LOCOMOTIVE EMISSIONS MONITORING REPORT

2020

Railway Association of Canada

RIGHT TRACK

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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 2020 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 third 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 2022 GHG emission intensity targets, which use 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 Canadian Class 1 freight railways are continuing to reduce their GHG emissions intensities. In light of the COVID-19 pandemic, and its effects on ridership (both personal and business travel), intercity passenger railways experienced a significant increase to their GHG emissions intensities.

Regional & shortline railways are typically more vulnerable to economic volatility, which was evident in 2020.[1] Due to variation across shortline railways in Canada, in terms of both size and efficiency, total regional & shortline emissions intensity also increased in 2020.

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), as expressed in kilograms (kg) of carbon dioxide equivalent (CO_2e) per productivity unit.

1 Also, RAC Regional and Shortline membership may change over time, affecting RTKs and fuel usage from one year to the next.

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GHG EMISSIONS INTENSITY AND MOU PROGRESS BY RAILWAY OPERATION

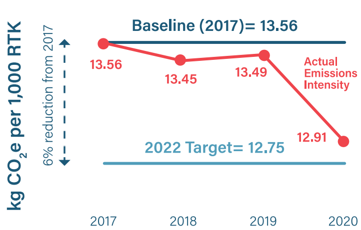
Railway Operation	Productivity Units	Baseline - 2017	2018	2019	2020	Change from 2017-2020	Change from 2019-2020	2022 Target	Progress to 2022 Target
Class I Freight	kg CO_2e per 1,000 RTK	13.56	13.45	13.49	12.91	-4.83%	-4.34%	12.75 (6% reduction from 2017)	80.56% Progress to target
Intercity Passenger*	kg CO_2e per passenger-km	0.098	0.097	0.089	0.178	82.40%	100.39%	0.092 (6% reduction from 2017)	Increase since 2017
Regional & Shortline	kg CO_2e per 1,000 RTK	14.08	15.02	14.77	15.27	8.45%	3.42%	13.66 (3% reduction from 2017)	Increase since 2017

Note: GHG emissions for all years have been calculated based on the emissions factors and global warming potentials in the 2022 National Inventory Report. Historical values have been updated.

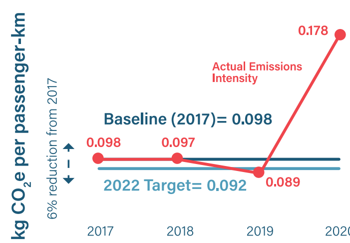
Note: The final column of the table indicates the percentage of the MOU target that has been achieved as of 2020; an increase indicates that emissions intensity was higher in 2020 than in 2017.

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

MOU PROGRESS: CLASS I FREIGHT

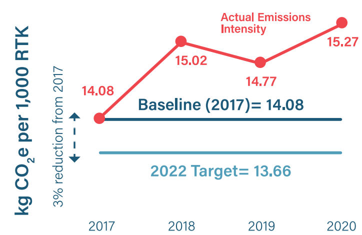


MOU PROGRESS: INTERCITY PASSENGER*



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

MOU PROGRESS: REGIONAL & SHORTLINE



As seen in the table and figure above, Class 1 freight GHG emissions intensity decreased by 4.3% from 2019 to 2020. GHG emissions intensity continues to be less than the 2017 baseline and represents 80.6% 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) increased by 100.4% (approximately doubled) from 2019 to 2020, further deviating from the 2022 MOU target.

This deviation was due to a significant decrease in intercity and commuter ridership throughout the COVID-19 pandemic, while passenger railways continued to maintain essential services.[2] During the same time frame, passenger fuel consumption also decreased, however, the drastic decrease in ridership still caused emissions intensity to approximately double. Regional & shortline emissions intensity increased by 3.4% from 2019 to 2020 and stood 8.5% above the 2017 baseline.

2 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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2020 KEY FINDINGS

IMPACTS OF COVID-19

Although Canadian railways faced major challenges during 2020 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, 2020 railway performance and emissions data diverges significantly from historical trends, specifically regarding all segments of passenger railway operations and emissions intensity.

While some impacts are expected to be temporary, there is the potential for a lasting impact on Canada's passenger railways.

RAILWAY TRAFFIC

Freight Traffic

- Gross Tonne-Kilometres (GTK): In 2020, the railways handled 846.76 billion GTK of traffic as compared to 863.98 billion GTK in 2019, representing a decrease of 2.0%. GTK traffic was 26.7% higher than it was in 2005, the reference year, having increased at an average rate of 1.6% per year.[3] Class 1 GTK traffic accounted for 95.3% of the total GTK hauled in 2020.
- Revenue Tonne-Kilometres (RTK): In 2020, the railways handled 451.67 billion RTK of traffic as compared to 455.06 billion RTK in 2019, representing a decrease of 0.7%. RTK traffic was 28.0% higher than it was in 2005, the reference year, having increased at an average rate of 1.7% per year. Of the freight RTK traffic handled in 2020, Class 1 freight railways were responsible for 95.3% of the total traffic.
- Intermodal Traffic: Intermodal tonnage decreased by 12.3% to 36.56 million tonnes in 2020 from 41.7 million tonnes in 2019. Overall, intermodal tonnage comprising both container-on-flat-car and trailer-on-flat-car traffic for railways in Canada has risen 18.5% since 2005, equating to an average growth rate of 1.1% per year.

Passenger Traffic

- Passenger traffic was significantly affected by the COVID-19 pandemic in 2020. Passenger ridership decreased dramatically and caused GHG emissions intensity (i.e., kg CO_2e per passenger-km) to increase by 100.4% compared to 2019, despite passenger fuel consumption also decreasing in 2020. Specifically:
  - Intercity passenger traffic in 2020 by all carriers totaled 1.15 million passengers compared to 5.05 million in 2019, a decrease of 77.3%.
  - Commuter rail traffic decreased from 101.94 million passengers in 2019 to 22.75 million in 2020, a decrease of 77.7%.[4]
  - In 2020, most tourist and excursion railways were not open for passenger service.
  - Of the total fuel consumed by all railway operations, Class 1 freight train operations consumed 88.8% and regional & shortlines consumed 5.2%. Yard switching and work train operations consumed 2.6%, and passenger operations accounted for 3.3%.

3 Growth rates are calculated using the compound annual growth rate (CAGR) formula. 2005 has been set as the reference year for the 2020 LEM Report and future reports, as it aligns with the Government of Canada's climate targets, among other merits. In previous reports, 1990 was set as the reference year.

4 In 2020, 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

- Fuel consumed by railway operations in Canada decreased by 7.4% from 2,259.24 million litres in 2019 to 2,090.94 million litres in 2020.
- For freight operations, overall fuel consumption in 2020 was 2,021.34 million litres, 4.8% below the 2019 level of 2,124.35 million litres.
- For total freight operations, fuel consumption per productivity unit (litres per 1,000 RTK) in 2020 was 4.48 litres per 1,000 RTK, a decrease of 4.1% from 2019 and 25.1% from 2005.
- For total passenger operations, overall fuel consumption in 2020 was 69.60 million litres, 48.4% below the 2019 level of 134.89 million litres.[5]

LOCOMOTIVE INVENTORY

Locomotive Fleet

The reported number of diesel-powered locomotives and diesel multiple units (DMUs) in active service in Canada operated by MOU signatory railways totaled 3,756 in 2020 versus 3,840 in 2019, a decrease of 2.2%.[6]

For freight operations in 2020, 2,645 were on Class 1 line haul, 133 were owned by regional railways, and 145 were owned by shortlines. A further 564 were in freight switching operations. A total of 239 locomotives and DMUs were used in 2020 to support passenger railway operations in Canada, of which 74 were for intercity passenger services, 163 for commuter railway services, and 2 for tourist and excursion services.

Locomotives Meeting Emissions Standards

In 2020, 82.7% of the fleet met emissions standards (as set out under the *Locomotive Emissions Regulations* (LER) or the United States Environmental Protection Agency (US EPA) Regulations).[7] A total of one Tier 3 and 46 Tier 4 high-horsepower locomotives were added to the Class 1 freight line haul fleet; 30 Class 1 freight line haul locomotives were upgraded to Tier 1+; and 139, mostly non-tier-level and lower-tier-level locomotives, were retired from Class 1s. Other railways added 22 locomotives that meet emissions standards (2 Tier 0 locomotives, 7 Tier 0+, 1 Tier 1+, 6 Tier 2+, and 6 Tier 3) and retired 9 non-tier-level and one lower-tier-level locomotives.

Locomotives Equipped with Anti-Idling Devices

The number of locomotives in 2020 equipped with a device to minimize unnecessary idling, such as an automatic engine stop-start (AESS) system or auxiliary power unit (APU), was 3,109, which represents 82.8% of the fleet, compared with 2,969 in 2019 (77.3% of the fleet).[8]

TROPOSPHERIC OZONE MANAGEMENT AREAS (TOMA)

Of the total GHGs emitted by the railway sector in 2020, 2.3% occurred in the Lower Fraser Valley of British Columbia, 11.5% in the Windsor-Québec City Corridor, and 0.1% in the Saint John area of New Brunswick. NO_x emissions for each TOMA were at the same ratios as GHGs.

EMISSIONS REDUCTION INITIATIVES BY RAILWAYS

Railways invested $2.6 billion into their Canadian networks in 2020 and continue to implement a number of initiatives to lower their emissions, including investments in fleet renewal, fuel saving technologies, employee training and use of low carbon fuels.

5 In 2020, 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).

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.

8 Ibid.

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1. INTRODUCTION

This report contains the Locomotive Emissions Monitoring (LEM) data filing for 2020 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 2020, the transportation sector emitted 190 Mt of CO_2e, accounting for 28.3% of Canada's total GHG emissions.[9] The majority of transportation GHGs are attributed to light-duty and heavy-duty on-road vehicles. Canadian railways accounted for only 3.8% of transportation GHGs, which is less than light-duty vehicles (38.0%), heavy-duty vehicles (31.1%), and the pipeline transport sector (4.1%).[10] 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 reduce its GHG emissions significantly.

Railways have played and will continue to play a key role in contributing to Canada's climate targets, through reductions in emissions intensity and modal shift – shifting freight and passenger traffic from other modes of transport to rail. Since 2005, freight railways have reduced their GHG intensity by 25.1%. During the same timeframe, freight railways have experienced a 28.0% increase in revenue traffic. Passenger railways will contribute 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 third 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.

9 Source: Canada's National Inventory Report, 1990–2020: Greenhouse Gas Sources and Sinks in Canada, Environment and Climate Change Canada, 2022, Table A9–2

10 Ibid.

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1.1 OVERVIEW OF REPORT

This report provides an overview of 2020 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.

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 Windsor–Québec City Corridor, and the Saint John area in New Brunswick.

Data is presented from 2011 to 2020. For historical comparison purposes, the year 2005[11] has been set as the reference year and has also been included. LEM statistics from 1990 to 2019 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.

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.

GHG EMISSIONS INTENSITY AND MOU PROGRESS BY RAILWAY OPERATION

Railway Operation	Productivity Units	Baseline - 2017	2018	2019	2020	Change from 2017-2020	Change from 2019-2020	2022 Target	Progress to 2022 Target
Class I Freight	kg CO_2e per 1,000 RTK	13.56	13.45	13.49	12.91	-4.83%	-4.34%	12.75 (6% reduction from 2017)	80.56% Progress to 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 2022 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 2020; an increase indicates that emissions intensity was higher in 2020 than in 2017.

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

1.3 CAC COMMITMENTS

As stated in the MOU, Transport Canada has developed regulations to control CAC emissions under the *Railway Safety Act*. The *Locomotive Emissions Regulations* (LER) came into force on June 9, 2017 and apply to railway companies that the federal government regulates.[12] The Canadian regulations are aligned with the United States Environmental Protection Agency (US EPA) emission 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 emission 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 2005 has been set as the reference year for the 2020 LEM Report and future reports, 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.

12 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.

2. EMISSIONS REDUCTION INITIATIVES

In 2020, Canadian railways continued to invest in new technologies and improve operational practices to reduce locomotive emissions. In fact, despite the various challenges brought on by the COVID-19 pandemic, railways invested $2.6 billion into their Canadian networks in 2020, which is the second highest level on record, behind $3.1 billion in 2019.[13] 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.

2.1 FLEET RENEWAL/MODERNIZATION

In 2020, railways progressed on their multi-year initiatives to modernize their fleets through the acquisition of modern, fuel-efficient locomotives, as well as retrofitting and upgrading existing locomotives to improve fuel efficiency and reduce emissions. Initiatives from select railways are outlined below.

In 2020, Canadian Pacific (CP) invested $50 million into its locomotive modernization program to improve locomotive fuel efficiency by a minimum of 2.7 percent and reduce annual CO_2e by 2,810 tonnes. In 2020, CP upgraded 30 locomotives, increasing the total to 386 locomotives retrofitted through this initiative. Locomotive enhancements include technology upgrades, advanced diesel engines and improved cooling and traction control systems. All units were equipped with EPA-certified fuel/emissions reduction technologies and GE Trip Optimizer and Distributed Power systems.

CP's locomotive modernization project is estimated to improve locomotive fuel efficiency by a

MINIMUM OF 2.7%.

In 2020, CN took delivery of

42 NEW LOCOMOTIVES EQUIPPED WITH ENERGY MANAGEMENT SYSTEMS.

In 2020, Metrolinx performed work on testing and commissioning

16 NEW TIER 4 AC LOCOMOTIVES.

13 Railway Association of Canada, Rail Trends 2021. https://www.railcan.ca/wp-content/uploads/2021/12/RAC-RAIL-TRENDS-2021-Web-1.pdf

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Canadian National Railway (CN) continued to purchase tier-compliant locomotives as part of its strategy to acquire, retire and upgrade its fleet. In 2020, CN took delivery of 42 new locomotives equipped with energy management systems. The company also equips all new locomotives with data telemetry systems as well as distributed power functionality to help maximize locomotive operating effectiveness and efficiency.

