LOCOMOTIVE EMISSIONS MONITORING REPORT

2021

Railway Association of Canada

PEOPLE. GOODS.
CANADA MOVES BY RAIL.

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MANAGEMENT COMMITTEE

Paula Vieira (Chair), Transport Canada (TC)

Ben Chursinoff, Railway Association of Canada (RAC)

Grant Hogg, Environment and Climate Change Canada (ECCC)

Nada Vrany, Natural Resources Canada (NRCAN)

François Bélanger, Canadian National Railway (CN)

David Huck, Canadian Pacific (CP)

Bruno Riendeau, VIA Rail Canada (VIA)

Steve McCauley, Pollution Probe

TECHNICAL REVIEW COMMITTEE

Jonathan Thibault (Chair), RAC

Jacob McBane, TC

Jaclyn Howell, TC

Simon Lizotte, CN

Nirwair Bajwa, CP

Murray Macbeth, Genesee & Wyoming Canada inc. (GWRR)

Françoise Granda Desjardins, VIA

Arjun Kasturi, GO Transit

Thomas Rolland, exo

Ursula Green, TC

Stephen Healey, TC

Kyle Beauliua, TC

Liam Vass, TC

Bassam Javed, ECCC

Maygan McGuire, NRCAN

Cedric Smith, Pollution Probe

CONSULTANTS

Matt Beck, Delphi

Erin Williamson, Delphi

Hayley MacVicar, Delphi

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READERS' COMMENTS

Comments on the contents of this report may be addressed to:

Jonathan Thibault
Manager, Economics, Data and Research
Railway Association of Canada
99 Bank Street, Suite 901
Ottawa, Ontario K1P 6B9

P: 613.564.8104
F: 613.567.6726
Email: JThibault@railcan.ca

REVIEW NOTICE

This report has been reviewed and approved by the Technical Review and Management Committees of the 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 2021 has been completed in accordance with the terms of the 2018–2022 memorandum of understanding (referred hereafter as "the MOU") signed on March 21, 2019, 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 fourth report prepared under the current MOU, though it is based on reporting for the LEM program governed by MOUs dating back to 1995.

As stated in the MOU, the RAC encourages its members to make every effort to reduce the GHG emission intensity from railway operations. The MOU's GHG emission intensity targets for 2018–2022, which uses 2017 as a baseline year, are included in the table below.

Under the MOU, the RAC continues to encourage CAC emission reductions and conformance with appropriate CAC emission standards for those locomotives not covered by the *Locomotive Emissions Regulations* (LER), which came into force on June 9, 2017. Reporting by the RAC of CAC emissions as agreed under the MOU and included in this LEM report do not fulfil any member reporting requirements under the LER.

2018-2022 MOU PROGRESS

This report highlights that, in light of the COVID-19 pandemic, all railway operations reduced their GHG emissions intensities in 2021 compared to 2020. Canadian Class 1 freight railways are continuing to reduce their GHG emissions intensities and have made 99.01% progress towards the MOU target. Despite the initial effects of the COVID-19 pandemic on ridership (both personal and business travel), intercity passenger railways experienced a significant decrease to their GHG emissions intensities compared to 2020; however, GHG emissions intensities are still above 2019 figures and historical reduction trends. Total regional & shortline emissions intensity also decreased in 2021.

In addition to the GHG emission intensity targets for 2018–2022, the following table presents the railway emission performance for baseline (2017) and reporting years (2018, 2019, 2020, 2021), as expressed in kilograms (kg) of carbon dioxide equivalent (CO_2e) per productivity unit.

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GHG EMISSIONS INTENSITY AND MOU PROGRESS BY RAILWAY OPERATION

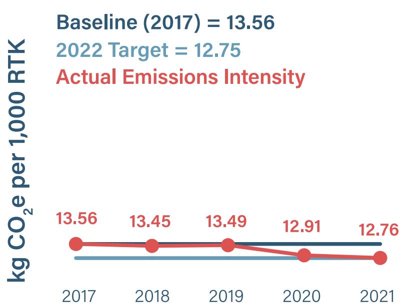
Railway Operation	Productivity Units	Baseline—2017	2018	2019	2020	2021	Change from 2017–2021	Change from 2020–2021	2022 Target	Progress to 2022 Target
Class I Freight	kg CO_2e per 1,000 RTK	13.56	13.45	13.49	12.91	12.76	-5.94%	-1.16%	12.75 (6% reduction)	99.01% progress to target
Intercity Passenger*	kg CO_2e per passenger-km	0.098	0.097	0.089	0.178	0.146	49.58%	-17.99%	0.092 (6% reduction)	increase since 2017
Regional & Shortline	kg CO_2e per 1,000 RTK	14.08	15.02	14.77	15.27	14.66	4.13%	-3.98%	13.66 (3% reduction)	increase since 2017

Note: GHG emissions for all years have been calculated based on the emissions factors and global warming potentials in the 2023 National Inventory Report. Historical values have been updated.

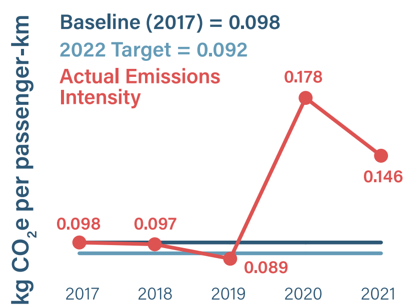
Note: The final column of the table indicates the percentage of the MOU target that has been achieved as of 2021; an increase indicates that emissions intensity was higher in 2021 than in 2017.

*In 2020 and 2021, passenger rail performance metrics were significantly impacted by the COVID-19 pandemic.

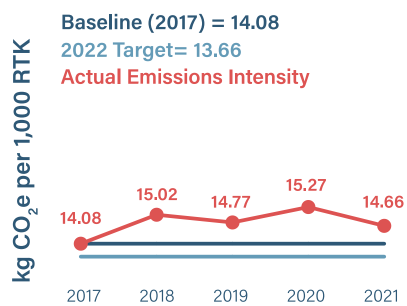
MOU PROGRESS: CLASS I FREIGHT



MOU PROGRESS: INTERCITY PASSENGER*



MOU PROGRESS: REGIONAL & SHORTLINE



* In 2020 and 2021, passenger rail performance metrics were significantly impacted by the COVID-19 pandemic.

As seen in the table and figure above, Class 1 freight GHG emissions intensity decreased by 1.16% from 2020 to 2021. GHG emissions intensity continues to be less than the 2017 baseline and represents 99.01% progress towards achieving the MOU target (of a 6% reduction from baseline). Intercity passenger GHG emissions intensity (i.e., kg CO_2e per passenger-km) decreased by 17.99% from the high level experienced in 2020; making some progress towards a return to the pre-pandemic normal. The deviation in 2020 from the improving trend was due to a significant decrease in ridership throughout the COVID-19 pandemic, while passenger railways continued to maintain essential services. During the same time frame, passenger fuel consumption also decreased, however, the drastic decrease in ridership still caused emissions intensity to approximately double from 2019 to 2020. Regional & shortline emissions intensity decreased by 3.98% from 2020 to 2021 and stood 4.13% above the 2017 baseline.

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2021 KEY FINDINGS

IMPACTS OF COVID-19

Although Canadian railways continued to face major challenges during 2021 throughout the COVID-19 pandemic, railways kept trains running, providing essential services to Canadians. As a consequence of changes to railway operations and passenger ridership, 2021 railway performance and emissions data diverges significantly from historical trends.

While some impacts were temporary, there is the potential for lasting impacts on Canada's passenger railways.

RAILWAY TRAFFIC

	2020	2021	Change from 2020–2021
GTK (billion)	846.76	833.21	-1.6%
RTK (billion)	451.67	442.97	-1.9%
Intermodal Tonnage (million)	36.56	41.01	12.2%
Intercity Passengers (million)	1.15	1.55	35.5%
Commuter Passengers (million)	22.75	13.32	-41.5%

Freight Traffic

- Gross Tonne-Kilometres (GTK): In 2021, the railways handled 833.21 billion GTK of traffic compared to 846.76 billion GTK in 2020, representing a decrease of 1.6%. GTK traffic was 24.6% higher than it was in 2005, the reference year, having increased at an average rate of 1.4% per year.[1] Class 1 GTK traffic accounted for 95.3% of the total GTK hauled in 2021.

- Revenue Tonne-Kilometres (RTK): In 2021, the railways handled 442.97 billion RTK of traffic compared to 451.67 billion RTK in 2020, representing a decrease of 1.9%. RTK traffic was 25.5% higher than it was in 2005, the reference year, having increased at an average rate of 1.4% per year. Of the freight RTK traffic handled in 2021, Class 1 freight railways were responsible for 95.1% of the total traffic.

- Intermodal Traffic: Intermodal tonnage increased by 12.2% to 41.01 million tonnes in 2021 from 36.56 million tonnes in 2020. Overall, intermodal tonnage comprising both container-on-flat-car and trailer-on-flat-car traffic for railways in Canada has risen 33.0% since 2005, equating to an average growth rate of 1.8% per year.

Passenger Traffic

- Passenger rail traffic continued to be impacted by the COVID-19 pandemic since it began in 2020. While the number of intercity rail passengers began increasing in 2021 (after a sharp decline in 2020), commuter rail ridership was lower in 2021 than it was in 2020. Specifically:
  - Intercity passenger traffic in 2021 by all carriers totaled 1.55 million passengers compared to 1.15 million in 2020, an increase of 35.5%.
  - Commuter rail traffic decreased from 22.75 million passengers in 2020 to 13.32 million in 2021, a decrease of 41.5%.[2] A significant contributor to the large variance from 2020 to 2021 is the few months of pre-pandemic "normal" ridership experienced in early 2020, while ridership was well-below pre-pandemic levels throughout 2021.
  - Following closures in 2020, several tourist and excursion railways reopened for passenger service in 2021.

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

2 In 2020 and 2021, the COVID-19 pandemic caused a reduction in travel and increase in teleworking, resulting in a significant decrease in the number of commuters and commuter railways' fuel consumption (also impacting total passenger rail fuel consumption).

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FUEL CONSUMPTION

	2020	2021	Change from 2020-2021
Total	2,090.94	2,033.33	-2.8%
Total Freight Operations	2,021.34	1,959.44	-3.1%
Class 1 Freight	1,857.42	1,796.77	-3.3%
Regional & Shortline	108.69	106.56	-2.0%
Yard Switching and Work Train	8.41	9.04	7.5%
Passenger Operations	69.60	73.89	6.2%

- Fuel consumed by railway operations in Canada decreased by 2.8% from 2,090.94 million litres in 2020 to 2,033.33 million litres in 2021.
- Of the total fuel consumed by all railway operations, Class 1 freight train operations consumed 88.4% and regional & shortlines consumed 5.2%. Yard switching and work train operations consumed 2.7%, and passenger operations accounted for 3.6%.
- For total freight operations, overall fuel consumption in 2021 was 1,959.44 million litres, 3.1% below the 2020 level of 2,021.34 million litres.
- For total freight operations, fuel consumption per productivity unit (litres per 1,000 RTK) in 2021 was 4.42 litres per 1,000 RTK, a decrease of 1.2% from 2020 and 25.9% from 2005.
- For total passenger operations, overall fuel consumption in 2021 was 73.89 million litres, 6.2% above the 2020 level of 69.60 million litres, but well-below pre-pandemic levels (e.g., 134.89 million litres in 2019).[3]

LOCOMOTIVE INVENTORY

Locomotive Fleet

	2020	2021	Change from 2020-2021
Total Locomotives	3,756	3,606	-4.0%
Line Haul Freight	2,923	2,801	-4.2%
Class 1	2,645	2,437	-7.9%
Regional	133	137	3.0%
*Shortline**	145	227	56.6%
Freight Switching Operations	594	551	-7.2%
Passenger	239	254	6.3%
Intercity	74	82	10.8%
Commuter	163	155	-4.9%
Tourist/Excursion	2	17	750.0%

*The significant increase in the number of line haul shortline locomotives in 2021 is the result of a methodology change from a reporting member. Without the methodology change, the 2020 and 2021 figures would be very similar.

The reported number of diesel-powered locomotives and diesel multiple units (DMUs) in active service in Canada operated by MOU signatory railways totaled 3,606 in 2021 versus 3,756 in 2020, a decrease of 4.0%.[4]

For line haul freight operations in 2021, 2,437 locomotives were operated by Class 1s, 137 by regional railways, and 227 by shortlines.[5] A further 551 locomotives were in freight switching operations. A total of 254 locomotives and DMUs were used in 2021 to support passenger railway operations in Canada, of which 82 were for intercity passenger services, 155 for commuter railway services, and 17 for tourist and excursion services.

Locomotives Meeting Emissions Standards

In 2021, 82.9% of the fleet met emissions standards (as set out under the LER or the United States Environmental Protection Agency (US EPA) Regulations).[6] A total of 80 locomotives were added to the locomotive fleet in 2021, including one Tier 0, one Tier 0+, five Tier 1, two Tier 1+, and 71 Tier 3; and 165, mostly non-tier-level and lower-tier-level locomotives, were retired. In addition, 33 locomotives were remanufactured: two to Tier 0+, 30 of them to Tier 1+, and one to Tier 3.

Locomotives Equipped with Anti-Idling Devices

The number of locomotives in 2021 equipped with a device to minimize unnecessary idling, such as an automatic engine stop-start (AESS) system or auxiliary power unit (APU), was 3,034, which represents 84.1% of the fleet, compared to 3,109 in 2020 (82.8% of the fleet).[7]

3 Ibid.

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.

5 The number of line haul shortline locomotives in 2021 was much higher than in 2020, as a result of a methodology change from a reporting member.

6 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.

7 Ibid.

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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 2021, 2.4% occurred in the Lower Fraser Valley of British Columbia, 12.3% in the Québec City-Windsor Corridor, and 0.2% in the Saint John area of New Brunswick. Estimated NO_x emissions for each TOMA were at the same ratios as GHGs.

EMISSIONS REDUCTION INITIATIVES BY RAILWAYS

Railways invested $2.3 billion into their Canadian networks in 2021 and continued to lower their emissions through investments in fleet renewal/modernization, fuel saving technologies, operational efficiencies, and use of low carbon fuels. Railways and their partners also made progress in their various partnerships as well as pilot projects in alternative propulsion.

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1. INTRODUCTION

This report contains the Locomotive Emissions Monitoring (LEM) data filing for 2021 in accordance with the terms of the memorandum of understanding (MOU) signed on March 21, 2019, between the Railway Association of Canada (RAC) and Transport Canada (TC) concerning voluntary arrangements to limit greenhouse gas (GHG) emissions and criteria air contaminant (CAC) emissions from locomotives operating in Canada.

Transportation is Canada's second largest source of GHG emissions. In 2021, the transportation sector emitted 188 Mt of CO_2e, accounting for 28% of Canada's total GHG emissions.[8] The majority of transportation GHGs are attributed to light-duty and heavy- duty on-road vehicles. Canadian railways accounted for less than 4% of transportation GHGs, which is less than light-duty vehicles (41%), heavy-duty vehicles (21%), and the pipeline transport sector (5%).[9] To meet Canada's commitment to cut GHGs by 40–45 percent below 2005 levels by 2030 and reach net-zero by 2050, the transport sector must make a major 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 25.9%. During the same timeframe, railways have experienced a 25.5% increase in revenue traffic. 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. Canada's railways will continue to contribute to national emissions reductions through investments in innovative solutions to increase efficiency and sustainability.

The fourth MOU signed by the RAC and the federal government since 1995 establishes a framework through which the RAC, its MOU signatory member companies (as listed in Appendix A), and TC can continue to address GHG and CAC emissions produced by locomotives in Canada. The MOU, which can be found on the RAC website, includes measures, targets, and actions that will further reduce GHG and CAC emission intensities from rail operations to help protect the environment and health of Canadians and address climate change. This is the fourth report prepared under the current MOU.

Data for this report was collected via a survey sent to each RAC member. Based on this 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 the RAC.

8 Source: Canada's National Inventory Report, 1990–2021: Greenhouse Gas Sources and Sinks in Canada, Environment and Climate Change Canada, 2023, Table ES-1 and Table 3-7.

9 Ibid.

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1.1 OVERVIEW OF REPORT

This report provides an overview of 2021 rail performance including traffic, fuel consumption, fleet inventory, and GHG and CAC emissions. Also included are sections on partnerships and initiatives being taken or examined by the sector to reduce fuel consumption and emissions.

1.2 GHG COMMITMENTS

As stated in the MOU, the RAC encourages its members to improve their GHG emissions intensity from railway operations and sets GHG emission targets for 2022. The 2017 baseline data and actual annual emissions (expressed as kilograms of CO_2e per productivity unit) are outlined in the following table.

Data is presented from 2012 to 2021. For historical comparison purposes, the year 2005[10] has been set as the reference year and has also been included. LEM statistics from 1990 to 2020 can be found in previously completed LEM Reports available from the RAC upon request. 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 table. Data in US (imperial) units are available upon request to the RAC.

In addition, this report contains winter and summer data on the 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.

GHG EMISSIONS INTENSITY AND MOU PROGRESS BY RAILWAY OPERATION

Railway Operation	Productivity Units	Baseline—2017	2018	2019	2020	2021	Change from 2017–2021	Change from 2020–2021	2022 Target	Progress to 2022 Target
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Note: GHG emissions for all years have been calculated based on the emissions factors and global warming potentials in the 2023 National Inventory Report. Historical values have been updated.

Note: The final column of the table indicates the percentage of the MOU target that has been achieved as of 2021; an increase indicates that emissions intensity was higher in 2021 than in 2017.

*In 2020 and 2021, passenger rail performance metrics were significantly impacted by the COVID-19 pandemic.

Greenhouse Gas Pollution Pricing Act

The Government of Canada passed the *Greenhouse Gas Pollution Pricing Act* in 2018, based on the consensus that greenhouse gas (GHG) emissions contribute to global climate change. In March 2021, Canada's Supreme Court deemed reducing GHG emissions a matter of national concern when it found the Act to be constitutional. The landmark decision allows provinces to design their own GHG pricing systems so long as they align with the federal government's outcome-based targets. Existing pricing regimes, such as in Québec and British Columbia, may stay in place, but the federal tax will apply for provinces that do not meet the standard or do not have a mechanism in place.

