel blends continued to progress. In 2023, a three-year (mid-2023 through 2026) renewable fuel trial was launched in British Columbia – operating 10 of CPKC's locomotives fueled by a blend of 20 percent biodiesel and conventional diesel (B20).

In 2023, CN consumed 504,898 MWh of sustainable biomass (biogasoline + biodiesel), representing 2.7% of total MWh consumed.

In 2023, CN consumed 504,898 MWh of sustainable biomass.

VIA Rail's new fleet operating in the Québec City–Windsor corridor is engineered to accommodate higher blends of low-carbon fuels (above 5%), offering greater flexibility as VIA Rail progresses toward decarbonisation.

2.5 ALTERNATIVE PROPULSION

Since 2020, CPKC has been developing North America's first line-haul hydrogen-powered locomotive. CPKC's engineering and mechanical experts are leading this program to research, develop and test the conversion of existing diesel-powered units into hydrogen-electric locomotives. CPKC's program is intended to spur innovation, demonstrate leadership and encourage collaboration to expedite the advancement of zero-emission fuel cell technology for the freight rail sector.

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In 2023, CPKC successfully converted two low horsepower units to hydrogen-electric locomotives, which entered into service within its Calgary terminal switching operations. As of December 2023, the units had successfully completed eight full eight-hour shifts operating at below freezing temperatures. Both units completed 48 mainline tests, accumulating a combined 3,840 miles in rail operations.

CPKC's hydrogen-powered locomotives completed eight full eight-hour shifts in switching operations accumulating a combined 3,840 miles in mainline tests.

In 2023, CPKC also advanced production on a high horsepower hydrogen-electric locomotive, which includes a tender car delivering 1,100 kilograms of additional hydrogen enabling a 500-mile range to facilitate mainline operations testing.

In 2023, CPKC and CSX (a U.S.-based Class 1 railroad), established a joint venture for CPKC to build and supply a hydrogen locomotive conversion kit in support of CSX converting a diesel-electric switch locomotive to operate on hydrogen.

Additionally, CPKC announced a pilot program with Teck Resources to deploy and test hydrogen locomotive operations as a component of CPKC's freight rail services in support of Teck's (now Elk Valley Resources) metallurgical coal mining operations.

In 2021, CN announced the purchase of Wabtec's FLXdrive battery-electric freight locomotive, the first 100% battery heavy-haul locomotive. The anticipated efficiencies and emission reductions from the technology will be significant, reducing locomotive consist fuel consumption and emissions by up to 30%. In 2023, design of the locomotive and of the method of charging continued to progress. CN also engaged in discussions with the electricity provider and undertook engineering work to assess the necessary infrastructure changes to deliver power.

VIA Rail is laying the groundwork for a long-term transition to alternative propulsion technologies. This transition is guided by a three-phase roadmap aligned with Canada's net-zero emissions target for 2050.

Highlights include:

- **Strategic Vision:** VIA Rail is actively exploring a range of alternative propulsion technologies—such as battery electric, hydrogen fuel cells, and potentially catenary electrification—as part of its ongoing assessment of decarbonization options. These technologies are being evaluated based on feasibility, operational needs, and infrastructure considerations.

- **Technology Readiness:** While not yet commercially viable at scale, these technologies are being closely monitored for future integration.

- **Fleet Compatibility:** The new fleet is designed to support higher blends of low-carbon fuels, ensuring adaptability for future propulsion systems.

- **Roadmap Alignment:** VIA Rail's strategy aligns with the Rail Decarbonization Roadmap developed by the Railway Association of Canada and Transport Canada.

In 2023, Alstom and Train de Charlevoix partnered on a hydrogen fuel cell demonstration project in Quebec. Alstom's Coradia iLint hydrogen train successfully carried more than 10,000 of its very first North American passengers in revenue service on the Train de Charlevoix from Parc de la Chute-Montmorency to Baie-St-Paul. The green hydrogen-powered train helped save approximately 8,400 litres of diesel during the pilot.

In 2022-23, Metrolinx released a specification for new locomotives and the winning proponent offered a solution which includes an electric locomotive platform. Metrolinx has worked to align requirements with the proposed solution

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and develop a consolidated technical electric locomotive specification document. A modification program for the legacy fleet is in development to enable existing assets to be paired with electric locomotives if introduced to the fleet.

As Metrolinx advances capital programs and looks to future operations, there will be the introduction of electric light rail vehicles on the Finch West, Eglinton Crosstown, Hazel McCallion and Hamilton lines, all of which will have a role in reducing emissions as more people travel across the region using cleaner, more sustainable modes of transportation.

- In 2023, the Eglinton Crosstown Light Rail Transit (ECLRT) project carried out Train-the-Trainer activities in collaboration with the Toronto Transit Commission (TTC) operations team. At that time, all 76 vehicles (Light Rail Vehicles, LRVs) had been procured and were stationed at the Eglinton Maintenance and Storage Facility (EMSF).
- The Finch West Light Rail Transit (FWLRT) project advanced through the commissioning phase of its Light Rail Vehicles, with all 18 vehicles (LRVs) commissioned by year-end. This milestone was followed by the initiation of system integration testing.
- The Hazel McCallion Light Rail Transit (HMLRT) project continued with the manufacturing of vehicles (LRVs) at the Alstom production facility. Meanwhile, the Hamilton LRT project remained in the early stages of capital project planning.

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2.6 PARTNERSHIPS

Partnerships between and among industry, governments, academia, and others will play a critical role in developing policy and technological solutions for continued decarbonization of the rail sector in Canada.

Transport Canada - RAC MOU for reducing locomotive emissions

In 2023, Transport Canada and the Railway Association of Canada jointly announced a renewed Memorandum of Understanding (MOU) for reducing locomotive emissions. This MOU reflects a shared vision of working toward net-zero emissions by 2050 and builds upon the meaningful progress made to date by the Canadian rail sector. Transport Canada and Railway Association of Canada members agreed to work together to:

- advance low-carbon fuel use,
- move more goods and people by rail where possible,
- accelerate the development of advanced net-zero solutions for locomotives, and
- advance knowledge of climate risks to rail infrastructure and enhance climate resiliency of Canada's rail network.

The Memorandum of Understanding outlines several areas for collaboration and sustainability milestones. These include: recognition of Class 1 railways (CPKC and CN) for their commitments to reduce GHG emissions intensity in line with their 2030 science-based targets (validated by SBTi), and to achieve absolute emissions reductions by 2030 aligned with SBTi modeled pathways; exploring the feasibility of achieving up to 20 percent of low-carbon fuel use within the rail sector by 2030; and working together to accelerate the research and development that supports retrofitting and upgrading locomotives toward net-zero technologies.

Canada – U.S. Collaboration

Transport Canada deepened its collaboration with the U.S. Department of Transportation, Federal Railroad Administration, and Department of Energy on the safe integration of emerging technologies, including hydrogen-powered and battery-electric locomotives. The departments worked towards alignment of decarbonization research priorities, engaged on approaches to accelerate the rail sector's safe transition from diesel-powered locomotives to zero-emission technologies, and collaborated on tools to model the rail sector's potential pathways to net-zero.

ECCC – ERP Progress Report

In December 2023, Environment and Climate Change Canada released the first progress report (2023 Progress Report) on the 2030 Emissions Reduction Plan (2030 ERP). Released in March 2022, the 2030 ERP is a sector-by-sector roadmap that identifies climate actions and strategies for Canada to reach its 2030 emissions reduction target and net-zero emissions by 2050. The 2023 Progress Report provided an update on progress towards Canada's emissions reduction targets described in the 2030 ERP, as well as a summary of the 2023 Greenhouse Gas and Air Pollutant Emissions Projections report. The ERP Progress Report reiterated the commitment to develop and implement a plan to reduce emissions from Canada's rail sector.

ECCC – Energy-Economy Analysis

Environment and Climate Change Canada commissioned a project with Navius Consulting to develop an energy-economy analysis of the Canadian rail sector. This initial study projected GHG emissions for various rail sector decarbonization trajectories and led to a more detailed study in 2024.

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Transport Canada and High Frequency Rail Project

The Government of Canada's High Frequency Rail project will transform intercity passenger rail in the Quebec City to Toronto Corridor, bringing faster, more frequent, and reliable service to travelers.

In Budget 2022, the Government of Canada allocated $396.8 million over two years, starting in 2022-23, to Transport Canada and Infrastructure Canada to advance HFR through the Procurement phase of the project, scheduled to end in 2024 — taking it into the Co-Development phase.

The HFR project supports many priorities of the MOU, including the vision for green and innovative transportation in Canada, and an improvement in the GHG and CAC emissions intensity of the rail sector, by supporting the construction of electrified rail tracks and inducing a modal shift from cars to passenger rail for travel in the Corridor.

Natural Resources Canada — Lignin-Derived Diesel Fuel

Through Natural Resources Canada, CanmetENERGY-Ottawa completed a project in Fall 2022 to develop a process to produce lignin-derived diesel fuel as a potential drop-in low-carbon biofuel. Lignin is present in softwoods, hardwoods, grasses, and other plants. It is a waste product as a residue from chemical pulp mills and from agriculture that can be converted into a drop-in replacement for diesel. Results to date have demonstrated that 100% lignin-derived diesel met 9 locomotive diesel specifications from CGSB-3.18-2010 and the same 9 from CGSB-3.517-2020.[8]

The low cloud point of 100% lignin-derived diesel (-36 °C by ASTM D5773) indicates that it has fairly good low-temperature operability. The specifications not met were for electrical conductivity, lubricity, and derived cetane number. These properties could be brought to standard by using fuel additives that are commonly used in ultra-low sulphur diesel, and a cetane enhancer additive that would boost the ignition quality of 100% lignin-derived diesel (from 39.1 to 40). These results indicate that the lignin-derived diesel that was produced is suitable for use in diesel locomotives at any blend up to and including 100% and would be compatible with existing infrastructure.

Natural Resources Canada—Hydrogen Strategy

Natural Resources Canada released Canada's Hyrdogen Strategy in 2020. The strategy aims to position Canada's ports as hosts for early deployment hubs of fuel cell equipment, with marine, rail, and on-road vehicles that could share hydrogen infrastructure at scale. The first Hydrogen Strategy Progress Report[9] highlights major developments across the hydrogen value chain from 2021-2024. Significant developments include initiatives from CPKC and Alstom that are demonstrating the use of hydrogen fuel technologies in Canada's rail operations.[10]

Transport Canada—Innovation Centre

The Innovation Centre's Rail RD&D group undertakes research and development activities to support the rail industry's adoption of new technologies that reduce the emissions of greenhouse gases and criteria air contaminants. The projects are designed to help the rail industry overcome technical challenges and build knowledge about how to operate new technologies safely. Projects undertaken in this program are selected through a consultation process that includes recommendations from federal government, academia, and the railway industry. The main forum for this consultation is the Rail Research Advisory Board. The Rail Research Advisory Board was created by Transport Canada in 1989, with the

8 In September 2021, the CAN/CGSB-3.18-2010 standard was withdrawn, and standard CAN/CGSB-3.517-2020 may be used for applications that were formerly covered by CAN/CGSB-3.18-2010.

9 Hydrogen Strategy for Canada: Progress Report, Natural Resources Canada.

10 Alstom's Coradia iLint, the world's first hydrogen-powered passenger train, will demonstrate green traction in Quebec. https://www.alstom.com/press-releases-news/2023/2/alstoms-coradia-ilint-worlds-first-hydrogen-powered-passenger-train-will-demonstrate-green-traction-quebec

purpose of optimizing collaboration and create synergies in railway research between industry, government, and academia. Meetings are held bi-annually in the spring and fall. At the Spring 2023 RRAB meeting, a piece of feedback provided by members was to create dedicated task teams under the themes of "Decarbonization", "Fire Risk", and "Advanced Track Inspection".

The *Decarbonization Task Team* held its first meeting in 2023, with the goal of advising TC about the highest priority barriers to decarbonizing rail that could be solved through applied research and testing. Common themes discussed were to:

- Reflect on the research needs for storing biodiesel and renewable diesel.
- Explore testing to populate a matrix showing the mechanical impacts of biodiesel blends against different locomotive engine types.
- Put more emphasis on the development of fueling and charging infrastructure.

Task team meetings will continue to be held each year in fall and spring. If you are a railway or academia partner that is interested in learning about this task team, please reach out to Innovation Centre through RAC's representative for the MOU.

Transport Canada—Innovation Centre Research Activities

Hydrogen and Battery Locomotives: Policy, market, and technology trends are positioning hydrogen and battery technologies as key parts of the solution for decarbonizing the rail sector over the long-term. Rail industry is pioneering the use of these technologies in locomotives. To support rail's leadership in testing hydrogen and batteries, Innovation Centre has focused on work that builds knowledge of how to use them safely in rail operations, namely in the areas of risk assessments and codes and standards. TC Innovation Centre's research and project results from 2023 related to hydrogen and battery locomotives are described below:

- **Continued the initiative to examine the risks and hazards associated with hydrogen fuel cell and battery powered locomotives.** In 2023, TC initiated Phase II of their Hydrogen and Battery Locomotives Risks and Hazards project. Phase I of the project was completed in 2021 and included a literature review of risks and hazards (online report), assessment of the risks and hazards (online report), review of existing codes and standards (online report).
  - The second phase built on the original analysis by doing a deeper risk assessment. This was done through a semi-quantitative risk assessment at the sub-system level in a reference locomotive. The final report is titled "Hydrogen and Battery Locomotive Risk Assessment – Companion Report" and will be made available at the following site in 2025: (Federal Open Science Repository).
  - As part of Phase II, an overview of batteries for locomotives was also included. It has information about common operational or manufacturing issues that can cause battery failures and an overview of the risks and hazards associated with them. The report is titled "Technical Report: Battery Electric Locomotives" and will be made available at the following site in 2025: (Federal Open Science Repository)
- **Conducted an engineering review of a hydrogen fuel cell passenger demonstration project in Canada.** In 2023, TC attended a demonstration project held by Alstom and Chemin De Fer Charlevoix to operate the Coradia iLint fuel cell battery passenger train from Parc de la Chute-Montmorency to Baie-St-Paul. From this, TC initiated a project with NRC to conduct an engineering review of the passenger train and its operation, looking to observe how risks were mitigated in the trainset designed to standards and requirements in Germany, where the passenger train originates from. This also offered an opportunity for federal and provincial railway

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inspectors to obtain first-hand experience about the unique aspects of hydrogen driven passenger trains.

- **Published a literature review and physical experiments with hydrogen/diesel blends.** The project evaluated overall feasibility for locomotive use of hydrogen-diesel blended combustion and examined potential changes in greenhouse gas and criteria air contaminant emission compared to diesel. This study used heavy-duty compression ignition engines operating at typical locomotive engine load conditions in a laboratory. The final report was completed in 2023 and is available online at the Innovation Centre reports page: (online report).

- **Supported the publication of technical specifications for hydrogen and battery locomotives.** Funded by the CTS-RD grant program, this project worked with CSA Group, a North American standards development organization, to develop technical specifications that outline the baseline design and operating requirements for hydrogen fuel cell and battery-powered locomotives.

  - CSA TS-602:23– Railway Applications – Rolling Stock – Onboard Lithium-ion Traction Batteries

  - CSA TS-601:24– Hydrogen Fuel Cell Power Systems for Rolling Stock

  - Working groups for the specifications included members from railway companies, manufacturers of locomotives, fuel cells, academia, and National Research Council of Canada.

  - In another part of this project, CSA Group carried out a project to identify codes and standards from international sources that could be used to inform safe design and operation of hydrogen fuel cell and battery-powered locomotives. The product of this work was a roadmap for developing a more robust codes and standards ecosystem and identify gaps where North American homegrown standards may be needed. A report was created, titled "Advancing the use of Hydrogen and Electrification in the Rail Industry" and will be made available at the following site in 2025: (Federal Open Science Repository).

- **Supported a quantitative risk assessment for hydrogen fuel cell powered locomotives.** Funded by the CTS-RD grant program, Canadian Nuclear Laboratories (CNL) conducted a high-level quantitative risk assessment of the use of hydrogen as a fuel in freight trains. Hydrogen detection and mitigation measures, and relevant regulations, codes and standards are being assessed to develop appropriate risk mitigation strategies where required. To further support this work, CNL created a quantitative risk assessment tool designed to be used for case studies. The project engaged industrial partners to provide operational data and feedback to support the risk assessment (online report).

- **Supported a feasibility study on replacing auxiliary power generators with hydrogen fuel cells onboard a passenger locomotive.** Funded by the CTS-RD grant program, Ballard Power Systems conducted a feasibility study to assess the viability of replacing diesel generators with hydrogen fuel cell (HFC) power generators to manage the train's auxiliary power demands, i.e. lighting, heating, power. The purpose was to study the technical feasibility and potential benefits, in order to form a potential future demonstration project. The final report is titled "Feasibility Study for Rocky Mountaineer Fuel Cell Powered Generator Van" and will be made available at the following site in 2025: (Federal Open Science Repository).

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- **Supported a feasibility study of a hydrogen-powered locomotive pilot project.** Funded by the CTS-RD grant program, the University of British Columbia investigated the technical feasibility of a hydrogen-powered locomotive pilot project by analyzing the technical parameters, operational constraints, and safety risks as well as mitigation strategies for the fuel cell and battery retrofits to be utilized in the locomotive. A techno-economic analysis and life cycle costing of the retrofits is being conducted in order to examine the economic viability of the hydrogen-powered locomotive, along with a study of the environmental sustainability and social acceptability of the retrofits. The project is also working on a multi-criteria decision support system for future hydrogen-powered locomotive projects considering their technical, economic, environmental, and social aspects. The final report is titled "Assessment of Technical, Economic, Environmental, and Social Sustainability of Canadian Pacific's Pilot-scale Hydrogen-powered Locomotive and Development of a Decision Support System for Future Projects" and will be made available at the following site in 2025: (Federal Open Science Repository).

