LOCOMOTIVE EMISSIONS MONITORING REPORT

2019

Railway Association of Canada

RIGHT TRACK

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MANAGEMENT COMMITTEE

Megan Nichols (Chair), Transport Canada (TC)

Ben Chursinoff, Railway Association of Canada (RAC)

Nathalie Morin, Environment and Climate Change Canada (ECCC)

Debbie Scharf, Natural Resources Canada (NRCAN)

Chantale Despres, Canadian National Railway (CN)

David Huck, Canadian Pacific Railway (CP)

Bruno Riendeau, VIA Rail Canada (VIA)

Steve McCauley, Pollution Probe

TECHNICAL REVIEW COMMITTEE

Jonathan Thibault (Chair), RAC

Lucas Mafaldo Oliveira, TC

Jean-François Boucher, VIA

Ursula Green, TC

Richard Holt, ECCC

Nirwair Bajwa, CP

Arjun Kasturi, GO Transit

Simon Lizotte, CN

Murray Macbeth, Genesee & Wyoming Railroad (GWRR)

Derek May, Pollution Probe

Thomas Rolland, exo

Devin O'Grady, NRCAN

Stephen Healey, TC

Paul Izdebski, TC

Kyle Beauliua, TC

CONSULTANTS

Matt Beck, Delphi

Erin Williamson, Delphi

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READERS' COMMENTS

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

Jonathan Thibault
Senior Research Analyst
Railway Association of Canada
99 Bank Street, Suite 901
Ottawa, Ontario K1P 6B9

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

REVIEW NOTICE

This report has been reviewed and approved by the Technical Review and Management Committees of the memorandum of understanding between Transport Canada and the Railway Association of Canada for reducing locomotive emissions.

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EXECUTIVE SUMMARY

INTRODUCTION

The Locomotive Emissions Monitoring Program (LEM) data filing for 2019 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 second 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 for the duration of the MOU. The GHG emission intensity targets for 2018–2022, which uses 2017 as a baseline year, are included in the table below.

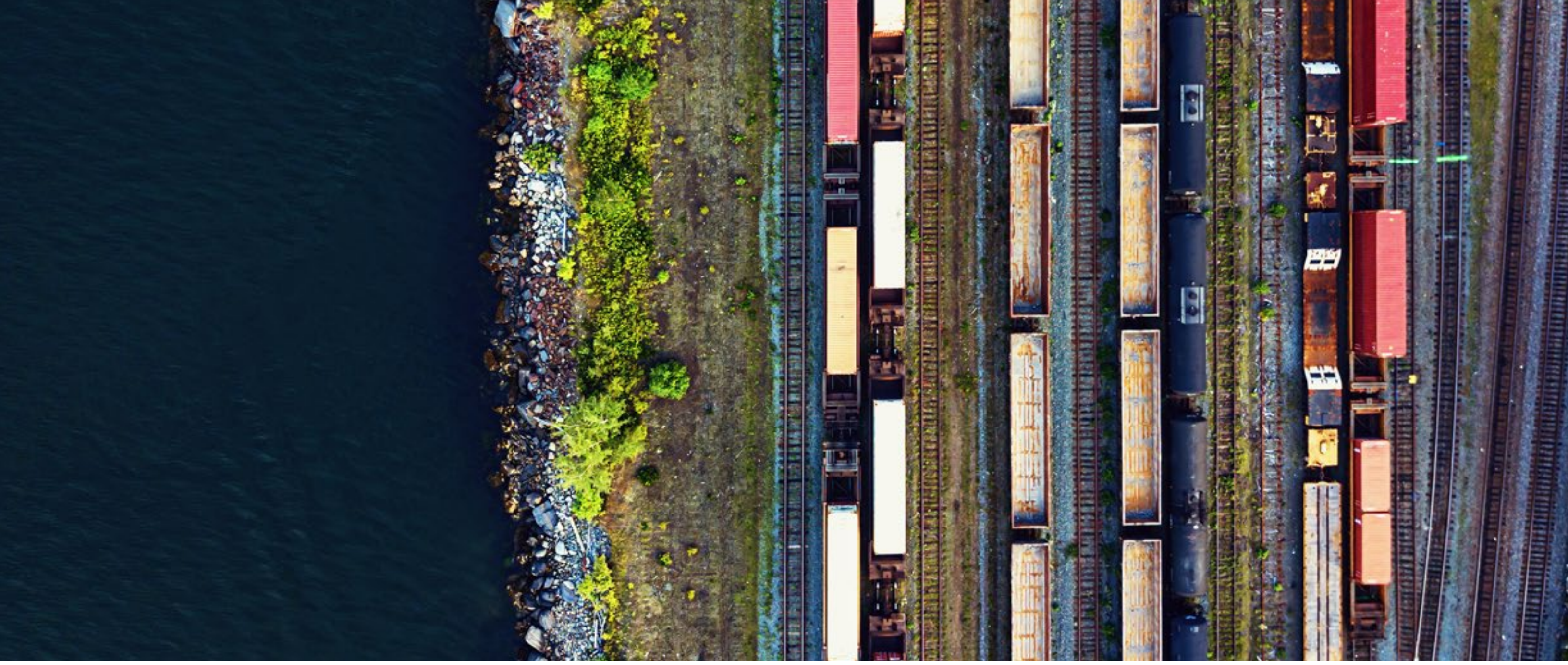
Under the MOU, the RAC continues to encourage CAC emission reductions and conformance with appropriate CAC emission standards for those locomotives not covered by the *Locomotive Emissions Regulations* (LER), which came into force on June 9, 2017. Reporting by the RAC of CAC emissions as agreed under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

2018 – 2022 MOU PROGRESS

This report highlights that Canadian Class 1 freight and intercity passenger railways are continuing to reduce their GHG emissions intensities. Regarding GHG emissions intensities, regional & shortline railways may be more vulnerable than Class 1s to economic volatility, as they are less diversified. This means that regional & shortline railways may be more strongly impacted by changes in shippers' production volumes, regional economic conditions, commodity prices, and natural resource extraction, among other factors.[1]

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), 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.

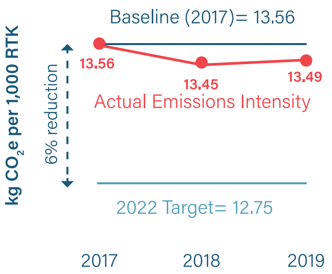


GHG EMISSIONS INTENSITY AND MOU PROGRESS BY RAILWAY OPERATION

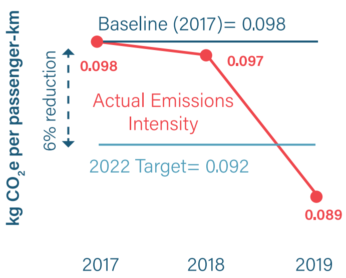
Railway Operation	Productivity Units	Baseline - 2017	2018	2019	Change from 2018-2019	2022 Target	Progress to 2022 Target
Class I Freight	kg CO_2e per 1,000 RTK	13.56	13.45	13.49	0.29%	12.75 (6% reduction)	8.58% progress to target
Intercity Passenger	kg CO_2e per passenger-km	0.098	0.097	0.089	-8.37%	0.092 (6% reduction)	149.62% target achieved
Regional & Shortline	kg CO_2e per 1,000 RTK	14.08	15.02	14.77	-1.72%	13.66 (3% reduction)	increase since 2017

GHG emissions have been calculated based on the 1990-2019 National Inventory Report. Historical values have been updated to use these most recent emission factors and global warming potentials.

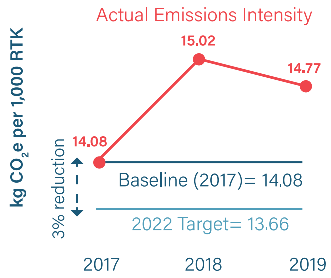
MOU PROGRESS: CLASS 1 FREIGHT



MOU PROGRESS: INTERCITY PASSENGER



MOU PROGRESS: REGIONAL & SHORTLINE



As seen in the table and figure above, Class 1 Freight GHG emissions intensity increased by 0.29% from 2018 to 2019. However, the 2019 GHG emissions intensity is still less than the 2017 baseline and represents 8.58% progress towards achieving the MOU target (of a 6% reduction from baseline). Intercity passenger GHG emissions intensity decreased by 8.37% from 2018 to 2019, surpassing the 2022 MOU target.[2] Regional & shortline emissions intensity decreased by 1.72% from 2018 to 2019 yet stood 4.86% above the 2017 baseline.

2 Intercity rail train efficiency (passenger-kilometres per train-kilometre) improved by 5.9% in 2019.

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2019 KEY FINDINGS

FREIGHT TRAFFIC

Freight Traffic

- Gross Tonne-Kilometres (GTK): In 2019, the railways handled 863.98 billion GTK of traffic as compared to 864.66 billion GTK in 2018, representing a decrease of 0.1%. GTK traffic was 99.7% higher than it was in 1990, the reference year, having increased at an average rate of 2.4% per year.[3] Class 1 GTK traffic accounted for 95.4% of the total GTK hauled in 2019.
- Revenue Tonne-Kilometres (RTK): In 2019, the railways handled 455.06 billion RTK of traffic as compared to 455.72 billion RTK in 2018, representing a decrease of 0.1%. RTK traffic was 95.0% higher than it was in 1990, the reference year, having increased at an average rate of 2.3% per year. Of the freight RTK traffic handled in 2019, Class 1 freight railways were responsible for 95.0% of the total traffic.
- Intermodal Traffic: Intermodal tonnage increased by 6.3% to 41.7 million tonnes in 2019 from 39.22 million tonnes in 2018. Overall, intermodal tonnage comprising both container-on-flat-car and trailer-on-flat-car traffic for railways in Canada has risen 88.2% since 1999, equating to an average growth rate of 3.21% per year.

Passenger Traffic

- Intercity passenger traffic in 2019 by all carriers totaled 5.05 million passengers compared to 5.03 million in 2018, an increase of 0.5%.
- Commuter rail traffic increased from 82.79 million passengers in 2018 to 101.94 million in 2019, an increase of 23.1%.[4] This represents an increase of 148.6% from 1997, the first year the RAC collected commuter railway statistics in Canada.
- In 2019, six RAC member railways reported tourist and excursion traffic totaling 316 thousand passengers, a decrease of 2% from the 321 thousand passengers transported in 2018.

FUEL CONSUMPTION

- Fuel consumed by railway operations in Canada increased by 0.8% from 2,242.19 million litres in 2018 to 2,259.24 million litres in 2019.
- Of the total fuel consumed by all railway operations, Class 1 freight train operations consumed 86% and regional & shortlines consumed 5%. Yard switching and work train operations consumed 3%, and passenger operations accounted for 6%.
- For freight operations, overall fuel consumption in 2019 was 2,124.35 million litres, 0.2% above the 2018 level of 2,120.46 million litres.
- For total freight operations, fuel consumption per productivity unit (litres per 1,000 RTK) in 2019 was 4.67 litres per 1,000 RTK, an increase of 0.3% from 2018. However, this is down from 8.40 litres per 1,000 RTK in 1990, an improvement of 44.4%.
- For total passenger operations, overall fuel consumption in 2019 was 134.89 million litres, 10.8% above the 2018 level of 121.72 million litres.[5]

3 Growth rates are calculated using the compound annual growth rate (CAGR) formula.
4 The significant increase in commuters and commuter railways' fuel consumption (which also impacts passenger rail fuel consumption) in 2019 is due to a combination of increasing ridership on commuter rail services compared to 2018, as well as the inclusion of one additional rail service that was not included in previous reports.
5 Ibid.