Enhanced 2030 and 2050 Targets

At the 2021 Leaders Summit on Climate, hosted by the United States on Earth Day, the Government of Canada raised its climate ambition and committed to reducing GHG emissions by 40 to 45% from 2005 levels by 2030 and reaching net-zero by 2050. In July 2021, the Minister of Environment and Climate Change, the Honourable Jonathan Wilkinson, formally submitted Canada's enhanced Nationally Determined Contribution (NDC) to the United Nations. Canada's NDC submission outlines a series of investments, regulations, and measures that the country is taking in pursuit of its ambitious target. It includes input from provincial, territorial, and Indigenous partners. These actions are also detailed in

10 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 all previous reports, 1990 was set as the reference year.

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a new publication, entitled "Canada's Climate Actions for a Healthy Environment and a Healthy Economy."

Canada Net-Zero Emissions Accountability Act

The Canadian Net-Zero Emissions Accountability Act, which became law on June 29, 2021, enshrines in legislation Canada's commitment to achieve net-zero GHG emissions by 2050, and provides a framework of accountability and transparency to deliver on it.

The Act also establishes a requirement to set national emissions reduction targets for 2035, 2040, and 2045, ten years in advance, to be supported by a science-based emissions reduction plan outlining the measures and strategies the Government of Canada will take to achieve the target along with progress reports on the plan's ongoing implementation. Decarbonizing the transportation network will be a crucial step in achieving these ambitious targets.

1.3 CAC COMMITMENTS

As stated in the MOU, Transport Canada has developed regulations to control CAC emissions under the *Railway Safety Act*. The LER came into force on June 9, 2017 and apply to railway companies that the federal government regulates.[11] 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, the RAC encouraged all members to conform to the US EPA emissions standards and to adopt operating practices aimed at reducing CAC emissions. The RAC continues to encourage its members, including those not covered by the LER, to improve their CAC emissions performance. Through this Memorandum, the RAC will continue to report on annual CAC emissions, in a manner and format that is agreeable to all parties, with a view to leverage the data railways provide under the regulations. CAC reporting under the MOU does not fulfill reporting requirements under the LER.

11 Baseline and some historical CAC performance reflected in this report predates the Locomotive Emission 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

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2. EMISSIONS REDUCTION INITIATIVES

In 2021, Canadian railways continued to invest in new technologies and improve operational practices to reduce locomotive emissions. In 2021, railways invested $2.3 billion into their Canadian networks, bringing the total to $20.9 billion over the past ten years. This section of the report highlights how Canadian railways lowered their emissions through investments in fleet renewal/modernization, fuel saving technologies, operational efficiencies, and use of low carbon fuels. In addition, pilot projects in alternative fuels and propulsion and partnerships that will drive emissions reductions in the coming years are also discussed.

2.1 FLEET RENEWAL/MODERNIZATION

Canadian National Railway Company (CN) continues to purchase the most fuel-efficient high-horsepower locomotives currently available with the acquisition of 69 units in 2021. These locomotives are equipped with energy management systems and data telemetry systems as well as distributed power functionality to help maximize locomotive operating effectiveness and efficiency.

The Canadian Pacific (CP) Locomotive Retrofit project is part of a multi-year locomotive fleet renewal program at CP. In 2021, CP upgraded 30 locomotive units with a spend of ~$50M towards this initiative. This investment includes technology upgrades, overhauled in kind or upgraded diesel engines, and improved traction systems. All units were equipped with EPA-certified fuel/emissions reduction technologies, GE Trip Optimizer and Distributed Power. Improvements directly influence locomotive fuel efficiency and corresponding greenhouse gas emissions, resulting in a 2.7 percent improvement guarantee. Emissions reductions associated with this project were conservatively estimated based on the fuel efficiency guarantee provided by the equipment vendor. CP anticipates the combined effect of locomotive upgrades coupled with installed fuel-saving technology will result in fuel savings beyond 2.7 percent. Through this

In 2021, CN acquired
69 OF THE MOST FUEL-EFFICIENT LOCOMOTIVES CURRENTLY AVAILABLE

CP's locomotive modernization project guarantees a
2.7% IMPROVEMENT IN LOCOMOTIVE FUEL EFFICIENCY

VIA Rail began testing of the first trainset that will offer an
UNPARALLELED, FULLY ACCESSIBLE, & BARRIER-FREE TRAVEL EXPERIENCE

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initiative, CP invested a total of over $560M and has modernized 416 locomotives out of total of 912 active line haul locomotives. These improvements have a direct and positive impact on CP's fuel efficiency and corresponding GHG and air pollutant emissions.

In 2021, the first trainset of 32 that will comprise **VIA Rail**'s new Québec City-Windsor corridor fleet was delivered for testing. Once put into service, the fleet will offer an unparalleled, fully accessible, and barrier-free travel experience and will be one of North America's most environmentally friendly fleet. The new Corridor fleet's locomotives meet Tier 4 emissions standards which will allow for an 85-95% reduction in particulate matter and Nitrogen Oxide emissions and hence significantly contribute to improving air quality.

In 2021, **VIA Rail** continued to make improvements to its existing fleet by upgrading two additional F40PH (GPA30) locomotives to meet Tier 0 emissions standards, following one upgraded in 2020.[12]

Genesee & Wyoming Inc. continued its efforts to reduce GHGs by upgrading locomotives to Tier 0+ and purchased more APUs and AESS.

In 2021, **West Coast Express** commuter rail service announced a project to refurbish six locomotives to Tier 2+ by 2026. The refurbished locomotives will reduce CAC emissions by up to 50% and provide an additional 15 years of service life. The project is co-funded by the government of Canada, government of British Columbia and Translink.

In 2021, as part of the Locomotive Retrofit project, CP

UPGRADED 30 LOCOMOTIVES

12 VIA Rail upgraded the locomotives to meet CND/40 CFR 1033 Tier 0 standards, which is referred to as "Tier 0+" in the rest of the LEM report.

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2.2 FUEL SAVING TECHNOLOGIES

CP has equipped over 400 high-horsepower locomotives with Trip Optimizer technology, and plans to continue implementation across 50 percent of its high-horsepower fleet by the end of 2022. CP's 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. CP enhanced the 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.

CN continues to install fuel-efficient technologies and utilize data analytics to optimize the efficiency of its fleet. These innovative technologies allow CN to continuously improve train handling, braking performance, and overall fuel efficiency, therefore, improving carbon efficiency in the years to come. Technologies include:

1. CN's Horsepower Tonnage Analyzer uses data from the system to optimize a locomotive's horsepower-tonnage ratio for efficiency.
2. Energy management system to regulate speed and compute the most fuel-efficient manner to handle the train.
3. Distributed Power to remotely control locomotives and improve braking performance, train handling and fuel efficiency.
4. Locomotive Telemetry System to collect data to improve performance and conserve fuel.

As part of its five-year sustainability plan, **VIA Rai**l initiated a pilot project to test artificial intelligence (AI) capabilities to reduce fuel consumption and greenhouse gas emissions in its rail operations. In collaboration with Transport Canada and Innovative Solutions Canada Testing Stream, VIA Rail worked with start-up company, RailVision Analytics, to test EcoRail, an AI-enabled software that can analyze many variables to provide driving recommendations to locomotive engineers to reduce fuel consumption. EcoRail monitors the driving behaviour between station stops to determine improvements that will allow for a reduction in fuel consumption. The software analyzes several factors such as equipment used, season and schedule, in order to recommend the most fuel-effective train handling behaviour without impacting travel time. The pilot project was launched in 2021 with locomotive engineers in VIA Rail's simulators for a six-month period until the end of March 2022.

In 2021, 3,034 of 3,606 locomotives (84.1%) in the total active Canadian fleet were equipped with an anti-idling device, such as an automatic engine stop-start (AESS) system or auxiliary power unit (APU), to minimize emissions from unnecessary idling.

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2.3 OPERATIONAL EFFICIENCIES

CN is building on its scheduled railroading model, providing on-the-job training on practices to optimize fuel efficiency and information on track performance in real time that enables fuel conservation through notch limiting, idling reduction and horsepower optimization. CN continues to educate its train crews and rail traffic controllers on best practices—from locomotive shutdowns to streamlined railcar handling, train pacing, coasting and braking strategies. In addition, locomotive engineers can leverage an energy management system (EMS), which helps to operate the train as efficiently as possible as well as to regulate its speed. In 2021, CN reported that locomotive fuel efficiency improved by 1.2 per cent to a record 0.884 US gallons of locomotive fuel consumed per 1,000 GTMs.[13]

CP uses Precision Scheduled Railroading, which focuses on improving operational efficiency. In addition to investments in its locomotive and rolling stock fleet (e.g., high-capacity hopper cars), CP is enhancing train configurations and using software for route and speed optimization.

2.4 LOW CARBON FUELS

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 that:

- biodiesel and HDRD have slightly lower energy density than fossil diesel;[14]
- fuel providers are not always required to disclose exact blend levels, so railways do not have a clear picture of the fuel they are using; 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.

CN is actively working with its fuel suppliers and locomotive manufacturers, focused on testing and exploring the greater use of sustainable renewable fuel blends, beyond regulated amounts, in its locomotives. In 2021, the use of sustainable renewable fuels in CN's fleet saved approximately 122,939 tonnes of CO_2e.

In 2021, the use of

SUSTAINABLE RENEWABLE FUELS IN CN'S FLEET SAVED APPROXIMATELY 122,939 TONNES OF CO_2e

13 Or 2.29 litres of locomotive fuel consumer per 1,000 GTKs.

14 HDRD has approximately two to four percent lower energy density than fossil diesel.

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2.5 ALTERNATIVE PROPULSION

CP has been developing North America's first line haul hydrogen-powered locomotive using fuel cells and batteries to power the locomotive's electric traction motors. This work will refine the process of converting diesel-electric powertrains to hydrogen-electric powertrains over a series of three distinct locomotive types, which collectively represent most locomotives currently in service across North America. In December 2021, CP completed its first successful hydrogen locomotive movement test.

In 2021, CP received funding from Emissions Reduction Alberta to expand the hydrogen locomotive program. This funding enables CP to increase the number of hydrogen locomotive conversions from one to three and add hydrogen and fueling facilities in Calgary and Edmonton. Fueling facilities will include electrolysis plants to produce hydrogen from water, and the Calgary facility will operate on renewable solar power generated at CP's headquarters campus, producing zero GHGs.

CP's Hydrogen Locomotive Program will generate critical industry knowledge and experience that will inform commercialization and future development.

In 2021, **CN** announced the purchase of a Wabtec FLXdrive battery-electric freight locomotive, the first 100% battery heavy-haul locomotive in support of its ambitious long-term goals. The anticipated efficiencies and emission reductions from this technology will be significant, reducing locomotive fuel consumption and emissions by up to 30%, and will help open the door to new alternatives beyond the diesel-powered locomotives used today.

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.

GOVERNMENT OF CANADA—ROADMAP FOR A RENEWED U.S.-CANADA PARTNERSHIP

In February 2021, President Biden and Prime Minister Trudeau announced the Roadmap for a Renewed U.S.-Canada Partnership, which establishes a blueprint for an ambitious and whole-of-government approach on a range of action items in key areas of cooperation, including trade, climate change, COVID-19 response and recovery, and global and regional security issues. The Roadmap also reaffirms a shared commitment to diversity, equity, and justice, and to ensure a just transition for workers, communities, and businesses. Through the Roadmap, Canada and the United States committed to working in tandem, and to encourage others to achieve net zero emissions no later than 2050.

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GOVERNMENT OF CANADA—JOINT STATEMENT BY TRANSPORT CANADA AND THE U.S. DEPARTMENT OF TRANSPORTATION ON THE NEXUS BETWEEN TRANSPORTATION AND CLIMATE CHANGE

In February 2021, Canada's Minister of Transport, the Honourable Omar Alghabra, and United States Transportation's Secretary, the Honourable Pete Buttigieg, issued the *Joint Statement by Transport Canada and the U.S. Department of Transportation on the Nexus between Transportation and Climate Change*. The Joint Statement recognizes that the transport sector constitutes one of the largest sources of GHG emissions for both Canada and the U.S. and that collaboration between both countries will be required to address climate change. The statement included a series of commitments for each mode of transportation, including a commitment to work collaboratively on new innovative solutions to decrease emissions and advance the use of cleaner fuels in rail transportation.

TRANSPORT CANADA AND CHANGE ENERGY SERVICES LOW CARBON-INTENSITY DIESEL REPORT

In 2021, Transport Canada engaged Change Energy Services to undertake a research project to explore the use of low carbon-intensity diesel fuels in Canada's rail sector through a review of relevant literature and published data, as well as direct interviews with industry representatives. The project serves to support the 2018–2022 MOU commitment to share information and identify opportunities to advance clean technology, clean fuels, and innovation in the railway sector through research. The project is set to conclude in mid-2022.

NATURAL RESOURCES CANADA—LIGNIN-DRIVED DIESEL FUEL & HYDROGEN STRATEGY

Through Natural Resources Canada, CanmetENERGYOttawa has been undertaking a project 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[15]. 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.

Commercial hydrogenation-derived renewable diesel (HDRD or hydrotreated vegetable oil—HVO) employs many of the same feedstocks as biodiesel. The hydrocarbons are chemically identical to some of the molecules found in petroleum diesel fuel. Considered to be a 'drop-in' fuel, it is compatible with existing infrastructure and locomotives; however, some OEMs have placed limits on the amount of HDRD that can be included when blended with petroleum diesel fuels.

Canada's Hydrogen Strategy (2020) continues to complement the strengthened climate plan, as the Strategy is working 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, and companies such as Alstom are exploring hydrogen rail demonstration.[16]

15 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.

16 Alstom Coradia iLint—the world's 1st hydrogen powered train (https://www.alstom.com/solutions/rolling-stock/alstom-coradia-ilint-worlds-1st-hydrogen-powered-train)

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ENVIRONMENT AND CLIMATE CHANGE CANADA—STRENGTHENED CLIMATE PLAN

In December 2020, the Government of Canada released its strengthened climate plan, A Healthy Environment and a Healthy Economy , which outlines the next steps Canada will take to decarbonize the transportation sector to help meet Canada's climate targets. This includes working with rail stakeholders to accelerate clean technology development; supporting pilot deployments to de-risk clean technology adoption; providing support to encourage the implementation of commercially-ready solutions (e.g., low carbon and renewable fuels, etc.); and examining options to help deploy low-carbon fuel equipment at rail hubs.

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 address technical challenges, build knowledge about how to operate new technologies safely, and how to mitigate operational risks. Projects undertaken in this program are selected through a consultation process that includes recommendations from federal government, academia, and the railway industry. Notable updates from 2021, the final year of the 2019–2021 rail RD&D work plan are:

- Commission and completion of a study of the technical, operational, economic, and societal factors (TOES) that would affect the viability of converting a diesel driven railway industry in Canada to one powered by hydrogen. This work is documented in a report that defines the challenges and the opportunities inherent in this process.
- Launch of an initiative that is examining the risks and hazards associated with hydrogen fuel cell and battery-powered locomotives. This work is being done to help industry and regulators be prepared for the new hazards that come with these new technologies and to develop the appropriate safeguards. The scope of this work includes a literature review and assessment of the risks and hazards, research into appropriate risk mitigation design and operating practices, and review of relevant codes and standards.
- Continued support for NRCan's work to develop lignin-derived renewable diesel and means of addressing CAC emissions with dual NO_x-PM catalytic converters.

Documents can be obtained from the Innovation Centre reports website.

Transport Canada also supports the development of technologies for reducing emissions through the Clean Transportation System—Research and Development Program. This is a grant program; projects are selected through a competitive process and funded to carry out research and demonstration testing work. The rail projects that received grant funding in 2021 are described below.

1. Ballard Power Systems: The project is a feasibility study to assess the viability of replacing diesel generators with hydrogen fuel cell (HFC) power generators to manage the train's auxillary power demands, i.e. lighting, heating, power. The purpose is to study the technical feasibility and potential benefits, in order form a potential future demonstration project.
2. Canadian Nuclear Laboratories: CNL is conducting 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 is developing a quantitative risk assessment tool designed to be used for case studies. This forms a part of CNL's in-kind contributions to the project. The analysis from this work will help to determine fatalities per year for a given hydrogen installation. The project is engaging industrial partners to provide operational data and feedback to support the risk assessment.

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3. CSA Group: Is developing technical specifications for hydrogen fuel cell and battery-powered locomotives. Working groups include members from railway companies, manufacturers of locomotives, fuel cells, academia, and National Research Council of Canada. In another part of this project, CSA Group is conducting 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. They will produce a roadmap for developing a more robust codes and standards ecosystem and identify gaps where North American homegrown standards may be needed.

4. Southern Railway of British Columbia (SRY) Limited: Has launched a pilot project to transition one diesel locomotive engine to 100% biodiesel, also known as "B100." The test locomotive is being used in SRY's day-to-day freight rail operations in southern British Columbia. The project will evaluate train performance and emissions. This is believed to be the only rail B100 pilot test in Canada.

5. University of British Columbia: Is investigating 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 developing a multi-criteria decision support system for future hydrogen-powered locomotive projects considering their technical, economic, environmental, and social aspects.

SRY Limited has launched a pilot project to transition one diesel locomotive engine to

100% BIODIESEL, ALSO KNOWN AS "B100."

CN—COLLABORATION WITH THE UNIVERSITÉ DE MONTRÉAL

As part of CN's R&D strategy, CN is collaborating with the Université de Montréal to develop mathematical models that have the potential to improve operational and fuel efficiency (and reduce carbon emissions). These models focus on two key areas for efficiency improvements: optimized locomotive power on trains, and improved aerodynamics of intermodal trains. Models are currently under review. CN is in year 5 of this 5-year optimization research project.