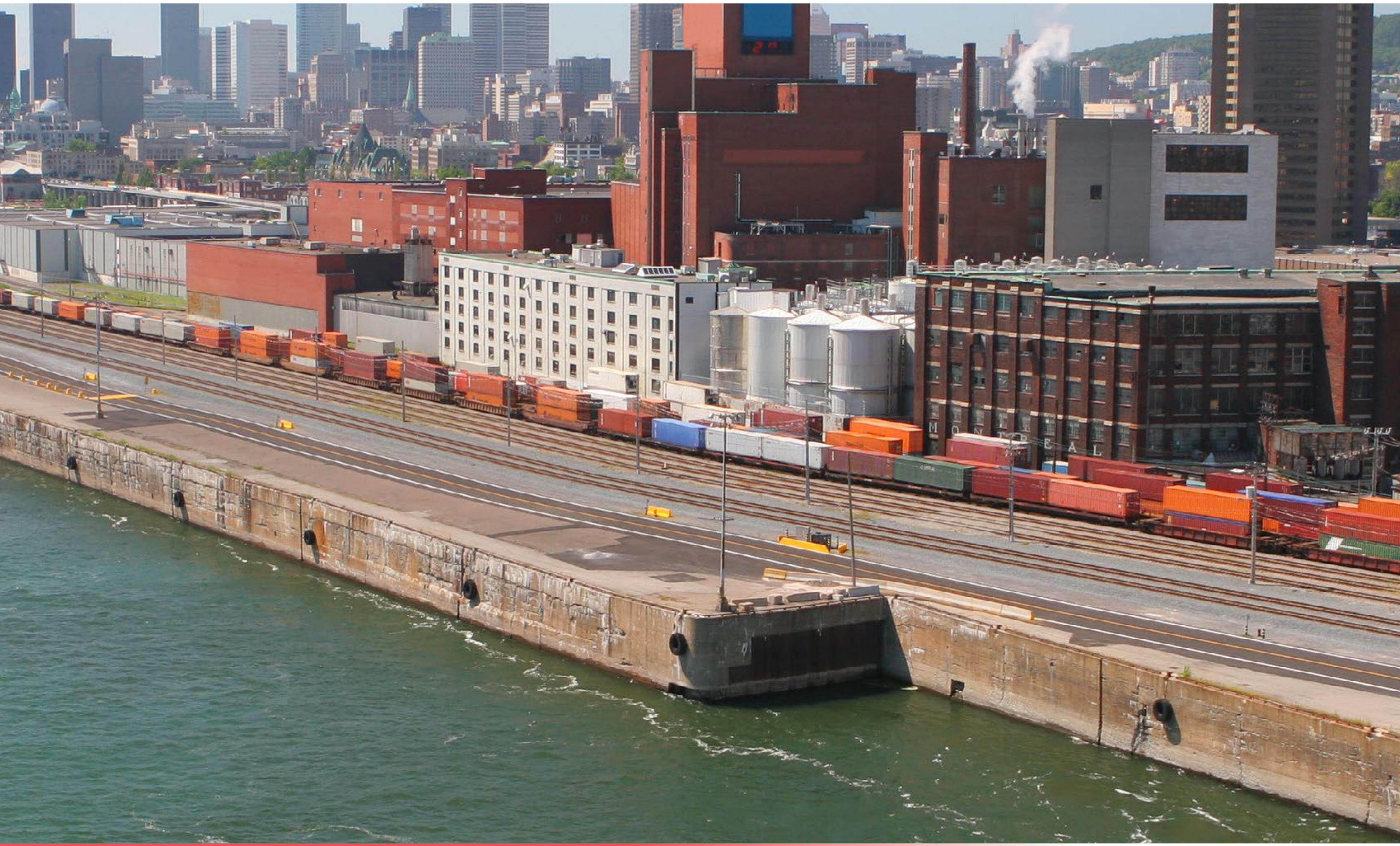
In 2020, VIA Rail progressed in the development of its new Corridor fleet, which will be powered by Tier 4 locomotives. The final design review of the rolling stock was completed; the production on trainsets #1 and #2 began; the selection of the provider for onboard Wi-Fi was made; and progress was made on the implementation of the computerized maintenance management information system, which will be an important tool for managing how trains are maintained. Progress also continued on the High Frequency Rail (HFR) Project. Once operational, HFR will lower GHGs in the Toronto to Québec City corridor through modal shift (reducing automobile use) and rail electrification (90% of the new network is planned to be electrified).

In 2020, Metrolinx performed work on testing and commissioning 16 new Tier 4 AC locomotives.

Genesee & Wyoming is continuing to work on upgrading its fleet and investing in emissions saving technologies. The company is exploring the feasibility of purchasing higher horsepower locomotives and retiring older locomotives, including moving some of the fleet from older Tier 0 locomotives to Tier 1+.

VIA Rail progressed in the development of the HFR Project, a passenger train network that is planned to be

90% ELECTRIFIED.



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2.2 FUEL SAVING TECHNOLOGIES

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

CP has equipped 432 high-horsepower locomotives with Trip Optimizer technology over the past six years, and plans to continue implementation across 50 percent of its high-horsepower fleet by the end of 2022. In 2020, Trip Optimizer technology helped CP save 6.7 million litres of fuel and avoid 19,000 tonnes of GHG emissions. 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 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.

Genesee & Wyoming continues to upgrade its Auxiliary Power Units for newer, more efficient models.

In 2020, 3,109 of 3,756 locomotives (82.8%) 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.

In 2020, Trip Optimizer technology helped CP save

6.7 MILLION LITRES OF FUEL AND AVOID 19,000 TONNES OF GHG EMISSIONS.

2.3 OPERATIONAL EFFICIENCIES

Railways are not only investing in modern technology, but they are also investing in their people and in optimizing operational practices to drive fuel efficiency and emissions reductions.

Process improvements and changes to operating practices associated with CP's precision scheduled railroading (PSR) model drove a 1.4% improvement in fuel efficiency between 2019 and 2020. PSR involves constant monitoring and optimization of all railway assets and processes to maximize operational efficiency and safety. Notable factors contributing to improved fuel economy in 2020 include enhanced productivity from running longer, heavier trains, increased network fluidity and velocity, and proficient operating plan efficiency.

CN is building on its PSR 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. All of these initiatives combined with the efforts of operations and mechanical teams allowed CN to improve its fuel efficiency performance by 4.5% in 2020.

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Process improvements and changes to operating practices associated with CP's precision scheduled railroading model drove a

1.36% IMPROVEMENT IN FUEL EFFICIENCY BETWEEN 2019 AND 2020.

Capitalizing on CN's locomotive telemetry systems and advanced data analytics, also key Digitized Scheduled Railroading (DSR) initiatives, will help CN identify additional opportunities for fuel-conservation operating practices in the coming years.

Due to the impacts of the COVID-19 pandemic on passenger ridership, Metrolinx ran shorter trains throughout most of 2020, which requires less fuel per train-mile. In 2020, Metrolinx continued on its multi-year initiative to monitor excess idling, with the goal of reducing total fuel consumption.

2.4 LOW CARBON FUELS

Railways make use of low carbon 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. Research is being conducted to determine how to reduce possible negative impacts associated with using higher biofuel blends.

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.

CP's procurement group engages with fuel suppliers, equipment manufacturers, industry experts, industry associations, and regulatory agencies to explore advancements in the use of alternative and next-generation fuels in the rail sector.[15] CP has conducted technology trials on a range of fuel sources, including diesel fuels with varying sulphur profiles and other emissions-reducing qualities, plant-based diesel (biodiesel), liquefied natural gas systems, compressed natural gas, and battery-hybrid technologies.[16] CP is currently undertaking a hydrogen-powered locomotive pilot project to evaluate the use of zero-emissions technology in line-haul freight locomotives.[17]

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 2020, the use of sustainable renewable fuels in CN's fleet saved approximately 77,000 tonnes of CO_2e.

In 2020, the use of sustainable renewable fuels in CN's fleet saved approximately

77,000 TONNES OF CO_2E.

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

15 https://sustainability.cpr.ca/operational-excellence/climate-change/#climate-action

16 Ibid.

17 Ibid.

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2.5 PARTNERSHIPS

Continuous improvements in fuel and operational efficiency over the past decades have resulted in significant improvements in emissions intensity, but much work remains to be done. Canadian railways are looking ahead and establishing partnerships with government, academia, and industry stakeholders to continue advancing the transition to a more sustainable future.

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 GHGs and CACs. 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. This work contributes to the development of industry codes and standards. Projects undertaken in this program are selected through a consultation process that spans the federal government, academia, and the railway industry. Notable updates for 2020, the second year of the 2019-2021 rail RD&D work plan are:

- CUTRIC, working with Transport Canada, completed its rail innovation technology scan. Based on the focus group sessions with freight and passenger railways, rail technology developers, academia, industry consultants, and government, it highlighted 10 technology areas that could prove most effective for reducing rail emissions. Major themes that emerged were hydrogen as a fuel for locomotives, the use of artificial intelligence for managing fleets and traffic, propulsion simulations, and light-weight materials for railcars. The full report is accessible from Transport Canada's open science portal.
- Completion of a preliminary study examining the state of hydrogen locomotive technology, what a testing deployment might look like, and what it means for operational safety. This study was completed in 2020 and posted on Transport Canada's open science portal.
- Support for evaluating lignin-derived renewable diesel being developed by CanmetENERGY-Ottawa/NRCan for locomotive applications. TC is also helping to evaluate CanmetENERGY-Ottawa/NRCan's novel dual-catalytic converter design for reducing NO_x and PM emissions.

Transport Canada also supports the development of technologies for reducing emissions through the Clean Transportation System – Research and Development Program. This is a program where projects are awarded grant funding to carry out research and demonstration work for aviation, marine, and rail modes of transportation. The rail projects that received grant funding in 2020 are carrying out research to reduce the costs of hydrogen production, assessing various options for alternative fuels such as hydrogen, ammonia, methanol, ethanol, and dimethyl ether, and testing variable speed generators that better match output from diesel engines.

NATURAL RESOURCES CANADA – LINGIN-DERIVED DIESEL FUEL

Through Natural Resources Canada, CanmetENERGY-Ottawa 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 a diesel blend containing 5 and 10% lignin- derived diesel meets the CGSB 3.18 locomotive fuel specifications.[18] These blends would be compatible with existing infrastructure and locomotives. The next stage of the project will be to explore blends greater than 10%.

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.

18 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.

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GOVERNMENT OF CANADA - STRENGTHENED CLIMATE PLAN AND HYDROGEN STRATEGY

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.

Canada's Hydrogen Strategy (2020) complements the strengthened climate plan, as the Strategy aims to position Canada's ports as hosts for early deployment hubs of fuel cell equipment, with marine, rail, and on-road vehicles that could share hydrogen infrastructure at scale.

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. Preliminary results have been produced and are under review. CN is in year 4 of this 5-year optimization research project.

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 – PARTNERING WITH BALLARD POWER SYSTEMS ON HYDROGEN LOCOMOTIVES

CP is working to develop North America's first hydrogen-powered line-haul freight locomotive by retrofitting a diesel-powered locomotive with hydrogen fuel cells; these fuel cells will power the locomotive's electric traction motors.

CP is partnering with Ballard Power Systems to employ Ballard fuel cell modules into 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.

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2.6 RAIL PATHWAYS INITIATIVE - PHASE 1

The Rail Pathways Initiative is being led by a team from Pollution Probe, one of Canada's leading low-carbon transportation NGOs, and The Delphi Group, a leading sustainability consulting firm. The Initiative is being supported by both Transport Canada and the Railway Association of Canada, and fulfills a key commitment of the 2018-2022 MOU between these parties. This commitment calls for a "comprehensive pathway document for aligning government and industry efforts to reduce emissions produced by the railway sector."

The primary focus of Phase 1 was to catalogue ongoing domestic and global activities related to rail sector decarbonization. This work culminated in the development of a landscape document which fulfilled three objectives:

1. Develop a common understanding of the current state of rail sector decarbonization in Canada, to assist with collaborations between industry and government;
2. create a repository of current federal and provincial legislative instruments and activities impacting rail sector decarbonization; and
3. contribute to next-phase work on a roadmap to achieving future GHG reductions in the rail sector.

Phase 1 was completed in 2020, with the finalization of the landscape document. Phase 2 of the Pathways Initiative – Towards Net Zero: *Developing a Rail Decarbonization Roadmap for Canada* - was launched in 2021. Phase 2 outputs will identify and assess potential GHG reduction measures and outline stakeholder roles in leveraging those measures for meaningful emissions reductions. Work on Phase 2 is scheduled to wrap up in mid-2022.

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3. TRAFFIC DATA

3.1 FREIGHT TRAFFIC HANDLED

As shown in Table 1 and Figure 1, traffic in 2020 handled by Canadian railways totaled 846.76 billion gross tonne-kilometres (GTK) compared with 863.98 billion GTK in 2019, a decrease of 2.0%. The 2020 GTK represents an increase of 26.7% from the reference year of 2005. Revenue traffic in 2020 decreased to 451.67 billion revenue tonne-kilometres (RTK) from 455.06 billion RTK in 2019, a decrease of 0.7%. When compared to 352.91 billion RTK in 2005, this represents an increase of 28.0%. Since 2005, the average annual growth rates for GTK and RTK were 1.6% and 1.7%, respectively.