Low-Carbon Fuels: Low-carbon fuels have been flagged by the rail industry as an important tool in the breadth of options that are being investigated for decarbonization in rail. Much of the testing for low-carbon fuels is taking place within the rail industry. Innovation Centre's support has been focused on specific technical challenges that have been raised by railways who are testing these fuels. As of this report, this has primarily been focused on advancing 100% biodiesel fuels (B100). TC Innovation Centre's research and project results from 2023 related to low-carbon fuels are described below:

- **Supported a test of B100 biodiesel fuel in freight revenue operation.** Funded by the CTS-RD grant program, the Southern Railway of British Columbia (SRY) conducted a pilot project to transition one diesel locomotive engine to 100% biodiesel, also known as "B100." The test locomotive was used in SRY's day-to-day freight rail operations in Southern British Columbia. The project tested train performance and emission reductions. This was the first known rail B100 pilot test in Canada. The final report is titled "Evaluation of Emissions and Engine Wear with 100% Soy Methyl Ester Biodiesel on an EMD567 Switcher" and will be made available at the following site in 2025: (Federal Open Science Repository).

- **Launched a project to test B100 biodiesel fuel in mild sub-zero temperatures.** Over the course of the initial B100 pilot project with SRY, concerns arose surrounding the behaviour of B100 in mild sub-zero temperatures, and SRY ceased B100 fueling during the winter months. Clouding and gelling of B100 would be a common concern for any railway seeking to use higher blends of biodiesel in colder climates. Following the initial pilot project, the Innovation Centre supported a subsequent project to investigate ways to permit B100 use in temperatures below 0 degrees. The final report is titled "Viability of 100% Biodiesel (B100) in a Locomotive at Mild Sub-Zero Temperatures", and will be published to the following site in 2025: (Federal Open Science Repository).

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CN—Collaboration with the Université de Montréal

CN has renewed its investment in operations research partnering with Université de Montréal for development of mathematical models to potentially find new operational and fuel efficiencies. More optimal assignment and routing of locomotives, loading of intermodal trains to improve aerodynamics, and integrated planning can drive possible carbon emission reductions and are focus areas within this research. Some preliminary results have been produced and CN is reviewing model performance to evaluate their potential to drive business impact.

CN—Progress Rail and Chevron Renewable Energy Group to Test High-Level Renewable Fuel Blends

CN is building important partnerships, actively working with the industry on testing and exploring the greater use of sustainable renewable fuel blends, beyond regulated amounts, in its locomotives. Along with Progress Rail and Chevron Renewable Energy Group, CN continues to test high-level renewable fuel.
See 2.4 Low-Carbon Fuels.

CN—Customer Engagement on Environmental Issues

In 2023, CN continued to promote its publicly-available web-based carbon calculator, which is a business tool that allows existing and potential customers to estimate the emissions from rail, marine and truck transportation.

In 2023, CN launched a new self-service, sustainability tool, My Carbon Emissions. The new tool provides customers with a detailed report of their estimated GHG emissions based on all their loaded shipments moved on CN, as well as the emissions avoided by choosing rail over truck.

CN's EcoConnexions partnership program aims to both partner with and recognize customers who are committed to building an efficient and more sustainable future, including leveraging the environmental benefits of shipping heavy freight over long distances by rail rather than truck to reduce emissions.

CPKC—Customer Engagement

CPKC provides its customers with resources and GHG planning tools, including CPKC's publicly available online rail transport Carbon Emissions Calculator. In 2023, the Carbon Emissions Calculator was updated for the combined CPKC network.

This web-based tool is designed to give customers greater insight into the carbon footprint of their freight rail transportation services. The tool allows for complex, tailored emissions calculations, enabling current and prospective customers to compare an estimate of the GHG emissions related to transportation of freight by CPKC's rail services versus heavy haul trucking alternatives. This information assists potential and current customers in estimating the GHG emissions savings of shipping freight across user-selected origin and destination pairs for a wide variety of commodities commonly shipped by rail.

Collaboration is Central to VIA Rail's Sustainability Journey

The organisation is actively engaging with:

- **Government and Industry:** Working with federal partners and industry stakeholders to align on climate strategies and share best practices.
- **Knowledge Networks:** Participating in working groups and forums to stay ahead of regulatory and technological developments.
- **Strategic Alliances:** Exploring partnerships to advance alternative propulsion, enhance infrastructure resilience, and improve data capabilities.

These partnerships are vital to building capacity, accelerating innovation, and achieving VIA Rail's long-term sustainability goals.

3. Traffic Data

3.1 FREIGHT TRAFFIC HANDLED

As shown in Table 3 and Figure 1, there was a small increase in freight traffic in 2023. Traffic handled by Canadian railways totaled 824.19 billion gross tonne-kilometres (GTK) compared to 822.62 billion GTK in 2022, an increase of 0.2%. The 2023 GTK represented an increase of 23.3% from the 2005 reference year. Revenue traffic in 2023 increased to 444.56 billion revenue tonne-kilometres (RTK) from 438.73 billion RTK in 2022, an increase of 1.3%. When compared to 352.91 billion RTK in 2005, this represented an increase of 26.0%. Since 2005, the average annual growth rates for GTK and RTK were 1.2% and 1.3%, respectively.

Table 3: Total Freight Traffic, 2005, 2014–2023 (billion tonne-kilometres)

	2005	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
GTK											
Class 1	628.09	754.24	752.30	722.33	778.86	820.67	824.53	807.01	793.87	779.42	780.97
Regional & Shortline	40.45	39.19	42.09	44.07	44.59	43.98	39.45	39.75	39.33	43.20	43.22
Total	668.54	793.43	794.39	766.40	823.45	864.66	863.98	846.76	833.21	822.62	824.19
RTK											
Class 1	328.24	399.47	394.10	383.47	411.22	433.45	432.38	430.39	421.23	415.03	420.91
Regional & Shortline	24.67	23.01	23.98	25.05	24.25	22.27	22.68	21.29	21.73	23.70	23.65
Total	352.91	422.49	418.08	408.53	435.46	455.72	455.06	451.67	442.97	438.73	444.56
Ratio RTK/GTK*	**0.53**	**0.53**	**0.53**	**0.53**	**0.53**	**0.53**	**0.53**	**0.53**	**0.53**	**0.53**	**0.54**

* A higher RTK/GTK ratio may be indicative of greater asset utilization efficiency. However, this ratio may be influenced by non-efficiency factors such as a change in the composition of a railway's commodity portfolio (for example, increasing share of carloads of relatively lighter goods leading to a lower RTK/GTK ratio).

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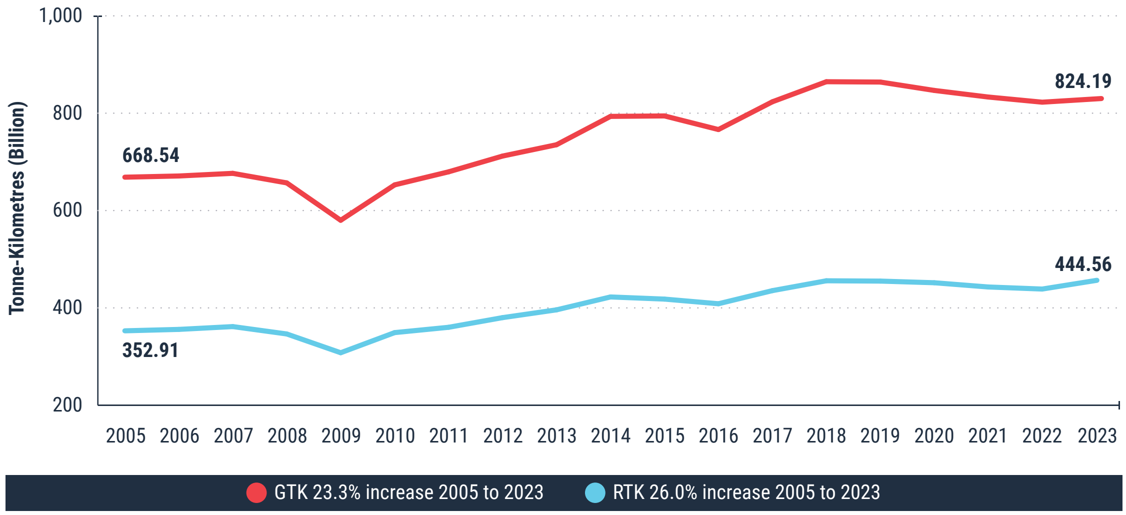
Figure 1: Total Freight Traffic, 2005–2023



In 2023, Class 1 GTK traffic increased by 0.2% to 780.97 billion from 779.42 billion in 2022 (Table 3) and accounted for 94.8% of the total GTK hauled. Class 1 RTK traffic increased by 1.4% in 2023 to 420.91 billion from 415.03 billion in 2022 and accounted for 94.7% of the total RTK.

Of the total freight traffic in 2023, regional & shortline railways were responsible for 43.22 billion GTK (or 5.2% of total GTK) and 23.65 billion RTK (or 5.4% of total RTK). In 2023, regional & shortline railways experienced a small, 0.2% reduction in RTK compared to 2022 while GTK increased by 0.1%.

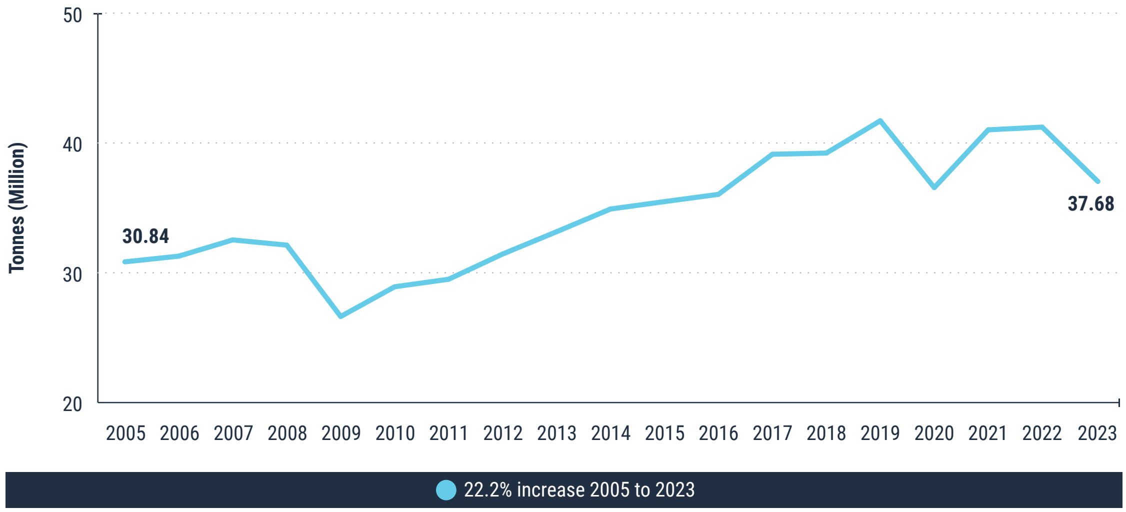
3.1.1 Intermodal Traffic

Intermodal service includes the movement of trailers or containers by rail and other modes. Intermodal traffic is, in general, more truck-competitive than other types of freight moved by rail. Each intermodal train replaces hundreds of long-haul truck loads, thus reducing highway congestion and emissions. Modal shift to rail is an objective of the 2023-2030 MOU to create immediate GHG emissions reductions from Canada's transportation sector.

In 2023, intermodal tonnage decreased by 8.6% to 37.68 million tonnes from 41.22 million tonnes in 2022. Several factors contributed to the reduction in intermodal volumes, including soft consumer demand throughout the year, a weak macroeconomic environment, the 13-day British Columbia ports strike in July 2023 that resulted in traffic diversions to U.S. ports, as well as enhanced pricing pressure from the trucking sector.

Overall, since 2005, intermodal tonnage, comprising both container-on-flat-car and trailer-on-flat-car traffic, has risen by 22.2%, as illustrated in Figure 2.

Figure 2: Intermodal Tonnage, 2005–2023

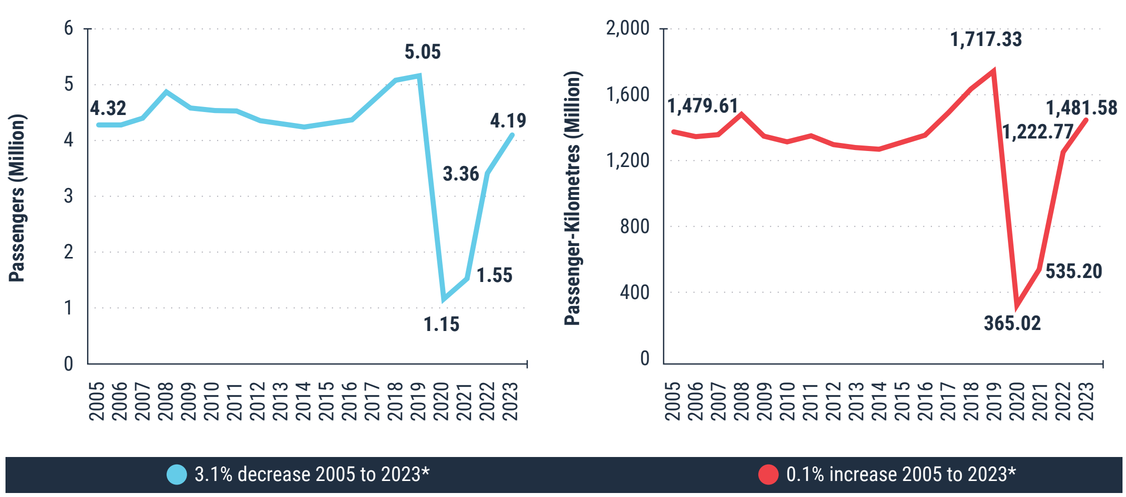


3.2 PASSENGER TRAFFIC HANDLED

3.2.1 Intercity Passenger Services

In 2023, intercity passenger traffic continued to recover from the COVID-19 pandemic and was 12% below the 2019 (pre-pandemic) level of 5.05 million passenger. 2023 traffic totaled 4.19 million passengers compared to 3.36 million passengers in 2022, an increase of 24.6%, but was 3.1% below the 2005 level of 4.32 million passengers (Figure 3).

Figure 3: Intercity Rail Passenger Traffic, 2005–2023



* Starting in 2020, passenger rail performance metrics have been significantly impacted by the COVID-19 pandemic.

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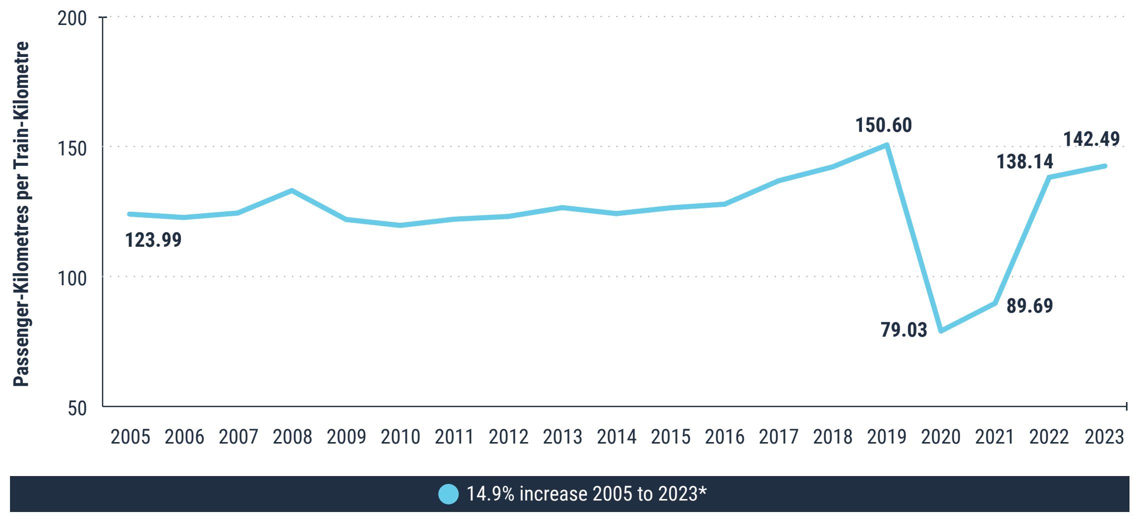
Revenue passenger-kilometres (RPK) for intercity passenger traffic totaled 1,481.58 million. This is an increase of 21.2% compared to 1,222.77 million in 2022 and 0.1% from 1,479.61 million in 2005 (Figure 3).

Intercity train efficiency is expressed in terms of average passenger-kilometres (km) per train-km. As shown in Figure 4, intercity train efficiency in 2023 was 142.49 passenger-km per train-km, a 3.2% improvement from 138.14 in 2022 and a 14.9% improvement compared to 123.99 in 2005.

Intercity train efficiency peaked in 2019 at 150.60 passenger-km per train-km, and then fell to 79.03 in 2020 as a result of fewer passengers per train during COVID-19 pandemic restrictions and a reduction in overall travel. However, as seen in Figure 4, since the initial steep decline in 2020, intercity rail efficiency has improved each year with a continued increase in ridership.

Figure 4: Intercity Rail Train Efficiency, 2005–2023



* Starting in 2020, passenger rail performance metrics have been significantly impacted by the COVID-19 pandemic.

3.2.2 Commuter Rail

In 2023, commuter rail passengers totaled 47.45 million (Figure 5), up 70.5% from 27.83 million in 2022.[11] Despite this recent increase, overall commuter traffic remained 18.5% below the 2005 base year level of 58.24 million passengers, and 53.5% below the 2019 peak of 101.94 million.

Commuter operations in Canada using diesel locomotives and/or diesel multiple units (DMUs) included exo serving the Montreal-centred region (previously Réseau de transport metropolitain), Capital Railway serving Ottawa,[12] Metrolinx serving the Greater Toronto Area, and West Coast Express serving the Vancouver-Lower Fraser Valley region.