CN—PROGRESS RAIL AND CHEVRON RENEWABLE ENERGY GROUP TO TEST HIGH-LEVEL RENEWABLE FUEL BLENDS

In 2021, CN announced a partnership with Progress Rail and Chevron Renewable Energy Group (REG) to test high-level renewable fuel blends including both biodiesel and renewable diesel in support of its sustainability goals. Trials and qualifications of up to 100% biobased diesel fuel are important steps in reducing GHG emissions from CN's existing locomotive fleet. The program will allow CN and Progress Rail to better understand the long-term durability and operational impacts of renewable fuels on locomotives, especially in cold weather, and plan needed modifications to leverage their usage over the next decade.

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CN—WORKING WITH SUPPLY CHAIN PARTNERS TO REDUCE END-TO-END EMISSIONS

CN is working closely with its customers and supply chain partners, including ports, to reduce supply chain emissions. The greater use of combined modes and allowing each mode to be used for the portion of the trip to which it is best suited (such as trucking for short distances and rail for the long haul), is reducing transportation costs and end-to-end emissions across the entire supply chain.

CP—ENGAGING CUSTOMERS ON CLIMATE-RELATED BENEFITS OF SHIPPING BY RAIL

CP provides the opportunity for 100% of its customers to engage with CP on climate-related programs and information, raising awareness of CP's climate commitments and the benefits of using freight rail services to reduce the overall impact of their supply chains. Engagement activities include one-on-one meetings with customers, customer surveys, customer forums, and company website resources and online shipment management tools such as CP's Customer Station. CP also directs its customers to additional resources and GHG planning tools, including its online rail transport carbon calculator.

CP—PARTNERING WITH BALLARD POWER SYSTEMS ON HYDROGEN LOCOMOTIVES

CP is partnering with Ballard Power Systems to employ Ballard fuel cell modules in CP's Hydrogen Locomotive Program. This program is intended to spur innovation, demonstrate leadership and encourage supply chain collaboration to expedite zero-emission fuel cell technology for the freight transportation sector. At the end of 2021, CP announced plans to expand the scope of this program after securing additional funding from Emissions Reduction Alberta (ERA). See 2.5 Alternative Propulsion.

2.7 RAIL PATHWAYS INITIATIVE—PHASE 2

The Pathways Initiative is a partnership between RAC and its members, Transport Canada, Pollution Probe and the Delphi Group. In 2021, Phase 2 of the Rail Pathways Initiative launched with an objective of creating a roadmap to rail decarbonization based on emerging low-carbon technologies. This entailed developing a framework for assessing GHG reduction opportunities in Canada's rail sector and creating a strategy to apply it to inform decision-making on decarbonization in the years and decades ahead.

The technologies shortlisted for assessment included biodiesel (B20), HDRD-30, battery electric, catenary electric, and hydrogen fuel cell technology.

To complete the assessments, an analytical assessment framework was developed to examine the costs related to development, implementation, and operation, and the challenges related to operations, refuelling, safety and regulatory compliance. Also assessed was the carbon reduction potential of each technology. This framework was applied to generate ratings of each technology in 2021.

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3. TRAFFIC DATA

3.1 FREIGHT TRAFFIC HANDLED

As shown in Table 1 and Figure 1, traffic in 2021 handled by Canadian railways totaled 833.21 billion gross tonne-kilometres (GTK) compared to 846.76 billion GTK in 2020, a decrease of 1.6%. The 2021 GTK represents an increase of 24.6% from the reference year of 2005. Revenue traffic in 2021 decreased to 442.97 billion revenue tonne-kilometres (RTK) from 451.67 billion RTK in 2020, a decrease of 1.9%. When compared to 352.91 billion RTK in 2005, this represents an increase of 25.5%. Since 2005, the average annual growth rates for GTK and RTK were both 1.4%.

TABLE 1 TOTAL FREIGHT TRAFFIC, 2005, 2012-2021 (BILLION TONNE-KILOMETRES)

	2005	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
GTK											
Class 1	628.09	674.62	695.58	754.24	752.30	722.33	778.86	820.67	824.53	807.01	793.87
Regional & Shortline	40.45	37.32	39.62	39.19	42.09	44.07	44.59	43.98	39.45	39.75	39.33
Total	**668.54**	**711.94**	**735.19**	**793.43**	**794.39**	**766.40**	**823.45**	**864.66**	**863.98**	**846.76**	**833.21**
RTK											
Class 1	328.24	356.92	371.77	399.47	394.10	383.47	411.22	433.45	432.38	430.39	421.23
Regional & Shortline	24.67	23.08	24.23	23.01	23.98	25.05	24.25	22.27	22.68	21.29	21.73
Total	**352.91**	**380.00**	**396.00**	**422.49**	**418.08**	**408.53**	**435.46**	**455.72**	**455.06**	**451.67**	**442.97**
Ratio RTK/GTK*	**0.53**	**0.53**	**0.53**	**0.53**	**0.52**	**0.53**	**0.53**	**0.53**	**0.53**	**0.53**	**0.53**

*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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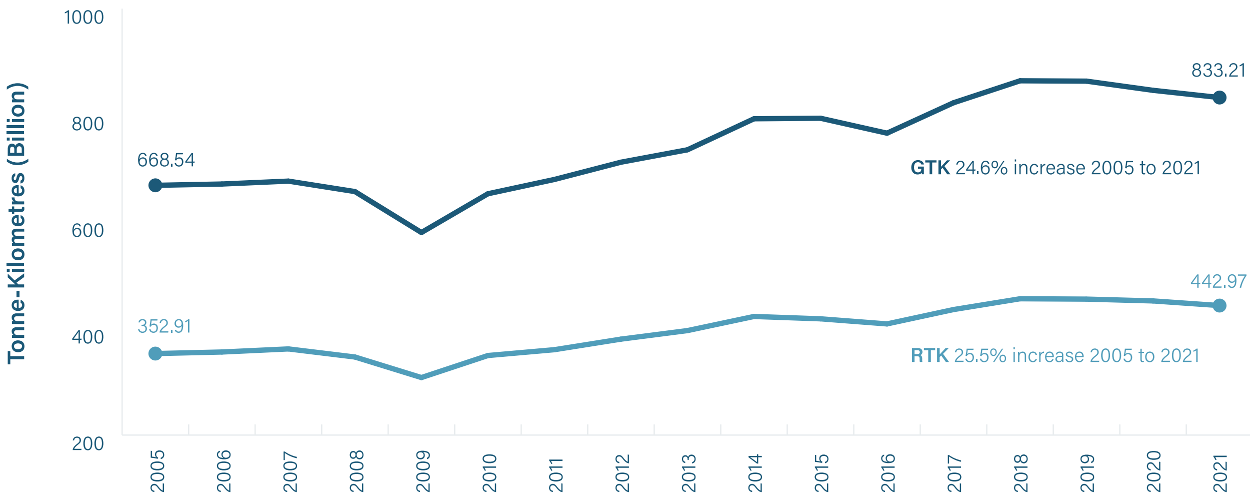
FIGURE 1 TOTAL FREIGHT TRAFFIC, 2005-2021



In 2021, Class 1 GTK traffic decreased by 1.6% to 793.87 billion from 807.01 billion in 2020 (Table 1) and accounted for 95.3% of the total GTK hauled. Class 1 RTK traffic decreased by 2.1% in 2021 to 421.23 billion from 430.39 billion in 2020 and accounted for 95.1% of the total RTK.

Of the total freight traffic in 2021, regional & shortlines were responsible for 39.33 billion GTK (or 4.7%) and 21.73 billion RTK (or 4.9%). In 2021, regional & shortline railways experienced a 2.1% increase in RTK compared to 2020 and a decrease of 1.0% of their GTK traffic.

3.1.1 FREIGHT CARLOADS BY COMMODITY GROUPING

The total 2021 freight carloads for 11 commodity groups are shown in Figure 2 and Table 2 below.

FIGURE 2 CANADIAN RAIL ORIGINATED CARLOADS BY COMMODITY GROUPING, 2021

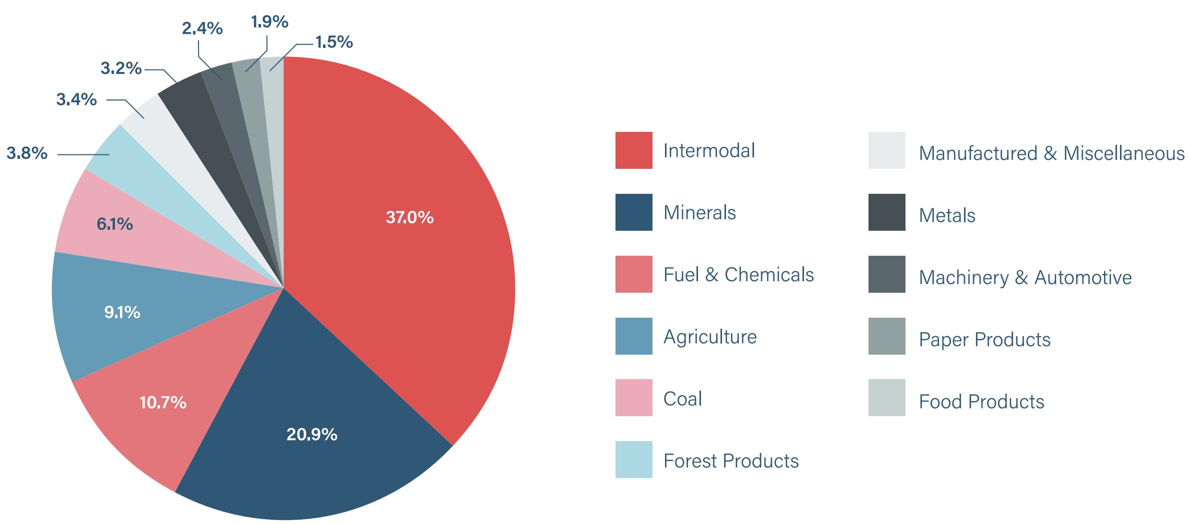


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TABLE 2 CANADIAN RAIL ORIGINATED FREIGHT CARLOADS BY COMMODITY GROUPING, 2005, 2020-2021

	Agriculture	Coal	Minerals	Forest Products	Metals	Machinery & Automotive	Fuel & Chemicals	Paper Products	Food Products	Manufactured & Miscellaneous	Intermodal	Total
2005	416,473	353,197	657,410	433,138	295,022	235,480	469,655	333,830	44,169	65,629	769,936	**4,073,939**
2020	615,441	323,880	1,086,036	213,474	156,271	154,487	535,268	113,001	87,050	194,640	1,905,493	**5,385,041**
2021	483,085	321,232	1,105,311	198,714	168,593	126,451	565,748	97,884	79,547	180,944	1,955,771	**5,283,280**
2005-2021	16.0%	-9.1%	68.1%	-54.1%	-42.9%	-46.3%	20.5%	-70.7%	80.1%	175.7%	154.0%	**29.7%**
2020-2021	-21.5%	-0.8%	1.8%	-6.9%	7.9%	-18.1%	5.7%	-13.4%	-8.6%	-7.0%	2.6%	**-1.9%**

The impact of the COVID-19 pandemic, along with ongoing supply chain issues, continue to affect freight carloads. The number of carloads in all but four commodity groups decreased from 2020 to 2021.

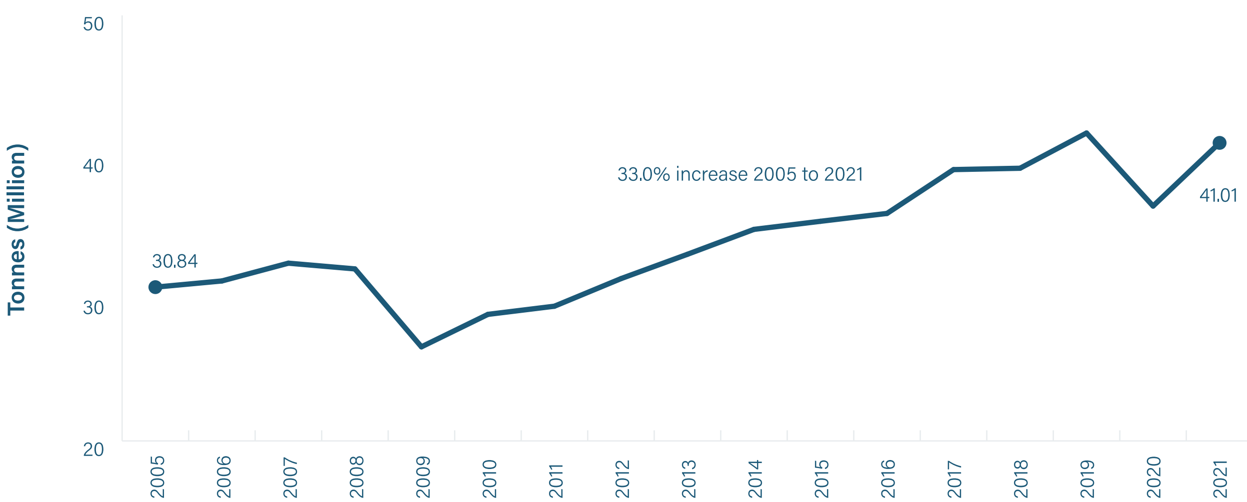
Despite the fluctuations across commodity groups, total freight carloads only decreased by 1.9%, which mirrors the 1.9% decrease in total revenue tonne-kilometres (see Table 1).

3.1.2 INTERMODAL TRAFFIC

Of the total freight carloads in 2021, intermodal made up the largest share at 37.0%, as illustrated in Figure 2 and Table 2 above. The number of intermodal carloads handled by railways in Canada increased to 1,955,771 from 1,905,493 in 2020, an increase of 2.6%. In 2021, Intermodal tonnage increased by 12.2% to 41.01 million tonnes from 36.56 million tonnes in 2020.

Global supply chain issues, including the global container shortage, affected intermodal shipments in 2020 and 2021. Overall, since 2005, intermodal tonnage, comprising both container-on-flat-car and trailer-on-flat-car traffic, has risen by 33.0%, equating to an average annual growth of 1.8% as illustrated in Figure 3.

FIGURE 3 INTERMODAL TONNAGE, 2005-2021



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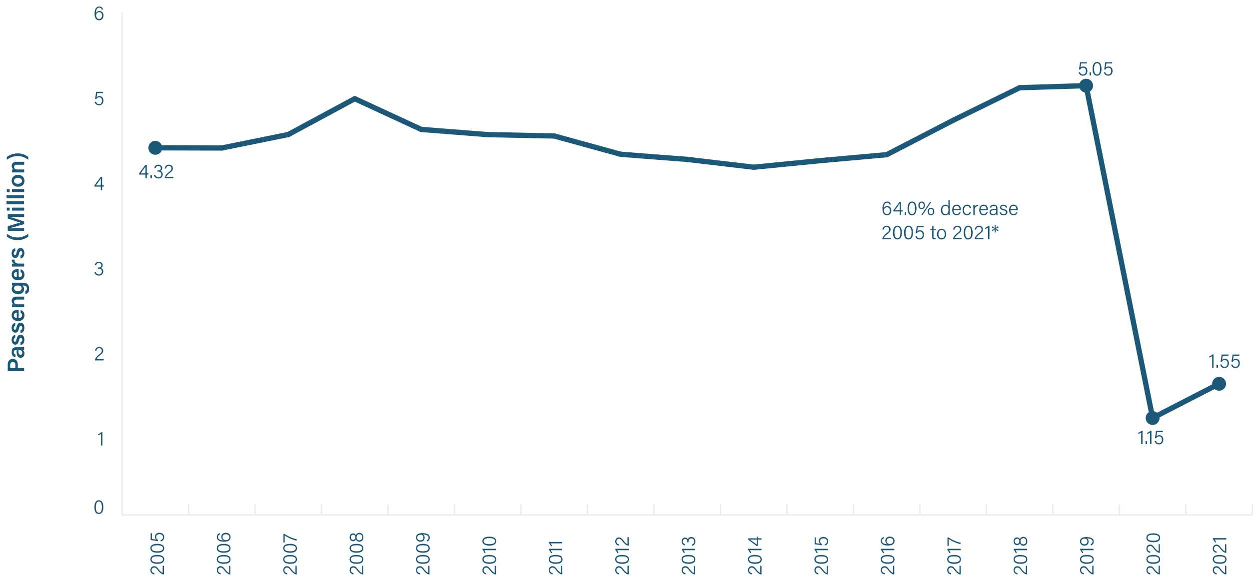
3.2 PASSENGER TRAFFIC HANDLED

3.2.1 INTERCITY PASSENGER SERVICES

Intercity passenger traffic in 2021 totaled 1.55 million passengers, compared to 1.15 million passengers in 2020, an increase of 35.5%, and a 64.0% decrease from 4.32 million passengers in 2005 (Figure 4).

FIGURE 4 INTERCITY RAIL PASSENGER TRAFFIC, 2005-2021



* In 2020 and 2021, passenger rail performance metrics were significantly impacted by the COVID-19 pandemic.

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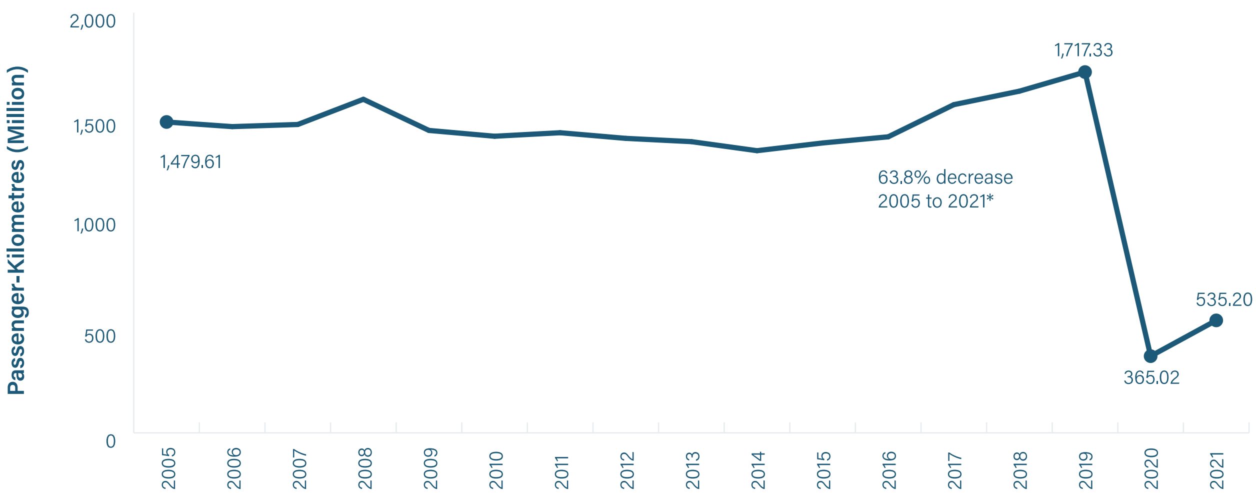
The total revenue passenger-kilometres (RPK) for intercity passenger traffic totaled 535.20 million. This is an increase of 46.6% compared to 365.02 million in 2020 and 63.8% decrease from 1,479.61 million in 2005 (Figure 5).