TABLE 1 TOTAL FREIGHT TRAFFIC, 2005, 2011-2020 (BILLION TONNE-KILOMETRES)

	2005	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
GTK											
Class 1	628.09	644.75	674.62	695.58	754.24	752.30	722.33	778.86	820.67	824.53	807.01
Regional & Shortline	40.45	34.79	37.32	39.62	39.19	42.09	44.07	44.59	43.98	39.45	39.75
Total	**668.54**	**679.54**	**711.94**	**735.19**	**793.43**	**794.39**	**766.40**	**823.45**	**864.66**	**863.98**	**846.76**
RTK											
Class 1	328.24	337.91	356.92	371.77	399.47	394.10	383.47	411.22	433.45	432.38	430.39
Regional & Shortline	24.67	22.25	23.08	24.23	23.01	23.98	25.05	24.25	22.27	22.68	21.29
Total	**352.91**	**360.16**	**380.00**	**396.00**	**422.49**	**418.08**	**408.53**	**435.46**	**455.72**	**455.06**	**451.67**
Ratio RTK/GTK*	**0.53**	**0.52**	**0.53**	**0.53**	**0.53**	**0.52**	**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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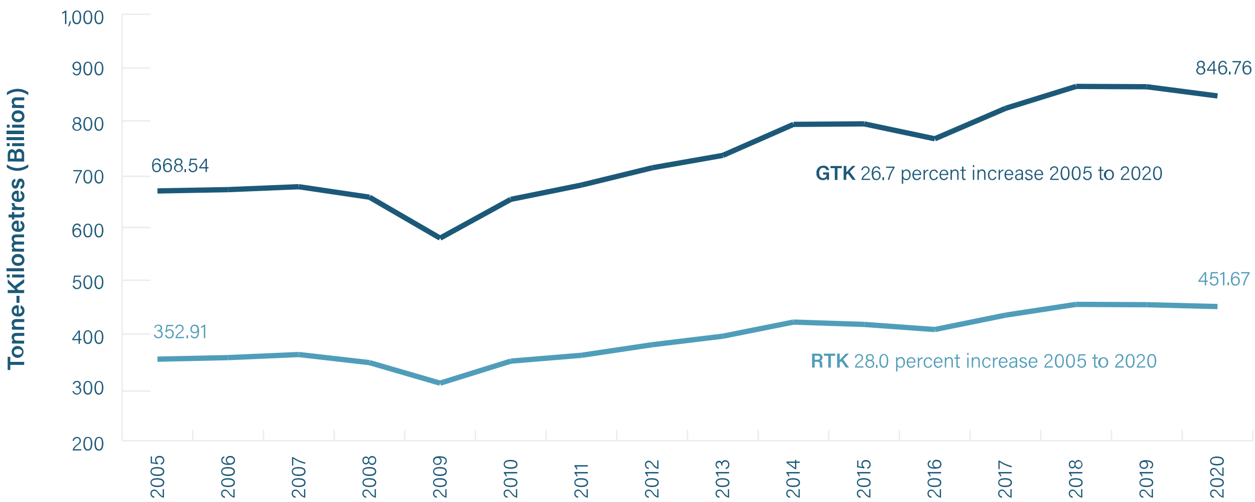
FIGURE 1 TOTAL FREIGHT TRAFFIC, 2005-2020



In 2020, Class 1 GTK traffic decreased by 2.1% to 807.01 billion from 824.53 billion in 2019 (Table 1) and accounted for 95.3% of the total GTK hauled. Class 1 RTK traffic decreased by 0.5% in 2020 to 430.39 billion from 432.38 billion in 2019 and accounted for 95.3% of the total RTK.

Of the total freight traffic in 2020, regional & shortlines were responsible for 39.75 billion GTK (or 4.7%) and 21.29 billion RTK (or 4.7%). In 2020, regional & shortline railways experienced a 6.2% decrease in RTK compared to 2019 and an increase of 0.7% of their GTK traffic.

3.1.1 FREIGHT CARLOADS BY COMMODITY GROUPING

The total 2020 freight carloads for 11 commodity groups are shown in Figure 2 and Table 2 below.

FIGURE 2 CANADIAN RAIL ORIGINATED CARLOADS BY COMMODITY GROUPING, 2020

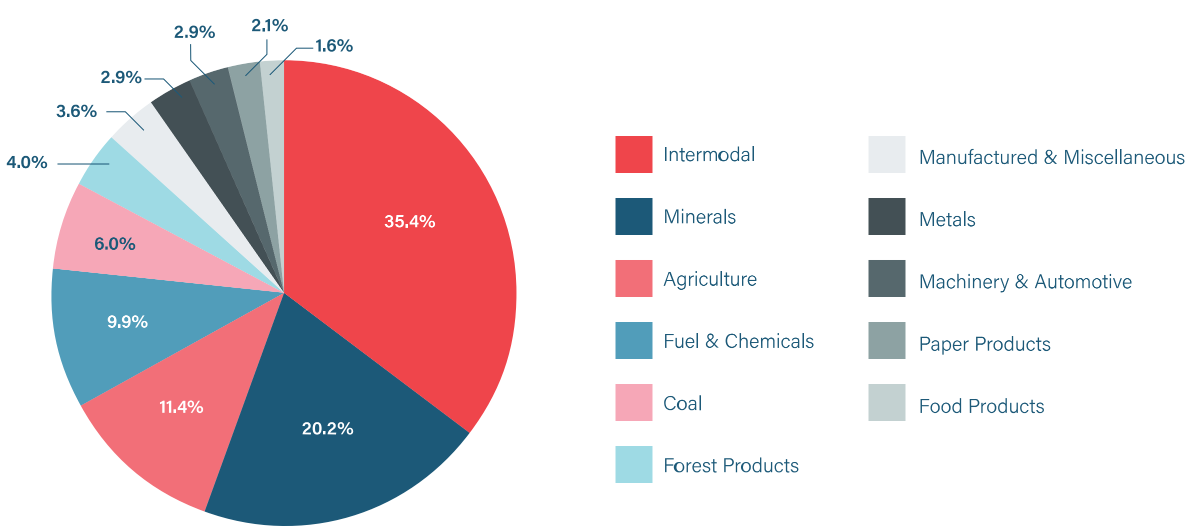


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TABLE 2 CANADIAN RAIL ORIGINATED FREIGHT CARLOADS BY COMMODITY GROUPING, 2005, 2019-2020

	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**
2019	538,726	361,067	1,027,286	225,031	164,230	208,879	645,268	127,821	80,009	178,379	1,927,291	**5,483,989**
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**
2005-2020	47.8%	-8.3%	65.2%	-50.7%	-47.0%	-34.4%	14.0%	-66.2%	97.1%	196.6%	147.5%	**32.2%**
2019-2020	14.2%	-10.3%	5.7%	-5.1%	-4.8%	-26.0%	-17.0%	-11.6%	8.8%	9.1%	-1.1%	**-1.8%**

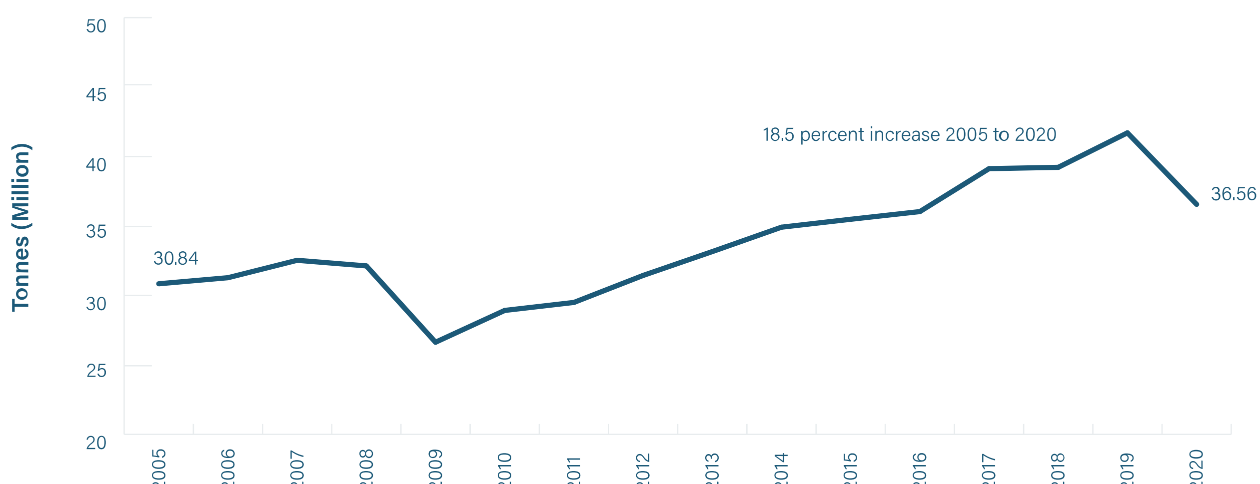
There were significant changes in carloads by commodity in 2020 compared to previous years, owing in part to the impacts of the COVID-19 pandemic. Demand for Canada's agricultural products remained strong, however, there was a global container shortage affecting intermodal shipments, most automotive manufacturers were shut down for approximately two months in the spring, and the demand for energy fell significantly. Despite the fluctuations across commodity groups, total freight carloads only decreased by 1.8%, which is similar to the 0.7% decrease in total revenue tonne-kilometres (see Table 1).

Global supply chain issues, including the global container shortage, affected intermodal shipments in 2020. Overall, since 2005, intermodal tonnage, comprising both container-on-flat-car and trailer-on-flat-car traffic, has risen by 18.5%, equating to an average annual growth of 1.1% as illustrated in Figure 3.

3.1.2 INTERMODAL TRAFFIC

Of the total freight carloads in 2020, intermodal made up the largest share at 35.4%, as illustrated in Figure 2 and Table 2 above. The number of intermodal carloads handled by railways in Canada decreased to 1,905,493 from 1,927,291 in 2019, a decrease of 1.1%. Intermodal tonnage decreased by 12.3% to 36.56 million tonnes from 41.7 million tonnes in 2019, as shown in Figure 3.

FIGURE 3 INTERMODAL TONNAGE, 2005-2020



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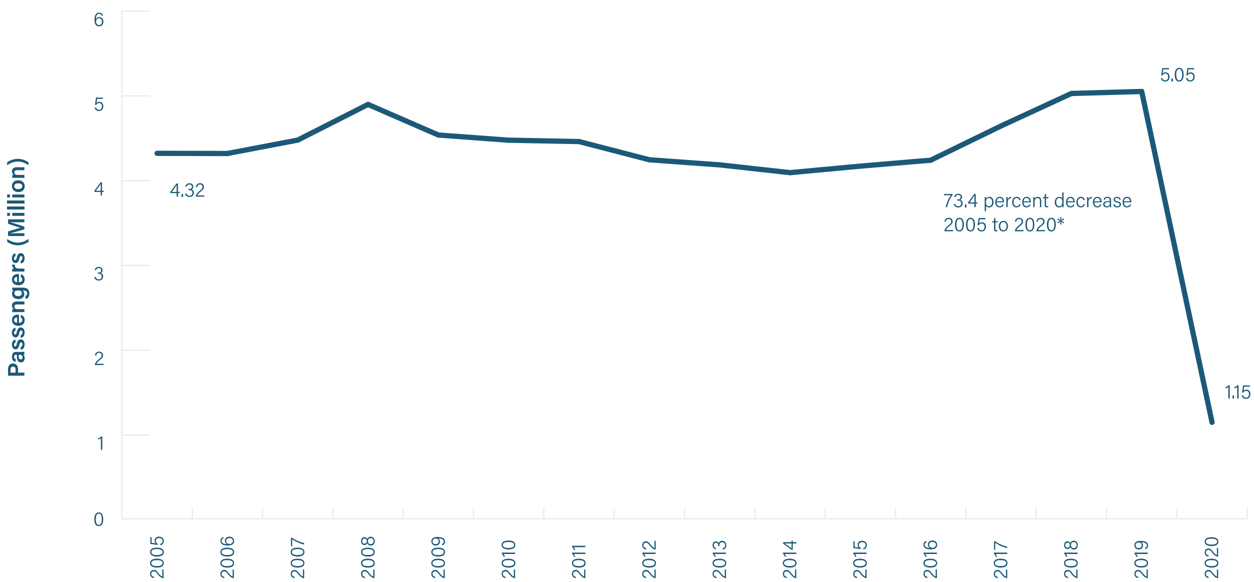
3.2 PASSENGER TRAFFIC HANDLED

3.2.1 INTERCITY PASSENGER SERVICES

Intercity passenger traffic in 2020 totaled 1.15 million passengers, as compared to 5.05 million passengers in 2019, a decrease of 77.3%, and a 73.4% decrease from 4.32 million passengers in 2005 (Figure 4).

FIGURE 4 INTERCITY RAIL PASSENGER TRAFFIC, 2005-2020



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

The total revenue passenger-kilometres (RPK) for intercity passenger traffic totaled 365.02 million. This is a decrease of 78.7% as compared to 1,717.33 million in 2019 and 75.3% decrease from 1,479.61 million in 2005 (Figure 5).