13 The significant decrease in commuters since 2019 is due to an unprecedented drop in ridership on commuter rail services, as a consequence of the COVID-19 pandemic.

14 Capital Railway's DMUs were not in operation in 2023 due to construction of the expanded passenger rail service.

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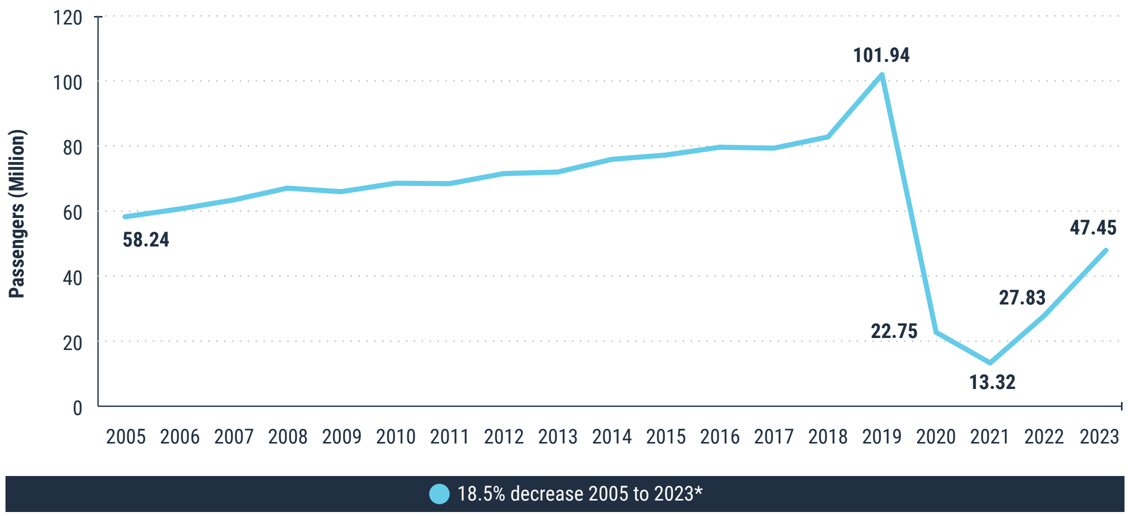
Figure 5: Commuter Rail Passengers, 2005–2023



* Starting in 2020, passenger rail performance metrics have been significantly impacted by the COVID-19 pandemic.

3.3.3 Tourist and Excursion Services

Canada's tourist and excursion railways provide a unique experience to domestic and foreign travellers alike. In 2023, tourist and excursion railways served 372,000 passengers while consuming 2.72 million litres of fuel – approximately 7.3 litres per passenger.

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4. Fuel Consumption Data

Total rail sector fuel consumption in 2023 was 2,057.07 million litres, a 1.9% increase from 2022 but a 6.9% decrease from 2005. In 2023, freight operations consumed 1,946.65 million litres of fuel, a 7.6% reduction from 2,107.90 million litres in 2005. Over this same period (2005–2022), freight traffic (RTKs) increased by 26.0%.
The 2023 LEM report uses an improved methodology, which introduces year-specific GHG emissions factors that account for the use of biofuels in the overall locomotive fuel mix. Since 2005, improvements in locomotive fuel efficiency and a reduction in the carbon intensity of fuel resulted in a 28.6% improvement in freight GHG intensity (efficiency). From 2022 to 2023, passenger rail fuel consumption increased by 11.9% to support a 24.6% increase in the number of intercity passengers and a 70.5% increase in commuters.

Of the total fuel consumed by all railway operations, Class 1 and regional & shortline line-haul operations consumed 91.8%, yard switching and work train operations consumed 2.9%, and passenger operations accounted for 5.4%. In 2023, freight fuel efficiency was 4.38 litres per 1,000 RTK.[13]

Table 4 shows biofuels usage in locomotives in Canada. This is the first Locomotive Emissions Monitoring Report to account for biofuels in the fuel consumed in Canadian rail operations.

In 2023, an estimated 61.45 million litres of biofuels (2.99% of total fuel litres) were consumed by locomotives in Canada. With consideration that biofuels produce GHG emissions, the reduction in GHG emissions attributable to the use of biofuels in 2023 was slightly below its 2.99% share of total fuel litres. In 2023, the use of biofuels contributed to a 2.6% reduction in GHG emissions compared to using 100% diesel fuel (through lower emissions factors, i.e., fewer grams of CO_2, CH_4, and N_2O per litre of fuel).[14]

Table 4: Canadian Rail Operations Fuel Consumption, 2005, 2014-2023 (million litres)

	2005	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Class 1 Freight	1,893.19	1,918.27	1,852.98	1,732.20	1,864.83	1,949.92	1,950.71	1,857.42	1,796.77	1,750.57	1,774.22
Regional & Shortline	140.13	108.91	105.45	101.83	114.15	111.88	111.99	108.69	106.56	113.24	113.75
Yard Switching	67.85	62.02	52.97	46.95	50.29	51.56	51.71	46.81	47.07	49.43	51.76

15 The 2023 LEM report introduces year-specific GHG emissions factors (see Table 8). As a result, the trends in fuel efficiency and emissions intensity no longer follow the same path. Since the trend in emissions intensity is more relevant with respect to decarbonization, and to avoid confusion, the LEM report will no longer report on the trend in fuel efficiency.

14 The emissions factor calculations assume that all biofuels were biodiesel, even though a mix of biodiesel and renewable diesel may have been consumed. Data collection and emissions calculation methodologies will continue to evolve with the industry's adoption of renewable fuels.

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Work Train	6.73	10.80	11.35	10.84	10.01	7.10	9.94	8.41	9.04	6.73	6.92
Total Freight Operations	2,107.90	2,100.00	2,022.75	1,891.82	2,039.28	2,120.46	2,124.35	2,021.34	1,959.44	1,919.98	1,946.65
Intercity*	64.05	44.89	46.98	47.93	51.02	52.77	51.05	21.74	26.15	38.07	43.30
Commuter*	35.31	49.67	60.50	59.43	64.46	65.74	79.53	47.85	47.28	57.28	64.39
Tourist/ Excursion*	1.74	2.61	2.65	2.79	3.22	3.22	4.30	0.00	0.46	3.28	2.72
Total Passenger Operations*	101.10	97.16	110.13	110.15	118.70	121.72	134.89	69.60	73.89	98.63	110.41
Total Rail Operations	**2,209.00**	**2,197.17**	**2,132.88**	**2,001.97**	**2,157.98**	**2,242.19**	**2,259.24**	**2,090.94**	**2,033.33**	**2,018.61**	**2,057.07**
Biofuels consumption**	**0.00**	**53.42**	**51.81**	**54.23**	**63.97**	**66.39**	**67.08**	**62.78**	**61.00**	**60.59**	**61.45**
Biofuels share of total fuel litres	0.00%	2.43%	2.43%	2.71%	2.96%	2.96%	2.97%	3.00%	3.00%	3.00%	2.99%
Freight Fuel Efficiency (L per 1,000 RTK)	**5.97**	**4.97**	**4.84**	**4.63**	**4.68**	**4.65**	**4.67**	**4.48**	**4.42**	**4.38**	**4.38**

* Starting in 2020, passenger rail performance metrics have been significantly impacted by the COVID-19 pandemic.
** Biofuels consumption is an ECCC estimate based on provincial and national fuel standards.

4.1 FREIGHT OPERATIONS

Fuel consumption in 2023 for all freight train, yard switching, and work train operations was 1,946.65 million litres, an increase of 1.4% from 1,919.98 million litres consumed in 2022 but a decrease of 7.6% from the 2005 level of 2,107.90 million litres. Based on total traffic moved by railways in Canada, measured in revenue tonne-kilometres, in 2023 railways could move one tonne of freight 228.37 kilometres on just one litre of fuel.

Member railways have implemented many practices to improve fuel efficiency over the years. Improved fuel efficiency has been achieved primarily by replacing older locomotives with modern, fuel-efficient locomotives that meet emissions standards, investing in fuel saving technologies, and efficient asset utilization.

Additionally, operating practices and various strategies that reduce fuel consumption have been implemented. Section 2 presented initiatives that are being undertaken by the railways, including details on partnerships with government, academia, equipment manufacturers, fuel providers, and other industry stakeholders to continue the transition to a more sustainable future.

4.2 PASSENGER SERVICES

Overall passenger rail fuel consumption— the sum of intercity, commuter, and tourist and excursion train operations—totaled 110.41 million litres in 2023, an increase of 11.9% from the 98.63 million litres consumed in 2022. The increase in passenger rail fuel consumption supported strong increases in ridership, including a 24.6% increase in intercity passengers and a 70.5% increase in commuters.

Intercity passenger rail fuel consumption increased by 13.7% from 38.07 million litres in 2022 to 43.30 million litres in 2023. Fuel consumption for commuter rail increased by 12.4% from 57.28 million litres in 2022 to 64.39 million litres in 2023. Lastly, tourist and excursion rail fuel consumption decreased by 17.0% to 2.72 million litres in 2023 from 3.28 in 2022.

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4.3 DIESEL FUEL PROPERTIES

The sulphur content of railway diesel fuel in Canada is regulated by the *Sulphur in Diesel Fuel Regulations* at 15 parts per million (ppm).

Beginning in 2023, the carbon intensity of diesel fuel in Canada is regulated by the *Clean Fuel Regulations*. Under the regulations, the carbon-intensity limit of diesel fuel in Canada is reduced by 1.5 gCO_2e/MJ each year, from 89.5 gCO_2e/MJ in 2023 to 79.0 gCO_2e/MJ in 2030 – resulting in an 11.7% reduction in diesel fuel's carbon intensity throughout the 2023-2030 period. In addition, the regulations include a national minimum renewable fuel blending requirement of 2% in diesel.

In 2023, some provinces, including British Columbia, Manitoba, Ontario, and Quebec, required a minimum renewable fuel content above 2% for diesel.[15]

For details on low-carbon fuels, see sections 2.4 Low-Carbon Fuels and 2.6 Partnerships.

15 In 2023, provincial blend mandates required a range of minimum renewable fuel content for diesel: 4% in British Columbia (increased to 8% April 1, 2025), 5% in Manitoba, 4% in Ontario, and 3% in Quebec (increased to 5% January 1, 2025).

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5. Locomotive Inventory

5.1 FLEET OVERVIEW

Table 5 presents an overview of the active locomotive fleet in Canada for freight and passenger railways. The detailed locomotive fleet inventory is presented in Appendix B.

Table 5: Active Canadian Locomotive Fleet Summary, 2023

	Locomotives	Share of Fleet
Line Haul: Class 1	3,138	73.9%
Line Haul: Regional	150	3.5%
Line Haul: Shortline	129	3.0%
Yard Switching and Work Train: Class 1	453	10.7%
Yard Switching and Work Train: Regional	17	0.4%
Yard Switching and Work Train: Shortline	97	2.3%
Total Freight Operations	3,984	93.8%
Passenger Locomotives	247	5.8%
Passenger DMUs	18	0.4%
Total Passenger Operations	265	6.2%
Total Rail Operations	4,249	100.0%

Note: numbers include all active fleet equipment.

5.2 LOCOMOTIVES MEETING EMISSION STANDARDS

Locomotives operated by federally regulated railways are subject to the emission standards set out under the *Locomotive Emissions Regulations* (LER), which came into force on June 9, 2017. These emission standards align with US EPA emission standards. RAC's member railways that are not federally regulated will continue to be encouraged to meet the emission standards. on a voluntary basis.

The CAC emissions intensity for the Canadian fleet is projected to decrease as railways continue to acquire new locomotives, retrofit high-horsepower and medium-horsepower in-service locomotives when remanufactured, and retire non- and lower-tier locomotives.

Table 6 shows the total number of in-service locomotives meeting emission standards[16] compared to the total number of active locomotives in the fleet. Since the locomotive fleet as reported under the LER and in the LEM Report is based on a snapshot of the locomotive fleet on December 31 of a given year, year-to-year variations are to be expected.

16 The emission standards include the following Tier levels: Tier 0, Tier 0+, Tier 1, Tier 1+, Tier 2, Tier 2+, Tier 3, and Tier 4 (see Appendix D).

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Table 6: Active Locomotives in Canadian Fleet Meeting Emission Standards, 2005, 2014–2023

	2005	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Number of freight and passenger locomotives meeting an emission standard	888	1,538	1,266	1,267	2,157	2,995	2,982	3,108	2,989	3,136	3,769
Number of freight and passenger locomotives in Canadian Fleet	2,986	2,700	2,400	2,318	3,177	3,782	3,840	3,756	3,606	3,715	4,249
Percentage of locomotives meeting an emission standard	29.7%	57.0%	52.8%	54.7%	67.9%	79.2%	77.7%	82.7%	82.9%	84.4%	88.7%

Note 1: Canada's *Locomotive Emissions Regulations* came into force on June 9, 2017. Prior to this date, locomotives in Canada were not subject to regulations but were encouraged to meet US EPA emission standards under the MOU.

Note 2: Not all locomotives need to meet emission standards. Provincially regulated railways are not subject to the *Locomotive Emissions Regulations*; and not all locomotives of federally regulated railways are subject to the Regulations. Exceptions include: steam- and electric-powered locomotives; locomotives manufactured prior to 1973 that have not been upgraded; and locomotives with less than 1,006 horsepower. Only new locomotives, not active existing locomotives, are required to meet emission standards. Locomotives become new when they are freshly manufactured, remanufactured, upgraded or imported.

In 2023, 88.7% of the active fleet (3,769 of 4,249) met emission standards (set-out under the LER or the US EPA regulations), a notable improvement from 84.4% in 2022 and 29.7% in 2005. In 2023, a total of 344 locomotives were remanufactured or added to the active fleet, including 81 Tier-4s.

Table 7 provides an overview of the 2023 active locomotive fleet and includes details about the total number of locomotives meeting each tier level, including those that have been added, retired, and remanufactured in 2023. It also presents the number of locomotives with anti-idling devices.

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Table 7: Active Canadian Locomotive Fleet Breakdown by Tier Level, 2023

Tier Level*	Locomotives		Locomotives with anti-idling devices	Added	Retired	Remanufactured
	Number	% of fleet				
Elec/Steam/Other	6	0.1%	–	–	–	–
No Tier	474	11.2%	270	2	16	–
Tier 0	175	4.1%	161	1	3	–
Tier 0+	786	18.5%	747	6	57	54
Tier 1	31	0.7%	31	–	–	–
Tier 1+	809	19.0%	805	2	46	100
Tier 2	186	4.4%	181	–	–	–
Tier 2+	742	17.5%	727	3	1	84
Tier 3	624	14.7%	622	–	–	11
Tier 4	416	9.8%	416	18	–	63
Total	**4,249**	**100.0%**	**3,960 (93.2%)**	**32**	**123**	**312**

* See Appendix D for additional information regarding tier levels.

Note: In the 2023 LEM report, an added locomotive is a locomotive with active new status for railways that report to TC under the LER, as well as locomotives defined as "acquired in 2023" for railways that report their fleet directly to RAC. A remanufactured locomotive is a locomotive that was remanufactured in 2023 with active new status for railways that report to TC under the LER, as well as locomotives identified as "remanufactured in 2023" for railways that report their fleet directly to RAC.

In 2023, the active fleet increased by 534 locomotives compared to 2022 through the acquisition of new and remanufactured locomotives, bringing locomotives out of storage and into active service, as well as the combination of CP and KCS locomotive fleets.

Compared to 2022, there were 99 fewer no tier locomotives in the Canadian active fleet, while the number of locomotives meeting an emission standard increased by 633, including an increase of 219 Tier 2+ locomotives, 122 Tier 3s, and 112 Tier 4s.

In 2023, 32 locomotives were added to the active Canadian fleet, including two No Tier, one Tier 0, six Tier 0+, two Tier 1+, three Tier 2+, and 18 Tier 4. A total of 312 locomotives were remanufactured, 54 to Tier 0+, 100 to Tier 1+, 84 to Tier 2+, 11 to Tier 3, and 63 to Tier 4; and 123 mostly non-tier-level and lower-tier-level locomotives were retired.

Anti-idling devices on locomotives reduce emissions by ensuring that locomotive engines are shut down during periods of inactivity. The number of active locomotives in 2023 equipped with a device to minimize unnecessary idling, such as an automatic engine shut down/start up (AESS) system or auxiliary power unit (APU), was 3,960 (93.2% of the fleet), compared to 3,355 in 2022 (90.3% of the 2022 fleet).

6. Locomotive Emissions

6.1 GREENHOUSE GASES

6.1.1 Emission Factors for Greenhouse Gases

The emissions factors (EFs) and global warming potentials (GWPs) used to calculate GHGs (i.e., CO_2, CH_4, and N_2O) emitted from diesel locomotive engines are the same factors used by ECCC to create the *National Inventory Report 1990–2023: Greenhouse Gas Sources and Sinks in Canada*, which is submitted annually to the United Nations Framework Convention on Climate Change (UNFCCC).[17]

The 2023 LEM report introduces year-specific GHG EFs, presented in Table 8. The EFs account for the mix of biofuels[18] and diesel fuel used in locomotives each year. In earlier LEM reports, all fuel litres were assumed to be diesel fuel. EFs for 2009 to 2022 have been revised to account for estimated biofuel consumption, and EFs for 2008 and earlier use the EFs for diesel fuel (assuming no biofuel blending). In 2023, the consideration of biofuel (assumed to be biodiesel) in the EFs contributed to a 2.6% reduction in calculated GHG emissions (combustion emissions) compared to using 100% diesel fuel.[19]

The 2023 LEM report uses the 100-year GWP values from the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (CO_2: 1, CH_4: 28, N_2O: 265), consistent with ECCC's latest National Inventory Report. The 2022 LEM reported used GWP values from the IPCC Fourth Assessment Report (CO_2: 1, CH_4: 25, N_2O: 298). Updating the GWPs from 4th to 5th IPCC assessments reduces the CO_{2e} EFs in all years by about 1.1%. EFs for all years have been revised.