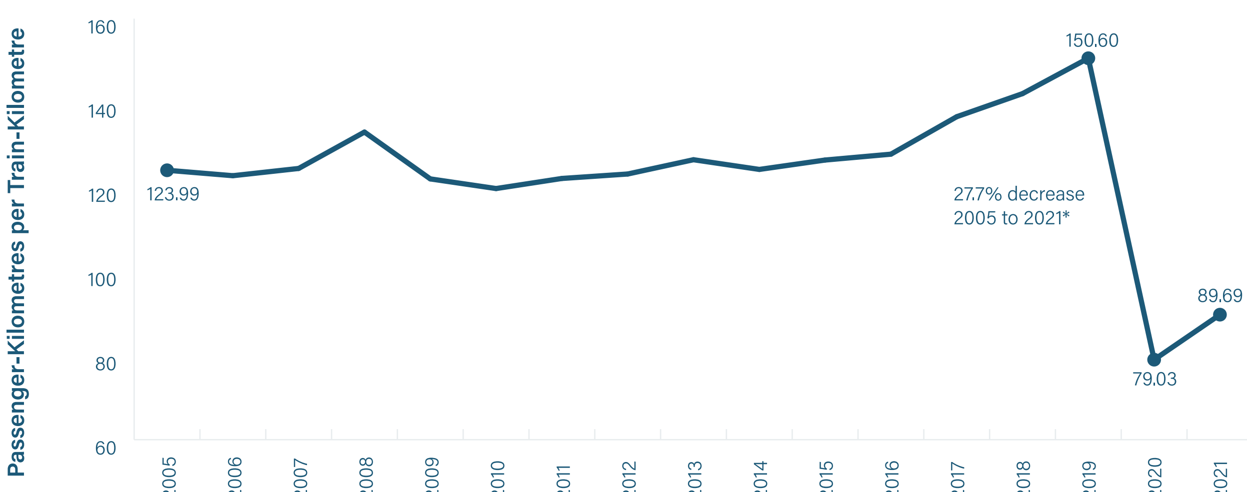
FIGURE 5 INTERCITY RAIL REVENUE PASSENGER-KILOMETRES, 2005-2021



* In 2020 and 2021, passenger rail performance metrics were significantly impacted by the COVID-19 pandemic.

Intercity train efficiency is expressed in terms of average passenger-kilometres (km) per train-km. As shown in Figure 6, intercity rail train efficiency in 2021 was 89.69 passenger-km per train-km, 79.03 in 2020, and 123.99 in 2005. As a percentage, train efficiency in 2021 was 27.7% below that in 2005. The decrease in intercity rail train efficiency (compared to 2019 and earlier) is because there were fewer passengers per train, as a result of COVID-19 restrictions and reduction in overall travel. However, as seen in Figure 6, intercity rail efficiency improved in 2021 compared to 2020 with an increase in ridership.

FIGURE 6 INTERCITY RAIL TRAIN EFFICIENCY, 2005-2021



* In 2020 and 2021, passenger rail performance metrics were significantly impacted by the COVID-19 pandemic.

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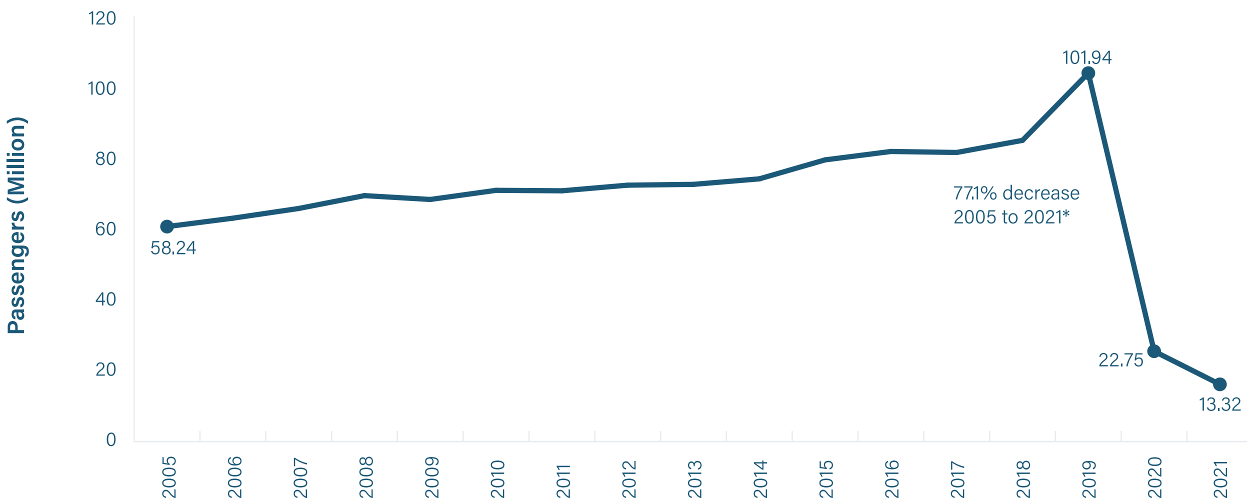
3.2.2 COMMUTER RAIL

In 2021, commuter rail passengers totaled 13.32 million (Figure 7). This is down from 22.75 million in 2020, a decrease of 41.5%.[17] Commuter railways continued to provide essential transportation services, and with a decreased number of passengers per train, efficiency metrics for commuter railways worsened in 2021. As shown in Figure 7, by 2021, commuter traffic decreased 77.1% below the 2005 base year level of 58.24 million passengers. The commuter operations in Canada using diesel locomotives and/or diesel multiple units (DMUs) are exo serving the Montreal-centred region (previously Reseau de transport metropolitain), Capital Railway serving Ottawa,[18] Metrolinx serving the Greater Toronto Area, and West Coast Express serving the Vancouver-Lower Fraser Valley region.

FIGURE 7 COMMUTER RAIL PASSENGERS, 2005-2021



* In 2020 and 2021, passenger rail performance metrics were significantly impacted by the COVID-19 pandemic.

3.3.3 TOURIST AND EXCURSION SERVICES

Tourist and excursion services were significantly impacted by COVID-19. Following closures in 2020, several tourist and excursion railways reopened for passenger service in 2021.

17 The significant decrease in commuters in 2020 is due to an unprecedented drop in ridership on commuter rail services compared to 2019, as a consequence of the COVID-19 pandemic.

18 Capital Railway's DMUs were not in operation in 2021 due to construction of the expanded passenger rail service.

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4. FUEL CONSUMPTION DATA

Total rail sector fuel consumption in 2021 was 2,033.33 million litres—a 2.8% decrease from 2020 and an 8.0% decrease from 2005. In 2021, freight operations consumed 1,959.44 million litres of fuel—a 7.0% decrease from 2,107.90 in 2005. Over this same period (2005–2021), freight traffic (RTKs) increased by 25.5%, resulting in a 25.9% improvement in freight fuel efficiency. Passenger rail operations increased fuel consumption by 6.2% in 2021 compared to 2020, to accommodate a slight increase in ridership levels since the onset of COVID-19 pandemic.

Fuel consumption was lower in 2021 compared to 2020. Of the total fuel consumed by all railway operations, Class 1 and regional & shortline operations consumed 93.6%, yard switching and work train operations consumed 2.7%, and passenger operations accounted for 3.6%. For total freight train operations fuel consumption, Class 1 railways accounted for 91.7%, regional & shortlines 5.4%, and yard switching and work trains 2.9%.

TABLE 3 CANADIAN RAIL OPERATIONS FUEL CONSUMPTION, 2005, 2012–2021 (MILLION LITRES)

	2005	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Class 1 Freight	1,893.19	1,875.85	1,849.57	1,918.27	1,852.98	1,732.20	1,864.83	1,949.92	1,950.71	1,857.42	1,796.77
Regional & Shortline	140.13	96.55	101.72	108.91	105.45	101.83	114.15	111.88	111.99	108.69	106.56
Yard Switching	67.85	46.85	41.77	62.02	52.97	46.95	50.29	51.56	51.71	46.81	47.07
Work Train	6.73	8.77	10.30	10.80	11.35	10.84	10.01	7.10	9.94	8.41	9.04
Total Freight Operations	**2,107.90**	**2,028.01**	**2,003.36**	**2,100.00**	**2,022.75**	**1,891.82**	**2,039.28**	**2,120.46**	**2,124.35**	**2,021.34**	**1,959.44**
Intercity*	64.05	50.99	46.17	44.89	46.98	47.93	51.02	52.77	51.05	21.74	26.15
Commuter*	35.31	50.22	48.61	49.67	60.50	59.43	64.46	65.74	79.53	47.85	47.28
Tourist/ Excursion*	1.74	2.27	2.25	2.61	2.65	2.79	3.22	3.22	4.30	0.00	0.46
Total Passenger Operations*	**101.10**	**103.48**	**97.03**	**97.16**	**110.13**	**110.15**	**118.70**	**121.72**	**134.89**	**69.60**	**73.89**
Total Rail Operations	**2,209.00**	**2,131.49**	**2,100.39**	**2,197.17**	**2,132.88**	**2,001.97**	**2,157.98**	**2,242.19**	**2,259.24**	**2,090.94**	**2,033.33**

* In 2020 and 2021, passenger rail performance metrics were significantly impacted by the COVID-19 pandemic.

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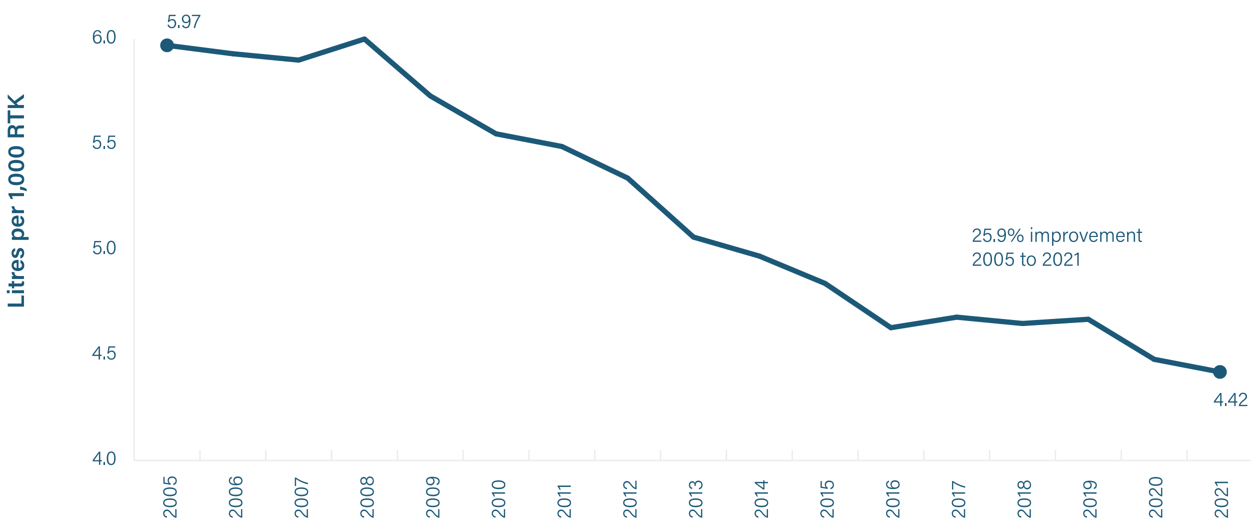
4.1 FREIGHT OPERATIONS

Fuel consumption in 2021 for all freight train, yard switching, and work train operations was 1,959.44 million litres, a decrease of 3.1% from the 2,021.34 million litres consumed in 2020 and a decrease of 7.0% 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 2021 railways moved one tonne of freight approximately 226 kilometres on just one litre of fuel.

The amount of fuel consumed per 1,000 RTK can be used as a measure of freight traffic fuel efficiency. As shown in Figure 8, the value in 2021 for overall rail freight traffic was 4.42 litres per 1,000 RTK. This value is a 1.2% decrease from the 4.48 L/1,000 RTK in 2020 and 25.9% below (i.e., improved efficiency) the 2005 level of 5.97 L/1,000 RTK. The improvement since 2005 shows the ability of Canadian freight railways to accommodate traffic growth while reducing fuel consumption per unit of work.

FIGURE 8 FREIGHT FUEL EFFICIENCY, 2005-2021



Note: Includes yard switching and work train 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 that reduce fuel consumption have been implemented, and new strategies are emerging to accommodate specific commodities, their respective weight, and destination. 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.

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4.2 PASSENGER SERVICES

Overall passenger rail fuel consumption—that is the sum of intercity, commuter, and tourist and excursion train operations—was 73.89 million litres in 2021, an increase of 6.2% from the 69.60 million litres consumed in 2020. The increase in passenger rail fuel consumption is largely due to growth in intercity operations and some tourist and excursion train operations reopening since the onset of the COVID-19 pandemic. The breakdown and comparison with previous years is provided in Table 3.

Intercity passenger rail fuel consumption increased by 20.2% from 21.74 million litres in 2020 to 26.15 million litres in 2021. Fuel consumption for commuter rail decreased by 1.2% from 47.85 million litres in 2020 to 47.28 million litres in 2021. Lastly, tourist and excursion rail fuel consumption increased to 0.46 million litres in 2021 from zero in 2020.

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). Renewable fuel content for diesel fuel sold and imported in Canada is also regulated by the *Renewable Fuels Regulations*, mandating at least 2% biodiesel and/or HDRD content. In 2021, some provinces, such as Ontario, British Columbia, and Manitoba required a minimum renewable fuel content above 2%.[19]

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

19 For some provinces, renewable fuel requirements are planned to become more stringent in the coming years (e.g., Manitoba increased to 3.5% in 2021 and will increase to 5.0% in 2022; Québec is increasing the low-carbon fuel content in diesel to 3% in 2023 and 10% in 2030).

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5. LOCOMOTIVE INVENTORY

5.1 FLEET OVERVIEW

Table 4 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 4 CANADIAN LOCOMOTIVE FLEET SUMMARY, 2021

	Locomotives	Share of Fleet
Line Haul: Class 1	2,437	67.6%
Line Haul: Regional	137	3.8%
Line Haul: Shortline*	227	6.3%
Freight Switching Operations	551	15.3%
Total Freight Operations	**3,352**	**92.9%**
Passenger Locomotives	230	6.4%
Passenger DMUs	24	0.7%
Total Passenger Operations	**254**	**7.0%**
Total Rail Operations	**3,606**	**100.0%**

Note: numbers include all active fleet equipment.
* The number of line haul shortline locomotives in 2021 was much higher than in 2020, as a result of a methodology change from a reporting member.

5.2 LOCOMOTIVES MEETING EMISSION STANDARDS

Locomotives operated by federally regulated railways are subject to the emission standards set out under the LER, which came into force on June 9, 2017. These emission standards align with US EPA emissions standards. The RAC's member railways that are not federally regulated will continue to be encouraged to meet the emission standards.

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

Table 5 shows the total number of in-service locomotives meeting emission standards[20] compared to the total number of active freight and passenger locomotives. Because 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.

20 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 5 LOCOMOTIVES IN CANADIAN FLEET MEETING EMISSION STANDARDS, 2005, 2012–2021

	2005	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Number of freight and passenger locomotives meeting an emission standard	888	1,512	1,631	1,538	1,266	1,267	2,157	2,995	2,982	3,108	2,989
Number of freight and passenger locomotives in Canadian Fleet	2,986	3,092	3,063	2,700	2,400	2,318	3,177	3,782	3,840	3,756	3,606
Percentage of locomotives meeting an emission standard	29.7%	48.9%	53.2%	57.0%	52.8%	54.7%	67.9%	79.2%	77.7%	82.7%	82.9%

Note: 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 emission standards under the MOU.

Note: 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 emissions standards. Locomotives become new when they are freshly manufactured, remanufactured, upgraded or imported.

In 2021, 82.9% of the fleet (2,989 locomotives of 3,606) met emission standards (set-out under the LER or the US EPA regulations).

Table 6 provides an overview of the 2021 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 2021. It also presents the number of locomotives with anti-idling devices.

TABLE 6 LOCOMOTIVE FLEET BREAKDOWN BY TIER LEVEL, 2021

Tier Level*	Locomotives		Locomotives with anti-idling devices	Added	Retired	Remanufactured
	Number	Percent of fleet				
Elec/Steam/Other	6	0.2%	—	—	—	—
No Tier	611	16.9%	290	—	24	—
Tier 0	190	5.3%	140	1	4	—
Tier 0+	716	19.9%	653	1	98	2
Tier 1	28	0.8%	26	5	—	—
Tier 1+	638	17.7%	629	2	31	30
Tier 2	178	4.9%	109	—	—	—
Tier 2+	480	13.3%	477	—	2	—
Tier 3	454	12.6%	442	71	—	1
Tier 4	305	8.5%	268	—	6	—
Total	**3,606**	**100.0%**	**3,034**	**80**	**165**	**33**

*See *Appendix D* for additional information regarding tier levels.

In 2021, 80 locomotives were added to the Canadian fleet, including one Tier 0, one Tier 0+, five Tier 1, two Tier 1+, and 71 Tier 3 locomotives. A total of 33 locomotives were remanufactured (upgraded); two to Tier 0+, 30 to Tier 1+, and one to Tier 3; and 165, 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, reducing engine activity and therefore emissions. The number of locomotives in 2021 equipped with a device to minimize unnecessary idling, such as an AESS system or APU, was 3,034, which represents 84.1% of the fleet, compared to 3,109 in 2020 (82.8% of the fleet).