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LOCOMOTIVE INVENTORY

Locomotive Fleet

The reported number of diesel-powered locomotives and diesel multiple units (DMUs) in active service in Canada belonging to RAC member railways totaled 3,840 in 2019 versus 3,782 in 2018, an increase of 1.5%.[6]

For freight operations in 2019, 2,663 were on Class 1 line haul, 132 were owned by regional railways, and 140 were owned by shortlines. A further 619 were in freight switching operations. A total of 286 locomotives and DMUs were used in 2019 to support passenger railway operations in Canada, of which 81 were for intercity passenger services, 161 for commuter railway services, and 39 for tourist and excursion services. There were 5 locomotives in passenger yard switching operations in 2019.

Locomotives Compliant with Emissions Standards

In 2019, 88.6% of the fleet met emission standards (as set out under the *Locomotive Emissions Regulations* (LER) or the United States Environmental Protection Agency (USEPA) Regulations). A total of 74 Tier 3 and 82 Tier 4 high-horsepower locomotives were added to the Class 1 freight line haul fleet; 61 Class 1 freight line haul locomotives were upgraded to Tier 1+; and 146, mostly non-tier-level and lower-tier-level locomotives, were retired from Class 1s. Other railways added 16 Tier 4 locomotives and retired one Tier 3 and three non-tiered locomotives.

Locomotives Equipped with Anti-Idling Devices

The number of locomotives in 2019 equipped with a device to minimize unnecessary idling, such as an automatic engine stop-start (AESS) system or auxiliary power unit (APU), was 2,969, which represents 77.3% of the fleet, compared with 2,168 in 2018 (57.3% of the fleet).[7]

TROPOSPHERIC OZONE MANAGEMENT AREAS (TOMA)

Of the total GHGs emitted by the railway sector in 2019, 2.4% occurred in the Lower Fraser Valley of British Columbia, 13.5% 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 a record-breaking $3.1 billion into their Canadian networks in 2019 and continue to implement a number of initiatives outlined in the Locomotive Emissions Monitoring Program Action Plan for Reducing GHG Emissions.[8]

This action plan presents a variety of initiatives for railways, governments, and the RAC to implement to reduce GHGs produced by the railway sector in Canada.[9]

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 Railway Association of Canada. Locomotive Emissions Monitoring Program 2011-2015 Action Plan for Reducing GHG Emissions. https://www.railcan.ca/wp-content/uploads/2016/10/LEM-Program-2011-2015-Action-Plan-for-Reducing-GHG-Emissions.pdf
9 Note this action plan refers to the previous MOU and has not yet been updated for the current MOU.

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1. INTRODUCTION

This report contains the Locomotive Emissions Monitoring (LEM) data filing for 2019 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 2019, the transportation sector emitted 217 Mt of CO_2e, accounting for 29.7% of Canada's total GHG emissions.[10] The majority of transportation GHGs are attributed to light- and heavy-duty road vehicles. Canadian railways accounted for only 3.5% of transportation GHGs, which is less than the domestic aviation sector (3.9%) and the pipelines sector (3.8%).[11] To meet Canada's commitment to cut GHGs by 40-45 percent below 2005 levels by 2030 and reach net-zero by 2050, the transport sector must make a major contribution.

Railways have played and will continue to play a key role in contributing to Canada's climate targets. Since 1990, freight railways have reduced their GHG intensity by 44.4% while experiencing a 94.9% increase in revenue traffic. Intercity passenger railways' emissions intensities have decreased by 41.9%, while ridership has increased by 26.2%. 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 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 second 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), 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.

10 Source: Canada's National Inventory Report, 1990–2019: Greenhouse Gas Sources and Sinks in Canada, Environment and Climate Change Canada, 2021, Table A9–2
11 Ibid.

1.1 OVERVIEW OF REPORT

This report provides an overview of 2019 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, consequently, all emissions, particularly GHGs. 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 2010 to 2019. For historical comparison purposes, the year 1990[12] has been set as the reference year and has also been included. LEM statistics from 1990 to 2018 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. To facilitate comparison with American railway operations, traffic, fuel consumption, and emissions 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. The 2017 baseline data, the GHG emission targets for 2022 and the actual emissions from 2018 and 2019, expressed as kilograms (kg) of CO_2e per productivity unit, for the rail industry are outlined in the following table.

GHG EMISSIONS INTENSITY AND MOU PROGRESS BY RAILWAY OPERATION

Railway Operation	Productivity Units	Baseline - 2017	2018	2019	Change from 2018-2019	2022 Target	Progress to 2022 Target
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GHG emissions have been calculated based on the 1990-2019 National Inventory Report. Historical values have been updated to use these most recent emission factors and global warming potentials.

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.[13] 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.

12 1990 was set as the reference year in the first RAC-TC MOU and it is the first year of available locomotive data.
13 Baseline and some historical CAC performance reflected in this report predates the Locomotive Emission Regulations for CACs. The *Locomotive Emissions Regulations* came into force on June 9, 2017. https://laws-lois.justice.gc.ca/PDF/SOR-2017-121.pdf

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2. EMISSIONS REDUCTION INITIATIVES

In 2019, Canadian railways continued to invest in new technologies and improve operational practices to reduce locomotive emissions. In fact, railways invested a record-breaking $3.1 billion into their Canadian networks in 2019.[14] This section of the report highlights how Canadian railways lowered their emissions through investments in fleet renewal, fuel saving technologies, employee training, use of low carbon fuels, and investments in equipment, infrastructure, and facilities.

2.1 FLEET RENEWAL & MODERNIZATION

In 2019, 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.

CP's multi-year locomotive modernization program is estimated to reduce annual CO_2e by 16,714 tonnes. In 2019, CP upgraded 61 locomotives, increasing the total number of locomotives retrofitted through this initiative to 171. 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 (TO) and Distributed Power systems.

CN continued to purchase tier-compliant locomotives as part of its strategy to acquire, retire and upgrade its fleet. In 2019, CN took delivery of 154 new high horsepower locomotives. The company equips all new locomotives with energy management and data telemetry systems as well as distributed power functionality to help maximize locomotive operating effectiveness and efficiency.

In 2019, VIA completed the concept and design phases for the 32 new train sets that they will be acquiring for use in the Québec-City – Windsor Corridor. The trains will be brought into service starting in 2022 and are expected to reduce fuel consumption and GHG emissions by 15 to 20% and reduce overall CAC emissions by 90%. VIA is also three years into its program to refurbish 71 train cars in its HEP fleet – completing work on nine cars in 2019, as well as partial overhauls of 14 out of 15 P42 locomotives.

CP's multi-year locomotive modernization program is estimated to reduce annual CO_2e
BY 16,714 TONNES.

VIA's new train sets are expected to reduce fuel consumption and GHG emissions by 15 to 20% and
REDUCE OVERALL CAC EMISSIONS BY 90%.

14 Railway Association of Canada, 2020 Rail Trends, March 2021. https://www.railcan.ca/wp-content/uploads/2021/03/Rail-Trends-2020-Eng.pdf

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-to-tonnage ratio for efficiency; and
3. Distributed Power to remotely control the locomotive and improve braking performance, train handling and fuel efficiency.

Since 2009, CP has installed Trip Optimizer (TO) technology on 432 of its active line haul locomotives and intends to continue implementation across the majority of its high-horsepower locomotive fleet in the coming years. TO technology automatically calculates factors such as train length, weight, and track grade to determine the optimal speed profile for a given section of track, resulting in immediate improved fuel economy. TO systems have demonstrated an average GHG emissions reduction of 5%.

In 2019, a significant driver of VIA's improvement in fuel efficiency was attributed to car cycling optimization (matching the supply of passenger cars with demand), which increased the passenger load factor from 57% to 60%.

In 2019, 2,969 of 3,840 (77%) locomotives 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.

Trip Optimizer systems have demonstrated an

AVERAGE GHG EMISSIONS REDUCTION OF 5%.

2.3 EMPLOYEE TRAINING

Railways are not only reducing emissions by investing in modern technology; they are investing in training their people to reduce emissions through improved operational practices.

CN is training its crews and rail traffic controllers on best practices for fuel conservation, including locomotive shutdowns in yards, streamlined railcar handling, train pacing, coasting, and braking strategies.

VIA Rail's locomotive engineers receive train handling training for both Safety and Fuel Conservation via simulators and on the job training. They are monitored for compliance with train handling instructions through regular check rides, event recorder downloads and Wi-Tronix alerts, and receive corrective coaching when required.

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2.4 LOW CARBON FUELS

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

- Biodiesel and HDRD have slightly lower energy density than fossil diesel, which reduces a locomotive's range and requires more frequent refueling.[15]
- 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.
- Locomotive performance may be adversely impacted with higher renewable fuel content and manufacturer warranties may be voided.

Canadian railways continue to work collaboratively with fuel suppliers, equipment manufacturers, industry experts, railway associations, and government agencies to address the challenges and opportunities presented by increasing the renewable fuels content used in locomotives.

2.5 INVESTMENTS IN EQUIPMENT, INFRASTRUCTURE, AND FACILITIES

CP's 8,500-foot High Efficiency Product (HEP) train features new high-capacity grain hopper cars that can move approximately 44% more grain per train than previous models. The initiative is estimated to save over 1,000 tonnes of CO_2e annually.

At VIA's Toronto, Ottawa, Halifax, and Jasper stations, VIA installed and upgraded 480-volt panels, enabling the trains' heating/cooling systems to run on electricity instead of diesel during maintenance activities.

2.6 PARTNERSHIPS

Continuous improvements in fuel and operational efficiency since 1990 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 rail industry address technical challenges, or support development of overarching codes and standards, which are broader than the scope of any individual organization. Projects undertaken by this program are selected through a consultation process that spans the federal government, academia, and the railway industry. Notable updates for 2019 are:

- A new three-year RD&D work plan covering 2019-2021 launched this year. This work plan continues research into lignin-derived drop-in replacement diesel fuel. It includes new focus on emerging interest in hydrogen propulsion, as well as means of addressing CAC emissions without the reduction in fuel efficiency associated with many current NO_x and PM controls.
- CUTRIC is continuing its consultations with rail industry leaders to provide research and development direction for Transport Canada to utilize for advancing rail research that would enable a greener, more environmentally sustainable rail transportation system. CUTRIC is conducting three focus group sessions on rail innovation: alternative propulsion, energy efficiency, and alternative materials. A fourth focus group is examining operational optimization and integrated mobility.

15 HDRD has 5.7 percent lower energy density than fossil diesel.

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SRY & UBC Hydrogen Fuel Cell – Lithium-ion Battery Switcher Locomotive

Southern Railway of British Columbia Ltd.'s (SRY) partnership with UBC-Okanagan's research and development project began in 2017. The initial part of the project involved Dr. Gordon Lovegrove's feasibility study, to which SRY provided in-kind contributions in terms of technical support, expertise, and use of SRY's facilities for data collection.

The focus of the project is the development of hydrogen storage technology and fuel cell system. In 2019, data was collected using one of SRY's locomotives. Work also began on retrofitting small-scale equipment for pilot testing, as well as work on a larger sized hydrogen storage tank. As R&D progress, SRY is providing the frame of a locomotive to retrofit for a prototype hydrail switcher locomotive. SRY will contribute time and mechanical expertise preparing the frame and use of SRY's track and facilities to conduct in-field testing.

CN - Collaboration with the Université de Montréal

As part of its 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 3 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 - Engaging Customers About Climate Change Performance

CP engages its freight services customers to help them understand the benefits of using rail to reduce GHG emissions associated with their supply chains. CP's rationale for sharing this information with its customers is to provide awareness of CP's strong performance in reducing GHG emissions and how they can further benefit from the use of rail in reducing the overall impact of their supply chains. Engagement activities include regular customer one-on-one meetings, customer surveys, customer forums, company website resources and online shipment management tools such as CP's Customer Station.