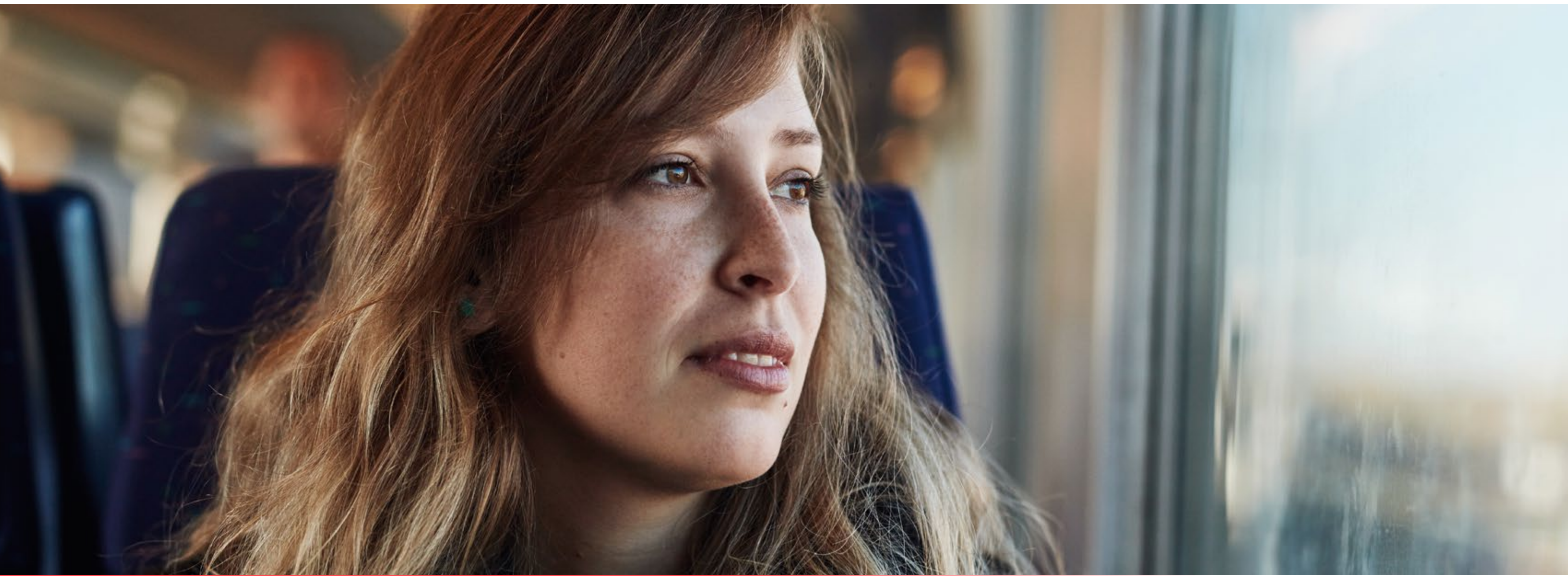


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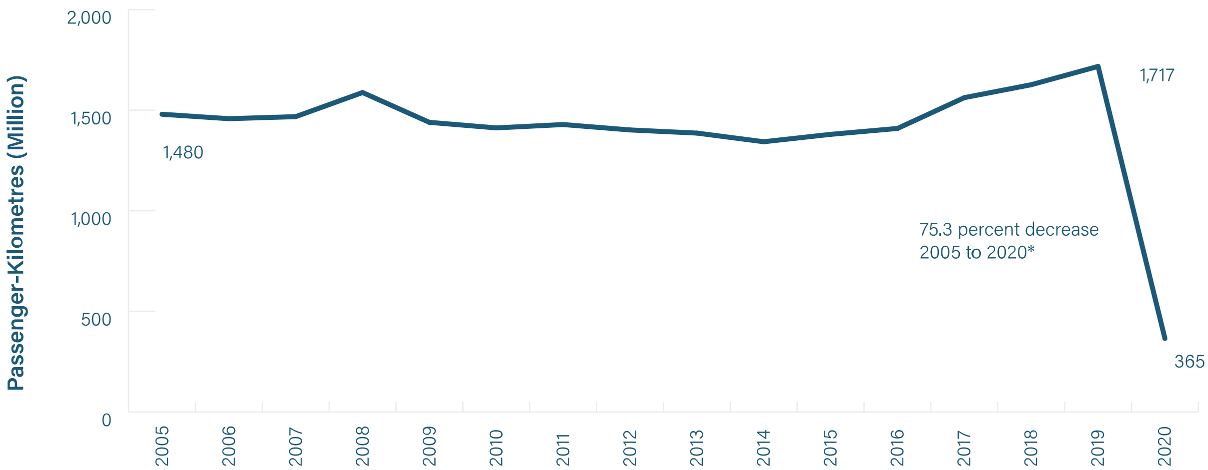
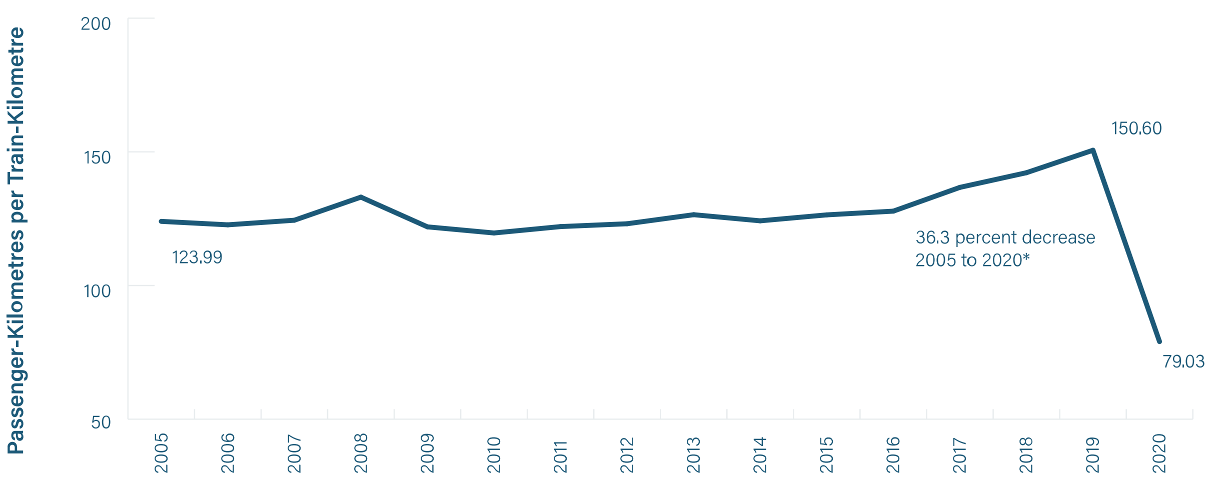
FIGURE 5 INTERCITY RAIL REVENUE PASSENGER-KILOMETRES, 2005-2020



* In 2020, 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 2020 was 79 passenger-km per train-km, 150.6 in 2019, and 123.99 in 2005. As a percentage, train efficiency in 2020 was 36.6% below that in 2005. The significant decrease in intercity rail train efficiency is because there were fewer passengers per train, as a result of COVID-19 restrictions and reduction in overall travel.

FIGURE 6 INTERCITY RAIL TRAIN EFFICIENCY, 2005-2020



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

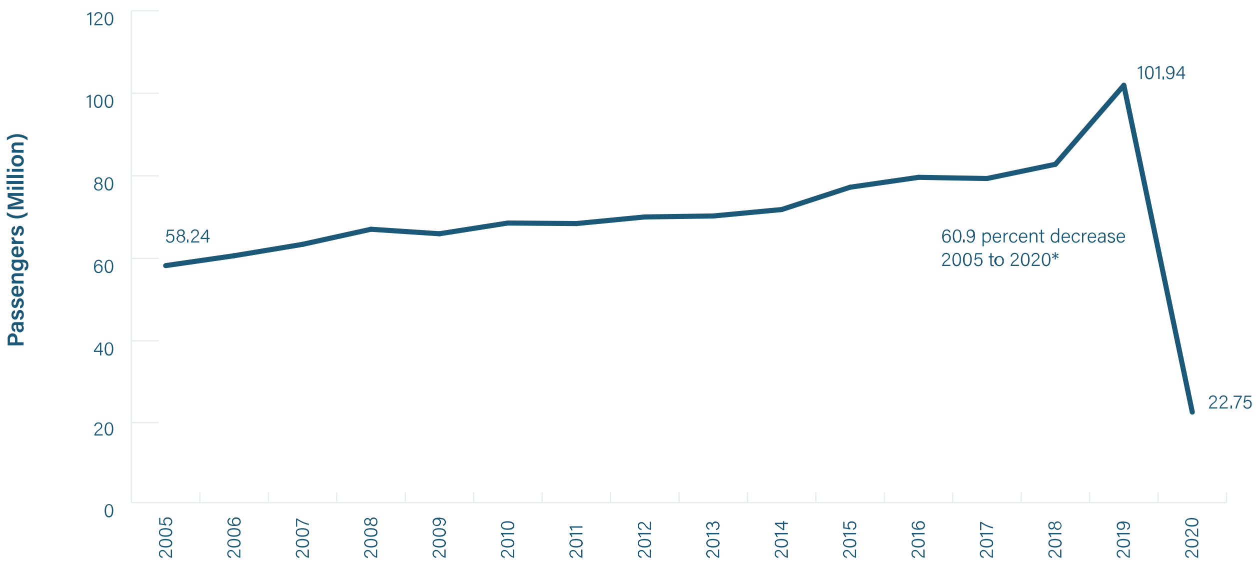
3.2.2 COMMUTER RAIL

In 2020, commuter rail passengers totaled 22.75 million (Figure 7). This is down from 101.94 million in 2019, a decrease of 77.7%.[19] Commuter railways continued to provide essential transportation services, and with a decreased number of passengers per train, efficiency metrics for commuter railways worsened in 2020. As shown in Figure 7, by 2020, commuter traffic decreased 60.9% below the 2005 base year level of 58.24 million passengers.

The four commuter operations in Canada using diesel locomotives and/or diesel multiple units (DMUs) are exo serving the Montréal-centred region (previously Réseau de transport métropolitain), Capital Railway serving Ottawa, Metrolinx serving the Greater Toronto Area, and West Coast Express serving the Vancouver-Lower Fraser Valley region.

19 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.

FIGURE 7 COMMUTER RAIL PASSENGERS, 2005-2020



* In 2020, 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 in 2020, as most tourist and excursion operators were not open for passenger service.

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4. FUEL CONSUMPTION DATA

Total rail sector fuel consumption in 2020 was 2,090.94 million litres – a 7.4% decrease from 2019 and a 5.3% decrease from 2005. In 2020, freight operations consumed 2,021.34 million litres of fuel – a 4.1% decrease from 2,107.90 in 2005. Over this same time period (2005-2020), freight traffic (RTKs) increased by 28.0%, resulting in a 25.1% improvement in freight fuel efficiency. Passenger rail operations reduced fuel consumption by 48.4% in 2020 compared to 2019, to accommodate lower ridership levels.

There was lower fuel consumption in 2020 compared to 2019. Of the total fuel consumed by all railway operations, Class 1 and regional & shortline operations consumed 94.0%, yard switching and work train operations consumed 2.6%, and passenger operations accounted for 3.3%.

For total freight train operations fuel consumption, Class 1 railways accounted for 91.9%, regional & shortlines 5.4%, and yard switching and work trains 2.7%.

TABLE 3 CANADIAN RAIL OPERATIONS FUEL CONSUMPTION, 2005, 2011-2020 (MILLION LITRES)

	2005	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Class 1	1,893.19	1,816.44	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
Regional & Shortline	140.13	107.91	96.55	101.72	108.91	105.45	101.83	114.15	111.88	111.99	108.69
Yard Switching	67.85	44.79	46.85	41.77	62.02	52.97	46.95	50.29	51.56	51.71	46.81
Work Train	6.73	7.72	8.77	10.30	10.80	11.35	10.84	10.01	7.10	9.94	8.41
Total Freight Operations	**2,107.90**	**1,976.86**	**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**
Intercity*	64.05	58.63	50.99	46.17	44.89	46.98	47.93	51.02	52.77	51.05	21.74
Commuter*	35.31	49.81	50.22	48.61	49.67	60.50	59.43	64.46	65.74	79.53	47.85
Tourist Train & Excursion*	1.74	2.19	2.27	2.25	2.61	2.65	2.79	3.22	3.22	4.30	0.00
Total Passenger Operations*	**101.10**	**110.63**	**103.48**	**97.03**	**97.16**	**110.13**	**110.15**	**118.70**	**121.72**	**134.89**	**69.60**
Total Rail Operations	**2,209.00**	**2,087.50**	**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**

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

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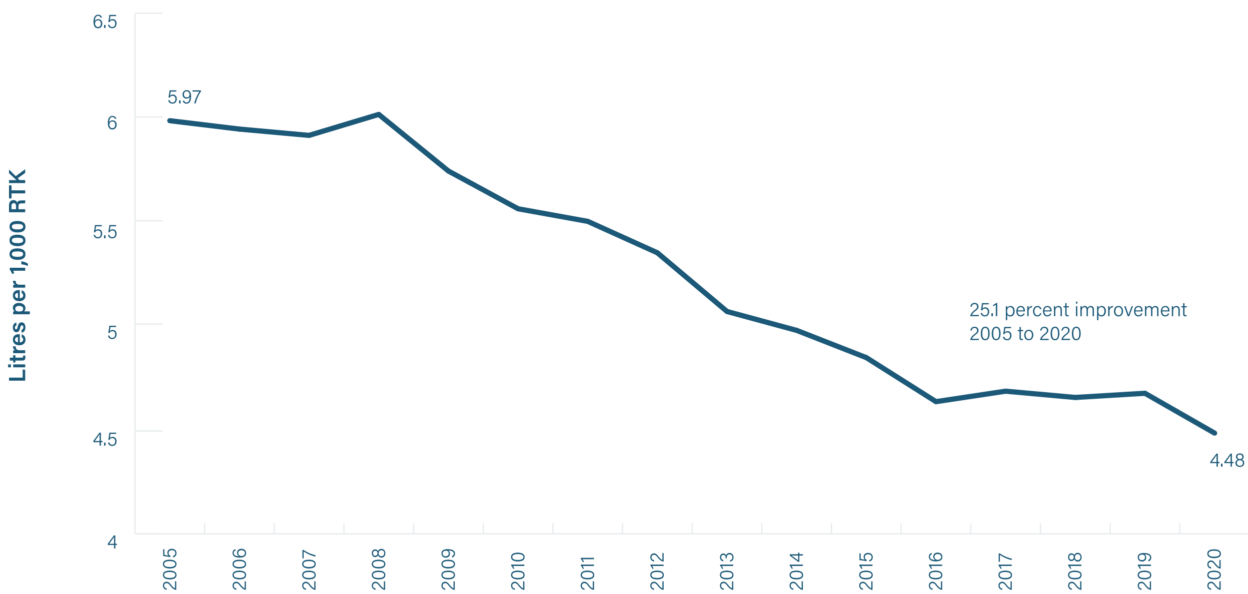
4.1 FREIGHT OPERATIONS

Fuel consumption in 2020 for all freight train, yard switching, and work train operations was 2,021.34 million litres, a decrease of 4.8% from the 2,124.35 million litres consumed in 2019 and a decrease of 4.1% 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 2020 railways moved one tonne of freight approximately 223 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 2020 for overall rail freight traffic was 4.48 litres per 1,000 RTK. This value is a 4.1% decrease from the 4.67 L/1,000 RTK in 2019 and 25.1% 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, 2005-2020



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, 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 that railways are establishing with government, academia, and 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 69.60 million litres in 2020, a decrease of 48.4% from the 134.89 million litres consumed in 2019. The decrease in passenger rail fuel consumption is related to the COVID-19 pandemic and significant changes to railway operations and ridership as a result. The breakdown and comparison with previous years is provided in Table 3.

Intercity passenger rail fuel consumption decreased by 57.4% from 51.05 million litres in 2019 to 21.74 million litres in 2020. Fuel consumption for commuter rail decreased by 39.8% from 79.53 million litres in 2019 to 47.85 million litres in 2020. Lastly, the COVID-19 pandemic caused a significant reduction in tourist and excursion rail fuel consumption.

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 2020, some provinces, such as Ontario and British Columbia, required a minimum renewable fuel content of 4%, while others required 2%.[20]

20 For some provinces, renewable fuel requirements are planned to become more stringent in the coming years (e.g., Manitoba increasing the biodiesel requirement to 3.5% in 2021 and 5.0% in 2022; Québec 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, 2020

	Locomotives	Share of Fleet
Line Haul: Class 1	2,645	70.4%
Line Haul: Regional	133	3.5%
Line Haul: Shortline	145	3.9%
Freight Switching Operations	594	15.8%
Total - Freight Operations	**3,517**	**93.6%**
Passenger Train Locomotives	215	5.7%
DMUs	24	0.6%
Total - Passenger Operations	**239**	**6.4%**
Total - Passenger & Freight Operations	**3,756**	**100.0%**

Note: Numbers include all active fleet equipment.