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6. LOCOMOTIVE EMISSIONS

6.1 GREENHOUSE GASES

6.1.1 EMISSION FACTORS FOR GREENHOUSE GASES

The emission factors (EFs) and global warming potentials used to calculate GHGs emitted from diesel locomotive engines (i.e., CO_2, CH_4, and N_2O) are the same factors used by ECCC to create the National Inventory Report 1990–2021: Greenhouse Gas Sources and Sinks in Canada, which is submitted annually to the United Nations Framework Convention on Climate Change (UNFCCC).[21]

Table 7 presents the 2021 GHG EFs for diesel locomotives.

The methodology document describing the calculation of GHG and CAC EFs referenced in the sections below is available upon request to the RAC.

TABLE 7 GHG EMISSIONS FACTORS FOR DIESEL LOCOMOTIVES, 2021

	Emissions Factors (kg/L)	Global Warming Potential
CO_2	2.6805	1
CH_4	0.000149	25
N_2O	0.001029	298
CO_2e	**2.990867**	**Not Applicable**

Note: Hydrofluorocarbons (HFC), Perfluorocarbons (PFC), and Sulphur hexafluoride (SF6) are not present in diesel fuel.
Source: National Inventory Report 1990–2021: Greenhouse Gas Sources and Sinks in Canada, Environment and Climate Change Canada, 2023.

21 National Inventory Report 1990–2021: Greenhouse Gas Sources and Sinks in Canada, Environment and Climate Change Canada, 2023.

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6.1.2 GREENHOUSE GAS EMISSIONS

In 2021, GHG emissions produced by the railway sector (expressed as CO_2e) were 6,081.41 kt, a decrease of 2.8% as compared to 6,253.72 kt in 2020. The 2021 emissions represent an 8.0% decrease from 6,606.83 kt in 2005 (despite a rise in RTK traffic of 25.5% over the same period).

Table 8 displays the GHG emissions produced in 2005 and annually since 2012; and Figure 9 presents the annual trend graphically. The GHG emissions for years prior to 2012 are available upon request to the RAC.

TABLE 8 GHG EMISSIONS BY RAILWAY SERVICE IN CANADA, 2005, 2012-2021 (KILOTONNES)

	2005	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
LINE HAUL FREIGHT											
CO_2	5,450.31	5,287.00	5,230.42	5,433.86	5,249.57	4,916.11	5,304.66	5,526.65	5,529.07	5,270.18	5,101.87
CH_4	7.57	7.35	7.27	7.55	7.30	6.83	7.37	7.68	7.68	7.32	7.09
N_2O	623.50	604.82	598.35	621.62	600.54	562.39	606.84	632.23	632.51	602.89	583.64
CO_2e	**6,081.39**	**5,899.17**	**5,836.04**	**6,063.03**	**5,857.41**	**5,485.34**	**5,918.87**	**6,166.57**	**6,169.26**	**5,880.40**	**5,692.60**
YARD SWITCHING AND WORK TRAIN											
CO_2	199.91	149.09	139.58	195.20	172.41	154.91	161.64	157.25	165.27	148.03	150.41
CH_4	0.28	0.21	0.19	0.27	0.24	0.22	0.22	0.22	0.23	0.21	0.21
N_2O	22.87	17.05	15.97	22.33	19.72	17.72	18.49	17.99	18.91	16.93	17.21
CO_2e	**223.06**	**166.35**	**155.74**	**217.80**	**192.37**	**172.85**	**180.36**	**175.45**	**184.40**	**165.17**	**167.82**
TOTAL FREIGHT OPERATIONS											
CO_2	5,650.22	5,436.09	5,370.00	5,629.06	5,421.98	5,071.03	5,466.30	5,683.90	5,694.33	5,418.21	5,252.28
CH_4	7.85	7.55	7.46	7.82	7.53	7.05	7.60	7.90	7.91	7.53	7.30
N_2O	646.37	621.87	614.31	643.95	620.26	580.11	625.33	650.22	651.42	619.83	600.85
CO_2e	**6,304.45**	**6,065.52**	**5,991.78**	**6,280.83**	**6,049.78**	**5,658.18**	**6,099.22**	**6,342.02**	**6,353.66**	**6,045.57**	**5,860.42**
TOTAL PASSENGER OPERATIONS*											
CO_2	271.00	277.38	260.09	260.45	295.20	295.25	318.17	326.28	361.56	186.55	198.05
CH_4	0.38	0.39	0.36	0.36	0.41	0.41	0.44	0.45	0.50	0.26	0.28
N_2O	31.00	31.73	29.75	29.79	33.77	33.78	36.40	37.33	41.36	21.34	22.66
CO_2e	**302.38**	**309.50**	**290.21**	**290.60**	**329.38**	**329.44**	**355.01**	**364.06**	**403.43**	**208.15**	**220.98**
TOTAL RAIL OPERATIONS											
CO_2	5,921.23	5,713.47	5,630.10	5,889.51	5,717.19	5,366.28	5,784.47	6,010.18	6,055.90	5,604.76	5,450.33
CH_4	8.23	7.94	7.82	8.18	7.94	7.46	8.04	8.35	8.42	7.79	7.57
N_2O	677.37	653.61	644.07	673.74	654.03	613.89	661.73	687.55	692.78	641.17	623.50
CO_2e	**6,606.83**	**6,375.02**	**6,281.99**	**6,571.44**	**6,379.16**	**5,987.62**	**6,454.24**	**6,706.08**	**6,757.09**	**6,253.72**	**6,081.41**

*In 2020 and 2021, passenger rail performance metrics were significantly impacted by the COVID-19 pandemic.

Note: GHG emissions for all years have been calculated based on the emissions factors and global warming potentials in the 2023 National Inventory Report. Historical values have been updated.

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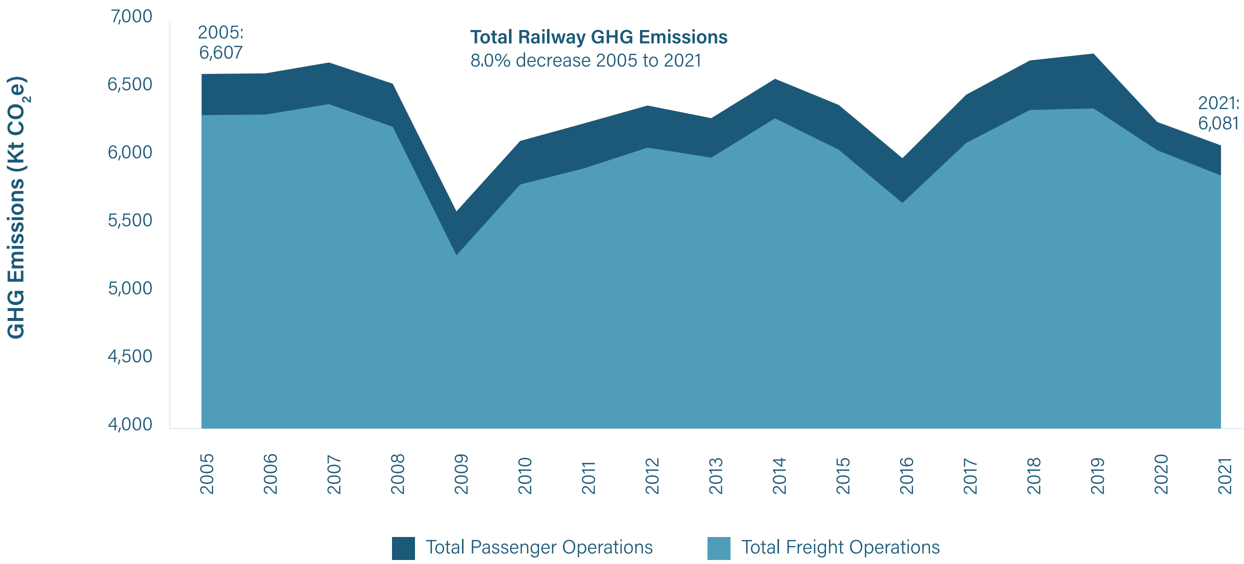
FIGURE 9 GHG EMISSIONS 2005-2021



The MOU sets out targets to be achieved in 2022 for GHG emissions intensities by category of railway operation (Class 1 freight, regional & shortline freight, and intercity passenger). Table 9 shows the 2021 GHG emissions intensity levels for these categories, as well as for commuter rail.

TABLE 9 GHG EMISSIONS INTENSITIES BY RAILWAY SERVICE IN CANADA, 2005, 2012-2021

	2005	2012	2013	2014	2015	2016	2017 (MOU Baseline)	2018	2019	2020	2021	2022 (Target)
Total Freight Operations (kg CO_2e/1,000 RTK)	17.86	15.96	15.13	14.87	14.47	13.85	14.01	13.92	13.96	13.38	13.23	No Target
Class 1 Freight (kg CO_2e/1,000 RTK)	17.25	15.72	14.88	14.36	14.06	13.51	13.56	13.45	13.49	12.91	12.76	12.75
Regional & Shortline Freight (kg CO_2e/1,000 RTK)	16.99	12.51	12.56	14.15	13.15	12.16	14.08	15.02	14.77	15.27	14.66	13.66
Intercity Passenger (kg CO_2e/Passenger-km)*	0.13	0.109	0.100	0.100	0.102	0.102	0.098	0.097	0.089	0.178	0.146	0.092
Commuter Rail (kg CO_2e/Passenger)*	1.81	2.10	2.02	1.96	2.34	2.23	2.43	2.37	2.33	6.29	10.62	No Target

* In 2020 and 2021, passenger rail performance metrics were significantly impacted by the COVID-19 pandemic.

Note: GHG emissions for all years have been calculated based on the emissions factors and global warming potentials in the 2023 National Inventory Report. Historical values have been updated.

The GHG emissions intensities for total freight traffic (which includes yard switching and work train operations) decreased in 2021 by 1.2% to 13.23 kg CO_2e/1,000 RTK from 13.38 kg CO_2e/1,000 RTK in 2020. Since 2005, the GHG emissions intensity for total freight has decreased 25.9% from 17.86 kg CO_2e/1,000 RTK. Class 1 freight saw a 1.2% decrease in GHG emissions intensity from 12.91 kg CO_2e/1,000 RTK in 2020 to 12.76 kg CO_2e/1,000 RTK in 2021. Regional and shortline freight emissions intensity decreased from 15.27 kg CO_2e/1,000 RTK in 2020 to 14.66 kg CO_2e/1,000 RTK in 2021. Emissions intensity for intercity passenger rail decreased by 18.0% to 0.146 kg CO_2e/1,000 RTK compared to 2020. Commuter rail operations was the only category where emissions intensities increased, by 68.8% to 10.62 kg CO_2e/1,000 RTK in 2021, which was largely a consequence of lower ridership.

Figure 10 shows the trend in GHG emissions intensities for freight and intercity passenger rail, since 2005.

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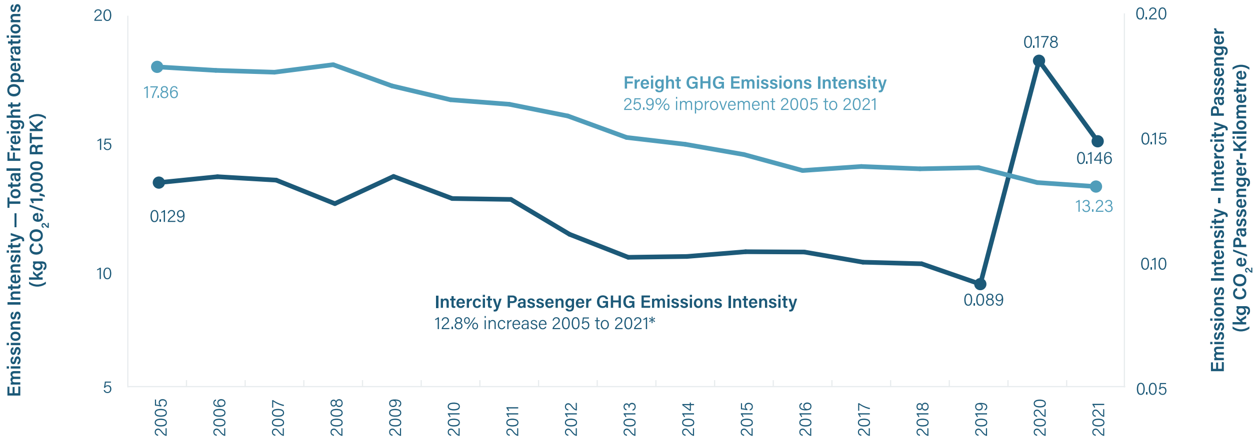
FIGURE 10 GHG EMISSIONS INTENSITIES, 2005–2021



* In 2020 and 2021, passenger rail performance metrics were significantly impacted by the COVID-19 pandemic.

6.2 CRITERIA AIR CONTAMINANTS

6.2.1 EMISSION FACTORS FOR CRITERIA AIR CONTAMINANT EMISSIONS

CAC EFs for 2021 have been 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). As railways continued to upgrade their fleets with higher tiered locomotives, all freight line haul CAC EFs decreased in 2021 compared to 2020, except for SO_2 (the EF for SO_2 is identical for each tier of locomotive). EFs for yard operations stayed the same or decreased in 2021 compared to 2020, while EFs for passenger operations stayed the same or increased. The increase in passenger sector EFs compared to 2020 can be explained by non-tiered tourism locomotives coming back on line, as well as a higher share of total passenger fuel consumed in intercity operations relative to commuter operations (the commuter fleet is generally higher-tiered than the intercity fleet).

The CAC EFs are estimated based on the active fleet on December 31.

The EFs to calculate emissions of SO_x (calculated as SO_2) are based on the sulphur content of the diesel fuel. The CAC EFs are listed in Table 10 for 2005 and 2012–2021. EFs for years prior to 2012 are available upon request to the RAC.

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TABLE 10 CAC EMISSIONS FACTORS FOR DIESEL LOCOMOTIVES, 2005, 2012-2021 (g/L)

Year	NO_x	PM_{10}	CO	HC	SO_2
LINE HAUL FREIGHT					
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
2013	44.41	1.01	7.05	2.00	0.02
2012	46.09	1.09	7.05	2.13	0.07
2005	56.12	1.54	6.97	2.56	2.25
YARD SWITCHING AND WORK TRAIN					
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
2013	68.79	1.50	7.35	4.01	0.02
2012	69.19	1.52	7.35	4.03	0.07
2005	69.88	1.64	7.35	4.06	2.25
TOTAL PASSENGER OPERATIONS					
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
2013	51.64	1.06	7.03	2.03	0.02
2012	54.04	1.13	7.03	2.17	0.07
2005	71.44	1.58	7.03	2.64	2.25

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6.2.2 CRITERIA AIR CONTAMINANT EMISSIONS

Table 11 displays the CAC emissions produced annually by locomotives in operation in Canada for the reference year (2005) and annually from 2012 to 2021, namely NO_x, PM_{10}, CO, HC, and SO_2. The values presented are for both absolute amounts and intensities per productivity unit. The emissions and intensities for years before 2021 are available upon request to the RAC.

The CAC of key concern for the railway sector is NO_x.[22] As shown in Table 11, NO_x emissions in 2021 for total railway operations was 66.50 kt, down 5.9% from 70.70 kt in 2020. Freight operations accounted for 95.3% of railway-generated NO_x emissions in Canada.

The total freight NO_x emissions intensity (i.e., the quantity of NO_x emitted per unit of productivity) was 0.14 kg per 1,000 RTK in 2021, a 4.8% decrease from 2020. Total freight NO_x emissions intensity has decreased by 57.7% since 2005 (0.34 kg per 1,000 RTK).

22 NO_x is one of the most harmful CACs that can lead to the formation of smog and acid rain and has been linked to adverse health impacts.

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TABLE 11 LOCOMOTIVE CAC EMISSIONS, 2005, 2012-2021 (KILOTONNES, UNLESS OTHERWISE SPECIFIED)

Year	NO_x	PM_{10}	CO	HC	SO_2 (tonnes)
LINE HAUL FREIGHT					
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
2013	86.65	1.98	13.76	3.90	48.09
2012	90.91	2.14	13.91	4.20	129.97
2005	114.12	3.13	14.18	5.21	4,580.20
YARD SWITCHING AND WORK TRAIN					
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
2013	3.58	0.08	0.38	0.21	1.28
2012	3.85	0.08	0.41	0.22	3.66
2005	5.21	0.12	0.55	0.30	168.00
TOTAL FREIGHT OPERATIONS[1]					
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
2013	90.23	2.05	14.14	4.11	49.37
2012	94.75	2.23	14.32	4.42	133.63
2005	119.33	3.25	14.73	5.52	4,748.19

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TABLE 11 LOCOMOTIVE CAC EMISSIONS, 2005, 2012-2021 (KILOTONNES, UNLESS OTHERWISE SPECIFIED)

Year	NO_x	PM_{10}	CO	HC	SO_2 (tonnes)
TOTAL PASSENGER OPERATIONS*					
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
2013	4.95	0.10	0.67	0.19	2.12
2012	5.51	0.12	0.72	0.22	6.72
2005	7.18	0.16	0.71	0.26	226.29
TOTAL RAIL OPERATIONS(2)					
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
2013	95.19	2.16	14.82	4.30	51.50
2012	100.26	2.34	15.03	4.64	140.35
2005	126.50	3.41	15.43	5.78	4,974.49
TOTAL FREIGHT EMISSIONS INTENSITY (KG/1,000 RTK)					
2021	0.14	0.0028	0.0309	0.0056	0.00011
2020	0.15	0.0030	0.0313	0.0060	0.00011
2019	0.16	0.0033	0.0327	0.0065	0.00012
2018	0.16	0.0037	0.0327	0.0074	0.00011
2017	0.17	0.0035	0.0330	0.0072	0.00012
2016	0.18	0.0037	0.0327	0.0075	0.00011
2015	0.20	0.0040	0.0345	0.0085	0.00012
2014	0.21	0.0046	0.0352	0.0094	0.00012
2013	0.23	0.0052	0.0357	0.0104	0.00012
2012	0.25	0.0059	0.0377	0.0116	0.00035
2005	0.34	0.0092	0.0417	0.0156	0.01345

* In 2020 and 2021, passenger rail performance metrics were 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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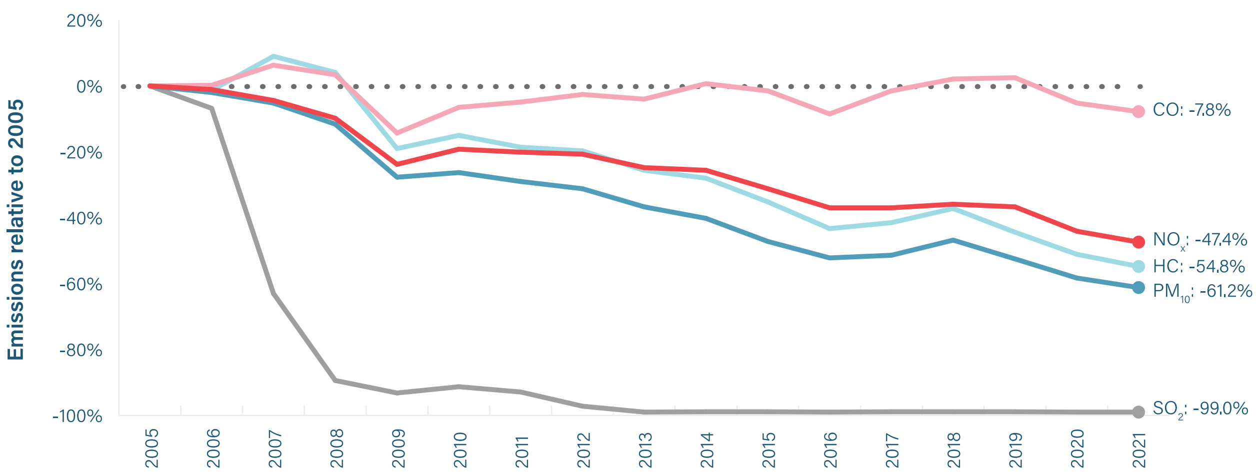
Figure 11 shows the reductions in CAC emissions from total railway operations in Canada, since 2005. Despite a general increase in traffic over this time, CAC emissions have decreased for CO (-7.8%), NO_x (-47.4%), HC (-54.8%), PM_{10} (-61.2%), and SO_2 (-99.0%).