ECCC – Hydrogen Fuel Cell Switcher Locomotive

Environment and Climate Change Canada (ECCC) engaged an engineering service firm in partnership with railway equipment overhaul and refurbishment specialists, a hydrogen fuel cell manufacturer, and a transportation energy efficiency consultant to assess the potential to retrofit a diesel switcher locomotive to use hydrogen fuel cells as the prime mover. Finding no significant technical barriers, the resulting recommendations were to partner with industry and other key stakeholders to scale the technology up to commercial application.

3. TRAFFIC DATA

3.1 FREIGHT TRAFFIC HANDLED

As shown in **Table 1** and **Figure 1**, traffic in 2019 handled by Canadian railways totaled 863.98 billion gross tonne-kilometres (GTK) compared with 864.66 billion GTK in 2018, a decrease of 0.1%. The 2019 GTK represents an increase of 99.7% from the reference year of 1990. Revenue traffic in 2019 decreased to 455.06 billion revenue tonne-kilometres (RTK) from 455.72 billion RTK in 2018, a decrease of 0.1%. When compared to 233.45 billion RTK in 1990, this represents an increase of 94.9%. Since 1990, the average annual growth rates for GTK and RTK were 2.4% and 2.3%, respectively.

TABLE 1 TOTAL FREIGHT TRAFFIC, 1990, 2010-2019 (BILLION TONNE-KILOMETRES)

	1990	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
GTK											
Class 1		620.16	644.75	674.62	695.58	754.24	752.30	722.33	778.86	820.67	824.53
Regional & Shortline		32.57	34.79	37.32	39.62	39.19	42.09	44.07	44.59	43.98	39.45
TOTAL	**432.74***	**652.73**	**679.54**	**711.94**	**735.19**	**793.43**	**794.39**	**766.40**	**823.45**	**864.66**	**863.98**
RTK											
Class 1		327.81	337.91	356.92	371.77	399.47	394.10	383.47	411.22	433.45	432.38
Regional & Shortline		21.44	22.25	23.08	24.23	23.01	23.98	25.05	24.25	22.27	22.68
TOTAL	**233.45***	**349.24**	**360.16**	**380.00**	**396.00**	**422.49**	**418.08**	**408.53**	**435.46**	**455.72**	**455.06**
RATIO RTK/ GTK**	**0.54**	**0.53**	**0.52**	**0.53**	**0.53**	**0.53**	**0.52**	**0.53**	**0.53**	**0.53**	**0.53**

* Data is not available separating Class I and Regional & Shortline traffic for the reference year, 1990.
** 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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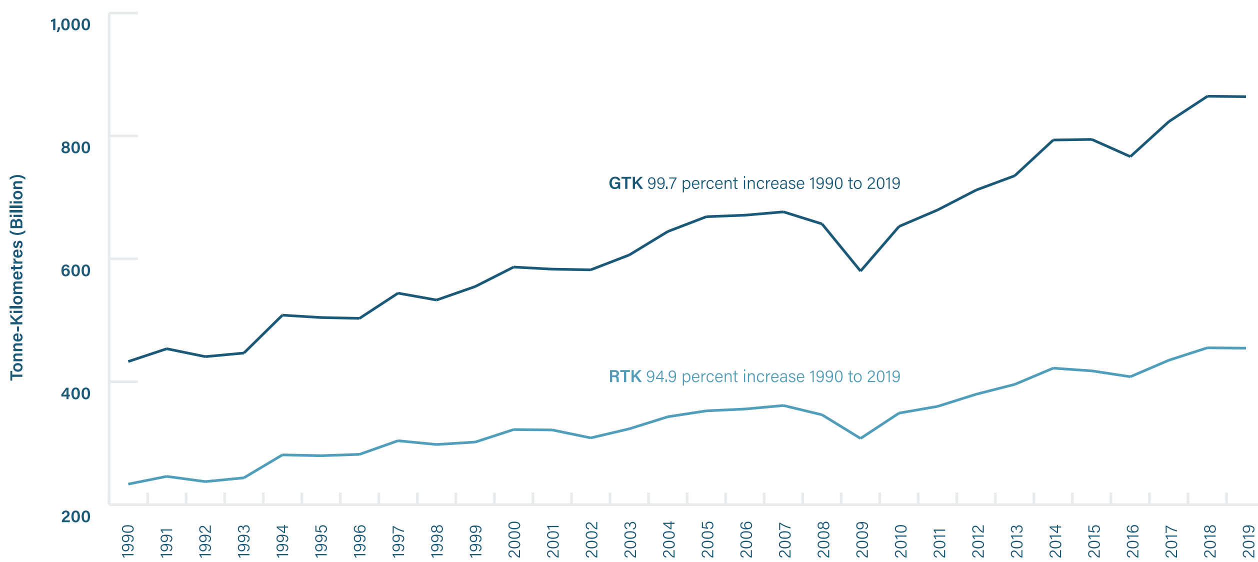
FIGURE 1 TOTAL FREIGHT TRAFFIC, 1990-2019



In 2019, Class 1 GTK traffic increased by 0.5% to 824.53 billion from 820.67 billion in 2018 (**Table 1**) and accounted for 95.4% of the total GTK hauled. Class 1 RTK traffic decreased by 0.2% in 2019 to 432.38 billion from 433.45 billion in 2018 and accounted for 95% of the total RTK.

Of the total freight traffic in 2019, regional & shortlines were responsible for 39.45 billion GTK (or 4.6%) and 22.68 billion RTK (or 5%). In 2019, regional & shortline railways experienced a 1.8% increase in RTK compared to 2018 and a decrease of 10.3% of their GTK traffic.

3.1.1 FREIGHT CARLOADS BY COMMODITY GROUPING

The total 2019 freight carloads for 11 commodity groups are shown in **Figure 2** and **Table 2** below.

FIGURE 2 - CANADIAN RAIL ORIGINATED CARLOADS BY COMMODITY GROUPING, 2019

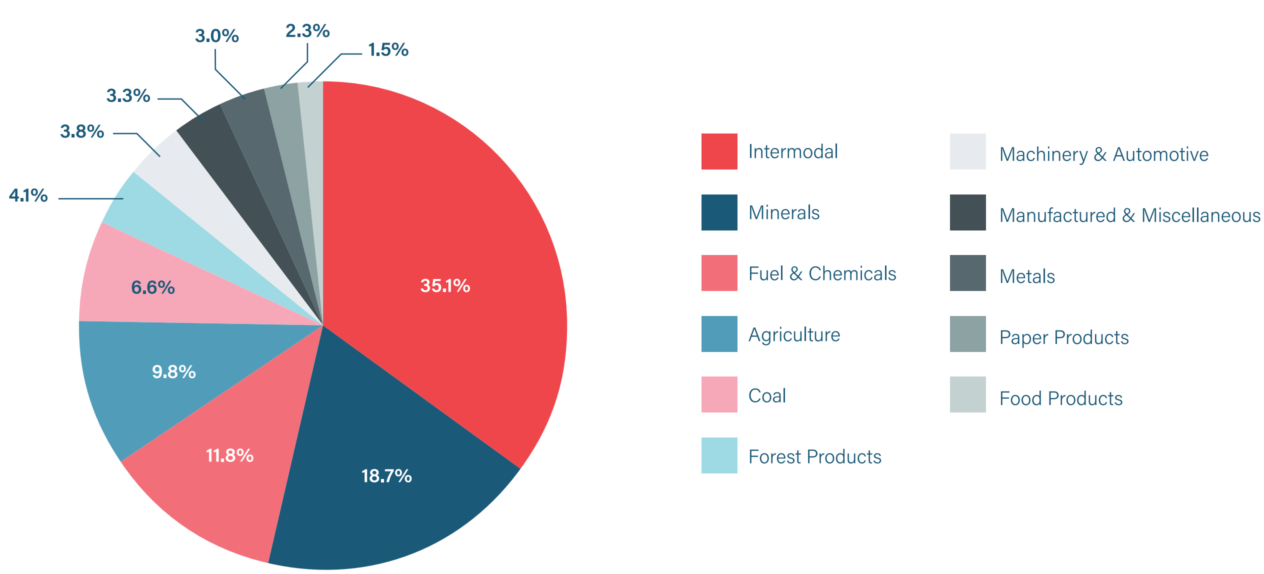


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TABLE 2 CANADIAN RAIL ORIGINATED FREIGHT CARLOADS BY COMMODITY GROUPING, 2019

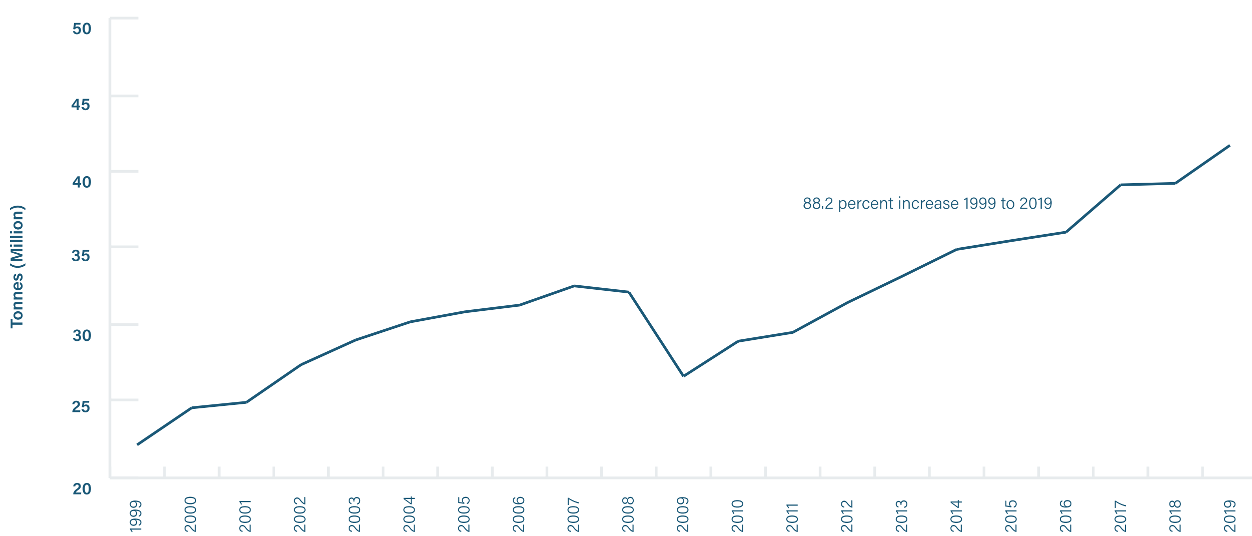
Agriculture	Coal	Minerals	Forest Products	Metals	Machinery & Automotive	Fuel & Chemicals	Paper Products	Food Products	Manufactured & Miscellaneous	Intermodal	Total
538,726	361,067	1,027,286	225,031	164,230	208,879	645,268	127,821	80,009	178,379	1,927,291	5,483,989

3.1.2 INTERMODAL TRAFFIC

Of the total freight carloads in 2019, intermodal made up the largest share at 35.1%, as illustrated in **Figure 2** and **Table 2** above. The number of intermodal carloads handled by railways in Canada increased to 1,927,291 from 1,878,392 in 2018, an increase of 2.6%.

Intermodal tonnage increased by 6.3% to 41.7 million tonnes from 39.22 million tonnes in 2018. Overall, since 1999, intermodal tonnage, comprising both container-on-flat-car and trailer-on-flat-car traffic, has risen 88.2%, equating to an average annual growth of 3.21%, as illustrated in **Figure 3**.