Table 8: GHG Emission Factors for Diesel Locomotives, 2005, 2014-2023

	Global Warming Potential	Emissions Factors (kg/L)										
	All years	2005	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
CO_2	1	2.680500	2.618339	2.618386	2.611240	2.604700	2.604787	2.604587	2.603734	2.603793	2.603758	2.604272
CH_4	28	0.000149	0.000149	0.000149	0.000149	0.000149	0.000149	0.000149	0.000149	0.000149	0.000149	0.000149
N_2O	265	0.001029	0.001027	0.001027	0.001027	0.001026	0.001026	0.001026	0.001026	0.001026	0.001026	0.001026
CO_2e	Not Applicable	2.957357	2.894601	2.894648	2.887434	2.880831	2.880919	2.880717	2.879856	2.879915	2.879880	2.880399

Note: Hydrofluorocarbons (HFC), Perfluorocarbons (PFC), and Sulphur hexafluoride (SF6) are not present in diesel fuel.

Source: Calculation based on global warming potential and emissions factors for diesel and biodiesel contained in the National Inventory Report 1990-2023: Greenhouse Gas Sources and Sinks in Canada, Environment and Climate Change Canada, 2025. The GHG emissions factors presented in the table are calculated based on the mix of biofuels and diesel fuel used in locomotives in each year.

17 National Inventory Report 1990–2023: Greenhouse Gas Sources and Sinks in Canada, Environment and Climate Change Canada, 2025.

18 The emissions factor calculations assume that all biofuels were biodiesel, even though a mix of biodiesel and renewable diesel may have been consumed.

19 The 2023 LEM report follows methodology employed in the 2025 NIR. The emissions factor calculations assume that all biofuels used in locomotives were biodiesel, even though a mix of biodiesel and renewable diesel may have been consumed. The 2025 NIR assumed that 5% of biodiesel is from non-biological origin. The non-biological portion of the fuel is assumed to be derived from methanol used for esterification and is obtained from non-renewable natural gas. As such, the emissions factors (combustion emissions only) multiplied by their GWP in this report are as follows: 2.9574 kg/L for diesel fuel, 2.7246 kg/L for the non-renewable portion of biodiesel, and 0.2524 kg/L for the renewable portion of biodiesel.

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6.1.2 Greenhouse Gas Emissions

In 2023, RAC members' locomotive operations produced 5,925.17 kilotonnes (kt) of CO_2e. This represents a 1.9% increase compared to 2022 but a 9.3% decrease compared to 2005.

In 2023, railways accounted for just 0.9% of Canada's total GHG emissions and 3.0% of Canada's transportation sector emissions.[20] Table 9 displays the GHG emissions produced in 2005 and annually since 2014; Figure 6 presents the annual trend graphically. GHG emissions for years prior to 2014 are available upon request to RAC.

Table 9: GHG Emissions by Railway Service in Canada, 2005, 2014–2023 (kilotonnes)

	2005	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Line Haul Freight											
CO_2	5,450.31	5,307.85	5,127.93	4,789.09	5,154.65	5,370.55	5,372.48	5,119.25	4,955.87	4,852.91	4,916.80
CH_4	8.48	8.44	8.15	7.63	8.23	8.58	8.58	8.18	7.92	7.76	7.86
N_2O	554.46	551.59	532.89	498.91	538.22	560.75	560.99	534.71	517.63	506.88	513.46
CO_2e	6,013.25	5,867.88	5,668.97	5,295.64	5,701.11	5,939.88	5,942.05	5,662.14	5,481.43	5,367.55	5,438.12
Yard Switching and Work Train											
CO_2	199.91	190.67	168.41	150.91	157.07	152.80	160.59	143.79	146.10	146.24	152.82
CH_4	0.31	0.30	0.27	0.24	0.25	0.24	0.26	0.23	0.23	0.23	0.24
N_2O	20.34	19.81	17.50	15.72	16.40	15.95	16.77	15.02	15.26	15.27	15.96
CO_2e	220.56	210.79	186.18	166.87	173.72	169.00	177.61	159.04	161.59	161.75	169.03
Total Freight Operations											
CO_2	5,650.22	5,498.52	5,296.34	4,940.00	5,311.72	5,523.35	5,533.07	5,263.04	5,101.97	4,999.15	5,069.62
CH_4	8.79	8.74	8.42	7.87	8.49	8.82	8.84	8.41	8.15	7.99	8.10
N_2O	574.79	571.41	550.39	514.64	554.62	576.70	577.76	549.73	532.89	522.16	529.42
CO_2e	6,233.81	6,078.67	5,855.15	5,462.51	5,874.83	6,108.88	6,119.66	5,821.17	5,643.02	5,529.30	5,607.14
Total Passenger Operations*											
CO_2	271.00	254.41	288.36	287.62	309.17	317.07	351.33	181.21	192.38	256.81	287.54
CH_4	0.42	0.40	0.46	0.46	0.49	0.51	0.56	0.29	0.31	0.41	0.46
N_2O	27.57	26.44	29.97	29.96	32.28	33.11	36.69	18.93	20.09	26.82	30.03
CO_2e	298.99	281.25	318.79	318.05	341.95	350.68	388.57	200.42	212.78	284.04	318.03
Total Rail Operations											
CO_2	5,921.23	5,752.93	5,584.70	5,227.62	5,620.89	5,840.42	5,884.39	5,444.25	5,294.36	5,255.96	5,357.16
CH_4	9.22	9.15	8.88	8.33	8.98	9.33	9.40	8.70	8.46	8.40	8.56
N_2O	602.36	597.85	580.36	544.60	586.91	609.81	614.44	568.65	552.99	548.98	559.45
CO_2e	6,532.81	6,359.92	6,173.94	5,780.55	6,216.78	6,459.56	6,508.24	6,021.60	5,855.80	5,813.35	5,925.17

* Starting in 2020, passenger rail performance metrics have been significantly impacted by the COVID-19 pandemic.

Note: GHG emissions (combustion) for all years have been calculated based on IPCC Fifth Assessment Global Warming Potentials (CO_2: 1, CH_4: 28, N_2O: 265) and emissions factors that consider the mix of biofuels and diesel fuel used in locomotives. Historical values have been updated.

20 RAC analysis based on National Inventory Report 1990-2023: Greenhouse Gas Sources and Sinks in Canada, Table 2-3, Environment and Climate Change Canada, 2025.

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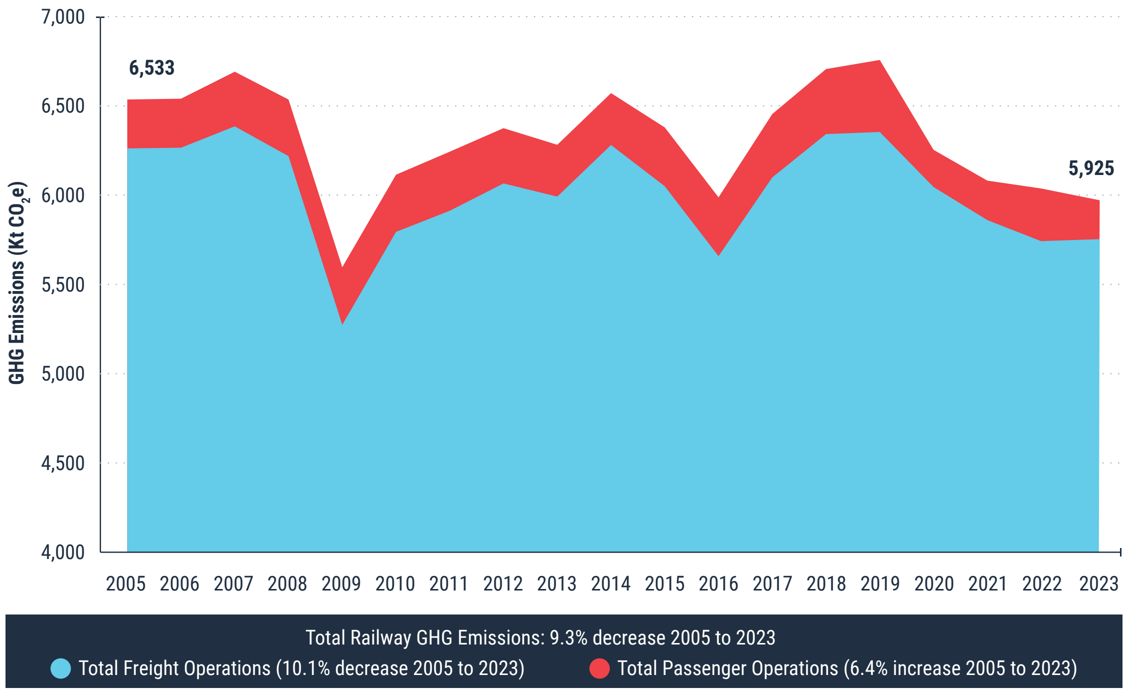
Figure 6: GHG Emissions, 2005–2023



In addition to reporting on absolute emissions, the LEM reports present GHG emissions intensities by category of railway operation, including total freight operations, Class 1 freight, regional & shortline freight, intercity passenger, and commuter rail (Table 10).

Table 10: GHG Emissions Intensities by Railway Service in Canada, 2005, 2014–2023

	2005	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total Freight Operations (kg CO_2e/1,000 RTK)**	17.66	14.39	14.00	13.37	13.49	13.40	13.45	12.89	12.74	12.60	12.61
Class 1 Freight (kg CO_2e/1,000 RTK)	17.06	13.90	13.61	13.04	13.06	12.96	13.00	12.43	12.28	12.15	12.14
Regional & Shortline Freight (kg CO_2e/1,000 RTK)	16.80	13.70	12.73	11.74	13.56	14.47	14.22	14.71	14.12	13.76	13.85
Intercity Passenger (kg CO_2e/Passenger-km)*	0.128	0.097	0.099	0.098	0.094	0.093	0.086	0.172	0.141	0.090	0.084
Commuter Rail (kg CO_2e/Passenger)*	1.79	1.89	2.27	2.16	2.34	2.29	2.25	6.06	10.22	5.93	3.91

* Starting in 2020, passenger rail performance metrics have been significantly impacted by the COVID-19 pandemic.

** Includes yard switching and work train GHG emissions.

Note: GHG emissions (combustion) for all years have been calculated based on IPCC Fifth Assessment Global Warming Potentials (CO_2: 1, CH_4: 28, N_2O: 265) and emissions factors that consider the mix of biofuels and diesel fuel used in locomotives. Historical values have been updated.

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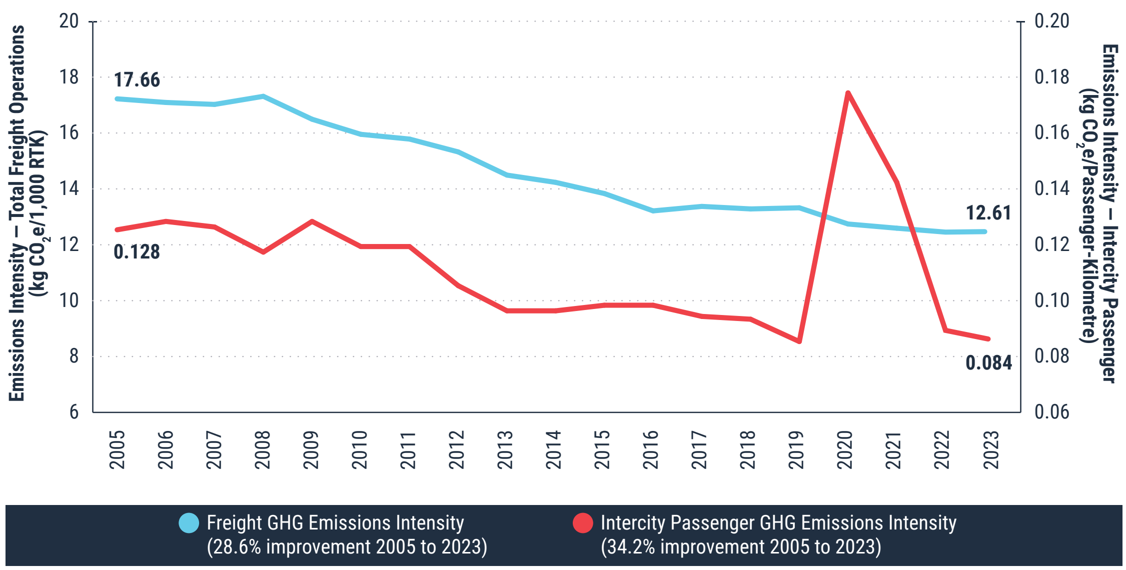
The GHG emissions intensity for total freight traffic (which includes yard switching and work train operations) was nearly flat, increasing by 0.1%, from 12.60 CO_2e/1,000 RTK in 2022 to 12.61 CO_2e/1,000 RTK in 2023. Since 2005, the GHG emissions intensity of total freight has decreased by 28.6%. At 12.15 CO_2e/1,000 RTK, the emissions intensity of Class 1 freight remained relatively unchanged from 2022 (improving by 0.04%). Regional & shortline freight emissions intensity was also relatively flat, increasing by 0.7%, from 13.76 kg CO_2e/1,000 RTK in 2022 to 13.85 kg CO_2e/1,000 RTK in 2023.

In 2023, emissions intensity of intercity passenger railways improved by 6.11% to 0.084 kg CO_2e/passenger-km compared to 0.090 in 2022. Since 2005, the emissions intensity of intercity passenger railways has improved by 34.2%.

A recovery in the number of commuters supported an improvement in emissions performance. Commuter rail operations reduced emissions intensity by a significant 34.1%, from 5.93 kg CO_2e/passenger in 2022 to 3.91 kg CO_2e/passenger in 2023.

Figure 7 shows the trend in GHG emissions intensities for total freight and for intercity passenger railways since 2005.

Figure 7: GHG Emissions Intensities, 2005–2023



* Starting in 2020, passenger rail performance metrics have been significantly impacted by the COVID-19 pandemic.

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6.2 CRITERIA AIR CONTAMINANTS

6.2.1 Emission Factors for Criteria Air Contaminant Emissions

Criteria Air Contaminant (CAC) EFs are calculated in grams per litre (g/L) of fuel consumed for NO_x, PM_{10}, CO, HC, and SO_2, for each category of operation (i.e., line haul freight, yard switching and work train, and passenger operations).

Fleet modernization, the acquisition of higher-tiered locomotives and retiring of non- and lower-tiered locomotives, drives reductions in CAC EFs. In 2023, EFs for NO_x, PM_{10}, and HC were reduced by around three to six percent compared to 2022. NO_x EFs decreased by 4.6% for line haul freight, 3.0% for yard switching and work train, and 3.7% for passenger operations. PM_{10} EFs decreased by 5.6% for line haul freight, 4.9% for yard switching and work train, and 4.0% for passenger operations. HC EFs decreased by 6.0% for line haul freight, 3.8% for yard switching and work train, and 3.8% for passenger operations.

The EPA emissions factors (reconstituted to account for ultra-low sulphur diesel) used in the LEM for CO and SO_2 are constant across all locomotive tier levels, and thus fleet modernization does not affect these two CACs' EFs.[21]

The CAC EFs used are for diesel fuel and do not account for the use of biofuels. MOU signatories will keep abreast of CAC emissions research and testing of renewable fuels, with an opportunity to consider updating the LEM report's EFs in the future.

The CAC EFs are estimated based on the active fleet on December 31 of each year. The CAC EFs are listed in Table 11 for 2005 and 2014–2023. EFs for years prior to 2014 are available upon request to RAC.

Table 11: CAC Emission Factors for Diesel Locomotives, 2005, 2014–2023 (g/L)

Year	NO_x	PM_{10}	CO	HC	SO_2
Line Haul Freight					
2023	30.30	0.59	6.98	1.14	0.02
2022	31.76	0.63	6.98	1.21	0.02
2021	31.67	0.63	6.98	1.21	0.02
2020	32.97	0.66	6.99	1.29	0.02
2019	34.17	0.69	6.99	1.34	0.02
2018	34.56	0.78	7.02	1.54	0.02
2017	34.79	0.72	7.04	1.46	0.02
2016	38.17	0.78	7.05	1.54	0.02
2015	39.50	0.81	7.13	1.68	0.02
2014	41.40	0.90	7.07	1.81	0.02
2005	56.12	1.54	6.97	2.56	2.25

21 The EFs are: 0.02 grams of SO_2 per litre across all services, 7.03 grams of CO per litre for Class 1 freight and passenger line-haul, 6.35 grams of CO per litre for shortline & regional, and 7.35 grams of CO per litre for yard switching and work trains.

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Yard Switching and Work Train					
2023	53.74	1.05	7.35	3.05	0.02
2022	55.42	1.10	7.35	3.17	0.02
2021	54.96	1.10	7.35	3.16	0.02
2020	55.34	1.13	7.35	3.23	0.02
2019	57.32	1.18	7.35	3.34	0.02
2018	56.15	1.15	7.35	3.27	0.02
2017	69.14	1.50	7.35	4.01	0.02
2016	65.68	1.46	7.35	3.92	0.02
2015	68.38	1.48	7.35	3.96	0.02
2014	68.93	1.50	7.35	3.99	0.02
2005	69.88	1.64	7.35	4.06	2.25
Total Passenger Operations					
2023	38.90	0.80	7.03	1.52	0.02
2022	40.40	0.84	7.03	1.58	0.02
2021	42.45	0.88	7.03	1.68	0.02
2020	40.87	0.85	7.03	1.64	0.02
2019	45.13	0.92	7.03	1.77	0.02
2018	40.87	0.85	7.03	1.64	0.02
2017	56.34	1.15	7.03	2.19	0.02
2016	54.05	1.11	7.03	2.12	0.02
2015	48.96	1.00	7.03	1.91	0.02
2014	54.58	1.14	7.03	2.18	0.02
2005	71.44	1.58	7.03	2.64	2.25

6.2.2 Criteria Air Contaminant Emissions

Table 12 displays the CAC emissions produced annually by locomotives in operation in Canada, including NO_x, PM_{10}, CO, HC, and SO_2. Absolute CAC emissions are presented for both passenger and freight operations, and CAC emissions intensity is provided for freight operations. CAC emissions data for years prior to 2014 are available upon request to RAC.