Within the methodology for calculating CAC emissions, the CO emissions factors are constant across tier levels (see Table 10). 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 available upon request.

Similarly, within the methodology for calculating SO_2 emissions, since 2013, the SO_2 emissions factor has been constant as Canadian railways have been using ULSD. As such, the reductions in SO_2 since 2013 are driven by reductions in locomotive diesel fuel consumption.

FIGURE 11 CAC EMISSIONS, 2005-2021



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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, Montréal, Trois-Rivières, and Québec City.

TOMA No. 3

The Saint John TOMA is represented by the 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

The fuel consumption in each TOMA region is derived from the total traffic in the area as provided by the railways. Table 12 shows the fuel consumption and the GHG emissions in the TOMA regions as a percentage of the total fuel consumption for all rail operations in Canada and as a percentage of total railway CO_2e. Table 13 shows NO_x emissions in the TOMA regions as a percentage of the total NO_x emissions for all rail operations.

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TABLE 12 TOMA PERCENTAGES OF TOTAL FUEL CONSUMPTION AND GHG EMISSIONS, 2005, 2012-2021

	2005	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Lower Fraser Valley, B.C.	3.2	2.9	2.9	2.2	2.3	2.5	2.4	2.3	2.4	2.3	2.4
Québec City-Windsor Corridor	17.4	14.3	14.2	14.1	14.1	14.0	13.8	13.0	13.5	11.5	12.3
Saint John, N.B.	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.2

TABLE 13 TOMA PERCENTAGES OF TOTAL NO_x EMISSIONS, 2005, 2012-2021

	2005	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Lower Fraser Valley, B.C.	3.2	2.9	2.9	2.3	2.3	2.5	2.4	2.3	2.4	2.3	2.4
Québec City-Windsor Corridor	17.9	14.4	14.2	14.1	14.1	14.0	13.8	13.0	13.5	11.5	12.3
Saint John, N.B.	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.2

The emissions of GHGs for the TOMA regions were calculated using the respective GHG emissions factors as discussed in Section 6.1 and the fuel consumption data available for each TOMA region.

The CAC emission factors and emissions for the TOMA regions were calculated based on the total fuel usage for each region. The emission factors for each CAC presented for these three regions is a weighted average of the calculated freight, switch, and passenger EFs, as presented in Section 6.1, and based on the reported passenger and freight fuel usage. Since the freight fuel usage includes both the freight train fuel usage and the switching fuel usage, the percentage of fuel allocated for these TOMA regions to switching was based on the percentage of fuel used Canada-wide. Once these weighted CAC emission factors were derived, the emissions for each CAC were calculated by multiplying the EFs by the fuel usage for each TOMA region.

7.2 SEASONAL DATA

The emissions in each TOMA have been split according to two seasonal periods:

- Winter (seven months): January to April and October to December, inclusively.
- Summer (five months): May to September, inclusively.

The division of traffic in the TOMA regions in the seasonal periods was taken as equivalent to that on the whole system for each railway. The fuel consumption in each of the TOMA was divided by the proportion derived for the traffic on each railway. For TOMA No. 1, it was assumed that 50% of the fuel consumption for B.C. tourism operators was applicable to this region. The 2021 traffic, fuel consumption, and emissions data in the seasonal periods for each railway are summarized in Table 14.

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TABLE 14 TROPOSPHERIC OZONE MANAGEMENT AREAS, 2021

	TOMA No.1— Lower Fraser Valley, B.C.			TOMA No.2—Québec City-Windsor Corridor			TOMA No.3 - Saint John Area, New Brunswick		
	Seasonal Split			Seasonal Split			Seasonal Split		
	Total 100%	Winter 58%	Summer 42%	Total 100%	Winter 58%	Summer 42%	Total 100%	Winter 58%	Summer 42%
TRAFFIC (MILLION GTK)									
CN	13,347	7,741	5,606	57,145	33,144	24,001	794	460	333
CP	6,375	3,697	2,677	20,756	12,038	8,717	—	—	—
Regional & Shortline	200	116	84	1,444	838	607	1,072	622	450
Total Freight Traffic	**19,922**	**11,554**	**8,367**	**79,345**	**46,020**	**33,325**	**1,866**	**1,082**	**784**
FUEL CONSUMPTION (MILLION LITRES) FREIGHT FUEL RATE (L/1,000 GTK) = 2.35[1]									
Total Freight Fuel Consumption	**46.85**	**27.17**	**19.68**	**186.60**	**108.23**	**78.37**	**4.39**	**2.55**	**1.84**
Passenger Fuel Consumption: **Intercity Passenger**	0.17	0.10	0.07	17.49	10.14	7.35	—	—	—
Passenger Fuel Consumption: **Tourism/Excursion**	0.22	0.13	0.09	—	—	—	—	—	—
Passenger Fuel Consumption: **Commuter**	0.77	0.45	0.32	46.51	26.97	19.53	—	—	—
Total Passenger Fuel Consumption	**1.17**	**0.68**	**0.49**	**64.00**	**37.12**	**26.88**	**0.00**	**0.00**	**0.00**
Total Rail Fuel Consumption	**48.01**	**27.85**	**20.17**	**250.59**	**145.34**	**105.25**	**4.39**	**2.55**	**1.84**

EMISSIONS

		Emission Factors (g/L)[2]	Kilotonnes/Year			Kilotonnes/Year			Kilotonnes/Year		
CACs	**NO_x**	**32.70**	1.57	0.91	0.66	8.20	4.75	3.44	0.14	0.08	0.06
CACs	**PM_{10}**	**0.65**	0.03	0.02	0.01	0.16	0.09	0.07	0.00	0.00	0.00
CACs	**CO**	**7.00**	0.34	0.19	0.14	1.75	1.02	0.74	0.03	0.02	0.01
CACs	**HC**	**1.29**	0.06	0.04	0.03	0.32	0.19	0.14	0.01	0.00	0.00
CACs	**SO_2**	**0.02**	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
GHGs[3]	**CO_2**	**2,680.50**	128.70	74.65	54.05	671.71	389.59	282.12	11.76	6.82	4.94
GHGs[3]	**CH_4**	**3.73**	0.18	0.10	0.08	0.93	0.54	0.39	0.02	0.01	0.01
GHGs[3]	**N_2O**	**306.64**	14.72	8.54	6.18	76.84	44.57	32.27	1.35	0.78	0.57
GHGs[3]	**CO_2e**	**2,990.87**	143.60	83.29	60.31	749.49	434.70	314.79	13.12	7.61	5.51

(1) The freight fuel rate has been calculated by dividing the total Canadian freight fuel usage (see *Table 3*) by the total Canadian freight GTK (see *Table 1*). In 2021, the Freight Fuel Rate was 2.35 litres per 1,000 GTK.
(2) The emissions factors used in the emissions calculations are a weighted average of the overall freight, yard and passenger emissions 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: 25; N_2O: 298)

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8. SUMMARY AND CONCLUSIONS

The 2021 Locomotive Emissions Monitoring Report highlights that 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 are looking ahead and establishing partnerships with government, academia, and industry stakeholders to advance the development of alternative propulsion and other zero-emission technologies in support of the transition to a more sustainable future.

GHG emissions reductions in year four of the MOU have demonstrated progress towards MOU targets for each category of railway operations with targets. As with the previous MOU (2011–2017), commuter railways do not have an intensity target, but continue to report on performance and efforts to reduce GHG emissions intensity. Similarly, as with previous MOUs, CAC emissions are reported and RAC continues to encourage its members to improve their CAC emissions performance.

The rail industry's performance against the GHG emission targets for 2022 are set out in the following table, which includes the 2017 baseline data and annual emissions from 2018 to 2021 (expressed as kilograms of CO_2e per productivity unit).

GHG EMISSIONS INTENSITY AND MOU PROGRESS BY RAILWAY OPERATION

Railway Operation	Productivity Units	Baseline—2017	2018	2019	2020	2021	Change from 2017–2021	Change from 2020–2021	2022 Target	Progress to 2022 Target
Class I Freight	kg CO_2e per 1,000 RTK	13.56	13.45	13.49	12.91	12.76	-5.94%	-1.16%	12.75 (6% reduction)	99.01% progress to target
Intercity Passenger*	kg CO_2e per passenger-km	0.098	0.097	0.089	0.178	0.146	49.58%	-17.99%	0.092 (6% reduction)	increase since 2017
Regional & Shortline	kg CO_2e per 1,000 RTK	14.08	15.02	14.77	15.27	14.66	4.13%	-3.98%	13.66 (3% reduction)	increase since 2017

Note: GHG emissions for all years have been calculated based on the emissions factors and global warming potentials in the 2023 National Inventory Report. Historical values have been updated.

Note: The final column of the table indicates the percentage of the MOU target that has been achieved as of 2021; an increase indicates that emissions intensity was higher in 2021 than in 2017.

*In 2020 and 2021, passenger rail performance metrics were significantly impacted by the COVID-19 pandemic.

Class 1 freight GHG emissions intensity decreased by 1.16% from 2020 to 2021. GHG emissions intensity continues to be lower than the 2017 baseline and represents 99.01% progress towards achieving the MOU target. Regional and shortline emissions intensity decreased by 3.98% from 2020 to 2021 and stood 4.13% above the 2017 baseline. GHG emissions intensity for total freight operations (including yard switching and work train) decreased by 1.16% from 13.38 kg CO_2e/1,000 RTK in 2020 to 13.23 kg CO_2e/1,000 RTK in 2021. Intercity passenger GHG emissions intensity decreased by 17.99% from 2020 to 2021 despite challenges associated with the COVID-19 pandemic,

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making some progress towards a return to the pre-pandemic normal.[23]

GHG emissions from all railway operations in Canada totaled 6,081.41.72 kt in 2021, which is a decrease of 2.8% from 6,253.72 kt in 2020.

CAC emissions from all railway operations decreased, with total locomotive NO_x emissions decreasing to 66.50 kt in 2021 from 70.70 kt in 2020. In 2021, the total freight NO_x emissions intensity decreased to 0.14 kg/1,000 RTK compared to 0.15 kg/1,000 RTK in 2020, a 57.7% improvement from 2005 levels (at 0.34 kg/1,000 RTK).

In 2021, Canadian railways added 80 locomotives to the fleet: one Tier 0, one Tier 0+, five Tier 1, two Tier 1+, and 71 Tier 3. In addition, 33 locomotives were remanufactured (upgraded): two to Tier 0+, 30 to Tier 1+, and one to Tier 3. Non-tier-level and lower-tier-level locomotives continue to be retired, and in 2021, 165 locomotives were taken out of active duty.

The Canadian fleet totaled 3,606 locomotives in 2021, of which 2,989 locomotives (82.9%) met an emissions standard (not all locomotives in Canada are required to meet emission standards). The number of locomotives equipped with APUs or AESS systems to minimize unnecessary idling totaled 3,034, or 84.1% of the in-service fleet.

Through continued progress on emissions reduction initiatives and partnerships, along with federal initiatives (e.g., Strengthened Climate Plan, Hydrogen Strategy, Clean Fuel Regulation, *Greenhouse Gas Pollution Pricing Act*, etc.), Canadian railways and the Government of Canada will continue their efforts to reduce GHG emissions in the railway sector.

This report meets the filing requirements for 2021.

23 Intercity rail train efficiency (passenger-kilometres per train-kilometre) decreased by 47.5% in 2020. With fewer passengers per train, emissions per passenger-kilometre increased in 2020.

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APPENDIX A

RAC MEMBER RAILWAYS PARTICIPATING IN THE 2018—2022 MOU BY PROVINCE

Railway	Province(s) of Operation
Alberta Prairie Railway Excursions	Alberta
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 Pacific	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 Lanaudiere Inc.	Québec
Canadian National Railway	British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Québec, New Brunswick, Nova Scotia
Essex Terminal Railway Company	Ontario
Exo	Québec
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
Keewatin Railway Company	Manitoba
Knob Lake and Timmins Railway	Québec, Newfoundland and Labrador
Last Mountain Railway	Saskatchewan
Metrolinx	Ontario
New Brunswick Southern Railway Company Ltd.	New Brunswick
Nipissing Central Railway Company	Ontario, Québec
Ontario Northland Transportation Commission	Ontario, Québec
Ontario Southland Railway Inc.	Ontario
Orangeville Brampton Railway	Ontario
Ottawa Valley Railway	Ontario, Québec
Prairie Dog Central Railway	Manitoba
Québec Gatineau Railway Inc.	Québec
Québec Iron Ore Inc.	Québec
Québec North Shore andLabrador 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
Toronto Terminals Railway Company Limited	Ontario
Train Touristique de Charlevoix Inc.	Québec
Trillium Railway Co. Ltd.	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

2021 LOCOMOTIVE FLEET—FREIGHT TRAIN LINE HAUL OPERATIONS

OEM	Model	US EPA Tier Level	Engine	hp	Year of Manufacture	Class 1	Regional	Shortline*	Total Regional & Shortline	Total Freight Fleet
GM/EMD	GMD1	No Tier	12V-645	1200	1958–60	0	0	1	1	1
	GP10	No Tier	16V567D3A	1800	1973–1977	0	0	1	1	1
	GP10	No Tier	16V567D3A	1800	1967–1972	0	0	1	1	1
	GP30	No Tier	16V-567D3A	2250	1961–63	0	0	1	1	1
	GP35	No Tier	16-645E	2500	1960–1969	1	0	0	0	1
	GP35	No Tier	16-567C	2500	1960–1969	0	0	2	2	2
	GP35-2	No Tier	16V-645	2000	1963–66	0	0	1	1	1
	GP35-3	No Tier	16V-645	2500	1963–66	0	0	1	1	1
	GP35-C. Cab	No Tier	16V-645	2000	1964	0	0	1	1	1
	GP38	No Tier	16V-645	2000	1980–1986	0	0	1	1	1
	GP38	No Tier	16V-645	2000	1970–1979	0	0	1	1	1
	GP38 AC/QEG	No Tier	16V-645E	2000	1970–1971	0	0	1	1	1
	GP38-2	No Tier	16V-645E	2000	1972–86	0	0	1	1	1
	GP38-2	No Tier	16-645E	2000	1973–1979	0	0	1	1	1
	GP38-2	No Tier	16V-645E	2000	1970–1972	0	0	1	1	1
	GP38-2	No Tier	16-645E	2000	1970–1972	0	0	8	8	8
	GP38-2	No Tier	16-645E	2000	1960–1969	0	0	6	6	6
	GP38-2	No Tier	16V-645E	2000	1960–1969	0	0	1	1	1
	GP38-2	No Tier	16V-645E	2000	1973–1979	0	0	2	2	2
	GP38-2/QEG	No Tier	16V-645E	2000	1974–1979	0	0	1	1	1
	GP38-2/QEG	No Tier	16V-645E	2000	1980–1986	0	0	1	1	1
	GP38-3	No Tier	16V-645E	2000	1981–83	0	0	1	1	1
	GP38-3	No Tier	645E	2000	1960–1969	0	0	7	7	7
	GP38-3	No Tier	645E	2000	1970–1972	0	0	2	2	2
	GP39-2	No Tier	12V-645E3	2300	1974–79	0	0	1	1	1
	GP39-2	No Tier	12V-645E3	2300	1980–84	0	0	1	1	1
	GP40	No Tier	16V-645	3000	1975–79	0	0	1	1	1
	GP40	No Tier	16V-645	3000	1980–87	0	0	1	1	1
	GP40	No Tier	16-645E3	3000	1960–1969	0	0	1	1	1
	GP40-1	No Tier	16V-645E3B	3000	1968	0	0	1	1	1
	GP40-2	No Tier	16-645E3B	3000	1960–1969	0	0	3	3	3
	GP40-2	No Tier	16-645E3	3000	1960–1969	0	0	4	4	4
	GP40-2	No Tier	16V-645E3B	3000	1973–1979	10	0	0	0	10
	GP40-2	No Tier	16-645E3	3000	1973–1979	0	0	1	1	1
	GP40-2	No Tier	16-645E3B	3000	1970–1972	0	0	3	3	3
	GP40-2	No Tier	16V-645	3000	1980–86	0	0	1	1	1
	GP40-2	No Tier	16V-645	3000	1972–79	0	0	1	1	1
	GP40-2M	No Tier	16-645E3	3000	1960–1969	0	0	1	1	1
	GP40-2R	No Tier	16V-645E3B	3000	1966–1969	0	0	1	1	1
	GP40-2W	No Tier	16-645E3	3000	1973–1979	0	0	3	3	3
	GP40-3	No Tier	16-645E3	3000	1973–1979	0	0	1	1	1
	GP40-3	No Tier	16V-567	3000	1966–68	0	0	1	1	1
	GP40-3	No Tier	16-645E3	3000	1960–1969	0	0	1	1	1
	GP40-3	No Tier	16V-567	3100	1966–68	0	0	1	1	1
	GP40-3M	No Tier	16-645E3	3000	1960–1969	0	0	1	1	1
	GP9	No Tier	16V-645C	1800	1961–1973	0	0	1	1	1
	GP9	No Tier	16V-645C	1800	1950–1959	0	0	1	1	1
	GP9	No Tier	16V-645C	1800	1974–1981	0	0	1	1	1
	GP9	No Tier	16V-645C	1800	1954–1960	0	0	1	1	1
	GP9	No Tier	16V-645C	1800	1973–1979	0	0	7	7	7
	GP9	No Tier	16V-567	1750	1950–60	0	0	1	1	1
	GP9-3	No Tier	16-567C	1750	1950–1959	0	0	1	1	1
	RM1 — SLUG	No Tier	NA	0	1970–1972	0	0	2	2	2
	RM1 SLUG	No Tier	NA	0	1960–1969	0	0	1	1	1
	RM1-SLUG	No Tier	NA	0	1970–1972	0	0	3	3	3
	RM1-SLUG	No Tier	NA	0	1960–1969	0	0	1	1	1
	SD38	No Tier	16V-645	2000	1971–74	0	0	1	1	1
	SD38-2	No Tier	16V-645 or 16V-645E	2000	1970–1972	0	0	1	1	1
	SD38-2	No Tier	16V-645 or 16V-645E	2000	1973–1979	0	0	1	1	1