FIGURE 3 - INTERMODAL TONNAGE, 1999-2019



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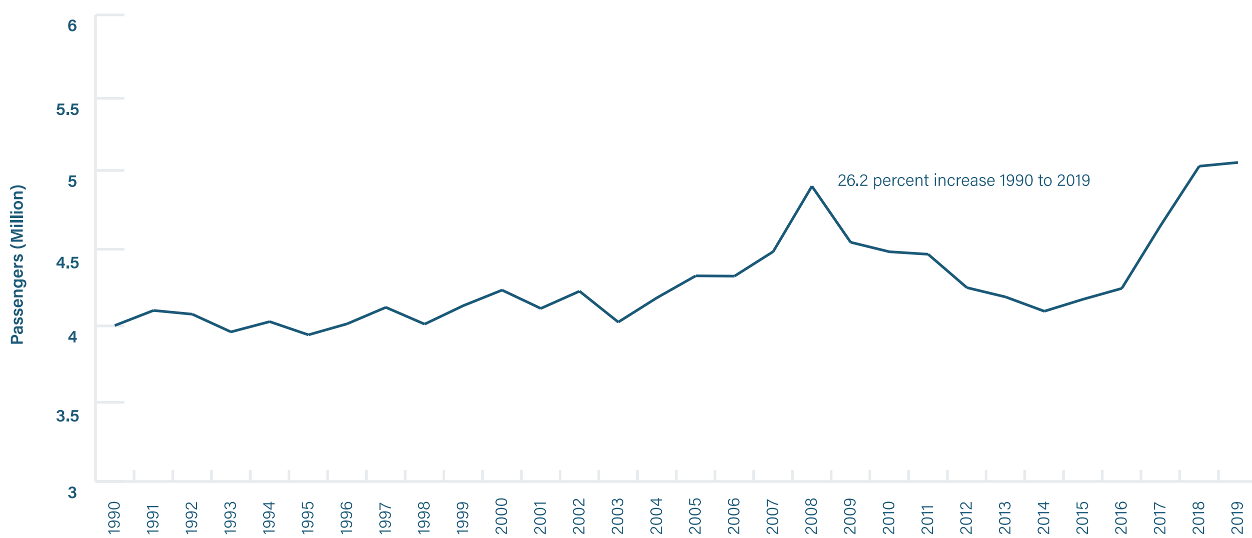
3.2 PASSENGER TRAFFIC HANDLED

3.2.1 INTERCITY PASSENGER SERVICES

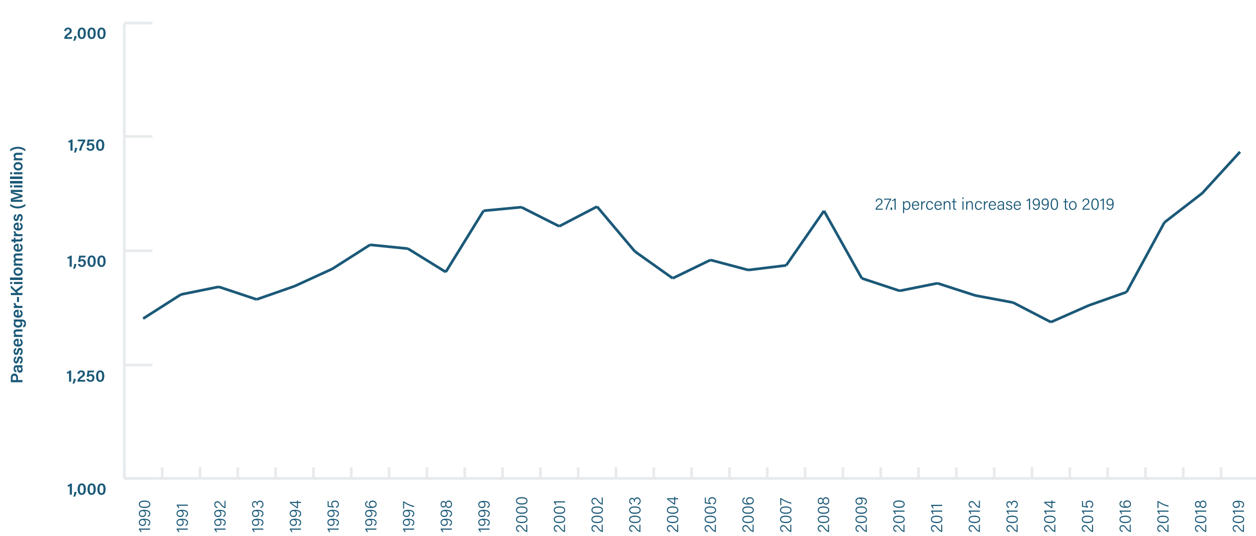
Intercity passenger traffic in 2019 totaled 5.05 million passengers, as compared to 5.03 million passengers in 2018, an increase of 0.5%, and a 26.2% increase from 4.00 million passengers in 1990 (**Figure 4**).

FIGURE 4 INTERCITY RAIL PASSENGER TRAFFIC, 1990-2019



The total revenue passenger-kilometres (RPK) for intercity passenger traffic totaled 1,717.33 million. This is an increase of 5.6% as compared to 1,626.36 million in 2018 and 27.1% increase from 1,350.71 million in 1990 (**Figure 5**).

FIGURE 5 INTERCITY RAIL REVENUE PASSENGER-KILOMETRES, 1990-2019



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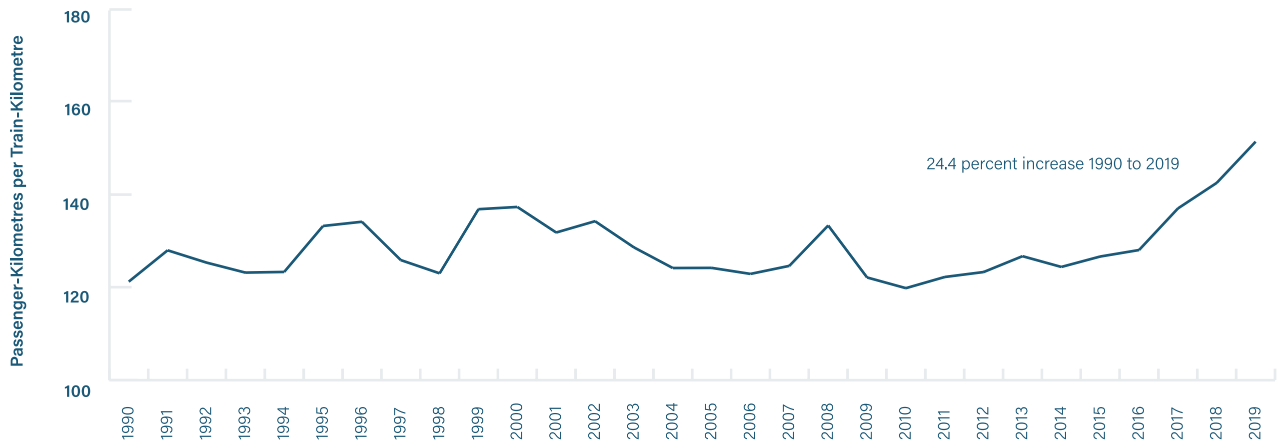
Intercity train efficiency is expressed in terms of average passenger-kilometres (km) per train-km. As shown in **Figure 6**, intercity rail train efficiency in 2019 was 151 passenger-km per train-km, 142.19 in 2018, and 121.04 in 1990. As a percentage, train efficiency in 2019 was 24.4% above that in 1990.

FIGURE 6 INTERCITY RAIL TRAIN EFFICIENCY, 1990-2019

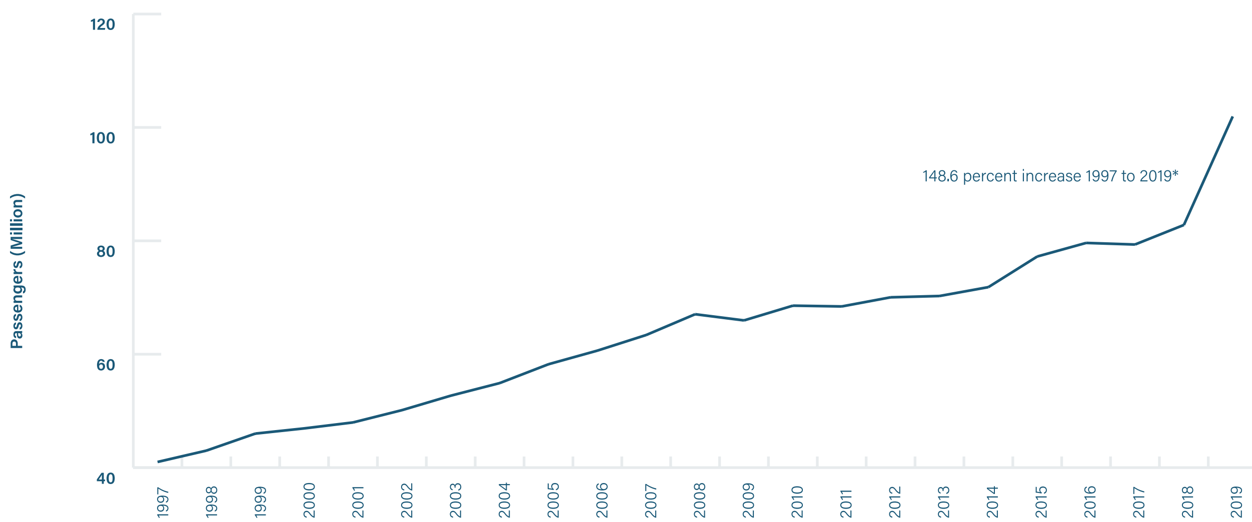


3.2.2 COMMUTER RAIL

In 2019, commuter rail passengers totaled 101.94 million (**Figure 7**). This is up from 82.79 million in 2018, an increase of 23.1%.[16] As shown in **Figure 7**, by 2019, commuter traffic increased 148.6% over the 1997 base year of 41.00 million passengers when the RAC first started to collect commuter rail statistics. This represents an average growth rate of 4.23% per year since 1997. 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.

16 The significant increase in commuters in 2019 is due to a combination of increasing ridership on commuter rail services compared to 2018, as well as the inclusion of one additional rail service that was not included in previous reports.

FIGURE 7 COMMUTER RAIL PASSENGERS, 1997-2019



*The significant increase in commuters in 2019 is due to a combination of increasing ridership on commuter rail services compared to 2018, as well as the inclusion of one additional rail service that was not included in earlier versions of the report.

3.3.3 TOURIST AND EXCURSION SERVICES

In 2019, the six RAC member railways offering tourist and excursion services transported 316 thousand passengers compared to 321 thousand in 2018, a decrease of 2%. Tourist and excursion railways include Alberta Prairie Railway Excursions, Great Canadian Railtour Company, Prairie Dog Central Railway, South Simcoe Railway, Train Touristique de Charlevoix and White Pass & Yukon.

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4. FUEL CONSUMPTION DATA

As shown in Table 3, total rail sector fuel consumption in 2019 was 2,259.24 million litres. This represents a 0.8% increase from 2,424.19 million litres in 2019, and a 9.5% increase from 2,063.55 million litres in 1990.

There was higher fuel consumption in 2019 despite a slight reduction (0.1%) in total freight traffic in 2019 compared to 2018. Of the total fuel consumed by all railway operations, freight train operations consumed 91.3%, yard switching and work train operations consumed 2.7%, and passenger operations accounted for 6%. For total freight train operations fuel consumption, Class 1 railways accounted for 91.8%, regional & shortlines 5.3%, and yard switching and work trains 2.9%.