From 2022 to 2023, despite a 1.9% increase in fuel consumption, the industry achieved reductions in absolute NO_x (-2.5%), PM_{10} (-3.5%), and HC (-3.7%) emissions. CO and SO_2 emissions increased by 1.9% due to the increase in total fuel consumption.

In 2023, freight operations accounted for 93.4% of the rail industry's NO_x emissions, 93.0% of PM_{10}, 94.6% of CO, 93.3% of HC, and 94.6% of SO_2.

In 2023, total freight CAC emissions intensities, measured in kg/1,000 RTK, improved for NO_x (-4.4%), PM_{10} (-5.5%), and HC (-5.7%), while they remained relatively flat for CO and SO_2 (both increased by 0.1%).

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Table 12: Locomotive CAC Emissions, 2005, 2014–2023 (kilotonnes, unless otherwise specified)

Year	NO_x	PM_{10}	CO	HC	SO_2 (tonnes)
Line Haul Freight					
2023	57.20	1.12	13.18	2.15	46.53
2022	59.20	1.17	13.01	2.26	45.93
2021	60.28	1.20	13.29	2.31	46.91
2020	64.83	1.30	13.73	2.53	48.46
2019	70.49	1.42	14.41	2.77	50.84
2018	71.25	1.61	14.48	3.18	50.81
2017	68.84	1.43	13.93	2.89	48.77
2016	70.01	1.42	12.94	2.82	45.20
2015	77.35	1.59	13.96	3.28	48.27
2014	83.92	1.82	14.34	3.66	49.96
2005	114.12	3.13	14.18	5.21	4,580.20
Yard Switching and Work Train					
2023	3.15	0.06	0.43	0.18	1.45
2022	3.11	0.06	0.41	0.18	1.38
2021	3.08	0.06	0.41	0.18	1.38
2020	3.02	0.06	0.40	0.17	1.34
2019	3.53	0.07	0.45	0.21	1.52
2018	3.32	0.07	0.43	0.20	1.45
2017	4.17	0.09	0.44	0.24	1.49
2016	3.80	0.08	0.42	0.23	1.42
2015	4.40	0.10	0.47	0.25	1.59
2014	5.02	0.11	0.54	0.29	1.79
2005	5.21	0.12	0.55	0.30	168.00
Total Freight Operations[1]					
2023	60.35	1.18	13.61	2.33	47.98
2022	62.31	1.23	13.42	2.44	47.32
2021	63.36	1.26	13.71	2.49	48.29
2020	67.85	1.36	14.13	2.71	49.80
2019	74.02	1.49	14.86	2.98	52.36
2018	74.58	1.68	14.91	3.38	52.26
2017	73.01	1.52	14.37	3.13	50.26
2016	73.80	1.51	13.36	3.05	46.63
2015	81.75	1.69	14.43	3.54	49.85
2014	88.94	1.93	14.87	3.95	51.76
2005	119.33	3.25	14.73	5.52	4,748.19

Table 12: Locomotive CAC Emissions, 2005, 2014–2023 (kilotonnes, unless otherwise specified)

Year	NO_x	PM_{10}	CO	HC	SO_2 (tonnes)
Total Passenger Operations*					
2023	4.29	0.09	0.78	0.17	2.72
2022	3.98	0.08	0.69	0.16	2.43
2021	3.14	0.06	0.52	0.12	1.82
2020	2.84	0.06	0.49	0.11	1.72
2019	6.09	0.12	0.95	0.24	3.32
2018	6.56	0.13	0.85	0.25	2.97
2017	6.63	0.14	0.83	0.26	2.90
2016	5.89	0.12	0.77	0.23	2.69
2015	5.33	0.11	0.77	0.21	2.69
2014	5.24	0.11	0.68	0.21	2.37
2005	7.18	0.16	0.71	0.26	226.29
Total Rail Operations[2]					
2023	64.65	1.27	14.39	2.50	50.70
2022	66.30	1.32	14.12	2.60	49.75
2021	66.50	1.32	14.23	2.61	50.11
2020	70.70	1.42	14.62	2.82	51.51
2019	80.11	1.62	15.81	3.22	55.68
2018	81.14	1.81	15.76	3.63	55.23
2017	79.64	1.66	15.20	3.38	53.16
2016	79.70	1.63	14.13	3.28	49.31
2015	87.08	1.80	15.20	3.75	52.54
2014	94.18	2.04	15.55	4.16	54.12
2005	126.50	3.41	15.43	5.78	4,974.49
Total Freight Emissions Intensity (kg/1,000 RTK)					
2023	0.1358	0.0027	0.0306	0.0052	0.00011
2022	0.1420	0.0028	0.0306	0.0056	0.00011
2021	0.1430	0.0028	0.0309	0.0056	0.00011
2020	0.1502	0.0030	0.0313	0.0060	0.00011
2019	0.1627	0.0033	0.0327	0.0065	0.00012
2018	0.1636	0.0037	0.0327	0.0074	0.00011
2017	0.1677	0.0035	0.0330	0.0072	0.00012
2016	0.1807	0.0037	0.0327	0.0075	0.00011
2015	0.1955	0.0040	0.0345	0.0085	0.00012
2014	0.2105	0.0046	0.0352	0.0094	0.00012
2005	0.3381	0.0092	0.0417	0.0156	0.01345

* Starting in 2020, passenger rail performance metrics have been significantly impacted by the COVID-19 pandemic.

1 Total Freight Operations = Line Haul Freight + Yard Switching and Work Train

2 Total Rail Operations = Total Freight Operations + Total Passenger Operations

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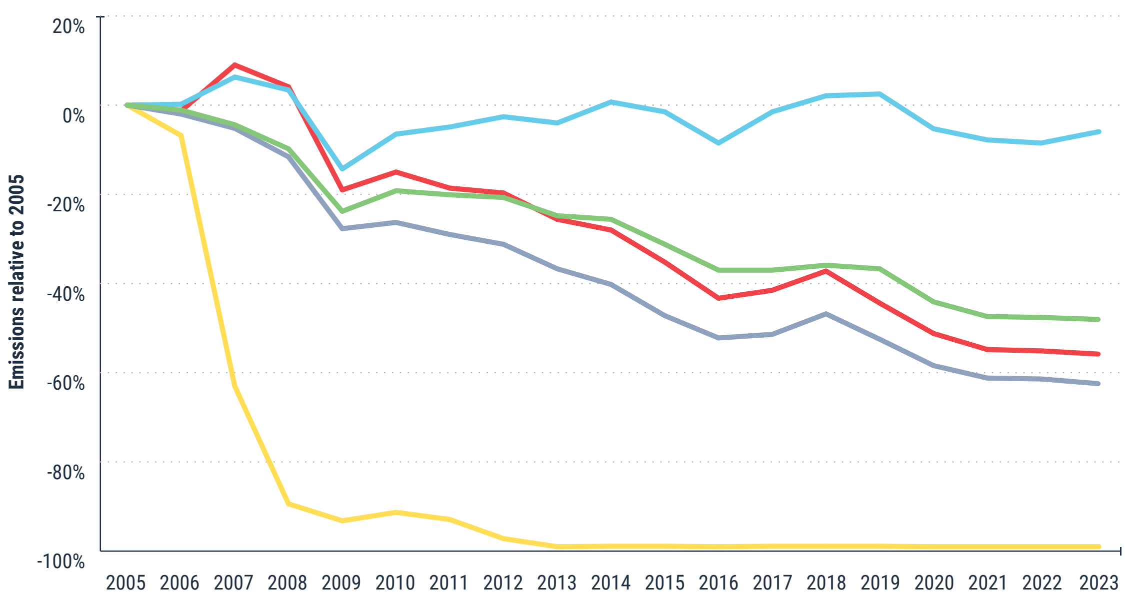
Figure 8 shows the reductions in CAC emissions from total railway operations in Canada since 2005. Despite a general increase in traffic over this time, CAC emissions have decreased for CO (-6.5%), NO_x (-48.9%), HC (-56.7%), PM_{10} (-62.7%), and SO_2 (-99.0%).

Within the methodology for calculating CAC emissions, the CO emission factors are the same for each tier level. As a result, fleet modernization through the acquisition of higher-tiered locomotives does not affect the calculated CO emissions. The reduction in CO emissions is primarily driven by the reduction in locomotive diesel fuel consumption. Methodology is available upon request to RAC.

Similarly, within the methodology for calculating SO_2 emissions, since 2013, the SO_2 emission factor has been constant as Canadian railways have been using ultra-low sulphur diesel (ULSD). As a result, the reductions in SO_2 since 2013 are driven by reductions in locomotive fuel consumption.

Figure 8: CAC Emissions, 2005–2023



Reductions from 2005 to 2023: CO: -6.5% NO_x: -48.9% HC: -56.7% PM_{10}: -62.7% SO_2: -99.0%

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7. Tropospheric Ozone Management Areas

Tropospheric Ozone Management Areas (TOMA) are geographically defined areas in which governments, stakeholders, and other interested parties work together to improve local air quality and manage air pollutant concentrations. The three TOMAs include the Lower Fraser Valley in British Columbia, the Québec City-Windsor Corridor, and the Saint John area in New Brunswick.

Tropospheric ozone is a greenhouse gas and atmospheric pollutant that contributes to global warming and is harmful to human health, agriculture, and ecosystems. Tropospheric ozone is the product of the reaction of several precursor pollutants in the atmosphere. Conventional railway activities, including diesel combustion, contribute to tropospheric ozone.

The following Tropospheric Ozone Management Areas are of interest both from an air quality and rail activity perspective.

TOMA NO. 1

The Lower Fraser Valley in British Columbia represents a 16,800 km^2 area in the southwestern corner of the province averaging 80 km in width and extending 200 km up the Fraser River Valley from the mouth of the river in the Strait of Georgia to Boothroyd, British Columbia. Its southern boundary is the Canada/United States (US) international boundary, and it includes the Greater Vancouver Regional District.

TOMA NO. 2

The Québec City-Windsor Corridor in Ontario and Québec represents a 157,000 km^2 area consisting of a strip of land 1,100 km long and averaging 140 km in width stretching from the City of Windsor (adjacent to Detroit in the US) in Ontario to Québec City. The Québec City-Windsor Corridor TOMA is located along the north shore of the Great Lakes and the St. Lawrence River in Ontario and straddles the St. Lawrence River from the Ontario/Québec border to Québec City. It includes the urban centres of Windsor, London, Hamilton, Toronto, Ottawa-Gatineau, Montréal, Trois- Rivières, and Québec City.

TOMA NO. 3

The Saint John TOMA is represented by two counties in southern New Brunswick—Saint John County and Kings County. The area covers 4,944.67 km^2.

7.1 FUEL CONSUMPTION AND EMISSIONS

Passenger railways' fuel consumption is provided directly for each TOMA and the freight fuel consumption is calculated by multiplying GTKs in the TOMA by the average national freight fuel rate (which was 2.36 litres per 1,000 GTK in 2023). Passenger and freight fuel is combined to obtain total fuel consumption within each TOMA region.

GHGs for the TOMA regions are calculated by multiplying the total TOMA fuel consumption by the emissions factors as described in section 6.1.1 (Table 8).

CACs for the TOMA regions are calculated by multiplying the total TOMA fuel consumption by a weighted average of the calculated line haul freight, yard switching and work train, and passenger operations CAC EFs, as presented in section 6.2.1 (Table 11).

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Table 13 shows the fuel consumption and GHG emissions in the TOMA regions as a percentage of total fuel consumption and GHG emissions for all rail operations in Canada. Table 14 shows NO_x emissions in the TOMA regions as a percentage of the total NO_x emissions for all rail operations.

Table 15 presents detailed calculations for GHGs and CACs in the TOMA regions in 2023.

Table 13: TOMA Percentage of Total Fuel Consumption and GHG Emissions, 2005, 2014–2023

	2005	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Lower Fraser Valley, B.C.	3.2	2.2	2.3	2.5	2.4	2.3	2.4	2.3	2.4	2.6	2.8
Québec City-Windsor Corridor	17.4	14.1	14.1	14.0	13.8	13.0	13.5	11.5	12.3	13.2	13.7
Saint John, N.B.	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.2	0.2	0.3

Table 14: TOMA Percentage of Total NO_x Emissions, 2005, 2014–2023

	2005	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Lower Fraser Valley, B.C.	3.2	2.3	2.3	2.5	2.4	2.3	2.4	2.3	2.4	2.6	2.8
Québec City-Windsor Corridor	17.9	14.1	14.1	14.0	13.8	13.0	13.5	11.5	12.3	13.2	13.7
Saint John, N.B.	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.2	0.2	0.3

Table 15: Tropospheric Ozone Management Areas, 2023

		TOMA No.1 Lower Fraser Valley, B.C.	TOMA No.2 Québec City-Windsor Corridor	TOMA No.3 Saint John Area, New Brunswick
Traffic (Million GTK)				
CN		16,203	58,513	819
CPKC		6,715	21,061	–
Regional & Shortline		217	1,024	1,902
Total Freight Traffic		23,135	80,598	2,721
Fuel Consumption (Million Litres) Freight Fuel Rate (L/1,000 GTK) = 2.36[1]				
Total Freight Fuel Consumption		54.64	190.36	6.43
Passenger Fuel Consumption				
Intercity Passenger		0.53	27.71	–
Tourism/Excursion		1.11	–	–
Commuter		1.12	63.27	–
Total Passenger Fuel Consumption		2.76	90.99	0.00
Total Rail Fuel Consumption		57.40	281.35	6.43
Emissions				
Emission Factors (g/L)[2]		Kilotonnes/Year	Kilotonnes/Year	Kilotonnes/Year
CACs	NO_x 31.43	1.80	8.84	0.20
CACs	PM_{10} 0.62	0.04	0.17	0.00
CACs	CO 6.99	0.40	1.97	0.04
CACs	HC 1.22	0.07	0.34	0.01
CACs	SO_2 0.02	0.00	0.01	0.00
GHGs[3]	CO_2 2,604.27	149.48	732.72	16.74
GHGs[3]	CH_4 4.16	0.24	1.17	0.03
GHGs[3]	N_2O 271.97	15.61	76.52	1.75
GHGs[3]	CO_2e 2,880.40	165.33	810.41	18.51

[1] The freight fuel rate has been calculated by dividing the total Canadian freight fuel usage (see Table 4) by the total Canadian freight GTK (see Table 3). In 2023, the Freight Fuel Rate was 2.36 litres per 1,000 GTK.

[2] The emission factors used in the emissions calculations are a weighted average of the overall freight, yard and passenger emission factors based on the quantity of freight and passenger fuel used.

[3] The emission factors for each GHG include their respective global warming potentials (CO_2:1; CH_4:28; N_2O:265).

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8. Summary and Conclusions

The 2023 Locomotive Emissions Monitoring Report highlights the successful, long-standing collaboration between RAC and TC to advance initiatives that reduce locomotive emissions and disseminate the results to the public. Canadian railways continued to improve their emissions performance through investments in fleet renewal/modernization, fuel saving technologies, operational efficiencies, and use of low-carbon fuels. Furthermore, railways' partnerships with government, academia, and industry stakeholders made progress in advancing the development of alternative propulsion and other zero-emissions technologies that support the transition to a more sustainable future.

Over the past several decades, Canada's railways have made significant progress in reducing both GHG and CAC emissions. Since the 2005 base year, GHG emissions intensities have been reduced by 17.54% (regional & shortline), 28.82% (Class 1 freight) and 34.25% (intercity passenger). In the same period, absolute CAC emissions have been cut by 6.8% (CO), 48.9% (NO_x), 56.7% (HC), 62.7% (PM_{10}), and 99.0% (SO_2).

From 2022 to 2023, the GHG emissions intensity of Canada's freight railways remained relatively flat, as both traffic and fuel consumption increased by a little more than one percent. The GHG emissions intensity of intercity passenger railways improved by 6.11%, as the increase in passenger-kilometres (21.9%) was much larger than the increase in fuel consumption (13.7%).

In 2023, Canadian railways continued to invest in fleet modernization, acquiring higher-tiered locomotives and retiring non- and lower-tiered locomotives. These investments enabled the industry to achieve year-over-year reductions in absolute emissions of NO_x (-2.5%), PM_{10} (-3.5%), and HC (-3.7%) despite an increase in freight traffic, passenger traffic, and fuel consumption.

Table 16 2023–2030 MOU Progress - GHG Emissions Intensities

Railway Operation	Productivity Units	2005 Base Year	2022	2023	Change from 2005–2023	Change from 2022–2023
Class I Freight	kg CO_2e per 1,000 RTK	17.06	12.15	12.14	-28.82%	-0.04%
Intercity Passenger	kg CO_2e per passenger-km	0.128	0.090	0.084	-34.25%	-6.11%
Regional & Shortline	kg CO_2e per 1,000 RTK	16.80	13.76	13.85	-17.54%	0.67%

Note: GHG emissions (combustion) for all years have been calculated based on IPCC Fifth Assessment Global Warming Potentials (CO_2: 1, CH_4: 28, N_2O: 265) and emissions factors that consider the mix of biofuels and diesel fuel used in locomotives. Historical values have been updated.