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OEM	Model	US EPA Tier Level	Engine	hp	Year of Manufacture	Class 1	Regional	Shortline*	Total Regional & Shortline	Total Freight Fleet
GM/EMD	SD38-2	No Tier	16V-645E	2000	1975	0	0	1	1	1
	SD38AC	No Tier	16V-645 or 16V-645E	2000	1970–1972	0	0	1	1	1
	SD40	No Tier	20V-645	3200	1966–72	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	4	0	4	4
	SD40-2	No Tier	16-645E3B	3000	1973–1979	2	0	0	0	2
	SD40-2	No Tier	16-645E3C	3000	1980–1989	2	0	0	0	2
	SD40-2	No Tier	16V-645E3	3000	1980–1989	0	5	0	5	5
	SD40-2	No Tier	16-645E3	3000	1973–1979	7	0	1	1	8
	SD40-2	No Tier	16V-645E3	3000	1980–90	0	0	1	1	1
	SD40-2	No Tier	16V-645E3B	3000	1980–1989	7	0	1	1	8
	SD40-2	No Tier	16V-645E3	3000	1972–79	0	0	1	1	1
	SD40-2	No Tier	16V-645E3B	3000	1973–1979	9	0	1	1	10
	SD40-2	No Tier	16-645E3B	3000	1980–1989	6	0	0	0	6
	SD40-2	No Tier	16-645E3	3000	1960–1969	0	0	1	1	1
	SD40-2	No Tier	16-645E3	3000	1980–1989	13	0	1	1	14
	SD40-2	No Tier	16-645E3B	3000	1970–1972	0	0	2	2	2
	SD40-2	No Tier	16-645E3	3000	1970–1972	0	0	2	2	2
	SD40-2/QEG	No Tier	16V-645E3B	3000	1978–1979	0	0	1	1	1
	SD40-2/QEG	No Tier	16V-645E3B	3000	1980–1985	0	0	1	1	1
	SD40-2F	No Tier	16-645E3	3000	1980–1989	8	0	0	0	8
	SD40-3	No Tier	16V-645E3B	3000	1960–1969	5	0	0	0	5
	SD40-3	No Tier	16V-645E3B	3000	1966–72	0	0	1	1	1
	SD40-3	No Tier	16V-645E3B	3000	1970–1972	1	0	0	0	1
	SD40-3	No Tier	16-645E3	3000	1960–1969	0	0	1	1	1
	SD40-3	No Tier	16V-567	3100	1978–79	0	0	1	1	1
	SD40-3	No Tier	16-645E3	3000	1970–1972	0	0	7	7	7
	SD40-3	No Tier	16V-567	3100	1980–85	0	0	1	1	1
	SD60	No Tier	16V-710	3800	1985–89	0	0	1	1	1
	SD70	No Tier	16V-710G3B	4000	1970–1972	0	0	5	5	5
	SD70ACE	No Tier	16V-710	4000	1995–2000	0	0	1	1	1
	SD70ACe	No Tier	16-710G3B-ES	4375	2010–2019	0	12	0	12	12
	SD70ACe	No Tier	16-710G3B-ES	4375	2000–2009	0	5	0	5	5
	SD70I	No Tier	16V-710G3B	4000	1995	0	0	1	1	1
	SD75I	No Tier	16V-710G3C	4300	1996–99	0	0	1	1	1
	SD90MAC	No Tier	16V-710G3C	4300	1998–2000	0	0	1	1	1
	GP38-2	Tier 0	16-645E	2000	1960–1969	0	0	1	1	1
	GP39-2C	Tier 0	12-645E3	2300	1970–1972	0	0	2	2	2
	GP40-2	Tier 0	16V-645E3B	3000	1973–1979	20	0	0	0	20
	GP40-3M	Tier 0	16-645E3B	3000	1970–1972	0	0	3	3	3
	SD40-2	Tier 0	16V-645E3B	3000	1973–1979	14	0	0	0	14
	SD40-2	Tier 0	16V-645E3	3000	1978–79	0	0	1	1	1
	SD40-2	Tier 0	16V-645E3B	3000	1980–1989	4	0	0	0	4
	SD40-2	Tier 0	16-645E3	3000	1980–1989	4	0	0	0	4
	SD40-2	Tier 0	16-645E3B	3000	1980–1989	1	0	0	0	1
	SD40-2	Tier 0	16V-645E3	3000	1980–1990	0	0	1	1	1
	SD40-2	Tier 0	16-645E3B	3000	1973–1979	1	0	0	0	1
	SD40-2/QEG	Tier 0	16V-645E3B	3000	1978–1979	0	0	1	1	1
	SD40-2/QEG	Tier 0	16V-645E3B	3000	1980–1985	0	0	1	1	1
	SD60	Tier 0	16V-710	3800	1985–89	0	0	1	1	1
	SD60	Tier 0	16V-710G3	3800	1980–1989	34	0	0	0	34
	SD60-3	Tier 0	16-710G3	3800	1980–1989	8	0	0	0	8
	SD60M	Tier 0	16-710G3	3800	1980–1989	1	0	0	0	1
	SD70I	Tier 0	16V-710G3B	4000	1990–1999	3	0	0	0	3
	SD70I	Tier 0	16V-710G3B	4000	1995	0	0	1	1	1
	SD75	Tier 0	16V-710	4300	1996–99	0	0	1	1	1
	SD75	Tier 0	16V-710	4300	1990–1999	0	5	0	5	5
	SD75I	Tier 0	16V-710G3C	4300	1990–1999	24	0	0	0	24
	SD90 MAC-H	Tier 0	16V-265H	6000	1999	0	0	1	1	1
	SD9043MAC	Tier 0	16-710G3C-ES	4300	1990–1999	3	0	0	0	3
	SD90MAC	Tier 0	16V-710	4300	1998	0	0	1	1	1
	GP15-1	Tier 0+	12-645E3B	1500	1973–1979	0	0	3	3	3
	GP38	Tier 0+	EMD 645E	2000	1970–1972	0	2	0	2	2
	GP38	Tier 0+	EMD 645E	2000	1973–1979	0	2	0	2	2
	GP38 AC	Tier 0+	16V-645E	2000	1970–1971	0	0	1	1	1
	GP38 AC/QEG	Tier 0+	16V-645E	2000	1970–1971	0	0	1	1	1
	GP38-2	Tier 0+	645E	2000	1972–1979	0	0	3	3	3
	GP38-2	Tier 0+	16V-645E	2000	1983–86	0	0	1	1	1
	GP38-2	Tier 0+	16V-645E	2000	1980–1989	0	8	0	8	8
	GP38-2/QEG	Tier 0+	16V-645E	2000	1980–1986	0	0	1	1	1
	GP38-2/QEG	Tier 0+	16V-645E	2000	1974–1979	0	0	1	1	1

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OEM	Model	US EPA Tier Level	Engine	hp	Year of Manufacture	Class 1	Regional	Shortline*	Total Regional & Shortline	Total Freight Fleet
GM/EMD	GP40	Tier 0+	645	3000	1973–1979	0	3	0	3	3
	GP40-2	Tier 0+	16V-645	3000	1972–79	0	0	1	1	1
	GP40-2	Tier 0+	16V-645E3B	3000	1973–1979	27	0	0	0	27
	GP40-2	Tier 0+	16V-645	3000	1973–1979	0	3	0	3	3
	GP40-2	Tier 0+	16V-645	3000	1980–86	0	0	1	1	1
	GP40-3	Tier 0+	16-645E3C	3000	1960–1969	2	0	0	0	2
	GP40-3M	Tier 0+	16-645E3B	3000	1970–1972	0	0	1	1	1
	SD-50	Tier 0+	645	3600	1980–1989	0	4	0	4	4
	SD30C-ECO	Tier 0+	12-710G3B	3000	1980–1989	22	0	0	0	22
	SD30C-ECO	Tier 0+	12-710G3B	3000	1970–1972	1	0	0	0	1
	SD30C-ECO	Tier 0+	12-710G3B	3000	1973–1979	23	0	0	0	23
	SD38-2	Tier 0+	16V-645E	2000	1975	0	0	1	1	1
	SD40-2	Tier 0+	645E3	3000	1970–1972	0	1	0	1	1
	SD40-2	Tier 0+	16-645E3	3000	1980–1989	1	0	1	1	2
	SD40-2	Tier 0+	16V-645E3B	3000	1973–1979	32	0	0	0	32
	SD40-2	Tier 0+	16V-645E3B	3000	1980–1989	15	0	0	0	15
	SD40-2	Tier 0+	16V-645E3	3000	1980–85	0	0	1	1	1
	SD40-2	Tier 0+	16-645E3	3000	1973–1979	0	0	1	1	1
	SD40-2	Tier 0+	16V-645E3	3000	1978–79	0	0	1	1	1
	SD40-3	Tier 0+	16V-645E3B	3000	1970–1972	3	0	0	0	3
	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
	SD40-3	Tier 0+	16V-645E3B	3000	1960–1969	14	0	0	0	14
	SD60	Tier 0+	16V-710G3	3800	1980–1989	43	0	0	0	43
	SD60	Tier 0+	16-710G3A	3800	1980–1989	25	0	0	0	25
	SD60	Tier 0+	16V-710	3800	1985–89	0	0	1	1	1
	SD60-3	Tier 0+	16-710G3A	3800	1980–1989	1	0	0	0	1
	SD60-3	Tier 0+	16-710G3	3800	1980–1989	1	0	0	0	1
	SD60-F	Tier 0+	16V-710G3	3800	1985–89	0	0	1	1	1
	SD60M	Tier 0+	16-710G3A	3800	1980–1989	4	0	0	0	4
	SD70	Tier 0+	16V-710G3B	4000	1996–1999	0	0	1	1	1
	SD70I	Tier 0+	16V-710G3B	4000	1990–1999	19	0	0	0	19
	SD70I	Tier 0+	16V-710G3B	4000	1995	0	0	1	1	1
	SD75	Tier 0+	16V-710	4300	1996–99	0	0	1	1	1
	SD75I	Tier 0+	16V-710G3C	4300	1990–1999	119	0	0	0	119
	SD70ACU	Tier 1+	16-710G3C	4300	1990–1999	60	0	0	0	60
	GS1B	Tier 2	QSK19C	2100	2008	0	0	1	1	1
	SD 70ACE	Tier 2	7103GC	4300	2000–2009	0	0	3	3	3
	SD70-ACE	Tier 2	710	4400	2010–2019	0	5	0	5	5
	SD70M-2	Tier 2	16V-710G3C	4300	2010–2019	34	0	0	0	34
	SD70M-2	Tier 2	16V-710G3C	4300	2000–2009	22	0	0	0	22
	SD-70ACe	Tier 2+	16-710G3C-ES	4375	2000–2009	0	6	0	6	6
	SD70M-2	Tier 2+	16V-710G3C	4300	2000–2009	72	0	0	0	72
	SD70M-2	Tier 2+	16V-710G3C	4300	2010–2019	46	0	0	0	46
	SD-70ACe	Tier 3	16-710G3C-ES	4375	2000–2009	0	7	0	7	7
	SD-70ACe	Tier 3	16-710G3C-ES	4375	2010–2019	0	2	0	2	2
	SD70ACE	Tier 3	16V-710G3C	4300	2010–2019	4	0	0	0	4
GM/EMD Sub-Total						**788**	**75**	**176**	**251**	**1,039**
GE	AC4400CM	No Tier	16-7FDL	4400	2000–2009	0	8	0	8	8
	B23-7	No Tier	7FDL12	2000	1973–1979	0	0	2	2	2
	C40-8M	No Tier	7FDL16	4000	1990–1993	0	0	1	1	1
	C40-8W	No Tier	7FDL16	4000	1992	0	0	1	1	1
	Dash 8-40CM	No Tier	7FDL16	4000	1990–1999	0	0	3	3	3
	Dash 8-40CM	No Tier	7FDL16	4000	1990–92	0	0	1	1	1
	Dash 9-44CW	No Tier	7FDL16	4400	1996–99	0	0	1	1	1
	Dash-9 44CW	No Tier	16-7FDL	4400	1990–1999	0	11	0	11	11
	GS1B	No Tier	567	1400	1970–1972	0	0	1	1	1
	AC4400CW	Tier 0	16V-710	4400	2000–2009	0	0	4	4	4
	AC4400CW	Tier 0	7FDL16	4400	1995–1999	0	0	1	1	1
	AC4400CW	Tier 0	7FDL16	4400	2000–2001	0	0	1	1	1
	C44-9W	Tier 0	7FDL-16	4400	2000–2009	1	0	0	0	1
	Dash 9-44CW	Tier 0	7FDL16	4400	2000–2001	0	0	1	1	1
	Dash 9-44CW	Tier 0	7FDL16	4400	1994–1999	0	0	1	1	1
	ES44AC	Tier 0	GEVO-12	4365	2000–2009	4	0	0	0	4
	AC4400CW	Tier 0+	7FDL16	4400	1995–1999	0	0	1	1	1
	AC4400CW	Tier 0+	7FDL16	4400	2000–2001	0	0	1	1	1
	C40-8	Tier 0+	7FDL-16	4000	1980–1989	14	0	0	0	14
	C40-8	Tier 0+	7FDL-16	4000	1990–1999	6	0	0	0	6
	C40-8	Tier 0+	7FDL16	4000	1989–1991	0	0	1	1	1
	Dash 8-40CM	Tier 0+	7FDL16	4400	1990–92	0	0	1	1	1
	AC4400CW	Tier 1	7FDL16	4400	2002–04	0	0	1	1	1

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OEM	Model	US EPA Tier Level	Engine	hp	Year of Manufacture	Class 1	Regional	Shortline*	Total Regional & Shortline	Total Freight Fleet
GE	AC4400CW	Tier 1	7FDL16	4400	2000–2009	0	26	0	26	26
	Dash 9-44CW	Tier 1	7FDL16	4400	2002–04	0	0	1	1	1
	AC4400CM	Tier 1+	16-7FDL	4400	2000–2009	0	4	0	4	4
	AC4400CW	Tier 1+	7FDL16	4400	2000–2009	171	0	0	0	171
	AC4400CW	Tier 1+	7FDL16	4400	1990–1999	74	0	0	0	74
	AC4400CW	Tier 1+	7FDL16	4400	2002–04	0	0	1	1	1
	AC44CWM	Tier 1+	7FDL16	4400	1990–1999	171	0	0	0	171
	C44-9W	Tier 1+	7FDL16	4400	2000–2001	0	0	1	1	1
	C44-9W	Tier 1+	7FDL-16	4400	1990–1999	68	0	0	0	68
	C44-9W	Tier 1+	7FDL-16	4400	2000–2009	85	0	0	0	85
	C44-9W	Tier 1+	7FDL16	4400	1994–1999	0	0	1	1	1
	Dash 9-44CW	Tier 1+	7FDL16	4400	1994–1999	0	0	1	1	1
	Dash 9-44CW	Tier 1+	7FDL16	4400	2000–2004	0	0	1	1	1
	AC4400CW	Tier 2	7FDL16	4400	2005–07	0	0	1	1	1
	ES44AC	Tier 2	GEVO12	4360	2010–2019	0	6	0	6	6
	ES44AC	Tier 2	GEVO 12	4360	2010–2011	0	0	1	1	1
	ES44AC	Tier 2	GEVO 12	4360	2005–2009	0	0	1	1	1
	ES44DC	Tier 2	GEVO 12	4400	2005–08	0	0	1	1	1
	ES44DC	Tier 2	GEVO-12	4400	2000–2009	22	0	0	0	22
	ES44DC	Tier 2	GEVO-12	4400	2010–2019	3	0	0	0	3
	ES44AC	Tier 2+	GEVO-12	4365	2010–2019	61	0	0	0	61
	ES44AC	Tier 2+	GEVO 12	4360	2005–2009	0	0	1	1	1
	ES44AC	Tier 2+	GEVO-12	4365	2000–2009	194	0	0	0	194
	ES44AC	Tier 2+	GEVO 12	4360	2010–2011	0	0	1	1	1
	ES44DC	Tier 2+	GEVO 12	4400	2012	0	0	1	1	1
	ES44DC	Tier 2+	GEVO-12	4400	2000–2009	67	0	0	0	67
	ES44DC	Tier 2+	GEVO-12	4400	2010–2019	31	0	0	0	31
	ES4400AC	Tier 3	GEVO 12	4400	2012	0	0	1	1	1
	ES44AC	Tier 3	GEVO-12	4400	2010–2019	378	0	0	0	378
	ES44AC	Tier 3	GEVO 12	4360	2012	0	0	1	1	1
	ES44AC	Tier 3	GEVO-12	4365	2010–2019	30	0	0	0	30
	ET44AC	Tier 3	ES44AC	4400	2010–2019	1	0	0	0	1
	ES44AC	Tier 4	GEVO 12	4400	2015–2016	0	0	1	1	1
	ES44AC	Tier 4	GEVO-12	4400	2010–2019	3	0	0	0	3
	ET44AC	Tier 4	ET44AC	4400	2010–2019	5	0	0	0	5
	ET44AC	Tier 4	GEVO 12	4400	2015–2016	0	0	1	1	1
	ET44AC	Tier 4	GEVO-12	4400	2020–2021	38	0	0	0	38
	ET44AC	Tier 4	GEVO-12	4400	2010–2019	222	0	0	0	222
GE Sub-Total						**1,649**	**55**	**40**	**95**	**1,744**
MLW	HR-412	No Tier	12V-251	2000	1975	0	0	1	1	1
	M-420(W)	No Tier	12V-251-B	2000	1971–75	0	0	1	1	1
	M-420R(W)	No Tier	12V-251-B	2000	1971–75	0	0	1	1	1
	RS-18	No Tier	12V-251	1800	1954–58	0	0	1	1	1
	RS-18	Tier 0	12V-251	1800	1950–1959	0	0	6	6	6
MLW Sub-Total						**0**	**0**	**10**	**10**	**10**
NRE	SD40-2	Tier 0+	645E3B	3000	1970–1972	0	6	0	6	6
	SD40-2	Tier 0+	645E3	3000	1970–1972	0	1	0	1	1
NRE Sub-Total						**0**	**7**	**0**	**7**	**7**
EMCC	SD70M-2	Tier 2	16V-710G3C	4300	2005–07	0	0	1	1	1
EMCC Sub-Total						**0**	**0**	**1**	**1**	**1**
Total Mainline Freight						**2,437**	**137**	**227**	**364**	**2,801**

*The number of line haul shortline locomotives in 2021 was much higher than in 2020 as a result of a methodology change from a reporting member.