TABLE 3 CANADIAN RAIL OPERATIONS FUEL CONSUMPTION, 1990, 2010-2019 (MILLION LITRES)

	1990	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Class 1	1,825.05	1,791.11	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
Regional & Shortline	n/a	104.65	107.91	96.55	101.72	108.91	105.45	101.83	114.15	111.88	111.99
Yard Switching	120.13	34.47	44.79	46.85	41.77	62.02	52.97	46.95	50.29	51.56	51.71
Work Train	15.67	7.06	7.72	8.77	10.30	10.80	11.35	10.84	10.01	7.10	9.94
TOTAL FREIGHT OPERATIONS	**1,960.85**	**1,937.28**	**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**
Intercity	n/a	58.11	58.63	50.99	46.17	44.89	46.98	47.93	51.02	52.77	51.05
Commuter	n/a	46.92	49.81	50.22	48.61	49.67	60.50	59.43	64.46	65.74	79.53
Tourist Train & Excursion	n/a	2.05	2.19	2.27	2.25	2.61	2.65	2.79	3.22	3.22	4.30
TOTAL PASSENGER OPERATIONS	**102.70**	**107.08**	**110.63**	**103.48**	**97.03**	**97.16**	**110.13**	**110.15**	**118.70**	**121.72**	**134.89**
TOTAL RAIL OPERATIONS	**2,063.55**	**2,044.37**	**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**

n/a = not available

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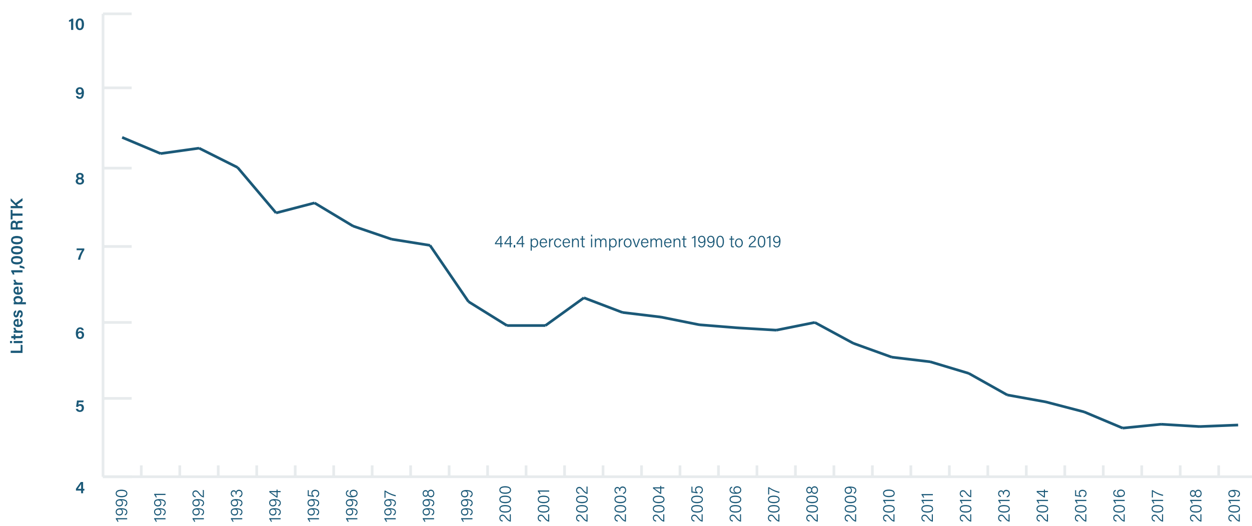
4.1 FREIGHT OPERATIONS

Fuel consumption in 2019 for all freight train, yard switching, and work train operations was 2,124.35 million litres, an increase of 0.2% from the 2,120.46 million litres consumed in 2018 and an increase of 8.3% from the 1990 level of 1,960.85 million litres. Based on total traffic moved by railways in Canada, measured in revenue tonne-kilometres, railways can move one tonne of freight approximately 215 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 2019 for overall rail freight traffic was 4.67 litres per 1,000 RTK. This value is a 0.3% increase (i.e., a decline in efficiency) from the 4.65 L/1,000 RTK in 2018 but is 44.4% below (i.e., improved efficiency) the 1990 level of 8.40 L/1,000 RTK. The improvement since 1990 shows the ability of the Canadian freight railways to accommodate traffic growth while reducing fuel consumption per unit of work.

FIGURE 8 FREIGHT FUEL CONSUMPTION PER 1,000 RTK, 1990-2019



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. A comprehensive list of emerging technologies and management options available to the railways can be viewed in the Locomotive Emissions Monitoring Program Action Plan for Reducing GHG Emissions available by request to the RAC.

4.2 PASSENGER SERVICES

Overall passenger rail fuel consumption—that is the sum of intercity, commuter, and tourist and excursion train operations—was 134.89 million litres in 2019, an increase of 10.8% from the 121.72 million litres consumed in 2018. The increase in passenger rail fuel consumption is related to the inclusion of an additional rail service that was not included in previous reports. The breakdown and comparison with previous years is provided in **Table 3**.

Intercity passenger's fuel consumption decreased by 3.2% from 52.77 million litres in 2018 to 51.05 million litres in 2019. Fuel consumption for commuter rail increased by 21% from 65.74 million litres in 2018 to 79.53 million litres in 2019. Tourist and excursion rail fuel consumption also increased (33.6%) from 3.22 million litres in 2018 to 4.3 million litres in 2019.

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 2019, some provinces, such as Ontario and British Columbia, require a minimum renewable fuel content of 4%.[17]

4.3.1 LOW CARBON FUELS

Through Natural Resources Canada, CanmetEnergy has been undertaking a project to develop a process to produce blends of lignin-derived diesel fuel with petroleum diesel. 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% lignin-derived diesel meets the CGSB 3.18 locomotive fuel specifications; blends up to 5% can be sold as "diesel fuel" without any required disclosure or labeling. The next stage of the project will be to produce a 10% blend, and then explore blends greater than 10%. Railways and manufacturers are working through issues stemming from high blend rates above 5% that may cause adverse operational impacts and void some original equipment manufacturers (OEM) warranties.

Hydrogenation-derived renewable diesel (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.

17 For some provinces, renewable fuel requirements are planned to become more stringent beyond 2019.

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5. LOCOMOTIVE INVENTORY

5.1 FLEET OVERVIEW

Table 4 presents an overview of the active fleet of diesel and non-diesel locomotives in Canada for freight and passenger railways. The detailed locomotive fleet inventory is presented in Appendix B.

TABLE 4 CANADIAN LOCOMOTIVE FLEET SUMMARY, 2019

Freight Operations	
Line Haul: Class 1	2,663
Line Haul: Regional	132
Line Haul: Shortline	140
Freight Switching Operations	619
TOTAL - FREIGHT OPERATIONS	**3,554**
Passenger Operations	
Passenger Train Locomotives	257
DMUs	24
Yard Switching Locomotives	5
TOTAL - PASSENGER OPERATIONS	**286**
TOTAL - PASSENGER & FREIGHT OPERATIONS	**3,840**

Note: numbers include all active fleet equipment.

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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[18] compared to the total number of freight and passenger line haul diesel locomotives. Excluded were steam locomotives, non-powered slug units, and electrical multiple units (EMUs) as they do not contribute diesel combustion emissions. 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.

TABLE 5 LOCOMOTIVES IN CANADIAN FLEET MEETING EMISSIONS STANDARDS, 2000, 2010-2019

	2000	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Freight and passenger locomotives subject to regulation (a)	1,498	2,196	2,112	2,290	2,293	1,925	1,828	1,674	2,742	3,233	3,366
Freight and passenger locomotives not subject to regulation (b)	1,578	752	866	802	770	775	572	644	435	549	474
Freight and passenger locomotives meeting an emissions standard	80	1,209	1,317	1,512	1,631	1,538	1,266	1,267	2,157	2,995	2,982

a Includes locomotives which are subject to the LER or the US EPA regulations (i.e., *Title 40 of the United States Code of Federal Regulations, Part 1033*, "Control of Emissions from Locomotives" and Part 92, "Control of Air Pollution from Locomotives and Locomotive Engines.").

b Includes locomotives which are not subject to the LER or the US EPA regulations.

18 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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In 2019, 88.6% of the fleet subject to regulation (2,982 locomotives of 3,366) met emission standards (set-out under the LER or the US EPA regulations). The emission standards have been phased in over time and are applicable only to "new" locomotives (i.e., originally manufactured and remanufactured locomotives). Locomotives manufactured prior to 1973 that have not been upgraded and locomotives below 1,006 horsepower (hp) are not required to meet the regulations. The remaining locomotive fleet is not required to meet the emission standards until the time of its next remanufacture.

Table 6 provides an overview of the 2019 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 2019. It also presents the number of locomotives with anti-idling devices.

TABLE 6 LOCOMOTIVE FLEET BREAKDOWN BY TIER LEVEL, 2019

Tier Level	Locomotives		Locomotives with anti-idling devices	Added	Retired	Remanufactured
	Number	Percent of fleet				
Not subject to regulation*	474	12.3%	109	-	11	-
Subject to regulation - Non Tier-Level Locomotives	384	10.0%	201	-	34	
Tier 0	212	5.5%	113	-	66	-
Tier 0+	788	20.5%	693	-	15	-
Tier 1	21	0.5%	21	-	-	-
Tier 1+	691	18.0%	682	-	23	61
Tier 2	196	5.1%	121	-	-	-
Tier 2+	445	11.6%	445	-	-	-
Tier 3	334	8.7%	324	74	1	-
Tier 4	295	7.7%	260	98	-	-
TOTAL	**3,840**	**100%**	**2,969**	**172**	**150**	**61**

* Includes locomotives which are not subject to the regulations because of exclusions. Regulations refer to the LER or *Title 40 of the United States Code of Federal Regulations, Part 1033*, "Control of Emissions from Locomotives", and Part 92, "Control of Air Pollution from Locomotives and Locomotive Engines".

In 2019, 74 Tier 3 and 98 Tier 4 high-horsepower locomotives were added to the Canadian fleet. A total of 61 locomotives were upgraded to Tier 1+ and 150, 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 2019 equipped with a device to minimize unnecessary idling, such as an AESS system or APU, was 2,969, which represents 77.3% of the fleet, compared with 2,168 in 2018 (57.3% of the fleet).

6. LOCOMOTIVE EMISSIONS

6.1 EMISSION FACTORS

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

6.1.1 EMISSION FACTORS FOR GREENHOUSE GASES

The EFs 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 1990–2019: Greenhouse Gas Sources and Sinks in Canada, which is submitted annually to the United Nations Framework Convention on Climate Change (UNFCCC).[19] For 2019, the National Inventory Report included an extra decimal place to improve transparency; however, the EFs are the same as the previous year. **Table 7** presents the 2019 GHG emission factors for diesel locomotives.

TABLE 7 GHG EMISSIONS FACTORS FOR DIESEL LOCOMOTIVES, 2019

	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 1990–2019: Greenhouse Gas Sources and Sinks in Canada, Environment and Climate Change Canada, 2021

6.1.2 EMISSION FACTORS FOR CRITERIA AIR CONTAMINANT EMISSIONS

CAC EFs for 2019 have been calculated in grams per litre (g/L) of fuel consumed for NO_x, PM, CO, HC, and SO_x for each category of operation (i.e., freight, switch, and passenger operations). All freight line haul CAC EFs decreased in 2019 compared to 2018, except for SO_2, which stayed the same. EFs for yard operations stayed the same or decreased in 2019 compared to 2018, except for NO_x and HC, which increased slightly. EFs for passenger operations stayed the same or decreased in 2019 compared to 2018. 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 8** for 1990 and 2010–2019. EFs for years prior to 2010 are available upon request to the RAC.