Table 17 2023–2030 MOU Progress – Absolute CAC Emissions (kilotonnes, unless otherwise specified)

CAC Emission	2005 Base Year	2022	2023	Change from 2005-2023	Change from 2022-2023
NO_x	126.50	66.30	64.65	-48.9%	-2.5%
PM_{10}	3.41	1.32	1.27	-62.7%	-3.5%
CO	15.43	14.12	14.39	-6.8%	1.9%
HC	5.78	2.60	2.50	-56.7%	-3.7%
SO_2 (tonnes)	4,974.49	49.75	50.70	-99.0%	1.9%

Note: The table presents CAC emissions for total rail operations (including line haul freight, yard switching and work train, and total passenger train operations).

Through continued progress on emissions reduction initiatives and aspirational goals as outlined in the 2023-2030 MOU, industry and government will continue to collaborate to reduce GHG emissions in the railway sector and broader transportation sector.

This report meets the filing requirements for the 2023 reporting year.

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Appendix A

RAC Member Railways Participating in the 2023–2030 MOU by Province

Railway	Province(s) of Operation
Agawa Canyon Railroad	Ontario
Alberta Prairie Railway Excursions	Alberta
Cartier Railway (Arcelor Mittal Infrastructure Canada s.e.n.c.)	Québec
Barrie-Collingwood Railway	Ontario
Battle River Railway	Alberta
BCR Properties	British Columbia
Big Sky Rail Corp.	Saskatchewan
Boundary Trail Railway Co.	Manitoba
Canadian National Railway	British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Québec, New Brunswick, Nova Scotia, Northwest Territories
Canadian Pacific Kansas City Limited	British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Québec
Cape Breton & Central Nova Scotia Railway	Nova Scotia
Capital Railway	Ontario
Carlton Trail Railway	Saskatchewan
Central Manitoba Railway Inc.	Manitoba
Chemin de fer Arnaud Québec	Québec
Compagnie du Chemin de Fer Lanaudière Inc.	Québec
Essex Terminal Railway Company	Ontario
Exo	Québec
GIO Rail Holdings Corp.	Ontario
Goderich-Exeter Railway Company Ltd.	Ontario
Great Canadian Railtour Company Ltd.	British Columbia, Alberta
Great Western Railway Ltd.	Saskatchewan
Hudson Bay Railway	Manitoba, Saskatchewan
Huron Central Railway Inc.	Ontario
Immeuble VDS inc.	Québec
Keewatin Railway Company	Manitoba
Knob Lake and Timmins Railway	Québec, Newfoundland and Labrador
Last Mountain Railway	Saskatchewan
Metrolinx (GO Transit)	Ontario
New Brunswick Southern Railway Company Ltd.	New Brunswick
Nipissing Central Railway Company	Ontario, Québec
Ontario Northland Transportation Commission	Ontario
Ontario Southland Railway Inc.	Ontario
Ottawa Valley Railway	Ontario, Québec
Prairie Dog Central Railway	Manitoba
Québec Gatineau Railway Inc.	Québec
Québec Iron Ore Inc.	Québec
Québec North Shore and Labrador Railway Company Inc.	Québec, Newfoundland and Labrador
Roberval and Saguenay Railway Company	Québec
Romaine River Railway Company	Québec
Société du chemin de fer de la Gaspésie	Québec
South Simcoe Railway	Ontario
Southern Ontario Railway	Ontario
Southern Railway of British Columbia Ltd.	British Columbia
St. Lawrence & Atlantic Railroad (Québec) Inc.	Québec
St. Paul & Pacific Northwest	British Columbia
Toronto Terminals Railway Company Limited	Ontario
Tshiuetin Rail Transportation Inc.	Québec, Newfoundland and Labrador
VIA Rail Canada Inc.	British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Québec, New Brunswick, Nova Scotia
West Coast Express Ltd.	British Columbia
White Pass and Yukon Route Railroad	Yukon, British Columbia

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Appendix B-1

2023 Active Canadian Locomotive Fleet—Freight Train Line Haul Operations

Model	US EPA Tier Level	Engine	HP	Year of Manufacture	Class 1	Regional	Shortline	Total Regional & Shortline	Total Freight Fleet
GM/EMD									
GP9	No Tier	645E	2000	1950-1959	0	1	0	1	1
GP9	No Tier	16V-645C	1800	1950-1959	0	0	1	1	1
GP35	No Tier	16-645E	2500	1960-1969	1	0	0	0	1
GP38-2	No Tier	16-645E	2000	1960-1969	0	0	7	7	7
GP38-2	No Tier	645E	2000	1960-1969	0	0	2	2	2
GP38-2	No Tier	16V-645E	2000	1960-1969	0	0	1	1	1
GP38-3	No Tier	645E	2000	1960-1969	0	0	6	6	6
GP38-3	No Tier	16-645E	2000	1960-1969	0	0	1	1	1
GP40	No Tier	16-645E3	3000	1960-1969	0	0	1	1	1
GP40-2	No Tier	16-645E3B	3000	1960-1969	0	0	3	3	3
GP40-3	No Tier	16-645E3	3000	1960-1969	0	0	3	3	3
GP40-3M	No Tier	16-645E3	3000	1960-1969	0	0	3	3	3
RM-1 SLUG	No Tier	NA	0	1960-1969	0	0	1	1	1
RM-1 SLUG	No Tier	NA	0	1960-1969	0	0	1	1	1
RM1 - SLUG	No Tier	NA	0	1960-1969	0	0	1	1	1
SD40-2	No Tier	16-645E3B	3000	1960-1969	0	0	1	1	1
SD40-2	No Tier	16V-645E3	3000	1960-1969	0	0	1	1	1
SD40-3	No Tier	16V-645E3B	3000	1960-1969	5	0	0	0	5
GP38-2	No Tier	16-645E	2000	1970-1972	0	0	4	4	4
GP38-3	No Tier	645E	2000	1970-1972	0	0	2	2	2
GP40-2	No Tier	16-645E3B	3000	1970-1972	0	0	2	2	2
GP40-3M	No Tier	16-645E3	3000	1970-1972	0	0	1	1	1
RM-1 SLUG	No Tier	NA	0	1970-1972	0	0	1	1	1
RM1-SLUG	No Tier	NA	0	1970-1972	0	0	3	3	3
SD38-2	No Tier	16V-645 or 16V-645E	2000	1970-1972	0	0	1	1	1
SD38AC	No Tier	16V-645 or 16V-645E	2000	1970-1972	0	0	1	1	1
SD40	No Tier	645	3000	1970-1972	0	1	0	1	1
SD40-2	No Tier	645E3	3000	1970-1972	0	3	0	3	3
SD40-2	No Tier	16V-645E3	3000	1970-1972	0	0	1	1	1
SD40-2	No Tier	16-645E3	3000	1970-1972	0	0	3	3	3
SD40-3	No Tier	16V-645E3B	3000	1970-1972	1	0	0	0	1
SD40-3	No Tier	16-645E3B	3000	1970-1972	0	0	2	2	2
GP15-1	No Tier	12-645E	1500	1973-1979	0	0	2	2	2
GP38-2	No Tier	16-645E	2000	1973-1979	0	0	2	2	2
GP38-2	No Tier	645E	2000	1973-1979	0	0	2	2	2
GP38-2/QEG	No Tier	16V-645E	2000	1973-1979	0	0	2	2	2

2023 Active Canadian Locomotive Fleet—Freight Train Line Haul Operations

Model	US EPA Tier Level	Engine	HP	Year of Manufacture	Class 1	Regional	Shortline	Total Regional & Shortline	Total Freight Fleet
GP40-2	No Tier	16V-645E3B	3000	1973-1979	10	0	0	0	10
GP40-2LW	No Tier	16-645EB	3000	1973-1979	0	0	1	1	1
GP40-2LW	No Tier	16-645E3	3000	1973-1979	0	0	1	1	1
GP40-2W	No Tier	16-645E3	3000	1973-1979	0	0	4	4	4
GP9	No Tier	16V-645C	1800	1973-1979	0	0	7	7	7
SD38-2	No Tier	16V-645 or 16V-645E	2000	1973-1979	0	0	1	1	1
SD40-2	No Tier	16-645E3	3000	1973-1979	7	0	0	0	7
SD40-2	No Tier	16-645E3B	3000	1973-1979	2	0	1	1	3
SD40-2	No Tier	645E	3000	1973-1979	0	6	1	7	7
SD40-2	No Tier	16V-645E3B	3000	1973-1979	4	0	0	0	4
SD40-2/QEG	No Tier	16V-645E3B	3000	1973-1979	0	0	1	1	1
SD40-3	No Tier	16-645E3B	3000	1973-1979	0	0	2	2	2
SD40-2	No Tier	16V-645E3B	3000	1980-1989	6	0	0	0	6
SD40-2	No Tier	16-645E3B	3000	1980-1989	4	0	1	1	5
SD40-2	No Tier	16-645E3	3000	1980-1989	3	0	0	0	3
SD40-2/QEG	No Tier	16V-645E3B	3000	1980-1989	0	0	1	1	1
SD40-2F	No Tier	16-645E3	3000	1980-1989	3	0	0	0	3
SD70ACe	No Tier	16-710G3B-ES	4375	2000-2009	0	2	0	2	2
SD70ACe	No Tier	16-710G3B-ES	4375	2010-2019	0	8	0	8	8
SD40-2	Tier 0	16-645E3B	3000	1960-1969	2	0	0	0	2
GP38-2	Tier 0	16-645E	2000	1970-1972	0	0	2	2	2
GP40-2	Tier 0	16V-645E3B	3000	1973-1979	20	0	0	0	20
SD40-2	Tier 0	16V-645E3B	3000	1973-1979	13	0	0	0	13
SD40-2	Tier 0	16-645EB	3000	1973-1979	1	0	0	0	1
SD40-2	Tier 0	16-645E3B	3000	1973-1979	1	0	0	0	1
SD40-2	Tier 0	16-645E3	3000	1980-1989	3	0	0	0	3
SD40-2	Tier 0	16V-645E3B	3000	1980-1989	1	0	0	0	1
SD60	Tier 0	16V-710G3	3800	1980-1989	35	0	0	0	35
SD60-3	Tier 0	16-710G3	3350	1980-1989	5	0	0	0	5
SD60-3	Tier 0	16-710G3	3800	1980-1989	2	0	0	0	2
SD60M	Tier 0	710G3A	3800	1980-1989	0	2	0	2	2
SD60M	Tier 0	16-710G3	3800	1980-1989	1	0	0	0	1
SD60M	Tier 0	710G3A	3800	1990-1999	0	3	0	3	3
SD70I	Tier 0	16V-710G3B	4000	1990-1999	4	0	0	0	4
SD75I	Tier 0	710G3C	4300	1990-1999	0	5	0	5	5
SD75I	Tier 0	16V-710G3C	4300	1990-1999	32	0	0	0	32
GP40-2	Tier 0+	645E	3000	1960-1969	0	1	0	1	1
GP40-3	Tier 0+	16-645E3C	3000	1960-1969	2	0	0	0	2
SD40-3	Tier 0+	16V-645E3B	3000	1960-1969	17	0	0	0	17

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2023 Active Canadian Locomotive Fleet—Freight Train Line Haul Operations

Model	US EPA Tier Level	Engine	HP	Year of Manufacture	Class 1	Regional	Shortline	Total Regional & Shortline	Total Freight Fleet
GP38-2	Tier 0+	16-645E	2000	1970-1972	0	0	2	2	2
GP39-2C	Tier 0+	12-645E3	2300	1970-1972	0	0	2	2	2
GP40-3M	Tier 0+	16-645E3B	3000	1970-1972	0	0	1	1	1
SD30C-ECO	Tier 0+	12-710G3B	3000	1970-1972	2	0	0	0	2
SD40-3	Tier 0+	16V-645E3B	3000	1970-1972	3	0	0	0	3
GP38-2	Tier 0+	16-645E	2000	1973-1979	0	0	4	4	4
GP38-2	Tier 0+	645E	2000	1973-1979	0	4	4	8	8
GP40-2	Tier 0+	16V-645E3B	3000	1973-1979	29	0	0	0	29
GP40-2	Tier 0+	645E	3000	1973-1979	0	4	0	4	4
GP40-3M	Tier 0+	16-645E3B	3000	1973-1979	0	0	1	1	1
SD30C-ECO	Tier 0+	12-710G3B	3000	1973-1979	25	0	0	0	25
SD40-2	Tier 0+	16V-645E3B	3000	1973-1979	40	0	0	0	40
SD40-2	Tier 0+	16-645E3	3000	1973-1979	3	0	0	0	3
SD40-2	Tier 0+	16-645E3B	3000	1973-1979	1	0	2	2	3
GP38-2	Tier 0+	645E	2000	1980-1989	0	2	0	2	2
GP40-3M	Tier 0+	16-645E3B	3000	1980-1989	0	0	1	1	1
SD30C-ECO	Tier 0+	12-710G3B	3000	1980-1989	22	0	0	0	22
SD40-2	Tier 0+	16-645E3C	3000	1980-1989	1	0	0	0	1
SD40-2	Tier 0+	16-645E3B	3000	1980-1989	9	0	0	0	9
SD40-2	Tier 0+	16-645E3	3000	1980-1989	6	0	0	0	6
SD40-2	Tier 0+	16V-645E3B	3000	1980-1989	18	0	0	0	18
SD40-2F	Tier 0+	16-645E3B	3000	1980-1989	5	0	0	0	5
SD40-3	Tier 0+	16-645E3B	3000	1980-1989	7	0	0	0	7
SD40-3	Tier 0+	16-645E3	3000	1980-1989	3	0	0	0	3
SD50	Tier 0+	645	3600	1980-1989	0	3	0	3	3
SD60	Tier 0+	16-710G3A	3800	1980-1989	24	0	0	0	24
SD60	Tier 0+	16V-710G3	3800	1980-1989	50	0	0	0	50
SD60-3	Tier 0+	16-710G3A	3350	1980-1989	1	0	0	0	1
SD60-3	Tier 0+	16-710G3A	3800	1980-1989	2	0	0	0	2
SD60M	Tier 0+	16-710G3A	3800	1980-1989	3	0	0	0	3
SD70I	Tier 0+	16V-710G3B	4000	1990-1999	22	0	0	0	22
SD75I	Tier 0+	16V-710G3C	4300	1990-1999	106	0	0	0	106
SD70M	Tier 1	710G3C	4000	2000-2009	0	5	0	5	5
SD70ACU	Tier 1+	16-710G3C	4300	1990-1999	52	0	0	0	52
SD70MAC	Tier 1+	16-710G3C	4000	1990-1999	0	0	5	5	5
SD70MACE	Tier 1+	16-710G3C	4000	1990-1999	11	0	0	0	11
SD70MACE	Tier 1+	16-710G3B	4000	1990-1999	1	0	0	0	1
SD70MACE	Tier 1+	16-710G3C	4000	2000-2009	4	0	0	0	4
SD70ACe	Tier 2	16-710G3C	4300	2000-2009	14	0	0	0	14

2023 Active Canadian Locomotive Fleet—Freight Train Line Haul Operations

Model	US EPA Tier Level	Engine	HP	Year of Manufacture	Class 1	Regional	Shortline	Total Regional & Shortline	Total Freight Fleet
SD70M-2	Tier 2	16V-710G3C	4300	2000-2009	24	0	0	0	24
SD70-ACE	Tier 2	16-710-G3C-T2	4400	2010-2019	0	3	0	3	3
SD70ACe	Tier 2	16-710G3C	4300	2010-2019	10	0	0	0	10
SD70M-2	Tier 2	16V-710G3C	4300	2010-2019	36	0	0	0	36
SD-70ACe	Tier 2+	16-710G3C-ES	4375	2000-2009	0	4	0	4	4
SD70ACe	Tier 2+	16-710G3C	4300	2000-2009	94	0	0	0	94
SD70M-2	Tier 2+	16V-710G3C	4300	2000-2009	76	0	0	0	76
SD70M-2	Tier 2+	16V-710G3C	4300	2010-2019	49	0	0	0	49
SD-70ACe	Tier 3	16-710G3C-ES	4375	2000-2009	0	5	0	5	5
SD70ACe	Tier 3	16-710G3C-ES	4375	2000-2009	0	1	0	1	1
SD70ACe	Tier 3	16-710G3B-ES	4375	2000-2009	0	4	0	4	4
SD70-ACE	Tier 3	16-710-G3C-T2+	4400	2010-2019	0	2	0	2	2
SD70ACE	Tier 3	16V-710G3C	4300	2010-2019	3	0	0	0	3
SD70ACe	Tier 3	16-710G3B-ES	4375	2010-2019	0	6	0	6	6
SD70ACe	Tier 3	16-710G3C	4300	2010-2019	59	0	0	0	59
GM/EMD Sub-Total					1,000	75	107	182	1,182
GE									
B23-7	No Tier	7FDL12	2000	1973-1979	0	0	2	2	2
Dash 8-40CM	No Tier	7FDL16	4000	1990-1999	0	0	3	3	3
Dash-9 44CW	No Tier	16-7FDL	4400	1990-1999	0	3	0	3	3
AC4400CM	No Tier	16-7FDL	4400	2000-2009	0	6	0	6	6
C44-9W	Tier 0	7FDL-16	4400	2000-2009	1	0	0	0	1
C40-8	Tier 0+	7FDL-16	4000	1980-1989	13	0	0	0	13
C40-8	Tier 0+	7FDL-16	4000	1990-1999	8	0	0	0	8
C40-8M	Tier 0+	7FDL-16	4000	1990-1999	1	0	0	0	1
AC4400CW	Tier 1	7FDL16	4400	2000-2009	0	26	0	26	26
AC4400CW	Tier 1+	7FDL16	4400	1990-1999	154	0	0	0	154
AC44C6M	Tier 1+	7FDL-A16	4400	1990-1999	9	0	0	0	9
AC44CWM	Tier 1+	7FDL16	4400	1990-1999	132	0	0	0	132
C44-9W	Tier 1+	7FDL-16	4400	1990-1999	69	0	0	0	69
AC4400CM	Tier 1+	16-7FDL	4400	2000-2009	0	6	0	6	6
AC4400CW	Tier 1+	7FDL16	4400	2000-2009	189	0	0	0	189
AC44C6M	Tier 1+	7FDL-A16	4400	2000-2009	1	0	0	0	1
C44-9W	Tier 1+	7FDL-16	4400	2000-2009	87	0	0	0	87
ES44DC	Tier 2	GEVO-12	4400	2000-2009	22	0	0	0	22
ES44AC	Tier 2	GEVO12	4360	2010-2019	0	6	0	6	6
ES44AC	Tier 2	GEVO-12	4400	2010-2019	18	0	0	0	18
ES44DC	Tier 2	GEVO-12	4400	2010-2019	3	0	0	0	3