5.2 LOCOMOTIVES MEETING EMISSION STANDARDS

Locomotives operated by federally regulated railways are subject to the emission standards set out under the 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-compliant locomotives.

Table 5 shows the total number of in-service locomotives meeting emission standards[21] compared to the total number of freight and passenger line haul diesel locomotives. Because the locomotive fleet as reported 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.

21 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.

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TABLE 5 LOCOMOTIVES IN CANADIAN FLEET MEETING EMISSION STANDARDS, 2005, 2011-2020

	2005	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Number of freight and passenger locomotives meeting an emission standard	888	1,317	1,512	1,631	1,538	1,266	1,267	2,157	2,995	2,982	3,108
Number of freight and passenger locomotives in Canadian Fleet	2,986	2,978	3,092	3,063	2,700	2,400	2,318	3,177	3,782	3,840	3,756
Percentage of locomotives meeting an emission standard	29.7%	44.2%	48.9%	53.2%	57.0%	52.8%	54.7%	67.9%	79.2%	77.7%	82.7%

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

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

In 2020, 82.7% of the fleet subject to regulation (3,108 locomotives of 3,756) met emission standards (set-out under the LER or the US EPA regulations). Not all locomotives need to meet emission standards. Provincially regulated railways are not subject to the *Locomotive Emissions Regulations*, and not all locomotives of federally regulated railways are subject to the Regulations. Exceptions include: steam-and electric-powered locomotives; locomotives manufactured prior to 1973 that have not been upgraded; and locomotives with less than 1,006 horsepower.

Only *new* locomotives, not *active* existing locomotives, are required to meet emission standards. Locomotives become new when they are freshly manufactured, remanufactured, upgraded or imported. Table 6 provides an overview of the 2020 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 2020. It also presents the number of locomotives with anti-idling devices.

TABLE 6 LOCOMOTIVE FLEET BREAKDOWN BY TIER LEVEL, 2020

Tier Level*	Locomotives		Locomotives with anti-idling devices	Added	Retired	Remanufactured
	Number	Percent of fleet				
Elec/Steam/Other	11	0.3%	-	-	-	-
No Tier	637	17.0%	294	-	59	-
Tier 0	205	5.5%	129	2	3	-
Tier 0+	841	22.4%	753	7	46	-
Tier 1	25	0.7%	25	-	-	-
Tier 1+	699	18.6%	690	1	40	30
Tier 2	180	4.8%	117	-	-	-
Tier 2+	477	12.7%	471	6	-	-
Tier 3	367	9.8%	351	7	-	-
Tier 4	314	8.4%	279	46	1	-
Total	**3,756**	**100%**	**3,109**	**69**	**149**	**30**

*See appendix D for additional information regarding tier levels.

In 2020, seven Tier 3 and 46 Tier 4 high-horsepower locomotives were added to the Canadian fleet. A total of 30 locomotives were remanufactured (upgraded) to Tier 1+ and 149, 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 2020 equipped with a device to minimize unnecessary idling, such as an AESS system or APU, was 3,109, which represents 82.8% of the fleet, compared with 2,969 in 2019 (77.3% 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 1990–2020: Greenhouse Gas Sources and Sinks in Canada, which is submitted annually to the United Nations Framework Convention on Climate Change (UNFCCC).[22] Table 7 presents the 2020 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, 2020

	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 (SF_6) are not present in diesel fuel.
Source: National Inventory Report 1990–2020: Greenhouse Gas Sources and Sinks in Canada, Environment and Climate Change Canada, 2022.

22 National Inventory Report 1990 – 2020: Greenhouse Gas Sources and Sinks in Canada, Environment and Climate Change Canada, 2022 https://unfccc.int/documents/461919.

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6.1.2 GREENHOUSE GAS EMISSIONS

In 2020, GHG emissions produced by the railway sector (expressed as CO_2e) were 6,253.72 kt, a decrease of 7.4% as compared to 6,757.09 kt in 2019. The 2020 emissions represent a 5.3% decrease from 6,606.83 kt in 2005 (despite a rise in RTK traffic of 28.0% over the same period).

Table 8 displays the GHG emissions produced in 2005 and annually since 2011; and figure 9 presents the annual trend graphically. The GHG emissions for years prior to 2011 are available upon request to the RAC.

TABLE 8 GHG EMISSIONS BY RAILWAY SERVICE IN CANADA, 2005, 2011-2020 (KILOTONNES)

	2005	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
FREIGHT - LINE HAUL											
CO_2	5,450.31	5,158.22	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
CH_4	7.57	7.17	7.35	7.27	7.55	7.30	6.83	7.37	7.68	7.68	7.32
N_2O	623.50	590.09	604.82	598.35	621.62	600.54	562.39	606.84	632.23	632.51	602.89
CO_2e	**6,081.39**	**5,755.48**	**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**
YARD SWITCHING AND WORK TRAIN											
CO_2	199.91	140.76	149.09	139.58	195.20	172.41	154.91	161.64	157.25	165.27	148.03
CH_4	0.28	0.20	0.21	0.19	0.27	0.24	0.22	0.22	0.22	0.23	0.21
N_2O	22.87	16.10	17.05	15.97	22.33	19.72	17.72	18.49	17.99	18.91	16.93
CO_2e	**223.06**	**157.06**	**166.35**	**155.74**	**217.80**	**192.37**	**172.85**	**180.36**	**175.45**	**184.40**	**165.17**
TOTAL FREIGHT OPERATIONS											
CO_2	5,650.22	5,298.98	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
CH_4	7.85	7.36	7.55	7.46	7.82	7.53	7.05	7.60	7.90	7.91	7.53
N_2O	646.37	606.19	621.87	614.31	643.95	620.26	580.11	625.33	650.22	651.42	619.83
CO_2e	**6,304.45**	**5,912.53**	**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**
PASSENGER - INTERCITY, COMMUTER, TOURIST/EXCURSION*											
CO_2	271.00	296.55	277.38	260.09	260.45	295.20	295.25	318.17	326.28	361.56	186.55
CH_4	0.38	0.41	0.39	0.36	0.36	0.41	0.41	0.44	0.45	0.50	0.26
N_2O	31.00	33.92	31.73	29.75	29.79	33.77	33.78	36.40	37.33	41.36	21.34
CO_2e	**302.38**	**330.89**	**309.50**	**290.21**	**290.60**	**329.38**	**329.44**	**355.01**	**364.06**	**403.43**	**208.15**
TOTAL RAILWAY											
CO_2	5,921.23	5,595.53	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
CH_4	8.23	7.78	7.94	7.82	8.18	7.94	7.46	8.04	8.35	8.42	7.79
N_2O	677.37	640.11	653.61	644.07	673.74	654.03	613.89	661.73	687.55	692.78	641.17
CO_2e	**6,606.83**	**6,243.42**	**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**

* In 2020, 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 2022 National Inventory Report. Historical values have been updated.

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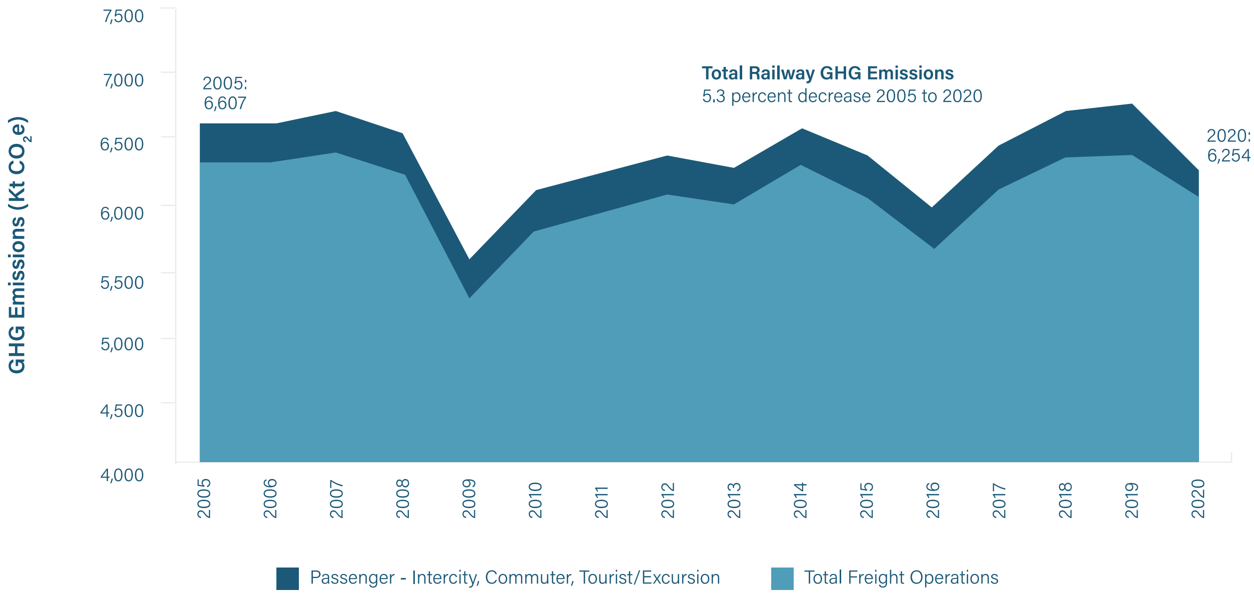
FIGURE 9 GHG EMISSIONS, 2005-2020



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 2020 GHG emissions intensity levels for these categories, as well as for commuter rail.

TABLE 9 GHG EMISSIONS INTENSITIES BY RAILWAY SERVICE IN CANADA, 2005, 2011-2020

	2005	2011	2012	2013	2014	2015	2016	2017 (MOU Baseline)	2018	2019	2020	2022 (Target)
Total Freight (kg CO_2e/1,000 RTK)	17.86	16.42	15.96	15.13	14.87	14.47	13.85	14.01	13.92	13.96	13.38	No Target
Class 1 Freight (kg CO_2e/1,000 RTK)	17.25	16.08	15.72	14.88	14.36	14.06	13.51	13.56	13.45	13.49	12.91	12.75
Regional & Shortline Freight (kg CO_2e/1,000 RTK)	16.99	14.51	12.51	12.56	14.15	13.15	12.16	14.08	15.02	14.77	15.27	13.66
Intercity Passenger (kg CO_2e/Passenger-km)*	0.13	0.123	0.109	0.100	0.100	0.102	0.102	0.098	0.097	0.089	0.178	0.092
Commuter Rail (kg CO_2e/Passenger)*	1.81	2.18	2.10	2.02	1.96	2.34	2.23	2.43	2.37	2.33	6.29	No Target

* In 2020, 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 2022 National Inventory Report. Historical values have been updated.

The GHG emissions intensities for freight traffic decreased in 2020 by 4.1% to 13.38 kg CO_2e/1,000 RTK from 13.96 kg CO_2e/1,000 RTK in 2019. Since 2005, the GHG emissions intensity for total freight has decreased 25.1% from 17.86 kg CO_2e/1,000 RTK. Class 1 freight saw a 4.3% decrease in GHG emissions intensity from 13.49 kg CO_2e/1,000 RTK in 2019 to 12.91 kg CO_2e/1,000 RTK in 2020. All other categories increased in emissions intensity from 2019 to 2020. There is significant variation in regional and shortline railways, in terms of both size and efficiency.

From 2019 to 2020, emissions intensity increased for half of the regional and shortline railways, while emissions intensity decreased for the other half; however, the overall emissions intensity of regional & shortline freight railways increased by 3.4%. Emissions intensity for intercity passenger rail increased by 100.4%, and commuter rail increased by 169.6% as a consequence of COVID-19 and decreased ridership.

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

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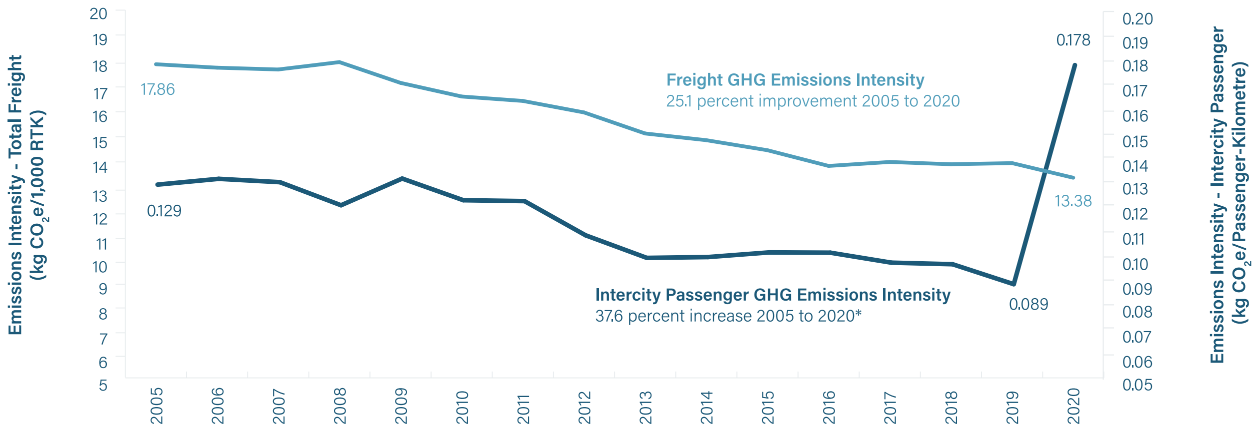
FIGURE 10 GHG EMISSIONS INTENSITIES, 2005-2020



* In 2020, 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 2020 have been calculated in grams per litre (g/L) of fuel consumed for NO_x, PM_{10}, CO, HC, and SO_x for each category of operation (i.e., freight, switching, and passenger operations). All freight line haul CAC EFs decreased in 2020 compared to 2019, except for CO and SO_2, which stayed the same. EFs for yard operations and passenger operations stayed the same or decreased in 2020 compared to 2019.

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 2011-2020. EFs for years prior to 2011 are available upon request to the RAC.