19 National Inventory Report 1990 – 2019: Greenhouse Gas Sources and Sinks in Canada, Environment and Climate Change Canada, 2021 [https://unfccc.int/ghg-inventories-annex-i-parties/2021.](https://unfccc.int/ghg-inventories-annex-i-parties/2021)

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TABLE 8 CAC EMISSIONS FACTORS FOR DIESEL LOCOMOTIVES, 1990, 2010-2019 (g/L)

Freight: Line Haul

Year	NO_x	PM_{10}	CO	HC	SO_2
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
2010	49.23	1.23	7.06	2.38	0.21
1990	71.44	1.59	7.03	2.64	2.47

Total Yard Switching

Year	NO_x	PM_{10}	CO	HC	SO_2
2019	57.32	1.18	7.35	3.34	0.02
2018	56.67	1.18	7.35	3.33	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
2010	69.65	1.54	7.35	4.06	0.21
1990	69.88	1.65	7.35	4.06	2.47

Total Passenger

Year	NO_x	PM_{10}	CO	HC	SO_2
2019	45.13	0.92	7.03	1.77	0.02
2018	54.37	1.11	7.03	2.10	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
2010	56.23	1.18	7.03	2.23	0.21
1990	71.44	1.59	7.03	2.64	2.47

6.2 EMISSIONS GENERATED

6.2.1 GREENHOUSE GASES

In 2019, GHG emissions produced by the railway sector (expressed as CO_2e) were 6,757.09 kt, an increase of 0.8% as compared to 6,706.08 kt in 2018. The 2019 emissions have increased by 9.5% from 6,171.81 kt in 1990 (with a rise in RTK traffic of 95% over the same period). **Table 9** displays the GHG emissions produced in 1990 and annually since 2010. The GHG emissions for years prior to 2010 are available upon request to the RAC.

TABLE 9 GHG EMISSIONS BY RAILWAY SERVICE IN CANADA, 1990, 2010-2019 (KILOTONNES)

Freight - Line Haul

	1990	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CO_2	4,892.04	5,081.57	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
CH_4	6.80	7.06	7.17	7.35	7.27	7.55	7.30	6.83	7.37	7.68	7.68
N_2O	559.64	581.32	590.09	604.82	598.35	621.62	600.54	562.39	606.84	632.23	632.51
CO_2e	**5,458.47**	**5,669.96**	**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**

Yard Switching and Work Train

	1990	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CO_2	364.03	111.31	140.76	149.09	139.58	195.20	172.41	154.91	161.64	157.25	165.27
CH_4	0.51	0.15	0.20	0.21	0.19	0.27	0.24	0.22	0.22	0.22	0.23
N_2O	41.64	12.73	16.10	17.05	15.97	22.33	19.72	17.72	18.49	17.99	18.91
CO_2e	**406.18**	**124.20**	**157.06**	**166.35**	**155.74**	**217.80**	**192.37**	**172.85**	**180.36**	**175.45**	**184.40**

Total Freight Operations

	1990	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CO_2	5,256.06	5,192.89	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
CH_4	7.30	7.22	7.36	7.55	7.46	7.82	7.53	7.05	7.60	7.90	7.91
N_2O	601.28	594.05	606.19	621.87	614.31	643.95	620.26	580.11	625.33	650.22	651.42
CO_2e	**5,864.65**	**5,794.16**	**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**

Passenger - Intercity, Commuter, Tourist/Excursion

	1990	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CO_2	275.29	287.04	296.55	277.38	260.09	260.45	295.20	295.25	318.17	326.28	361.56
CH_4	0.38	0.40	0.41	0.39	0.36	0.36	0.41	0.41	0.44	0.45	0.50
N_2O	31.49	32.84	33.92	31.73	29.75	29.79	33.77	33.78	36.40	37.33	41.36
CO_2e	**307.16**	**320.27**	**330.89**	**309.50**	**290.21**	**290.60**	**329.38**	**329.44**	**355.01**	**364.06**	**403.43**

Total Railway

	1990	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CO_2	5,531.35	5,479.93	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
CH_4	7.69	7.62	7.78	7.94	7.82	8.18	7.94	7.46	8.04	8.35	8.42
N_2O	632.77	626.89	640.11	653.61	644.07	673.74	654.03	613.89	661.73	687.55	692.78
CO_2e	**6,171.81**	**6,114.43**	**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**

GHG emissions have been calculated based on the 1990-2019 National Inventory Report. Historical values have been updated to use these most recent emission factors and global warming potentials.

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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 10** shows the 2019 GHG emissions intensity levels for these categories, as well as for commuter rail.

TABLE 10 GHG EMISSIONS INTENSITIES BY RAILWAY SERVICE IN CANADA, 1990, 2010-2019

	1990	2010	2011	2012	2013	2014	2015	2016	2017 (MOU Baseline)	2018	2019	2022 Target
Total Freight (kg CO_2e/1,000 RTK)	25.12	16.59	16.42	15.96	15.13	14.87	14.47	13.85	14.01	13.92	13.96	No Target
Class 1 Freight (kg CO_2e/1,000 RTK)	n/a	16.34	16.08	15.72	14.88	14.36	14.06	13.51	13.56	13.45	13.49	12.75
Regional & Shortline Freight (kg CO_2e/1,000 RTK)	n/a	14.60	14.51	12.51	12.56	14.15	13.15	12.16	14.08	15.02	14.77	13.66
Intercity Passenger (kg CO_2e/ Passenger-km)	n/a	0.123	0.123	0.109	0.100	0.100	0.102	0.102	0.098	0.097	0.089	0.092
Commuter Rail (kg CO_2e/Passenger)	n/a	2.05	2.18	2.10	2.02	1.96	2.34	2.23	2.43	2.37	2.33	No Target

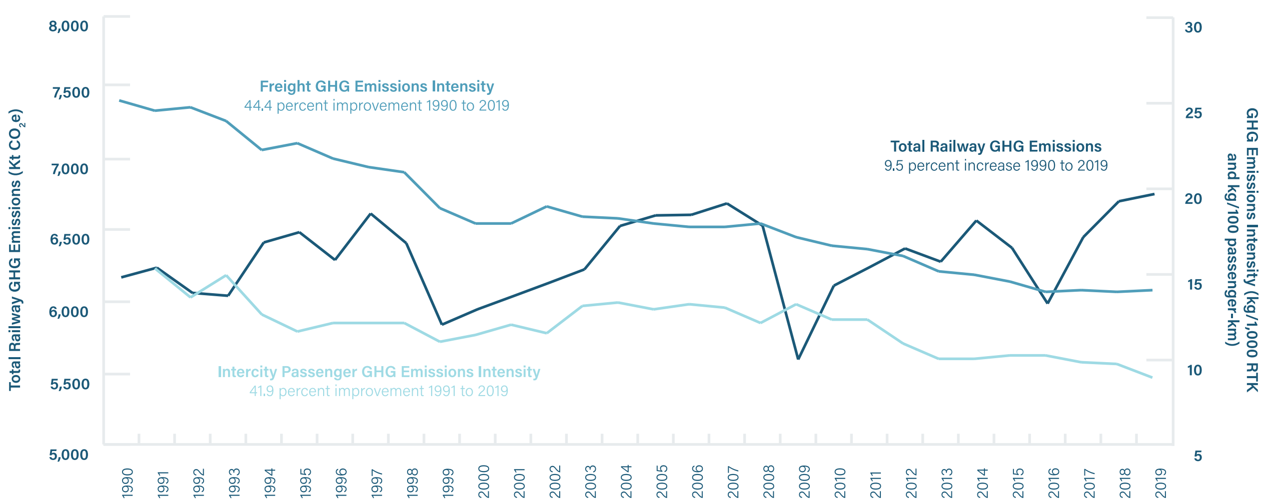
n/a = not available

GHG emissions have been calculated based on the 1990-2019 National Inventory Report. Historical values have been updated to use these most recent emission factors and global warming potentials.

The GHG emissions intensities for freight traffic increased in 2019 by 0.3% to 13.96 kg CO_2e/1,000 RTK from 13.92 kg CO_2e/1,000 RTK in 2018. However, since 1990, the GHG emissions intensity for total freight has decreased 44.4% from 25.12 kg CO_2e/1,000 RTK. Class 1 freight saw a 0.3% increase in GHG emissions intensity from 13.45 kg CO_2e/1,000 RTK in 2018 to 13.49 kg CO_2e/1,000 RTK in 2019. All other categories decreased in emissions intensity from 2018 to 2019. Regional & shortline freight improved by 1.7%, intercity passenger improved by 8.4%, and commuter rail improved by 1.7%.

Figure 9 shows the trend in GHG emissions for the total railway industry, as well as emissions intensities for freight and intercity passenger rail, since 1990.

FIGURE 9 - GHG EMISSIONS AND EMISSIONS INTENSITIES, 1990-2019



Note: Intercity passenger rail intensity is reported as kg/passenger-km throughout the rest of the LEM. The passenger rail intensity metric was modified to kg/100 passenger-km in figure 9 so that it could be reflected on the same axis as total freight emissions intensity, which is reported as kg/1,000 RTK

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6.2.2 CRITERIA AIR CONTAMINANTS

Table 11 displays the CAC emissions produced annually by locomotives in operation in Canada for the reference year (1990) and annually from 2010 to 2019, namely NO_x, PM, CO, HC, and SO_x.[20] The values presented are for both absolute amounts and intensities per productivity unit. The emissions and intensities for years before 2010 are available upon request to the RAC.

The CAC of key concern for the railway sector is NO_x.[21] As shown in **Table 11**, NO_x emissions in 2019 for total railway operations was 80.11 kt, down 1.3% from 81.14 kt in 2018. Freight operations accounted for 92.4% 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 0.16 kg per 1,000 RTK in 2019, the same as 2018. Total freight NO_x emissions intensity has decreased by 68.8% since 1990 (0.52 kg per 1,000 RTK).

20 In previous years, it was noted that there were some inconsistencies among member datasets regarding the application of rated horsepower of various locomotives. RAC is continuing to work with members to standardize the approach to hp ratings for their fleets, but there may still be some inconsistencies in the locomotive inventory used to calculate CACs.

21 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.

TABLE 11 LOCOMOTIVE CAC EMISSIONS, 1990, 2010-2019 (KILOTONNES, UNLESS OTHERWISE SPECIFIED)

Freight: Line Haul

Year	NO_x	PM_{10}	CO	HC	SO_2 (tonnes)
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
2010	93.32	2.32	13.38	4.51	402.39
1990	130.38	2.91	12.84	4.81	4,504.32

Total Yard Switching

Year	NO_x	PM_{10}	CO	HC	SO_2 (tonnes)
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
2010	2.89	0.06	0.31	0.17	8.81
1990	9.49	0.22	1.00	0.55	335.18

Total Freight Operations(1)

Year	NO_x	PM_{10}	CO	HC	SO_2 (tonnes)
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
2010	96.22	2.39	13.68	4.68	411.20
1990	139.87	3.13	13.84	5.36	4,839.50

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

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

Total Passenger

Year	NO_x	PM_{10}	CO	HC	SO_2 (tonnes)
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
2010	5.94	0.12	0.74	0.24	22.43
1990	7.35	0.16	0.72	0.27	253.80

Total Railway Operations(2)

Year	NO_x	PM_{10}	CO	HC	SO_2 (tonnes)
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
2010	102.16	2.51	14.43	4.92	433.63
1990	147.21	3.30	14.56	5.64	5,093.30

Total Freight Emissions Intensity (kg/1,000 RTK)

Year	NO_x	PM_{10}	CO	HC	SO_2 (tonnes)
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
2010	0.28	0.0068	0.0392	0.0134	0.00118
1990	0.52	0.0116	0.0513	0.0192	0.01801

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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.