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2023 Active Canadian Locomotive Fleet—Freight Train Line Haul Operations

Model	US EPA Tier Level	Engine	HP	Year of Manufacture	Class 1	Regional	Shortline	Total Regional & Shortline	Total Freight Fleet
ES44AC	Tier 2+	GEVO-12	4400	2000-2009	108	0	0	0	108
ES44AC	Tier 2+	GEVO-12	4365	2000-2009	197	0	0	0	197
ES44DC	Tier 2+	GEVO-12	4400	2000-2009	68	0	0	0	68
ES44AC	Tier 2+	GEVO-12	4400	2010-2019	10	0	0	0	10
ES44AC	Tier 2+	GEVO-12	4365	2010-2019	61	0	0	0	61
ES44DC	Tier 2+	GEVO-12	4400	2010-2019	31	0	0	0	31
ES44AC	Tier 3	GEVO-12	4365	2010-2019	30	0	0	0	30
ES44AC	Tier 3	GEVO-12	4400	2010-2019	430	0	0	0	430
ES44AC	Tier 3	GEVO12	4400	2010-2019	52	0	0	0	52
ET44AC	Tier 3	ES44AC	4400	2010-2019	1	0	0	0	1
ES44AC	Tier 4	GEVO-12	4400	2010-2019	60	0	0	0	60
ET44AC	Tier 4	ET44AC	4400	2010-2019	5	0	0	0	5
ET44AC	Tier 4	GEVO-12	4400	2010-2019	232	0	0	0	232
ET44AC	Tier 4	GEVO-12	4400	2020-2023	40	0	0	0	40
GE Sub-Total					2,032	47	5	52	2,084
MLW									
RS-18	No Tier	12V-251	1800	1950-1959	0	0	5	5	5
MLW Sub-Total					0	0	5	5	5
NRE									
SD40-2	Tier 0+	645E3B	3000	1970-1972	0	8	0	8	8
SD40-2	Tier 0+	645E3	3000	1970-1972	0	1	0	1	1
NRE Sub-Total					0	9	0	9	9
EMCC									
SD70M-2	Tier 2+	16V-710G3B	4000	2000-2009	0	0	12	12	12
EMCC Sub-Total					0	0	12	12	12
Wabtec									
AC44C6M	Tier 1+	16-7FDLA	4500	1990-1999	0	19	0	19	19
AC44C6M	Tier 1+	7FDL-A16	4400	1990-1999	21	0	0	0	21
AC44CWM	Tier 1+	7FDL16	4400	1990-1999	30	0	0	0	30
AC44C6M	Tier 1+	7FDL-A16	4400	2000-2009	19	0	0	0	19
ES44AC	Tier 3	GEVO-12	4400	2010-2019	1	0	0	0	1
ET44AC	Tier 4	GEVO-12	4400	2010-2019	25	0	0	0	25
ET44AC	Tier 4	GEVO-12	4400	2020-2023	10	0	0	0	10
Wabtec Sub-Total					106	19	0	19	125
Other									

2023 Active Canadian Locomotive Fleet—Freight Train Line Haul Operations

Model	US EPA Tier Level	Engine	HP	Year of Manufacture	Class 1	Regional	Shortline	Total Regional & Shortline	Total Freight Fleet
1750HP	No Tier	567	1800	1950-1959	0	0	2	2	2
Other Sub-Total					0	0	2	2	2
Total Mainline Freight					**3,138**	**150**	**129**	**279**	**3,417**

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Appendix B-2

2023 Active Canadian Locomotive Fleet - Freight Yard Switching & Work Train Operations

Model	US EPA Tier Level	Engine	HP	Year of Manufacture	Class 1	Regional	Shortline	Total Regional & Shortline	Total Freight Fleet
GM/EMD									
Cab slug	Elec/ Steam/ Other	NA	0	1950-1959	0	0	2	2	2
SLUG	Elec/ Steam/ Other	NA	0	1980-1989	0	0	1	1	1
SLUG	Elec/ Steam/ Other	NA	0	2000-2009	0	0	1	1	1
GP9	No Tier	16V-645	1750	1950-1959	0	0	2	2	2
GP9	No Tier	567C	1750	1950-1959	0	3	0	3	3
GP9	No Tier	16V-567	1750	1950-1959	0	0	2	2	2
GP9	No Tier	16V-645C	2000	1950-1959	0	0	2	2	2
GP9	No Tier	16V-645	2000	1950-1959	0	0	1	1	1
GP9 master	No Tier	16V-567	1750	1950-1959	0	0	5	5	5
GP9-3	No Tier	16-567C	1750	1950-1959	0	0	2	2	2
GP9-RM	No Tier	16V-645C	1800	1950-1959	64	0	0	0	64
SW1200RB	No Tier	12V-645C	1200	1950-1959	1	0	0	0	1
SW14	No Tier	12V-567	1400	1950-1959	0	0	1	1	1
SW900	No Tier	8V-645C	1000	1950-1959	0	0	1	1	1
SW900RS	No Tier	8V-567	900	1950-1959	0	0	8	8	8
GP38	No Tier	645	2000	1960-1969	0	2	0	2	2
GP40-3	No Tier	16V-645E3	3000	1960-1969	0	0	2	2	2
GP9	No Tier	16V-645	1700	1960-1969	0	0	1	1	1
GP9	No Tier	16V-567	1750	1960-1969	0	0	1	1	1
SD35-3	No Tier	16V-645E	2500	1960-1969	0	0	1	1	1
SW1000RS	No Tier	8V-645	1000	1960-1969	0	0	2	2	2
SW900	No Tier	8V-567	900	1960-1969	0	0	1	1	1
SW900RS	No Tier	8V-567	900	1960-1969	0	0	1	1	1
GP38	No Tier	16V-645C	2000	1970-1972	0	0	1	1	1
GP38-2	No Tier	16V-645E	2000	1970-1972	11	0	0	0	11
GP38-3	No Tier	16-645E	2000	1970-1972	2	0	0	0	2
GP38AC	No Tier	16-645E	2000	1970-1972	1	0	0	0	1
SD40	No Tier	645	3000	1970-1972	0	0	1	1	1

2023 Active Canadian Locomotive Fleet - Freight Yard Switching & Work Train Operations

Model	US EPA Tier Level	Engine	HP	Year of Manufacture	Class 1	Regional	Shortline	Total Regional & Shortline	Total Freight Fleet
SD40-2	No Tier	16V-645E3	3000	1970-1972	0	0	2	2	2
SW1500	No Tier	12-645E	1500	1970-1972	0	0	2	2	2
GP38-2	No Tier	16V-645E	2000	1973-1979	30	0	17	17	47
GP38-3	No Tier	16-645E	2000	1973-1979	1	0	0	0	1
GP40-2	No Tier	16V-645E3	3000	1973-1979	0	0	9	9	9
MP1500	No Tier	12V-567	1500	1973-1979	0	0	3	3	3
SD40-2	No Tier	16V-645E3	3000	1973-1979	0	0	4	4	4
GP38-2	No Tier	16-645E	2000	1980-1989	30	0	0	0	30
GP38-3	No Tier	16-645E	2000	1980-1989	3	0	0	0	3
MP15	No Tier	12V-645	1500	1980-1989	0	0	3	3	3
SD40-2	No Tier	16V-645E3	3000	1980-1989	0	0	2	2	2
GP15-1	Tier 0	12-645E	1500	1973-1979	0	0	3	3	3
GP38-2	Tier 0	16-645E	2000	1973-1979	13	0	0	0	13
GP38-2	Tier 0	16V-645E	2000	1973-1979	3	0	0	0	3
GP38-2	Tier 0	16-645E	2000	1980-1989	1	0	0	0	1
GP20C-ECO	Tier 0+	8-710G3B	2000	1950-1959	125	0	0	0	125
GP382	Tier 0+	EMD 645E	2000	1960-1969	0	7	0	7	7
GP38	Tier 0+	EMD 645E	2000	1970-1972	0	2	0	2	2
GP38-2	Tier 0+	16V-645E	2000	1970-1972	8	0	0	0	8
GP38-2	Tier 0+	16-645E	2000	1970-1972	3	0	0	0	3
GP382	Tier 0+	645E	2000	1970-1972	10	0	0	0	10
GP382	Tier 0+	EMD 645E	2000	1970-1972	0	1	0	1	1
GP38AC	Tier 0+	16-645E	2000	1970-1972	4	0	0	0	4
GP39-2C	Tier 0+	12-645E3	2300	1970-1972	0	0	2	2	2
GP40-3	Tier 0+	645E3B	3000	1970-1972	1	0	0	0	1
GP38	Tier 0+	EMD 645E	2000	1973-1979	0	2	0	2	2
GP38-2	Tier 0+	16V-645E	2000	1973-1979	53	0	0	0	53
GP38-2	Tier 0+	16-645E	2000	1973-1979	29	0	2	2	31
GP382	Tier 0+	645E	2000	1973-1979	3	0	0	0	3
GP40-3	Tier 0+	645E3B	3000	1973-1979	1	0	0	0	1
SD38-2	Tier 0+	16V-645E	2000	1973-1979	3	0	0	0	3
GP38-2	Tier 0+	16-645E	2000	1980-1989	48	0	0	0	48
GP38-2	Tier 0+	16V-645E	2000	1980-1989	1	0	0	0	1
GP38-3	Tier 0+	16-645E	2000	1980-1989	4	0	0	0	4
SD70ACE	Tier 0+	16V-710G3C	4400	1990-1999	0	0	4	4	4

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2023 Active Canadian Locomotive Fleet - Freight Yard Switching & Work Train Operations

Model	US EPA Tier Level	Engine	HP	Year of Manufacture	Class 1	Regional	Shortline	Total Regional & Shortline	Total Freight Fleet
SD70ACE	Tier 2+	16V-710G3C	4400	2000-2009	0	0	3	3	3
GM/EMD Sub-Total					453	17	95	112	565
ALCO									
RS-18	No Tier	12V-251-B	1800	1950-1959	0	0	1	1	**1**
S-13	No Tier	Inline 6 251	1000	1950-1959	0	0	1	1	1
ALCO Sub-Total					0	0	2	2	2
Yard Switching & Work Train Total					**453**	**17**	**97**	**114**	**567**

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Appendix B-3

2023 Active Canadian Locomotive and DMU Fleet - Passenger Train Operations

Model	US EPA Tier Level	Engine	HP	Year of Manufacture	Intercity	Commuter	Tourist/ Excursion	Total
GM/EMD								
GMD-1	No Tier	12V-567C	1200	1950-1959	0	0	1	1
GP9	No Tier	16V-567C	1750	1950-1959	0	0	1	1
GP9	No Tier	16V-645	1750	1950-1959	0	0	2	2
F40-PH	No Tier	16V-645E3B	3000	1973-1979	2	0	0	2
F40-PH	No Tier	16V-645E3B	3000	1973-1979	0	0	2	2
F40-PH-2D	No Tier	16-645E3C	3000	1980-1989	47	0	0	47
GP40-2	Tier 0	645E3B	3000	1960-1969	0	0	4	4
GP40-2LW	Tier 0	645E3B	3000	1973-1979	0	0	5	5
F59-PH	Tier 0	710	3000	1990-1999	0	8	0	8
F59-PHI	Tier 0	710	3000	1990-1999	0	4	0	4
F40-PH	Tier 0+	16V-645E3B	3000	1973-1979	0	0	1	1
F40-PH-2D	Tier 0+	16-645E3C	3000	1980-1989	5	0	0	5
GP38-2	Tier 0+	645E	2000	1980-1989	3	0	0	3
F59-PH	Tier 2	12V-710G3	3000	1980-1989	0	10	0	10
F59-PHI	Tier 2	12V-710G3	3000	1990-1999	0	11	0	11
F59-PH	Tier 2+	710	3000	1980-1989	0	1	0	1
F59-PHI	Tier 2+	710	3000	1990-1999	0	1	0	1
GM/EMD Sub-Total					57	35	16	108
GE								
70 ton	No Tier	Cummins 1710	600	1940-1949	0	0	1	1
Other	No Tier	Cummins	1200	1950-1959	0	0	2	2
P42DC	No Tier	7FDL16	4250	2000-2009	20	0	0	20
GE Sub-Total					20	0	3	23
Motive Power								
MP36PH-3C	Tier 0	645E3B	3600	2000-2009	0	1	0	1
MP40PH-3C	Tier 2	16V-710G3C	4000	2010-2019	0	29	0	29
MP40PH-3C	Tier 2+	16V-710G3C	4000	2000-2009	0	27	0	27
MP40PH-3C	Tier 3	16V-710G3C	4000	2010-2019	0	10	0	10
MP40PHT-T4-AC	Tier 4	Twin QSK 60 T4 -16 cyl	5400	2010-2019	0	16	0	16

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2023 Active Canadian Locomotive and DMU Fleet - Passenger Train Operations

Model	US EPA Tier Level	Engine	HP	Year of Manufacture	Intercity	Commuter	Tourist/ Excursion	Total
MP40PHTC-T4-DC	Tier 4	Twin QSK 60 T4 -16 cyl	5400	2010-2019	0	1	0	1
Motive Power Sub-Total					0	84	0	84
Bombardier								
ALP45-DP	Tier 3	3512C HD	4200	2010-2019	0	20	0	20
Bombardier Sub-Total					0	20	0	20
Cummins								
DMU A-Car	Tier 4	QSK19R	760	2010-2019	0	12	0	12
DMU C-Car	Tier 4	QSK19R	760	2010-2019	0	6	0	6
Cummins Sub-Total					0	18	0	18
Siemens								
Charger	Tier 4	16V-QSK95	4200	2020-2023	9	0	0	9
Siemens Sub-Total					9	0	0	9
Dubs								
Rogers 4-4-0 steam	Elec/Steam/Other	Other	0	1880-1889	0	0	1	1
Dubs Sub-Total					0	0	1	1
ALCO								
A2m 4-4-0	Elec/Steam/Other	Steam	600	1880-1889	0	0	1	1
ALCO Sub-Total					0	0	1	1
Other								
Other	Tier 0+	EMD16-645E3B	3000	2020-present	0	0	1	1
Other Sub-Total					0	0	1	1
Passenger Operations Total					**86**	**157**	**22**	**265**

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Appendix C

RAILWAYS OPERATING IN TROPOSPHERIC OZONE MANAGEMENT AREAS

TOMA Region No. 1: Lower Fraser Valley, British Columbia

CN

Division:	Mountain South
Subdivisions:	Rawlison, Yale

CPKC

Division:	Pacific
Subdivisions:	Cascade, Mission, Page, Westminster

Other

Southern Railway of BC Ltd	All
VIA Rail Canada	Part
Great Canadian Railtour Company	Part
West Coast Express	All

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TOMA Region No. 2: Québec City-Windsor Corridor, Ontario And Québec

CN

District:	Champlain
Subdivisions:	Becancour, Rouses Point, Bridge, Sorel, Deux Montagnes, St. Hyacinthe, Drummondville, St. Laurent, Joliette, Valleyfield, Montréal
District:	Great Lakes
Subdivisions:	Alexandria, Grimsby, Strathroy, Caso, Halton, Talbot, Chatham, Kingston, Uxbridge, Dundas, Oakville, Weston, Guelph, Paynes, York

CPKC

Division:	Canada Québec
Subdivisions:	Adirondack, Adirondack CMQ, Lacolle, Moosehead West, Newport North, Outremont Spur, Sherbrooke, St Luc Branch, Vaudreuil, Winchester
Division:	Canada Ontario
Subdivisions:	Belleville, Brockville, Dunnville spur, Galt, Hamilton, Havelock, Mactier, Montrose, Nephton, North Toronto, Stamford, Stevensville Spur, Waterloo, Windsor

Other

Essex Terminal Railway	All
Goderich—Exeter Railway	All
Québec Gatineau Railway	All
Southern Ontario Railway	All
St-Lawrence & Atlantic (Canada)	All
GIO Rail Holdings	All
VIA Rail Canada	Part
GO Transit (Metrolinx)	All
exo	All
Capital Railway	All

TOMA Region No. 3: Saint John Area, New Brunswick

CN

District:	Champlain
Subdivisions:	Denison, Sussex

Other

New Brunswick Southern	All

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Appendix D

LOCOMOTIVE EMISSION STANDARDS

Locomotive Emissions Regulations

THE LOCOMOTIVE EMISSIONS REGULATIONS

- Came into force on June 9, 2017 and were published in Canada Gazette, Part II on June 28, 2017.
- Were developed by Transport Canada under the *Railway Safety Act* subsection 47.1(2).
- Align with existing regulations in the U.S. (i.e., *Title 40 of the U.S. Code of Federal Regulations (CFR), Part 1033* administered by the U.S. Environmental Protection Agency (EPA)).
- Limit emissions of criteria air contaminants (CACs), including, nitrogen oxides (NO_x), particulate matter (PM), hydrocarbons (HC), and carbon monoxide (CO), as well as smoke.
- Apply to railway companies that operate under federal jurisdiction in Canada and the locomotives that they operate.

The *Locomotive Emissions Regulations* require railways companies to:

- meet emission standards for new locomotives;
- carry out emissions testing;
- follow labelling and anti-idling requirements;
- keep records; and
- file reports with Transport Canada.