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TABLE 10 CAC EMISSIONS FACTORS FOR DIESEL LOCOMOTIVES, 2005, 2011-2020 (g/L)

Year	NO_x	PM_{10}	CO	HC	SO_2
FREIGHT: LINE HAUL					
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
2011	47.50	1.15	7.03	2.21	0.17
2005	56.12	1.54	6.97	2.56	2.25
YARD SWITCHING AND WORK TRAIN					
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
2011	69.64	1.53	7.35	4.06	0.17
2005	69.88	1.64	7.35	4.06	2.25
TOTAL PASSENGER					
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
2011	54.94	1.16	7.02	2.19	0.18
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 2011 to 2020, namely NO_x, PM_{10}, CO, HC, and SO_x. The values presented are for both absolute amounts and intensities per productivity unit. The emissions and intensities for years before 2011 are available upon request to the RAC.

The CAC of key concern for the railway sector is NO_x.[23] As shown in Table 11, NO_x emissions in 2020 for total railway operations was 70.70 kt, down 11.7% from 80.11 kt in 2019. Freight operations accounted for 96.0% 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 0.15 kg per 1,000 RTK in 2020, a 7.6% decrease from 2019. Total freight NO_x emissions intensity has decreased by 55.6% since 2005 (0.34 kg per 1,000 RTK.)

23 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, 2011-2020 (KILOTONNES, UNLESS OTHERWISE SPECIFIED)

Year	NO_x	PM_{10}	CO	HC	SO_2 (tonnes)
FREIGHT: LINE HAUL					
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
2011	91.41	2.21	13.53	4.25	327.14
2005	114.12	3.13	14.18	5.21	4,580.20
YARD SWITCHING AND WORK TRAIN					
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
2011	3.66	0.08	0.39	0.21	8.93
2005	5.21	0.12	0.55	0.30	168.00
TOTAL FREIGHT OPERATIONS[(1)]					
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
2011	95.06	2.29	13.91	4.47	336.07
2005	119.33	3.25	14.73	5.52	4,748.19

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TABLE 11 LOCOMOTIVE CAC EMISSIONS, 2005, 2011-2020 (KILOTONNES, UNLESS OTHERWISE SPECIFIED)

Year	NO_x	PM_{10}	CO	HC	SO_2 (tonnes)
TOTAL PASSENGER*					
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
2011	5.99	0.13	0.77	0.24	19.17
2005	7.18	0.16	0.71	0.26	226.29
TOTAL RAILWAY OPERATIONS(2)					
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
2011	101.06	2.42	14.68	4.71	355.24
2005	126.50	3.41	15.43	5.78	4,974.49
TOTAL FREIGHT EMISSIONS INTENSITY (KG/1,000 RTK)					
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
2011	0.26	0.0064	0.0386	0.0124	0.00093
2005	0.34	0.0092	0.0417	0.0156	0.01345

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

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

(2) Total Railway Operations = Total Freight Operations + Total Passenger

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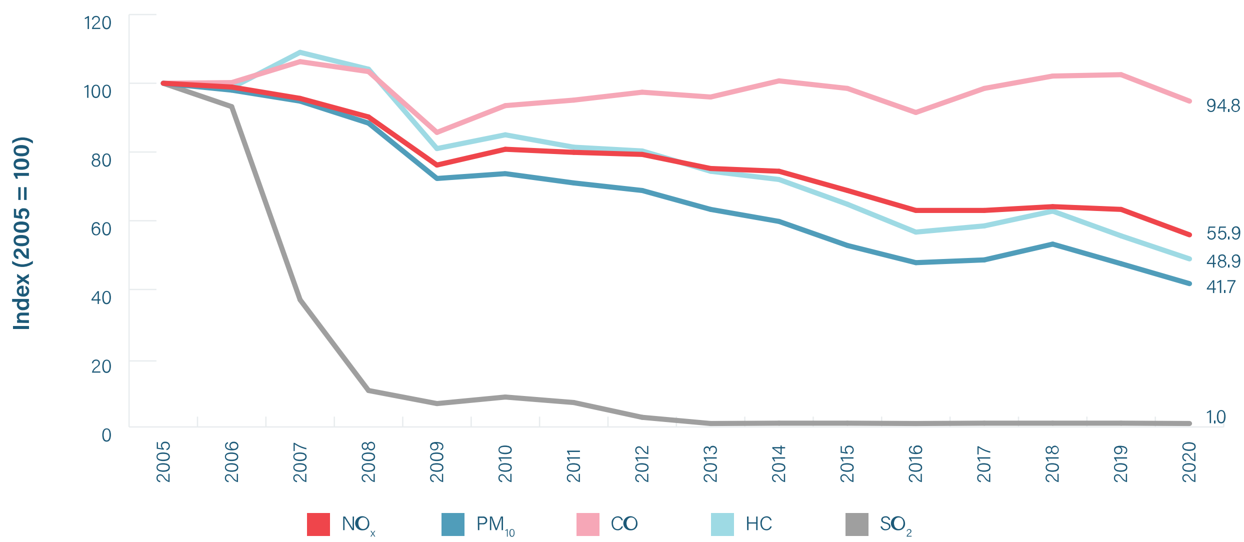
Figure 11 shows the reductions in CAC emissions from total railway operations in Canada, since 2005. Despite an increase in traffic over this time, CAC emissions have decreased for CO (-5.2%), NO_x (-44.1%), HC (-51.1%), PM_{10} (-58.3%), and SO_2 (-99.0%).

FIGURE 11 INDEX OF LOCOMOTIVE CAC EMISSIONS, 2005-2020



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7. TROPOSPHERIC OZONE MANAGEMENT AREAS

The three Tropospheric Ozone Management Areas (TOMA) relate to air quality for the Lower Fraser Valley in British Columbia, the Windsor–Québec City 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 and worsen 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 Windsor–Québec City 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 Windsor–Québec City 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, 2011-2020

	2005	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Lower Fraser Valley, B.C.	3.2	2.8	2.9	2.9	2.2	2.3	2.5	2.4	2.3	2.4	2.3
Windsor-Québec City Corridor	17.4	14.8	14.3	14.2	14.1	14.1	14.0	13.8	13.0	13.5	11.5
Saint John, N.B.	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1

TABLE 13 TOMA PERCENTAGES OF TOTAL NO_x EMISSIONS, 2005, 2011-2020

	2005	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Lower Fraser Valley, B.C.	3.2	2.8	2.9	2.9	2.3	2.3	2.5	2.4	2.3	2.4	2.3
Windsor-Québec City Corridor	17.9	14.8	14.4	14.2	14.1	14.1	14.0	13.8	13.0	13.5	11.5
Saint John, N.B.	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1

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 2020 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, 2020

		TOMA No.1 - Lower Fraser Valley, B.C.			TOMA No.2 - Windsor-Québec City 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		11,683	6,776	4,907	52,769	30,606	22,163	547	317	230
CP		7,983	4,630	3,353	19,861	11,520	8,342	-	-	-
Regional & Shortline Railways		218	127	92	1,355	786	569	656	380	275
Total Freight Traffic		**19,884**	**11,533**	**8,351**	**73,986**	**42,912**	**31,074**	**1,203**	**698**	**505**
FUEL CONSUMPTION (MILLION LITRES) FREIGHT FUEL RATE (L/1,000 GTK) = 2.39(1)										
Total Freight Fuel Consumption		**47.47**	**27.53**	**19.94**	**176.62**	**102.44**	**74.18**	**2.87**	**1.67**	**1.21**
Passenger Fuel Consumption	Intercity Passenger Rail	0.07	0.04	0.03	15.90	9.22	6.68	-	-	-
	Tourism Rail	0.00	0.00	0.00	-	-	-	-	-	-
	Commuter Rail	0.77	0.45	0.32	47.08	27.31	19.77	-	-	-
Total Passenger Fuel Consumption		**0.84**	**0.49**	**0.35**	**62.98**	**36.53**	**26.45**	**0.00**	**0.00**	**0.00**
Total Rail Fuel Consumption		**48.31**	**28.02**	**20.29**	**239.60**	**138.97**	**100.63**	**2.87**	**1.67**	**1.21**

EMISSIONS

		Emission Factors (g/L)(2)	Kilotonnes/Year			Kilotonnes/Year			Kilotonnes/Year		
CACs	NO_x	**33.81**	1.63	0.95	0.69	8.10	4.70	3.40	0.10	0.06	0.04
	PM_{10}	**0.68**	0.03	0.02	0.01	0.16	0.09	0.07	0.00	0.00	0.00
	CO	**6.99**	0.34	0.20	0.14	1.68	0.97	0.70	0.02	0.01	0.01
	HC	**1.35**	0.07	0.04	0.03	0.32	0.19	0.14	0.00	0.00	0.00
	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**	129.50	75.11	54.39	642.24	372.50	269.74	7.70	4.46	3.23
	CH_4	**3.73**	0.18	0.10	0.08	0.89	0.52	0.37	0.01	0.01	0.00
	N_2O	**306.64**	14.81	8.59	6.22	73.47	42.61	30.86	0.88	0.51	0.37
	CO_2e	**2,990.87**	144.49	83.81	60.69	716.60	415.63	300.97	8.59	4.98	3.61

(1) 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 2020, the Freight Fuel Rate was 2.39 litres per 1,000 GTK.

(2) The emissions factors used in the emissions calculations is 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_4:25; N_2O:298).

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8. SUMMARY AND CONCLUSIONS

The 2020 Locomotive Emissions Monitoring Report highlights that Canadian railways continue striving to improve their emissions performance through investments in fleet renewal, fuel saving technologies, employee training, and use of low carbon fuels. Furthermore, railways are looking ahead and establishing partnerships with government, academia, and industry stakeholders to continue the transition to a more sustainable future.

GHG emissions reductions in year three of the MOU have demonstrated progress towards MOU targets for select railway operations. 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 2020 (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	Change from 2017-2020	Change from 2019-2020	2022 Target	Progress to 2022 Target
Class I Freight	kg CO_2e per 1,000 RTK	13.56	13.45	13.49	12.91	-4.83%	-4.34%	12.75 (6% reduction from 2017)	80.56% Progress to target
Intercity Passenger*	kg CO_2e per passenger-km	0.098	0.097	0.089	0.178	82.40%	100.39%	0.092 (6% reduction from 2017)	Increase since 2017
Regional & Shortline	kg CO_2e per 1,000 RTK	14.08	15.02	14.77	15.27	8.45%	3.42%	13.66 (3% reduction from 2017)	Increase since 2017

Note: GHG emissions for all years have been calculated based on the emissions factors and global warming potentials in the 2022 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 2020; an increase indicates that emissions intensity was higher in 2020 than in 2017.

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

Class 1 freight GHG emissions intensity decreased by 4.3% from 2019 to 2020. GHG emissions intensity continues to be lower than the 2017 baseline and represents 80.6% progress towards achieving the MOU target. Regional and shortline emissions intensity increased by 3.4% from 2019 to 2020 and stood 8.5% above the 2017 baseline. GHG emissions intensity for total freight operations decreased by 4.1% from 13.96 kg CO_2e/1,000 RTK in 2019 to 13.38 kg CO_2e/1,000 RTK in 2020. However, compared to 17.86 kg CO_2e/1,000 RTK in 2005, total freight performance has improved by 25.1%. Intercity passenger GHG emissions intensity increased by 100.4% from 2019 to 2020 due to challenges associated with the COVID-19 pandemic, further deviating from the 2022 MOU target.[24]

24 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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GHG emissions from all railway operations in Canada totaled 6,253.72 kt in 2020, which is a decrease of 7.4% from 6,757.09 kt in 2019. This decrease was driven by fuel efficiency improvements of Class 1 freight railways, as well as a reduction in passenger rail activity due to the COVID-19 pandemic.

CAC emissions from all railway operations decreased, with total locomotive NO_x emissions decreasing to 70.70 kt in 2020 from 80.11 kt in 2019. In 2020, the total freight NO_x emissions intensity decreased to 0.15 kg/1,000 RTK compared to 0.16 kg/1,000 RTK in 2019, a 55.6% improvement from 2005 levels (at 0.34 kg/1,000 RTK).

In 2020, Canadian railways made substantive investments and added seven Tier 3 and 46 Tier 4 high-horsepower locomotives to the fleet. In addition, 30 locomotives were remanufactured (upgraded) to Tier 1+ by Class 1 railways. Older and lower-horsepower locomotives continue to be retired, and in 2020, 149 locomotives were taken out of active duty.

The Canadian fleet totaled 3,756 units in 2020, of which 3,108 locomotives (82.7%) 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 3,109, or 82.8% of the in-service fleet.

Through railways' various emissions reduction initiatives, the Rail Pathways Initiative, as well as federal initiatives (e.g., Strengthened Climate Plan, Hydrogen Strategy, Clean Fuel Regulations, Greenhouse Gas Pollution Pricing Act, etc.), Canadian railways and the Government of Canada will continue their efforts to reduce GHG emissions intensity in the railway sector.