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.

TABLE 12 TOMA PERCENTAGES OF TOTAL FUEL CONSUMPTION AND GHG EMISSIONS, 1999, 2010-2019

	1999	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Lower Fraser Valley, B.C.	4.2	3.1	2.8	2.9	2.9	2.2	2.3	2.5	2.4	2.3	2.4
Windsor-Quebec City Corridor	17.1	15.3	14.8	14.3	14.2	14.1	14.1	14.0	13.8	13.0	13.5
Saint John, N.B.	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1

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TABLE 13 TOMA PERCENTAGES OF TOTAL NO_x EMISSIONS*, 1999, 2010-2019

	1999	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Lower Fraser Valley, B.C.	4.4	3.1	2.8	2.9	2.9	2.3	2.3	2.5	2.4	2.3	2.4
Windsor-Quebec City Corridor	17.8	15.3	14.8	14.4	14.2	14.1	14.1	14.0	13.8	13.0	13.5
Saint John, N.B.	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1

* 2010-2013 values are the only values that were updated using the revised CAC EFs implemented in the 2009 LEM Report due to the CAC emission factor review as referenced in Section 6.1

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 only 50% of the fuel consumption for tourism was applicable to this region. The 2019 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, 2019

	TOMA No.1 - Lower Fraser Valley, B.C.			TOMA No.2 - Windsor-Quebec 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%
FREIGHT TRAFFIC (MILLION GTK)									
CN	11,012	6,387	4,625	57,998	33,639	24,359	551	320	231
CP	9,063	5,257	3,806	18,472	10,714	7,758	-	-	-
Regional & Shortline Railways	271	157	114	1,396	810	587	648	376	272
TOTAL FREIGHT TRAFFIC	**20,346**	**11,801**	**8,545**	**77,867**	**45,163**	**32,704**	**1,199**	**695**	**503**
FUEL CONSUMPTION (MILLION LITRES)									
TOTAL FREIGHT FUEL CONSUMPTION(1)	**50.03**	**29.02**	**21.01**	**191.46**	**111.05**	**80.41**	**2.95**	**1.71**	**1.24**
Intercity Passenger Rail	0.42	0.24	0.18	35.25	20.44	14.80	-	-	-
Tourism Rail	2.05	1.19	0.86	-	-	-	-	-	-
Commuter Rail	1.33	0.77	0.56	78.21	45.36	32.85	-	-	-
TOTAL PASSENGER FUEL CONSUMPTION	**3.80**	**2.20**	**1.59**	**113.46**	**65.80**	**47.65**	**0.00**	**0.00**	**0.00**
TOTAL RAIL FUEL CONSUMPTION	**53.82**	**31.22**	**22.61**	**304.92**	**176.85**	**128.06**	**2.95**	**1.71**	**1.24**

EMISSIONS

	Emission Factors (g/L)(2)		Kilotonnes/Year			Kilotonnes/Year			Kilotonnes/Year		
CACs	**NO_x**	35.38	1.90	1.10	0.80	10.79	6.26	4.53	0.10	0.06	0.04
CACs	**PM_{10}**	0.71	0.04	0.02	0.02	0.22	0.13	0.09	0.00	0.00	0.00
CACs	**CO**	7.00	0.38	0.22	0.16	2.13	1.24	0.90	0.02	0.01	0.01
CACs	**HC**	1.42	0.08	0.04	0.03	0.43	0.25	0.18	0.00	0.00	0.00
CACs	**SO_2**	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
GHGs(3)	**CO_2**	2,680.50	144.27	83.68	60.59	817.33	474.05	343.28	7.90	4.58	3.32
GHGs(3)	**CH_4**	3.73	0.20	0.12	0.08	1.14	0.66	0.48	0.01	0.01	0.00
GHGs(3)	**N_2O**	306.64	16.50	9.57	6.93	93.50	54.23	39.27	0.90	0.52	0.38
GHGs(3)	**CO_2e**	2,990.87	160.98	93.37	67.61	911.96	528.94	383.02	8.81	5.11	3.70

(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 2019, the Freight Fuel Rate was 2.46 litres per 1,000 GTK.

(2) The emission factor used in the emissions calculations is a weighted average of the overall freight, yard and passenger emissions factor based on the quantity of freight and passenger fuel used.

(3) The emission factors for each GHG include their respective global warming potential factor.

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8. SUMMARY AND CONCLUSIONS

The 2019 Locomotive Emissions Monitoring Report highlights that Canadian railways are continuing to improve their emissions performance through investments in fleet renewal, fuel saving technologies, employee training, use of renewable low carbon fuels, and investments in equipment, infrastructure, and facilities. 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 two of the MOU have demonstrated progress towards MOU targets. As with the previous MOU (2011 – 2017), commuter railways do not have an intensity target, but continue to report on performance and efforts to reduce GHG emissions intensity. Similarly, as with previous MOUs, CAC emissions are reported and RAC continues to encourage its members to improve their CAC emissions performance.

The 2017 baseline data, the GHG emission targets for 2022 and the actual emissions from 2018 and 2019, expressed as kilograms (kg) of CO_2e per productivity unit, for the rail industry are outlined in the following table.

GHG EMISSIONS INTENSITY AND MOU PROGRESS BY RAILWAY OPERATION

Railway Operation	Productivity Units	Baseline - 2017	2018	2019	Change from 2018-2019	2022 Target	Progress to 2022 Target
Class I Freight	kg CO_2e per 1,000 RTK	13.56	13.45	13.49	0.29%	12.75 (6% reduction)	8.58% progress to target
Intercity Passenger	kg CO_2e per passenger-km	0.098	0.097	0.089	-8.37%	0.092 (6% reduction)	149.62% target achieved
Regional & Shortline	kg CO_2e per 1,000 RTK	14.08	15.02	14.77	-1.72%	13.66 (3% reduction)	increase since 2017

GHG emissions have been calculated based on the 1990-2019 National Inventory Report. Historical values have been updated to use these most recent emission factors and global warming potentials.

Class 1 freight GHG emissions intensity increased by 0.29% from 2018 to 2019, however, the 2019 GHG emissions intensity is still less than the 2017 baseline and represents 8.58% progress towards achieving the MOU target. Regional and shortline emissions intensity decreased by 1.72% from 2018 to 2019 yet stood 4.86% above the 2017 baseline. GHG emissions intensity for total freight operations increased by 0.3% from 13.92 kg CO_2e/1,000 RTK in 2018 to 13.96 kg CO_2e/1,000 RTK in 2019. However, compared to 25.12 kg CO_2e/1,000 RTK in 1990, total freight performance has improved by 44.4%. Intercity passenger GHG emissions intensity decreased by 8.37% from 2018 to 2019, surpassing the 2022 MOU target.[22]

22 Intercity rail train efficiency (passenger-kilometres per train-kilometre) improved by 5.9% in 2019.

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GHG emissions from all railway operations in Canada totaled 6,757.09 kt in 2019, which is an increase of 0.8% from 6,706.08 kt in 2018. This increase primarily reflects an increase in traffic in the passenger sector.

CAC emissions from all railway operations decreased, with total locomotive NO_x emissions decreasing to 80.11 kt in 2019 from 81.14 kt in 2018. In 2019, the total freight NO_x emissions intensity stayed the same as in 2018 at 0.16 kg/1,000 RTK, a 68.8% improvement from 1990 levels (at 0.52 kg/1,000 RTK).

In 2019, Canadian railways made substantive investments and added 74 Tier 3 and 98 Tier 4 high-horsepower locomotives to the fleet. In addition, 61 Class 1 locomotives were remanufactured (upgraded) to Tier 1+. Older and lower-horsepower locomotives continue to be retired, and in 2019, 150 locomotives were taken out of active duty.

The Canadian fleet totaled 3,840 units in 2019, of which 3,366 locomotives were subject to the emissions standards. Of the locomotives subject to the emissions standards, 88.6% (2,982) met them. Not all locomotives in Canada are required to meet emission standards (474 were not subject to regulation in 2019). The number of locomotives equipped with APUs or AESS systems to minimize unnecessary idling totaled 2,969 or 77.3% of the in-service fleet.

Through implementation of the Locomotive Emissions Monitoring Program Action Plan for Reducing GHG Emissions, along with federal initiatives (e.g., Pan Canadian Framework on Clean Growth and Climate Change, Clean Fuel Regulation, 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 2019.

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
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 Inc.	Québec, Newfoundland and Labrador
Roberval and Saguenay Railway Company	Québec
Romaine River Railway Company	Québec
Société du chemin de fer de la Gaspésie	Québec
South Simcoe Railway	Ontario
Southern Ontario Railway	Ontario
Southern Railway of British Columbia Ltd.	British Columbia
St. Lawrence & Atlantic Railroad (Québec) Inc.	Québec
Toronto Terminals Railway Company Limited	Ontario
Train Touristique de Charlevoix Inc.	Québec
Trillium Railway Co. Ltd.	Ontario
Tshiuetin Rail Transportation Inc.	Québec, Newfoundland and Labrador
VIA Rail Canada Inc.	British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Québec, New Brunswick, Nova Scotia
West Coast Express Ltd.	British Columbia
White Pass and Yukon Route Railroad	Yukon, British Columbia