More information on the *Locomotive Emissions Regulations* can be found on the Transport Canada website at: https://tc.canada.ca/en/rail-transportation/rail-safety/regulations/overview-locomotive-emissions-regulations

More information on the U.S. regulations can be found on the U.S. EPA website at: https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-emissions-locomotives

EMISSION STANDARDS

Based on the type of locomotive (line haul or switch locomotive) and the year of original manufacture, new locomotives are required to meet the increasingly stringent tier of standards for NO_x, PM, HC and CO emissions, as well as smoke opacity. Locomotives are required to meet the applicable tier of standards for their entire useful life and, in certain cases, for their entire service life.

The U.S. first started regulating emissions from locomotives in 2000 under 40 CFR Part 92. These regulations included emission standards for 3 Tier levels (Tier of standards): Tier 0, Tier 1, and Tier 2.

The U.S. regulations were updated in 2008 under 40 CFR Part 1033. These are the current regulations, which set out emission standards for 5 Tier levels (Tier of standards): Tier 0, Tier 1, Tier 2, Tier 3 and Tier 4. Note: Tier 0, Tier 1, and Tier 2 are sometimes referred to as Tier 0+, Tier 1+, and Tier 2+ as these current emission standards under 40 CFR Part 1033 are more stringent than those under the older emission standards under 40 CFR Part 92.

The emission standards under the *Locomotive Emissions Regulations* are identical to the current emission standards set out in the U.S. regulations under 40 CFR Part 1033.

The *Locomotive Emissions Regulations* incorporate by reference specific tables, footnotes and paragraphs of 40 CFR Part 1033, which set out the emission standards and can be found online at: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-U/part-1033?toc=1

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The older emission standards, under the U.S. regulations 40 CFR Part 92, typically no longer apply, unless a locomotive is covered by an EPA certificate that sets out family emission limits (FELs), as family emission limits (FELs) are valid for the locomotive's service life. The older emission standards, are set out in section 92.8 of 40 CFR Part 92 and can be found online at: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-U/part-1033/appendix-Appendix%20I%20to%20Part%201033

A railway company's fleet can contain locomotives that:

- meet the current emission standards;
- meet the older emission standard; and
- do not meet any emission standards.

When reporting on Tier of standards for regulatory reporting, there are 9 Tier of standards options:

Tier of standards for regulatory reporting	Description	Tier of standards for LEM reporting
CDN/40 CFR 1033 Tier 0	Meets the current Canadian emission standards or the current U.S. emission standards under Title 40 CFR Part 1033. This Tier of standards is sometimes referred to as Tier 0+.	Tier 0+
CDN/40 CFR 1033 Tier 1	Meets the current Canadian emission standards or the current U.S. emission standards under Title 40 CFR Part 1033. This Tier of standards is sometimes referred to as Tier 1+.	Tier 1+
CDN/40 CFR 1033 Tier 2	Meets the current Canadian emission standards or the current U.S. emission standards under Title 40 CFR Part 1033. This Tier of standards is sometimes referred to as Tier 2+.	Tier 2+
CDN/40 CFR 1033 Tier 3	Meets the current Canadian emission standards or the current U.S. emission standards under Title 40 CFR Part 1033.	Tier 3
CDN/40 CFR 1033 Tier 4	Meets the current Canadian emission standards or the current U.S. emission standards under Title 40 CFR Part 1033.	Tier 4
40 CFR 92—Tier 0	Meets the older emission standards in the U.S. emission standards under Title 40 CFR Part 92.	Tier 0
40 CFR 92—Tier 1	Meets the older emission standards in the U.S. emission standards under Title 40 CFR Part 92.	Tier 1
40 CFR 92—Tier 2	Meets the older emission standards in the U.S. emission standards under Title 40 CFR Part 92.	Tier 2
No Tier	Does not meet any emission standards.	No Tier

For further information on the *Locomotive Emissions Regulations*, please contact Transport Canada's Rail Safety Directorate:

- Telephone: 613-998-2985, 1-844-897-7245 (toll-free)
- Email: RailSafety@tc.gc.ca

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Appendix E

GLOSSARY OF TERMS

Terminology Pertaining To Railway Operations

CLASS 1 RAILWAY
This is a class of railway within the legislative authority of the Parliament of Canada that realized gross revenues that exceed a threshold indexed to a base of $250 million annually in 1991 dollars for the provision of Canadian railway services. The three Canadian Class 1 railways are CN, CP and VIA Rail Canada.

INTERMODAL SERVICE
The movement of trailers on flat cars (TOFC) or containers on flat cars (COFC) by rail and at least one other mode of transportation. Import and export containers generally are shipped via marine and rail. Domestic intermodal services usually involve truck and rail modes.

LOCOMOTIVE ACTIVE FLEET
Refers to all locomotives, owned or leased, being used by a railway company for its railway operations in Canada. Not included in the active fleet are locomotives put in storage or removed as a result of being scrapped, sold or destroyed.

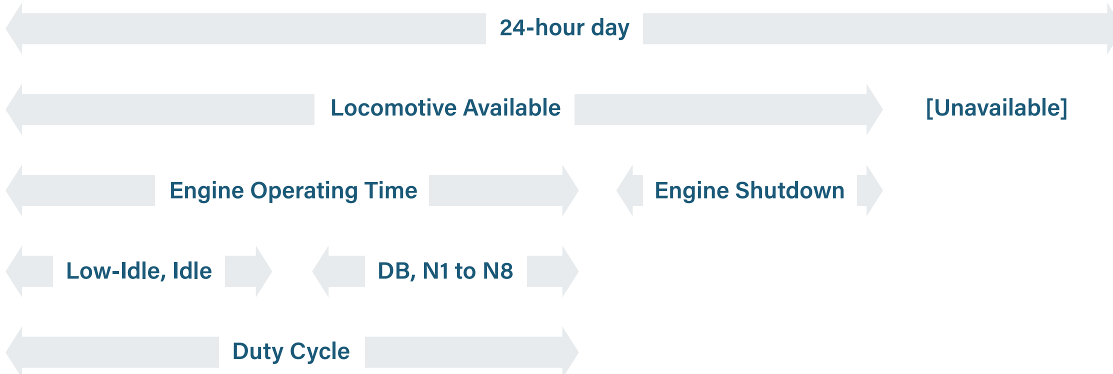
LOCOMOTIVE POWER RANGES
Locomotives are categorized as high horsepower (having engines greater than 3,000 hp), medium horsepower (2,000 to 3,000 hp) or low horsepower (less than 2,000 hp).

LOCOMOTIVE PRIME MOVERS
The diesel engine is the prime mover of choice for locomotives in operation on Canadian railways. Combustion takes place in a diesel engine by compressing the fuel and air mixture until auto-ignition occurs.

LOCOMOTIVE REMANUFACTURE
The “remanufacture” of a locomotive is a process in which all the power assemblies of a locomotive engine are replaced with freshly manufactured (containing no previously used parts) or refurbished power assemblies or those inspected and qualified. Inspecting and qualifying previously used parts can be done in several ways, including such methods as cleaning, measuring physical dimensions for proper size and tolerance, and running performance tests to ensure that the parts are functioning properly and according to specifications. Refurbished power assemblies could include some combination of freshly manufactured parts, reconditioned parts from other previously used power assemblies, and reconditioned parts from the power assemblies that were replaced. In cases where all the power assemblies are not replaced at a single time, a locomotive will be considered to be “remanufactured” (and therefore “new”) if all power assemblies from the previously new engine had been replaced within a 5-year period.

This definition for remanufactured locomotives is taken from the *U.S. Federal Register Volume 63, No. 73 April 16, 1998/Rules and Regulations for the Environmental Protection Agency* (US EPA) 40 CFR Parts 85, 89 and 92 *(Emission Standards for Locomotives and Locomotive Engines).*

LOCOMOTIVE UTILIZATION PROFILE
This is the breakdown of locomotive activity within a 24-hour day (based on yearly averages).



The elements in the above diagram constitute, respectively:

LOCOMOTIVE AVAILABLE

This is the time expressed in % of a 24-hour day that a locomotive could be used for operational service. Conversely, Unavailable is the percentage of the day that a locomotive is being serviced, repaired, remanufactured, or stored. Locomotive available time plus unavailable time equals 100%.

ENGINE OPERATING TIME

This is the percentage of Locomotive Available time that the diesel engine is turned on. Conversely, Engine Shutdown is the percentage of Locomotive Available time that the diesel engine is turned off.

IDLE

This is the % of the operating time that the engine is operating at idle or low-idle setting. It can be further segregated into Manned Idle (when an operating crew is on-board the locomotive) and Isolate (when the locomotive is unmanned).

DUTY CYCLE

This is the profile of the different locomotive power settings (Low-Idle, Idle, Dynamic Braking, or Notch levels 1 through 8) as percentages of Engine Operating Time.

RAILWAY PRODUCTIVITY UNITS

- Gross Tonne-Kilometres (GTK): This term refers to the product of the total weight (in tonnes) of the trailing tonnage (both loaded and empty railcars) and the distance (in kilometres) the freight train travelled. It excludes the weight of locomotives pulling the trains. Units can also be expressed in gross ton-miles (GTM).

- Revenue Tonne-Kilometres (RTK): This term refers to the product of the weight (in tonnes) of revenue commodities handled and the distance (in kilometres) transported. It excludes the tonne-kilometres involved in the movement of railway materials or any other non-revenue movement. The units can also be expressed in revenue ton-miles (RTM).

- Passenger-Kilometres per Train-Kilometre: This term is a measure of intercity train efficiency, which is the average of all revenue passenger kilometres travelled divided by the average of all train kilometres operated.

- Revenue Passenger-Kilometres (RPK): This term is the total of the number of revenue passengers multiplied by the distance (in kilometres) the passengers were transported. The units can also be expressed in revenue passenger-miles (RPM).

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TERMINOLOGY OF DIESEL LOCOMOTIVE EMISSIONS

Emission Factors (EFs): An emission factor is the average mass of a product of combustion emitted from a particular locomotive type for a specified amount of fuel consumed. The EF units are grams, or kilograms, of a specific emission product per litre of diesel fuel consumed (g/L).

Emissions of Criteria Air Contaminant (CAC): CAC emissions are by-products of the combustion of diesel fuel that impact on human health and the environment. The principal CAC emissions are:

- Nitrogen Oxides (NO_x): These result from high combustion temperatures. The amount of NO_x emitted is a function of peak combustion temperature. NO_x reacts with hydrocarbons to form ground-level ozone in the presence of sunlight which contributes to smog formation.

- Carbon Monoxide (CO): This toxic gas is a by-product of the incomplete combustion of fossil fuels. Relative to other prime movers, it is low in diesel engines.

- Hydrocarbons (HC): These are the result of incomplete combustion of diesel fuel and lubricating oil.

- Particulate Matter (PM): This is residue of combustion consisting of soot, hydrocarbon particles from partially burned fuel and lubricating oil and agglomerates of metallic ash and sulphates. It is known as primary PM. Increasing the combustion temperatures and duration can lower PM. It should be noted that NO_x and PM emissions are interdependent such that technologies that control NO_x (such as retarding injection timing) result in higher PM emissions, and conversely, technologies that control PM often result in increased NO_x emissions.

- Sulphur Oxides (SO_x): These emissions are the result of burning fuels containing sulphur compounds. For LEM reporting, sulphur emissions are calculated as SO_2. These emissions can be reduced by using lower sulphur content diesel fuel. Reducing fuel sulphur content will also typically reduce emissions of sulphate based PM.

EMISSIONS OF GREENHOUSE GASES (GHG)

In addition to CACs, GHG emissions are also under scrutiny due to their accumulation in the atmosphere and contribution to global warming. The GHG constituents produced by the combustion of diesel fuel are listed below:

- Carbon Dioxide (CO_2): This gas is by far the largest by-product of combustion emitted from engines and is the principal GHG, which due to its accumulation in the atmosphere, is considered to be the main contributor to global warming. It has a Global Warming Potential of 1.0. CO_2 and water vapour are normal by-products of the combustion of fossil fuels.

- Methane (CH_4): This is a colourless, odourless, and flammable gas, which is a by-product of incomplete diesel combustion. Relative to CO_2, it has a Global Warming Potential of 28.

- Nitrous Oxide (N_2O): This is a colourless gas produced during combustion that has a Global Warming Potential of 265 (relative to CO_2).

The sum of the constituent GHGs expressed in terms of their equivalents to the Global Warming Potential of CO_2 is depicted as CO_2e. This is calculated by multiplying the volume of fuel consumed by the emission factors of each constituent, then, in turn, multiplying the product by the respective Global Warming Potential, and then summing them. See Table 8 for conversion values pertaining to diesel fuel combustion.

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EMISSIONS METRICS

The unit of measurement for the constituent emissions is grams per brake horsepower- hour (g/bhp-hr). This is the amount (in grams) of a particular constituent emitted by a locomotive's diesel engine for a given amount of mechanical work (brake horsepower) over one hour for a specified duty cycle. This measurement allows a ready comparison of the relative cleanliness of two engines, regardless of their rated power.

RAC LEM PROTOCOL

This is the collection of financial and statistical data from RAC members and the RAC database (where data is systematically stored for various RAC applications). Data from the RAC database, which is used in this report, include freight traffic revenue tonne kilometres and gross tonne kilometres, intermodal statistics, passenger traffic particulars, fuel consumption, average fuel sulphur content and locomotive inventory. The Class 1 railways' Annual Reports and Financial and Related Data submissions to Transport Canada also list much of this data.

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Appendix F

Conversion Factors Related to Railway Operations

Imperial gallons to litres	4.5461
US gallons to litres	3.7853
Litres to Imperial gallons	0.2200
Litres to US gallons	0.2642
Miles to kilometres	1.6093
Kilometres to miles	0.6214
Metric tonnes to tons (short)	1.1023
Tons (short) to metric tonnes	0.9072
Revenue ton-miles to Revenue tonne-kilometres	1.4599
Revenue tonne-kilometres to Revenue ton-miles	0.6850

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Appendix G

Abbreviations and Acronyms Used in the Report

ABBREVIATIONS OF UNITS OF MEASURE

bhp	Brake horsepower
g	Gram
g/bhp-hr	Grams per brake horsepower hour
g/GTK	Grams per gross tonne-kilometre
g/L	Grams per litre
g/RTK	Grams per revenue tonne-kilometre
hr	Hour
kg/1,000 RTK	Kilograms per 1,000 revenue tonne-kilometres
km	Kilometre
kt	Kilotonne
L	Litre
L/hr	Litres/hour
lb	Pound
ppm	Parts per million

ABBREVIATIONS USED IN RAILWAY OPERATIONS

AESS	Automated Engine Start-Stop
APU	Auxiliary Power Unit
COFC	Container-on-Flat-Car
DB	Dynamic Brake
DMU	Diesel Multiple Unit
EMU	Electric Multiple Unit
GTK	Gross Tonne-Kilometres
LEM	Locomotive Emissions Monitoring
LER	*Locomotive Emissions Regulations*
LRV	Light Rail Vehicle
MOU	Memorandum of Understanding
N1, N2 . . .	Notch 1, Notch 2... Throttle Power Settings
RDC	Rail Diesel Car
RPK	Revenue Passenger-Kilometres
RPM	Revenue Passenger-Miles
RTK	Revenue Tonne-Kilometres
RTM	Revenue Ton-Miles
TOFC	Trailer-on-Flat-Car
ULSD	Ultra-low Sulphur Diesel Fuel

ABBREVIATIONS OF EMISSIONS AND RELATED PARAMETERS

CAC	Criteria Air Contaminant
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide equivalent of all six Greenhouse Gases
CO	Carbon Monoxide
EF	Emission Factor
GHG	Greenhouse Gas
HC	Hydrocarbons
NO_x	Nitrogen Oxides
PM	Particulate Matter
SO_x	Sulphur Oxides
SO_2	Sulphur Dioxide
TOMA	Tropospheric Ozone Management Areas

ACRONYMS OF ORGANIZATIONS

AAR	Association of American Railroads
ALCO	American Locomotive Company
CGSB	Canadian General Standards Board
CN	Canadian National Railway
CP	Canadian Pacific
CPKC	Canadian Pacific Kansas City Limited
ECCC	Environment and Climate Change Canada
GE	General Electric Transportation Systems
GM/EMD	General Motors Corporation Electro-Motive Division
MLW	Montreal Locomotive Works
OEM	Original Equipment Manufacturer
RAC	Railway Association of Canada
TC	Transport Canada
UNFCCC	United Nations Framework Convention on Climate Change
US EPA	United States Environmental Protection Agency
VIA	VIA Rail Canada

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Appendix H

CALCULATIONS METHODOLOGY

Data Collection

RAC members complete an annual statistical survey that forms the basis of the yearly LEM reports. The survey collects information pertaining to (but not limited to):

TRAFFIC DATA:

- Freight railways: revenue tonne-kilometres; gross tonne-kilometres; carloads by commodity.
- Passenger railways: number of passengers; passenger-kilometres; train kilometres; average length of journey; average number of passengers per train.

FUEL CONSUMPTION DATA:

- Fuel consumed across four service categories: line haul service; yard switching service; work train service; and passenger service.

LOCOMOTIVE INVENTORY:

- For each locomotive in the railway's fleet, details on: manufacturer, model, EPA tier level, engine, horsepower, year of original manufacture, anti-idle devices, and service type (line haul; yard).

Data Analysis

Internally, the RAC aggregates the information to produce industry statistics. In many cases, information is aggregated either by type of railway (Class 1; regional & shortline; intercity passenger; commuter passenger; and tourist/excursion passenger), by service (line haul, yard, work train, etc.), or by region (TOMAs).

Data on GHG emission factors are from Environment and Climate Change Canada, and data on CAC emission factors are from the United States Environmental Protection Agency.

Data Review

RAC's calculations are submitted to a consultant for a Quality Assurance / Quality Control process to validate the calculations. Afterwards, a report draft is submitted to a Technical Review Committee consisting of railway and government representatives to further review and approve the data calculations.

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