This report meets the filing requirements for 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
CN	British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, 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

Railway	Province(s) of Operation
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 and Labrador Railway Company	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

2020 LOCOMOTIVE FLEET - FREIGHT TRAIN LINE-HAUL OPERATIONS

OEM	Model	US EPA Tier Level	Engine	hp	Year of Manufacture	Class 1	Regional	Shortlines	Total Regional & Shortlines	Total Freight Fleet
GM/EMD	GMD-1	No Tier	12V-567C	1200	1950-1959	0	0	1	1	1
	GP10	No Tier	567	1800	1967-1977	0	0	3	3	3
	GP35	No Tier	16-645E	2500	1960-1969	2	0	0	0	2
	GP35-3	No Tier	16V-645	2500	1960-1969	0	0	3	3	3
	GP38-2	No Tier	16V-645E	2000	1970-1972	0	0	8	8	8
	GP38-2	No Tier	645	2000	1972-1973	0	0	7	7	7
	GP38-2	No Tier	16V-645E	2000	1960-1969	0	0	6	6	6
	GP38-2/QEG	No Tier	16V-645E	2000	1973-1979	0	0	2	2	2
	GP38-3	No Tier	16V-645E	2000	1960-1969	0	0	2	2	2
	GP38-3	No Tier	645	2000	1980-1989	0	0	3	3	3
	GP38-3	No Tier	645E	2000	1970-1972	0	0	2	2	2
	GP38-3	No Tier	645	2000	1970-1972	0	0	6	6	6
	GP39-2	No Tier	12V-645E3	2300	1970-1972	0	0	4	4	4
	GP40	No Tier	16V-645	3000	1960-1969	0	0	1	1	1
	GP40-2	No Tier	16V-645	3000	1960-1969	0	0	3	3	3
	GP40-2	No Tier	16V-645	3000	1973-1979	0	0	12	12	12
	GP40-2	No Tier	16V-645E3B	3000	1973-1979	11	0	0	0	11
	GP40-2	No Tier	16V-645	3000	1970-1972	0	0	5	5	5
	GP40-3	No Tier	16V-567	3000	1980-1989	0	0	2	2	2
	GP40-3	No Tier	16V-567	3000	1960-1969	0	0	5	5	5
	GP40-3	No Tier	16V-567	3000	1970-1972	0	0	2	2	2
	GP40-3	No Tier	16-645E3C	3000	1960-1969	2	0	0	0	2
	GP9	No Tier	16V-567C	1750	1950-1959	0	0	1	1	1
	GP9	No Tier	645	1800	1960-1969	0	0	6	6	6
	GP9	No Tier	16V-645C	1800	1950-1959	0	0	1	1	1
	GP9	No Tier	16V-645C	1800	1973-1979	0	0	7	7	7
	SD38-2	No Tier	16V-645	2000	1970-1972	0	0	1	1	1
	SD38-2	No Tier	16V-645	2000	1973-1979	0	0	1	1	1
	SD38-AC	No Tier	16V-645	2000	1970-1972	0	0	1	1	1
	SD40	No Tier	645	3000	1970-1972	0	1	0	1	1
	SD40	No Tier	16-645E3B	3000	1970-1972	1	0	0	0	1
	SD40	No Tier	16-645E3	3000	1960-1969	1	0	0	0	1
	SD40-2	No Tier	16-645E3B	3000	1980-1989	11	0	0	0	11
	SD40-2	No Tier	16-645E3C	3000	1980-1989	3	0	0	0	3
	SD40-2	No Tier	16-645E3	3000	1980-1989	18	0	0	0	18
	SD40-2	No Tier	16-645E3B	3000	1973-1979	6	0	0	0	6
	SD40-2	No Tier	645	3000	1980-1990	0	0	1	1	1
	SD40-2	No Tier	645	3000	1973-1979	0	0	2	2	2
	SD40-2	No Tier	12V-645E3	3000	1973-1979	0	0	1	1	1
	SD40-2	No Tier	16V-645E3B	3000	1980-1989	8	0	0	0	8
	SD40-2	No Tier	16V-645E3	3000	1960-1969	0	0	2	2	2
	SD40-2	No Tier	16V-645E3	3000	1970-1972	0	0	2	2	2
	SD40-2	No Tier	16-645E3	3000	1973-1979	16	0	0	0	16
	SD40-2	No Tier	16V-645E3B	3000	1973-1979	15	0	0	0	15
	SD40-2	No Tier	645	3000	1970-1972	0	0	5	5	5
	SD40-2	No Tier	16V-645E3	3000	1980-1989	0	5	0	5	5
	SD40-2	No Tier	12V-645E3	3000	1980-1989	0	0	3	3	3
	SD40-2	No Tier	645E3	3000	1970-1972	0	4	0	4	4
	SD40-2/QEG	No Tier	16V-645E3B	3000	1980-1989	0	0	2	2	2
	SD40-2F	No Tier	16-645E3	3000	1980-1989	9	0	0	0	9
	SD40-2R	No Tier	12V-645E3	3000	1960-1969	0	0	1	1	1
	SD40-3	No Tier	16V-645E3B	3000	1960-1969	6	0	0	0	6
	SD40-3	No Tier	16V-645E3B	3000	1970-1972	1	0	9	9	10
	SD70ACe	No Tier	16-710G3B-ES	4375	2010-2019	0	14	0	14	14
	SD70ACe	No Tier	16-710G3B-ES	4375	2000-2009	0	6	0	6	6
	GP40-2	Tier 0	16V-645E3B	3000	1973-1979	20	0	0	0	20
	GP40-2	Tier 0	645	3000	1973-1979	0	0	1	1	1

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2020 LOCOMOTIVE FLEET - FREIGHT TRAIN LINE-HAUL OPERATIONS

OEM	Model	US EPA Tier Level	Engine	hp	Year of Manufacture	Class 1	Regional	Shortlines	Total Regional & Shortlines	Total Freight Fleet
GM/EMD	SD40-2	Tier 0	16V-645E3	3000	1973-1979	0	0	4	4	4
	SD40-2	Tier 0	16-645E3B	3000	1980-1989	2	0	0	0	2
	SD40-2	Tier 0	16-645E3	3000	1973-1979	2	0	0	0	2
	SD40-2	Tier 0	16-645E3B	3000	1973-1979	1	0	0	0	1
	SD40-2	Tier 0	16-645E3	3000	1980-1989	8	0	0	0	8
	SD40-2	Tier 0	16V-645E3B	3000	1980-1989	4	0	0	0	4
	SD40-2	Tier 0	16V-645E3B	3000	1973-1979	12	0	0	0	12
	SD40-2F	Tier 0	16-645E3B	3000	1980-1989	1	0	0	0	1
	SD40-3	Tier 0	16-645E3	3000	1980-1989	1	0	0	0	1
	SD40-3	Tier 0	16-645E3B	3000	1980-1989	4	0	0	0	4
	SD60	Tier 0	16V-710G3	3800	1980-1989	37	0	0	0	37
	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	4	0	0	0	4
	SD75	Tier 0	16V-710	4300	1990-1999	0	5	0	5	5
	SD75I	Tier 0	16V-710G3C	4300	1990-1999	32	0	0	0	32
	SD90-MAC	Tier 0	710	4400	1990-1999	0	2	0	2	2
	GP38	Tier 0+	EMD 645E	2000	1973-1979	0	2	0	2	2
	GP38	Tier 0+	EMD 645E	2000	1970-1972	0	2	0	2	2
	GP38-2	Tier 0+	16V-645E	2000	1980-1989	0	8	0	8	8
	GP38-2	Tier 0+	645E	2000	1973-1979	0	0	3	3	3
	GP40	Tier 0+	645	3000	1973-1979	0	3	0	3	3
	GP40-2	Tier 0+	16V-645	3000	1970-1979	0	3	0	3	3
	GP40-2	Tier 0+	16V-645E3B	3000	1973-1979	24	0	0	0	24
	SD-50	Tier 0+	645	3600	1980-1989	0	4	0	4	4
	SD30C-ECO	Tier 0+	12-710G3B	3000	1973-1979	25	0	0	0	25
	SD30C-ECO	Tier 0+	12-710G3B	3000	1980-1989	23	0	0	0	23
	SD30C-ECO	Tier 0+	12-710G3B	3000	1970-1972	2	0	0	0	2
	SD40-2	Tier 0+	16V-645E3B	3000	1980-1989	12	0	0	0	12
	SD40-2	Tier 0+	16V-645E3B	3000	1973-1979	24	0	0	0	24
	SD40-3	Tier 0+	16-645E3	3000	1980-1989	2	0	0	0	2
	SD40-3	Tier 0+	16-645E3B	3000	1980-1989	3	0	0	0	3
	SD40-3	Tier 0+	16V-645E3B	3000	1970-1972	3	0	0	0	3
	SD40-3	Tier 0+	16V-645E3B	3000	1960-1969	13	0	0	0	13
	SD60	Tier 0+	16-710G3A	3800	1980-1989	27	0	0	0	27
	SD60	Tier 0+	16V-710G3	3800	1980-1989	47	0	0	0	47
	SD60-3	Tier 0+	16-710G3	3800	1980-1989	1	0	0	0	1
	SD60-3	Tier 0+	16-710G3A	3800	1980-1989	1	0	0	0	1
	SD60M	Tier 0+	16-710G3A	3800	1980-1989	4	0	0	0	4
	SD70I	Tier 0+	16V-710G3B	4000	1990-1999	22	0	0	0	22
	SD75I	Tier 0+	16V-710G3C	4300	1990-1999	133	0	0	0	133
	SD70ACU	Tier 1+	16-710G3C	4300	1990-1999	60	0	0	0	60
	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	35	0	0	0	35
	SD70M-2	Tier 2	16V-710G3C	4300	2000-2009	23	0	0	0	23
	SD-70ACe	Tier 2+	16-710G3C-ES	4375	2000-2009	0	6	0	6	6
	SD70M-2	Tier 2+	16V-710G3C	4300	2000-2009	73	0	0	0	73
	SD70M-2	Tier 2+	16V-710G3C	4300	2010-2019	48	0	0	0	48
	SD-70ACe	Tier 3	16-710G3C-ES	4375	2000-2009	0	6	0	6	6
	SD70ACE	Tier 3	16V-710G3C	4300	2010-2019	3	0	0	0	3
	SD70ACe-T4	Tier 4	12-1010J3	4300	2010-2019	6	0	0	0	6
GM/EMD Sub-Total						**861**	**76**	**134**	**210**	**1,071**
GE	AC4400CM	No Tier	16-7FDL	4400	2000-2009	0	10	0	10	10
	B23-7	No Tier	7FDL12	2000	1973-1979	0	0	2	2	2
	Dash 8-40CM	No Tier	7FDL16	4000	1990-1999	0	0	3	3	3
	Dash-9 44CW	No Tier	16-7FDL	4400	1990-1999	0	11	0	11	11
	AC4400CW	Tier 0	7FDL16	4400	1990-1999	1	0	0	0	1
	C44-9W	Tier 0	7FDL-16	4400	2000-2009	1	0	0	0	1
	AC4400CM	Tier 0+	16-7FDL	4400	2000-2009	0	1	0	1	1
	C40-8	Tier 0+	7FDL-16	4000	1990-1999	36	0	0	0	36
	C40-8	Tier 0+	7FDL-16	4000	1980-1989	25	0	0	0	25
	C40-8M	Tier 0+	7FDL-16	4000	1990-1999	47	0	0	0	47
	C40-8W	Tier 0+	7FDL-16	4000	1990-1999	55	0	0	0	55
	AC4400CW	Tier 1	7FDL16	4400	2000-2009	0	21	0	21	21
	AC4400CM	Tier 1+	16-7FDL	4400	2000-2009	0	1	0	1	1
	AC4400CW	Tier 1+	7FDL16	4400	2000-2009	173	0	0	0	173
	AC4400CW	Tier 1+	7FDL16	4400	1990-1999	120	0	0	0	120
	AC44CWM	Tier 1+	7FDL16	4400	1990-1999	141	0	0	0	141
	C40-8M	Tier 1+	7FDL-16	4000	1990-1999	2	0	0	0	2
	C44-9W	Tier 1+	7FDL-16	4400	1990-1999	98	0	0	0	98

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2020 LOCOMOTIVE FLEET - FREIGHT TRAIN LINE-HAUL OPERATIONS

OEM	Model	US EPA Tier Level	Engine	hp	Year of Manufacture	Class 1	Regional	Shortlines	Total Regional & Shortlines	Total Freight Fleet
GE	C44-9W	Tier 1+	7FDL-16	4400	2000-2009	104	0	0	0	104
	ES44AC	Tier 2	GEVO-12	4365	2000-2009	7	0	0	0	7
	ES44AC	Tier 2	GEVO12	4360	2010-2019	0	6	0	6	6
	ES44DC	Tier 2	GEVO-12	4400	2000-2009	22	0	0	0	22
	ES44DC	Tier 2	GEVO-12	4400	2010-2019	2	0	0	0	2
	ES44AC	Tier 2+	GEVO-12	4365	2000-2009	193	0	0	0	193
	ES44AC	Tier 2+	GEVO-12	4365	2010-2019	61	0	0	0	61
	ES44DC	Tier 2+	GEVO-12	4400	2000-2009	65	0	0	0	65
	ES44DC	Tier 2+	GEVO-12	4400	2010-2019	31	0	0	0	31
	ES44AC	Tier 3	GEVO-12	4365	2010-2019	30	0	0	0	30
	ES44AC	Tier 3	GEVO-12	4400	2010-2019	296	0	0	0	296
	ET44AC	Tier 3	ES44AC	4400	2010-2019	1	0	0	0	1
	ES44AC	Tier 4	GEVO-12	4400	2010-2019	3	0	0	0	3
	ET44AC	Tier 4	GEVO-12	4400	2020	40	0	0	0	40
	ET44AC	Tier 4	ET44AC	4400	2010-2019	5	0	0	0	5
	ET44AC	Tier 4	GEVO-12	4400	2010-2019	225	0	0	0	225
GE Sub-Total						**1,784**	**50**	**5**	**55**	**1,839**
MLW	RS-18	Tier 0	12V-251	1800	1950-1959	0	0	6	6	6
MLW Sub-Total						**0**	**0**	**6**	**6**	**6**
NRE	SD40-2	Tier 0+	645E3	3000	1970-1972	0	1	0	1	1
	SD40-2	Tier 0+	645E3B	3000	1970-1972	0	6	0	6	6
NRE Sub-Total						**0**	**7**	**0**	**7**	**7**
Total Mainline Freight						**2,645**	**133**	**145**	**278**	**2,923**