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APPENDIX B-2

2021 LOCOMOTIVE FLEET—FREIGHT YARD SWITCHING & WORK TRAIN OPERATIONS

OEM	Model	US EPA Tier Level	Engine	HP	Year of Manufacture	Class 1	Regonal	Shortline	Total Regional & Shortline	Total Freight Fleet
GM/EMD	Cab slug	Elec/Steam/ Other	Other	0	1950–1959	0	0	2	2	2
	SLUG	Elec/Steam/ Other	Other	0	2000–2009	0	0	1	1	1
	SLUG	Elec/Steam/ Other	Other	0	1980–1989	0	0	1	1	1
	F40-PH	No Tier	16V-645E3B	3000	1977–1978	0	0	1	1	1
	FP9A	No Tier	16-645C	1750	1950–1959	2	0	0	0	2
	FP9A-3	No Tier	16-645E	1750	1950–1959	1	0	0	0	1
	GMD1	No Tier	12V-645	1200	1958–1960	0	0	1	1	1
	GP15	No Tier	16V-645	1500	1981–84	0	0	1	1	1
	GP38	No Tier	16V-645	2000	1980–1986	0	0	1	1	1
	GP38	No Tier	16V-645	2000	1974–1979	0	0	1	1	1
	GP38	No Tier	645	2000	1960–1969	0	2	0	2	2
	GP38	No Tier	16V-645	2000	1970–1973	0	0	1	1	1
	GP38-2	No Tier	16V-645E	2000	1970–1972	11	0	0	0	11
	GP38-2	No Tier	16V-645	2000	1972–73	0	0	1	1	1
	GP38-2	No Tier	16-645E	2000	1980–1989	34	0	0	0	34
	GP38-2	No Tier	16V-645E	2000	1973–1979	32	0	0	0	32
	GP38-2	No Tier	16V-645	2000	1974–1976	0	0	1	1	1
	GP38-3	No Tier	16-645E	2000	1973–1979	1	0	0	0	1
	GP38-3	No Tier	16-645E	2000	1980–1989	5	0	0	0	5
	GP38AC	No Tier	16-645E	2000	1970–1972	2	0	0	0	2
	GP7	No Tier	16V-567	1500	1949–1954	0	0	1	1	1
	GP9	No Tier	16V-645E3	1800	1950–1959	0	0	6	6	6
	GP9	No Tier	16V-645	1800	1960–1973	0	0	1	1	1
	GP9	No Tier	16V-645	1800	1974–1981	0	0	1	1	1
	GP9	No Tier	16V-645	1750	1960–1973	0	0	1	1	1
	GP9	No Tier	16V-645	1750	1950–1959	0	0	2	2	2
	GP9	No Tier	16V-567	1750	1951–1959	0	0	1	1	1
	GP9	No Tier	16V-645	1800	1950–1959	0	1	0	1	1
	GP9	No Tier	16V-567	1750	1960–1963	0	0	1	1	1
	GP9	No Tier	16V-567	1750	1950–1959	0	0	2	2	2
	GP9	No Tier	16V-645	1700	1960–1969	0	0	1	1	1
	GP9	No Tier	16V-645	1750	1954–1959	0	0	1	1	1
	GP9	No Tier	16V-645	1700	1960	0	0	1	1	1
	GP9	No Tier	16V-645	1800	1954–1959	0	0	1	1	1
	GP9	No Tier	16V-645	1750	1974–1981	0	0	1	1	1
	GP9	No Tier	16V-567	1750	1960–1969	0	2	1	3	3
	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	1	1	1
	GP9-RM	No Tier	16V-645C	1800	1950–1959	72	0	0	0	72
	GP9-RM	No Tier	16V-645C	1800	1954–1959	0	0	1	1	1
	GP9-RM	No Tier	16V-645	1800	1974–1979	0	0	1	1	1
	GP9-RM	No Tier	16V-645	1800	1980–1981	0	0	1	1	1
	GP9-RM	No Tier	16V-645C	1800	1960–1973	0	0	1	1	1
	MP1500	No Tier	12V-567	1500	1973–1979	0	0	3	3	3
	SD35-3	No Tier	16V-645E	2500	1960–1969	0	0	1	1	1
	SD38-2	No Tier	16V-645	2000	1973–1976	0	0	1	1	1
	SD40-2	No Tier	16V-645	3000	1980–1990	0	0	1	1	1
	SD40-2	No Tier	16V-645	3000	1975–1979	0	0	1	1	1
	SW-12	No Tier	567	3600	1960–1969	0	1	0	1	1
	SW1000RS	No Tier	8V-645	1000	1960–1969	0	0	2	2	2
	SW1200	No Tier	12V-567	1200	1960–1962	0	0	1	1	1
	SW1200	No Tier	12V-567	1200	1955–1959	0	0	1	1	1
	SW1200-RB	No Tier	12V-645	1200	1957	0	0	1	1	1
	SW14	No Tier	12V-567	1400	1950	0	0	1	1	1
	SW14	No Tier	12V-567	1400	1950–1959	0	0	1	1	1
	SW1500	No Tier	12-645E	1500	1970–1972	0	0	2	2	2
	SW1500	No Tier	12V-567	1500	1970–1974	0	0	1	1	1
	SW1500	No Tier	12V-567	1500	1966–1969	0	0	1	1	1

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2021 LOCOMOTIVE FLEET—FREIGHT YARD SWITCHING & WORK TRAIN OPERATIONS

OEM	Model	US EPA Tier Level	Engine	HP	Year of Manufacture	Class 1	Regonal	Shortline	Total Regional & Shortline	Total Freight Fleet
GM/EMD	SW7SW9	No Tier	12V-645C	1200	1945–1952	0	0	1	1	1
	SW900	No Tier	8V-567	900	1954–1959	0	0	1	1	1
	SW900	No Tier	8V-567	900	1960–1965	0	0	1	1	1
	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
	SW900RS	No Tier	8V-567	900	1950–1959	0	0	8	8	8
	GP35	Tier 0	16V-567D3A	2500	1960–1969	0	0	1	1	1
	GP38-2	Tier 0	16-645E	2000	1973–1979	15	0	0	0	15
	GP38-2	Tier 0	16V-645E	2000	1973–1979	2	0	0	0	2
	GP38-2	Tier 0	16-645E	2000	1980–1989	1	0	0	0	1
	GP39-2C	Tier 0	12-645E3	2300	1970–1972	0	0	2	2	2
	MP15	Tier 0	12V-645	1500	1973–1979	0	0	1	1	1
	SD40-2	Tier 0	16V-645	3000	1983–85	0	0	1	1	1
	SD40-2	Tier 0	16V-645E3	3000	1973–1979	0	0	4	4	4
	F40-PH	Tier 0+	16V-645E3B	3000	1977–1978	0	0	1	1	1
	FP9B-3	Tier 0+	16-645E	1750	1950–1959	1	0	0	0	1
	GP20C-ECO	Tier 0+	8-710G3B	2000	1950–1959	130	0	0	0	130
	GP38-2	Tier 0+	16V-645E	2000	1970–1972	7	0	0	0	7
	GP38-2	Tier 0+	16V-645	2000	1980–1986	0	0	1	1	1
	GP38-2	Tier 0+	16V-645E	2000	1973–1979	43	0	0	0	43
	GP38-2	Tier 0+	16-645E	2000	1973–1979	27	0	0	0	27
	GP38-2	Tier 0+	16-645E	2000	1970–1972	3	0	0	0	3
	GP38-2	Tier 0+	16-645E	2000	1980–1989	45	0	0	0	45
	GP38-2	Tier 0+	16V-645	2000	1970–1979	0	0	1	1	1
	GP38-3	Tier 0+	16-645E	2000	1970–1972	2	0	0	0	2
	GP38-3	Tier 0+	16-645E	2000	1980–1989	4	0	0	0	4
	GP38AC	Tier 0+	16-645E	2000	1970–1972	3	0	0	0	3
	GP40-3	Tier 0+	645E3B	3000	1973–1979	1	0	0	0	1
	GP40-3	Tier 0+	645E3B	3000	1970–1972	1	0	0	0	1
	SD38-2	Tier 0+	16V-645E	2000	1973–1979	3	0	0	0	3
GM/EMD Sub-Total						**448**	**6**	**87**	**93**	**541**
GE	44T	No Tier	Cummins	300	1947	0	0	1	1	1
GE Sub-Total						**0**	**0**	**1**	**1**	**1**
MLW	M-420	No Tier	16V-251	2000	1972–73	0	0	1	1	1
	RS-18	No Tier	12V-251	1800	1954–58	0	0	1	1	1
	RS-23	No Tier	18V-251	1000	1959–60	0	0	1	1	1
MLW Sub-Total						**0**	**0**	**3**	**3**	**3**
ALCO	S-2	No Tier	6-539	1000	1944	0	0	1	1	1
	S-6	No Tier	567	900	1953	0	0	1	1	1
	RS-18	Tier 0	12V-251-B	1800	1950–1959	0	0	1	1	1
	S-13	Tier 0	Inline 6 251	1000	1950–1959	0	0	1	1	1
ALCO Sub-Total						**0**	**0**	**4**	**4**	**4**
Other	Budd RDC	No Tier	Cummins	600	1947	0	0	1	1	1
	Modesto Empire	No Tier	567	600	1970–1972	0	0	1	1	1
Other Sub-Total						**0**	**0**	**2**	**2**	**2**
Yard Switching & Work Train Total						**448**	**6**	**97**	**103**	**551**

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APPENDIX B-3

2021 LOCOMOTIVE AND DMU FLEET—PASSENGER TRAIN OPERATIONS

OEM	Model	US EPA Tier Level	Engine	HP	Year of Manufacture	Intercity	Commuter	Tourist/ Excursion	Total
GM/EMD	F40-PH	No Tier	16V-645E3B	3000	1973–1979	2	0	0	2
	F40PH-2	No Tier	16V-645E3C	3000	1980–1989	49	0	0	49
	F59PH	No Tier	710G3A EMD 12CYL	3200	1990–1994	0	8	0	8
	GMD-1	No Tier	12V-567C	1200	1950–1959	0	0	1	1
	GP-40	No Tier	645	3000	1973–1979	0	0	9	9
	GP9	No Tier	16V-645	1750	1950–1959	0	0	2	2
	GP9	No Tier	16V-567C	1750	1950–1959	0	0	1	1
	SW1000	No Tier	8-645E	1000	1960–1969	1	0	0	1
	F59-PHI	Tier 0	710	3000	1990–1999	0	4	0	4
	F40PH-2	Tier 0+	16V-645E3C	3000	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
GM/EMD Sub-Total						**55**	**33**	**13**	**101**
GE	35T	No Tier	6-236	275	1960–1969	0	0	1	1
	70 ton	No Tier	Cummins 1710	660	1940–1949	0	0	1	1
	P42DC	No Tier	7FDL16	4250	2000–2009	21	0	0	21
GE Sub-Total						**21**	**0**	**2**	**23**
Motive Power	MP36PH-3C	Tier 0	645E3B	3600	2000–2009	0	1	0	1
	MP40PH-3C	Tier 2	710G3B TIER 2 EMD 16CYL	4000	2007–2011	0	56	0	56
	MP40PH-3C	Tier 3	710G3B TIER 3 EMD 16 CYL	4000	2013–2014	0	10	0	10
	MP40PHT-T4-AC	Tier 4	Twin QSK 60 T4 -16 cyl	5400	2018–2019	0	16	0	16
	MP40PHTC-T4-DC	Tier 4	Twin QSK 60 T4 -16 cyl	5400	2010	0	1	0	1
Motive Power Sub-Total						**0**	**84**	**0**	**84**
Bombardier	ALP45-DP	Tier 3	3512C HD	4200	2010–2012	0	20	0	20
Bombardier Sub-Total						**0**	**20**	**0**	**20**
Cummins	RDC-1	No Tier	Cummins	900	1950–1959	1	0	0	1
	RDC-2	No Tier	Cummins	900	1950–1959	3	0	0	3
	RDC-4	No Tier	Cummins	450	1950–1959	2	0	0	2
	DMU A-Car	Tier 4	QSK19R	760	2011–2014	0	12	0	12
	DMU C-Car	Tier 4	QSK19R	760	2011–2014	0	6	0	6
Cummins Sub-Total						**6**	**18**	**0**	**24**
Dubs	4-4-0	Elec/Steam/Other	Other	0	1882	0	0	1	1
Dubs Sub-Total						**0**	**0**	**1**	**1**
ALCO	04/04/00	Elec/Steam/Other	Steam	600	1880–1889	0	0	1	1
ALCO Sub-Total						**0**	**0**	**1**	**1**
Passenger Operations Total						**82**	**155**	**17**	**254**

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APPENDIX C

RAILWAYS OPERATING IN TROPOSPHERIC OZONE MANAGEMENT AREAS

TOMA REGION NO. 1: LOWER FRASER VALLEY, BRITISH COLUMBIA

CN	
Division:	Pacific
Subdivisions:	Rawlison, Yale
CP	
Division:	Pacific
Subdivisions:	Cascade, Mission, Page
OTHER	
Southern Railway of BC Ltd	All
VIA Rail Canada	Part
Great Canadian Railtour Company	Part
West Coast Express	All

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
CP	
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
Orangeville Brampton Railway	All
Québec Gatineau Railway	All
Southern Ontario Railway	All
St-Lawrence & Atlantic (Canada)	All
VIA Rail Canada	Part
GO Transit	All
exo	All
Capital Railway	All

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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 EMISSIONS 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 emission 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/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).*

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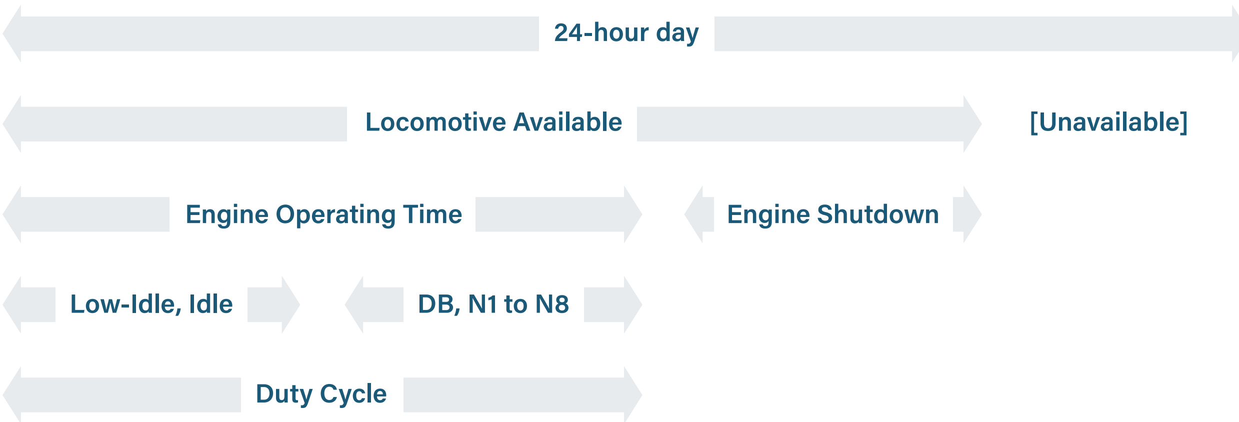
Locomotive Utilization Profile

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 25.
  - **Nitrous Oxide (N_2O):** This is a colourless gas produced during combustion that has a Global Warming Potential of 298 (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 7 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*
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	Emissions 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
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 emissions factors are from Environment and Climate Change Canada, and data on CAC emissions 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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