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APPENDIX B-2

2020 LOCOMOTIVE FLEET - FREIGHT YARD SWITCHING & WORK TRAIN OPERATIONS

OEM	Model	US EPA Tier Level	Engine	HP	Year of Manufacture	Class 1	Regonal	Shortlines	Total Regional & Shortlines	Total Freight Fleet
GM/EMD	Cab slug	Elec/Steam/ Other		0	1950-1959	0	0	2	2	2
	Slug	Elec/Steam/ Other		0	2000-2009	0	0	1	1	1
	Slug	Elec/Steam/ Other		0	1980-1989	0	0	1	1	1
	F40-PH	No Tier	16V-645E3B	3000	1973-1979	0	0	2	2	2
	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
	FP9B-3	No Tier	16-645E	1750	1950-1959	1	0	0	0	1
	GMD1	No Tier	12V-645C	1200	1950-1959	2	0	0	0	2
	GMD1	No Tier	12V-645C	1200	1960-1969	1	0	0	0	1
	GP15	No Tier	16V-645	1500	1980-1989	0	0	3	3	3
	GP38	No Tier	16-645E	2000	1960-1969	2	0	0	0	2
	GP38	No Tier	16-645E	2000	1970-1972	1	0	0	0	1
	GP38	No Tier	645	2000	1960-1969	0	2	0	2	2
	GP38-2	No Tier	16-645E	2000	1970-1972	1	0	0	0	1
	GP38-2	No Tier	16V-645E	2000	1970-1972	13	0	0	0	13
	GP38-2	No Tier	16-645E	2000	1980-1989	60	0	0	0	60
	GP38-2	No Tier	16-645E	2000	1960-1969	2	0	0	0	2
	GP38-2	No Tier	16V-645E	2000	1973-1979	33	0	0	0	33
	GP38-3	No Tier	16-645E	2000	1980-1989	6	0	0	0	6
	GP38-3	No Tier	16-645E	2000	1960-1969	3	0	0	0	3
	GP38-3	No Tier	16-645E	2000	1970-1972	2	0	0	0	2
	GP38-3	No Tier	16-645E	2000	1973-1979	1	0	0	0	1
	GP38AC	No Tier	16-645E	2000	1970-1972	8	0	0	0	8
	GP9	No Tier	16V-645	1700	1960-1969	0	0	1	1	1
	GP9	No Tier	16V-567	1750	1960-1969	0	2	1	3	3
	GP9	No Tier	16V-645	1750	1950-1959	0	0	2	2	2
	GP9	No Tier	16V-567	1750	1950-1959	0	0	4	4	4
	GP9	No Tier	16V-645	1800	1950-1959	0	1	0	1	1
	GP9 master	No Tier	16V-567	1750	1950-1959	0	0	5	5	5
	GP9-RM	No Tier	16V-645C	1800	1950-1959	74	0	0	0	74
	MP15	No Tier	645	1500	1973-1979	0	0	3	3	3
	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
	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	567	1200	1960-1969	0	0	2	2	2
	SW14	No Tier	12V-567	1400	1950-1959	0	0	1	1	1
	SW1500	No Tier	12V-567	1500	1970-1972	0	0	2	2	2
	SW900	No Tier	8V-567	900	1960-1969	0	0	1	1	1
	SW900	No Tier	8-567C	900	1950-1959	1	0	0	0	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	22	0	0	0	22
	GP38-2	Tier 0	16-645E	2000	1980-1989	4	0	0	0	4
	GP38-2	Tier 0	16-645E	2000	1970-1972	4	0	0	0	4
	GP38-2	Tier 0	16V-645E	2000	1973-1979	2	0	0	0	2
	GP38AC	Tier 0	16-645E	2000	1970-1972	1	0	0	0	1
	GP39-2	Tier 0	12-645E3	2300	1980-1989	1	0	0	0	1
	GP39-2	Tier 0	12-645E3	2300	1973-1979	1	0	0	0	1
	MP15	Tier 0	12V-645	1500	1973-1979	0	0	2	2	2
	GMD1	Tier 0+	12V-645C	1200	1950-1959	5	0	0	0	5
	GP20C-ECO	Tier 0+	8-710G3B	2000	1950-1959	130	0	0	0	130
	GP38-2	Tier 0+	16V-645E	2000	1970-1972	5	0	0	0	5
	GP38-2	Tier 0+	16-645E	2000	1980-1989	55	0	0	0	55
	GP38-2	Tier 0+	16-645E	2000	1970-1972	5	0	0	0	5

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2020 LOCOMOTIVE FLEET - FREIGHT YARD SWITCHING & WORK TRAIN OPERATIONS

OEM	Model	US EPA Tier Level	Engine	HP	Year of Manufacture	Class 1	Regonal	Shortlines	Total Regional & Shortlines	Total Freight Fleet
GM/EMD	GP38-2	Tier 0+	16-645E	2000	1973-1979	27	0	0	0	27
	GP38-2	Tier 0+	16V-645E	2000	1973-1979	35	0	0	0	35
	GP38-3	Tier 0+	16-645E	2000	1970-1972	2	0	0	0	2
	GP38-3	Tier 0+	16-645E	2000	1980-1989	5	0	0	0	5
	GP38AC	Tier 0+	16-645E	2000	1970-1972	6	0	0	0	6
	GP40-3	Tier 0+	645E3B	3000	1973-1979	1	0	0	0	1
	SD38-2	Tier 0+	16V-645E	2000	1973-1979	3	0	0	0	3
GM/EMD Sub-Total						**528**	**6**	**49**	**55**	**583**
GE	B23-7	No Tier	7FDL12	2250	1980-1989	1	0	0	0	1
	B23-7	No Tier	7FDL12	2250	1973-1979	4	0	0	0	4
	AC4400CW	Tier 1	16V-710	4400	2000-2009	0	0	4	4	4
GE Sub-Total						**5**	**0**	**4**	**4**	**9**
ALCO	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**	**2**	**2**	**2**
Yard Switching & Work Train Total						**533**	**6**	**55**	**61**	**594**

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APPENDIX B-3

2020 LOCOMOTIVE AND DMU FLEET - PASSENGER TRAIN OPERATIONS

OEM	Model	US EPA Tier Level	Engine	HP	Year of Manufacture	Intercity Rail	Commuter	Tourist & Excursion	Total
GM/EMD	F40PH-2	No Tier	16V-645E3C	3000	1980-1989	50	0	0	50
	F59-PH	No Tier	710G3A EMD 12CYL	3100	1988-1994	0	8	0	8
	GP9	No Tier	16V-645	1800	1950-1959	0	0	1	1
	SW1000	No Tier	8-645E	1000	1960-1969	1	0	0	1
	F40PH-2	Tier 0	16V-645E3C	3000	1980-1989	2	0	0	2
	F59-PHI	Tier 0	710	3000	1990-1999	0	5	0	5
	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						**53**	**34**	**1**	**88**
GE	P42DC	No Tier	7FDL16	4250	2000-2009	21	0	0	21
GE Sub-Total						**21**	**0**	**0**	**21**
Motive Power	MP36PH-3C	Tier 0	645E3B	3600	2000-2009	0	1	0	1
	MP40PH-3C	Tier 2	710G3B TIER 2 EMD 16CYL	4000	2007-2013	0	56	0	56
	MP40PH-3C	Tier 3	710G3B TIER 3 EMD 16 CYL	4000	2007-2013	0	10	0	10
	MP40PHT-T4-AC	Tier 4	Twin QSK 60 T4 -16 cyl	5400	2017-2018	0	16	0	16
	MP40PHTC-T4-DC	Tier 4	Twin QSK 60 T4 -16 cyl	5400	2010-2014	0	1	0	1
Motive Power Sub-Total						**0**	**84**	**0**	**84**
Bombardier	ALP45-DP	Tier 3	3512C HD	4200	2010-2012	0	21	0	21
Bombardier Sub-Total						**0**	**21**	**0**	**21**
Alstom	Coradia LINT 41	Elec/Steam/Other	DMU	780	2010-2019	0	6	0	6
Alstom Sub-Total						**0**	**6**	**0**	**6**
Cummins	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						**0**	**18**	**0**	**18**
Dubs	Dubs 4-4-0	Elec/Steam/Other	0	0	1882	0	0	1	1
Dubs Sub-Total						**0**	**0**	**1**	**1**
Passenger Operations Total						**74**	**163**	**2**	**239**

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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

Operations Service Area:	Vancouver
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: WINDSOR-QUÉBEC CITY CORRIDOR, ONTARIO AND QUÉBEC

CN

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

CP

Operations Service Area:	Montreal
Subdivisions:	All
Operations Service Area:	Southern Ontario
Subdivisions:	Belleville, Hamilton, North Toronto, Canpa, MacTier, St. Thomas, Galt, Montrose, 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 the truck and rail modes.

Locomotive Active Fleet

This refers to the total number of all locomotives owned and on long- term lease, including units that are stored but available for use. Not counted in the active fleet are locomotives on short-term lease and those declared surplus or have been retired or scrapped.

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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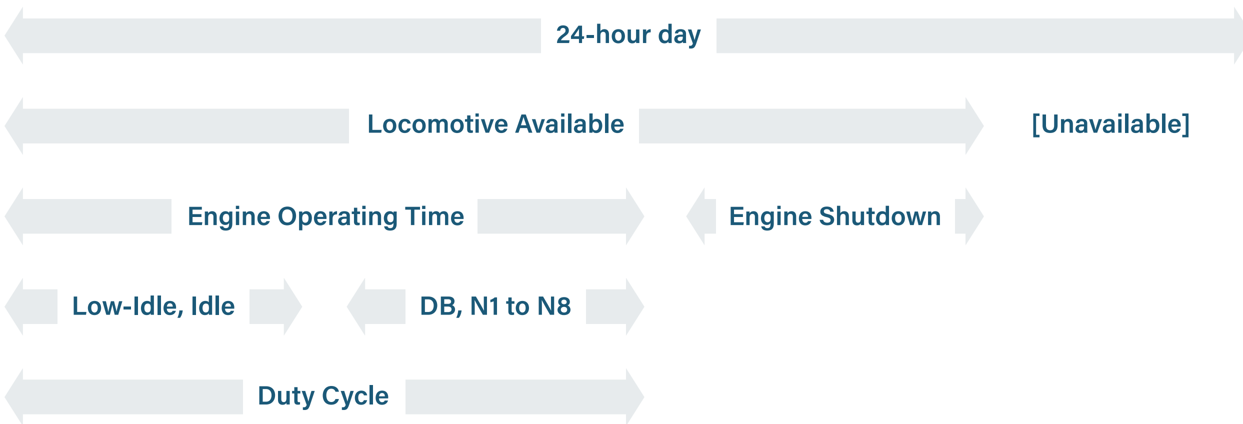
Locomotive Utilization Profile

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 Appendix F 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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APPENDIX I

HISTORICAL DATA

The 2020 LEM Report is the first report that uses 2005 as the reference year, rather than 1990. 2005 has been set as the reference year for the 2020 LEM Report and future reports, as it aligns with the Government of Canada's climate targets, among other merits. Appendix I provides the 1990 data that was found in the tables and figures of previous LEM reports.

TABLE 1 - FREIGHT TRAFFIC (BILLION TONNE-KILOMETRES)

	1990
GTK (total)	432.74
RTK (total)	233.45
Ratio RTK/GTK	0.54

TABLE 3 - FUEL CONSUMPTION (MILLION LITRES)

	1990
Class 1	1,825.05
Regional & Shortline	n/a
Yard Switching	120.13
Work Train	15.67
Total Freight Operations	**1,960.85**
Intercity	n/a
Commuter	n/a
Tourist Train & Excursion	n/a
Total Passenger Operations	**102.70**
Total Rail Operations	**2,063.55**

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TABLE 8 - GHG EMISSIONS (KILOTONNES)

	1990
FREIGHT - LINE HAUL	
CO_2	4,892.04
CH_4	6.80
N_2O	559.64
CO_2e	5,458.47
YARD SWITCHING AND WORK TRAIN	
CO_2	364.03
CH_4	0.51
N_2O	41.64
CO_2e	406.18
TOTAL FREIGHT OPERATIONS	
CO_2	5,256.06
CH_4	7.30
N_2O	601.28
CO_2e	5,864.65
PASSENGER - INTERCITY, COMMUTER, TOURIST/EXCURSION	
CO_2	275.29
CH_4	0.38
N_2O	31.49
CO_2e	307.16
TOTAL RAILWAY	
CO_2	5,531.35
CH_4	7.69
N_2O	632.77
CO_2e	6,171.81

Note: GHG emissions for all years have been calculated based on the emissions factors and global warming potentials in the 2022 National Inventory Report. Historical values have been updated.

TABLE 9 - GHG EMISSIONS INTENSITIES

	1990
Total Freight (kg CO_2e/1,000 RTK)	25.12
Class 1 Freight (kg CO_2e/1,000 RTK)	n/a
Regional & Shortline Freight (kg CO_2e/1,000 RTK)	n/a
Intercity Passenger (kg CO_2e/Passenger-km)	n/a
Commuter Rail (kg CO_2e/Passenger)	n/a

TABLE 10 - CAC EMISSIONS FACTORS (g/L)

	1990				
	NO_x	PM_{10}	CO	HC	SO_2
Freight: Line Haul	71.44	1.59	7.03	2.64	2.47
Yard Switching and Work Train	69.88	1.65	7.35	4.06	2.47
Total Passenger	71.44	1.59	7.03	2.64	2.47

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TABLE 11 - CAC EMISSIONS (KILOTONNES, UNLESS OTHERWISE SPECIFIED)

Railway Operation	1990				
	NO_x	PM_{10}	CO	HC	SO_2 (tonnes)
Freight: Line Haul	130.38	2.91	12.84	4.81	4,504.32
Yard Switching and Work Train	9.49	0.22	1.00	0.55	335.18
Total Passenger	7.35	0.16	0.72	0.27	253.80
Total Freight Operations(1)	**139.87**	**3.13**	**13.84**	**5.36**	**4,839.50**
Total Railway Operations(2)	**147.21**	**3.30**	**14.56**	**5.64**	**5,093.30**
Total Freight Emissions Intensity (kg/1,000 RTK)	**0.15**	**0.0030**	**0.0313**	**0.0060**	**0.00011**

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

(2) Total Railway Operations = Total Freight Operations + Total Passenger

1990 DATA FOR FIGURES

	1990
Figure 1 - Freight Traffic (GTK, Billion)	432.74
Figure 1 - Freight Traffic (RTK, Billion)	233.45
Figure 4 - Intercity Rail Passenger Traffic (Passengers, Million)	4.00
Figure 5 - Intercity Rail Passenger-Kilometres (Million)	1,351
Figure 6 - Intercity Passenger-Kilometres per Train-Kilometre	121.04
Figure 8 - Freight Fuel Efficiency (Litres per 1,000 RTK)	8.40
Figure 9 - GHG Emissions (Freight, kt CO_2e)	5,864.65
Figure 9 - GHG Emissions (Passenger, kt CO_2e)	307.16
Figure 9 - GHG Emissions (Total Railway, kt CO_2e)	6,171.81
Figure 10 - GHG Emissions Intensities (Total Freight, kg CO_2e/1,000 RTK)	25.12
Figure 10 - GHG Emissions Intensities (Intercity Passenger, kg CO_2e/Passenger-km)	n/a

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