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APPENDIX B-1

2019 LOCOMOTIVE FLEET - FREIGHT TRAIN LINE HAUL OPERATIONS - PART 1

Model	US EPA Tier Level	Engine	hp	Year of Manufacture	Class 1	Regional	Shortlines	Total Regional & Shortlines	Total Freight Fleet
GM/EMD									
FP7B		16-567C	1750	1950-1959	1	0	0	0	1
FP9A		16-645E3	3000	1950-1959	2	0	0	0	2
GP10		567	1800	1967-1977	0	0	3	3	3
GP35-3		645	2500	1963-1966	0	0	2	2	2
GP35-3		645	2500	1965	0	0	1	1	1
GP38		645	2000	1970-1979	0	3	1	4	4
GP38		645	2000	1970-1979	0	6	0	6	6
GP38-2		645	2000	1974-1979	0	0	1	1	1
GP38-2		645	2000	1972-1973	0	0	7	7	7
GP38-2		645	2000	1971	0	0	1	1	1
GP38-2		645	2000	1972-1986	0	0	10	10	10
GP38-2		645	2000	1966-1971	0	0	2	2	2
GP38-2/QEG		645	2000	1974-1986	0	0	2	2	2
GP38-3		645	2000	1980-1989	0	0	12	12	12
GP38-3		645	2000	1968-1973	0	0	7	7	7
GP38-3		645	2000	1967	0	0	1	1	1
GP39-2		645	2300	1970-1973	0	0	2	2	2
GP39-2		645	2300	1971	0	0	2	2	2
GP40		645	3000	1970-1979	0	4	0	4	4
GP40		12-645E3	2300	1970-1972	1	0	0	0	1
GP40		12-645E3	2300	1960-1969	3	0	0	0	3
GP40		645	3000	1966	0	0	1	1	1
GP40-2		645	3000	1972-1979	0	0	12	12	12
GP40-2		645	3000	1974	0	0	2	2	2
GP40-2		16V-645E3B	3000	1973-1979	19	0	0	0	19
GP40-2		12-645E3	2300	1960-1969	1	0	0	0	1
GP40-2R		645	3000	1969	0	0	1	1	1
GP40-3		645	3000	1966-1968	0	0	7	7	7
GP40-3		567	3000	1966-1968	0	0	2	2	2
GP9		645	1800	1974-1981	0	0	7	7	7
GP9		645	1800	1954-1960	0	0	1	1	1
GP9		645	1800	1960-1969	0	0	6	6	6
SD38		645	2000	1970-1979	0	0	1	1	1
SD38-2		645	2000	1970-1979	0	0	2	2	2
SD40-2		645	3000	1980	0	0	3	3	3
SD40-2		645	3000	1973-1979	0	0	5	5	5
SD40-2		645	3000	1970-1972	0	0	7	7	7
SD40-2		645	3000	1966-1971	0	0	3	3	3
SD40-2		645	3000	1980-1990	0	13	1	14	14
SD40-2		16V-645E3B	3000	1973-1979	20	0	0	0	20
SD40-2		16V-645E3B	3000	1980-1989	11	0	0	0	11
SD40-2		645	3000	1979	0	0	1	1	1
SD40-2		16-645E3	3000	1973-1979	35	0	0	0	35
SD40-2		16-645E3	3000	1980-1989	55	0	0	0	55
SD40-2/QEG		645	3000	1978-1985	0	0	2	2	2
SD40-3		645	3000	1966-1972	0	0	9	9	9
SD40-3		16V-645E3B	3000	1960-1969	7	0	0	0	7
SD40-3		567	3100	1970-1979	0	1	0	1	1
SD40-3		16-645E3	3000	1980-1989	1	0	0	0	1
SD60-3		16-710G3	3800	1980-1989	1	0	0	0	1
SD70-ACE		710	4000	1995-2000	0	28	0	28	28
SD90MAC		16-710G3	4300	1990-1999	26	0	0	0	26
FP7A	Tier 0	16-567C	1750	1950-1959	1	0	0	0	1
GP40	Tier 0	12-645E3	2300	1960-1969	2	0	0	0	2
GP40-2	Tier 0	16V-645E3B	3000	1973-1979	20	0	0	0	20
SD40-2	Tier 0	16-645E3	3000	1980-1989	13	0	0	0	13
SD40-2	Tier 0	16V-645E3B	3000	1980-1989	4	0	0	0	4
SD40-2	Tier 0	16-645E3	3000	1973-1979	6	0	0	0	6
SD40-2	Tier 0	16V-645E3B	3000	1973-1979	14	0	0	0	14
SD40-3	Tier 0	16-645E3	3000	1980-1989	3	0	0	0	3
SD60	Tier 0	16V-710G3	3800	1980-1989	34	0	0	0	34
SD60	Tier 0	16-710G3	3800	1980-1989	1	0	0	0	1
SD60-3	Tier 0	16-710G3	3800	1980-1989	7	0	0	0	7
SD70I	Tier 0	16V-710G3B	4000	1990-1999	3	0	0	0	3
SD75	Tier 0	710	4300	1996-1999	0	5	0	5	5
SD75I	Tier 0	16V-710G3C	4300	1990-1999	32	0	0	0	32
SD90-MAC	Tier 0	710	4300	1990-1999	0	2	0	2	2

2019 LOCOMOTIVE FLEET - FREIGHT TRAIN LINE HAUL OPERATIONS - PART 2

Model	US EPA Tier Level	Engine	hp	Year of Manufacture	Class 1	Regional	Shortlines	Total Regional & Shortlines	Total Freight Fleet
GP38-2	Tier 0+	645	2000	1974-1986	0	8	0	8	8
GP40	Tier 0+	12-645E3	2300	1960-1969	1	0	0	0	1
GP40-2	Tier 0+	645	3000	1972-1979	0	3	0	3	3
GP40-2	Tier 0+	16V-645E3B	3000	1973-1979	15	0	0	0	15
SD30ECO	Tier 0+	12-710	3000	1980-1989	2	0	0	0	2
SD30ECO	Tier 0+	12-710	3000	1980-1989	11	0	0	0	11
SD30ECO	Tier 0+	12-710	3000	1973-1979	15	0	0	0	15
SD30ECO	Tier 0+	12-710	3000	1970-1972	1	0	0	0	1
SD30ECO	Tier 0+	12-710	3000	1980-1989	10	0	0	0	10
SD30ECO	Tier 0+	12-710	3000	1970-1972	1	0	0	0	1
SD30ECO	Tier 0+	12-710	3000	1973-1979	10	0	0	0	10
SD40-2	Tier 0+	16V-645E3B	3000	1973-1979	20	0	0	0	20
SD40-2	Tier 0+	16V-645E3B	3000	1980-1989	10	0	0	0	10
SD40-2	Tier 0+	645	3000	1978-1979	0	4	0	4	4
SD40-3	Tier 0+	16V-645E3B	3000	1960-1969	14	0	0	0	14
SD40-3	Tier 0+	16-645E3	3000	1980-1989	6	0	0	0	6
SD40-3	Tier 0+	16V-645E3B	3000	1970-1972	3	0	0	0	3
SD60	Tier 0+	16V-710G3	3800	1980-1989	46	0	0	0	46
SD60	Tier 0+	16-710G3	3800	1980-1989	31	0	0	0	31
SD60-3	Tier 0+	16-710G3	3800	1980-1989	2	0	0	0	2
SD70I	Tier 0+	16V-710G3B	4000	1990-1999	19	0	0	0	19
SD75I	Tier 0+	16V-710G3C	4300	1990-1999	128	0	0	0	128
SD90MAC	Tier 0+	16-710G3	4300	1990-1999	2	0	0	0	2
SD70ACU	Tier 1+	16-710G3C	4300	1990-1999	30	0	0	0	30
SD70-ACE	Tier 2	710	4400	2010-2018	0	5	0	5	5
SD70M-2	Tier 2	16V-710G3C	4300	2000-2009	21	0	0	0	21
SD70M-2	Tier 2	16V-710G3C	4300	2010-2019	31	0	0	0	31
SD70M-2	Tier 2+	16V-710G3C	4300	2010-2019	39	0	0	0	39
SD70M-2	Tier 2+	16V-710G3C	4300	2000-2009	71	0	0	0	71
SD70ACE	Tier 3	16V-710G3C	4300	2010-2019	4	0	0	0	4
GM/EMD SUB-TOTAL					**866**	**82**	**127**	**209**	**1,075**
GE									
B23-7		7FDL12	2000	1979	0	0	3	3	3
Dash 8-40CM		7FDL16	4000	1990-1992	0	0	3	3	3
AC4400CW	Tier 0	7FDL16	4400	1990-1999	7	0	0	0	7
C44-9W	Tier 0	7FDL-16	4400	2000-2009	1	0	0	0	1
Dash 9-44CW	Tier 0	7FDL16	4400	1990-1999	0	11	0	11	11
C40-8	Tier 0+	7FDL-16	4000	1990-1999	39	0	0	0	39
C40-8	Tier 0+	7FDL-16	4000	1980-1989	23	0	0	0	23
C40-8M	Tier 0+	7FDL-16	4000	1990-1999	68	0	0	0	68
C40-8W	Tier 0+	7FDL-16	4000	1990-1999	58	0	0	0	58
AC4400CW	Tier 1	7FDL16	4400	2000-2009	0	21	0	21	21
AC4400CW	Tier 1+	7FDL16	4400	1990-1999	62	0	0	0	62
AC4400CW	Tier 1+	7FDL16	4400	1990-1999	53	0	0	0	53
AC4400CW	Tier 1+	7FDL16	4400	2000-2009	73	0	0	0	73
AC4400CW	Tier 1+	7FDL16	4400	2000-2009	132	0	0	0	132
AC4400CWM	Tier 1+	7FDL16	4400	1990-1999	10	0	0	0	10
AC4400CWM	Tier 1+	7FDL16	4400	1990-1999	131	0	0	0	131
C40-8M	Tier 1+	7FDL-16	4000	1990-1999	4	0	0	0	4
C44-9W	Tier 1+	7FDL-16	4400	2000-2009	99	0	0	0	99
C44-9W	Tier 1+	7FDL-16	4400	1990-1999	97	0	0	0	97
AC4400CW	Tier 2	7FDL16	4400	2005-2007	0	12	0	12	12
ES44AC	Tier 2	GEVO12	4360	2010-2018	0	6	0	6	6
ES44AC	Tier 2	GEVO12	4500	2010-2019	3	0	0	0	3
ES44AC	Tier 2	GEVO12	4500	2000-2009	17	0	0	0	17
ES44DC	Tier 2	GEVO-12	4400	2010-2019	3	0	0	0	3
ES44DC	Tier 2	GEVO-12	4400	2000-2009	21	0	0	0	21
ES44AC	Tier 2+	GEVO12	4500	2000-2009	160	0	0	0	160
ES44AC	Tier 2+	GEVO12	4500	2010-2019	58	0	0	0	58
ES44AC	Tier 2+	GEVO12	4500	2000-2009	23	0	0	0	23
ES44DC	Tier 2+	GEVO-12	4400	2000-2009	65	0	0	0	65
ES44DC	Tier 2+	GEVO-12	4400	2010-2019	29	0	0	0	29
ES44AC	Tier 3	GEVO-12	4400	2010-2019	271	0	0	0	271
ES44AC	Tier 3	GEVO12	4500	2010-2019	30	0	0	0	30
ES44AC	Tier 4	GEVO-12	4400	2010-2019	33	0	0	0	33
ET44AC	Tier 4	GEVO-12	4400	2010-2019	227	0	0	0	227
GE SUB-TOTAL					**1,797**	**50**	**6**	**56**	**1,853**
MLW									
M420 (W)		251	2000	1971-1975	0	0	1	1	1
RS-18		251	1800	1954-1958	0	0	6	6	6
MLW SUB-TOTAL					**0**	**0**	**7**	**7**	**7**
TOTAL LINE HAUL FREIGHT					**2,663**	**132**	**140**	**272**	**2,935**

APPENDIX B-2

2019 LOCOMOTIVE FLEET - FREIGHT YARD SWITCHING & WORK TRAIN OPERATIONS - PART 1

Model	US EPA Tier Level	Engine	HP	Year of Manufacture	Class 1	Regional	Shortlines	Total Regional & Shortlines	Total Freight Fleet
GM/EMD									
GMD1		12V-645C	1200	1960-1969	2	0	0	0	2
GMD1		12V-645C	1200	1950-1959	9	0	0	0	9
GP15		645	1500	1979	0	0	3	3	3
GP38		645	2000	1970-1979	0	3	0	3	3
GP38-2		16-645E	2000	1980-1989	1	0	0	0	1
GP38-2		16-645E	2000	1970-1972	4	0	0	0	4
GP38-2		16V-645E	2000	1970-1972	17	0	0	0	17
GP38-2		16V-645E	2000	1973-1979	49	0	0	0	49
GP38-2		16-645E	2000	1980-1989	72	0	0	0	72
GP38-3		16-645E	2000	1970-1972	1	0	0	0	1
GP38-3		16-645E	2000	1980-1989	4	0	0	0	4
GP38AC		16-645E	2000	1970-1972	3	0	0	0	3
GP38AC		16-645E	2000	1970-1972	6	0	0	0	6
GP40		16-645E	2000	1960-1969	2	0	0	0	2
GP40-3		16-645E3	3000	1960-1969	1	0	0	0	1
GP9		645	1750	1960-1973	0	0	2	2	2
GP9		567	1750	1960-1973	0	2	1	3	3
GP9		645	1800	1954-1960	0	1	0	1	1
GP9		567	1700	1960-1969	0	0	1	1	1
GP9		567	1750	1958	0	0	1	1	1
GP9		567	1750	1951-1959	0	0	9	9	9
GP9		645	1750	1950-1959	0	0	3	3	3
GP9-RM		16V-645C	1800	1950-1959	82	0	0	0	82
MP15		645	1500	1970-1972	0	0	1	1	1
MP15		645	1500	1973-1979	0	0	3	3	3
MP15-AC		645	1500	1972-1976	0	0	2	2	2
MP15-AC		645	1500	1974-1983	0	0	1	1	1
MP1500		567	1500	1975	0	0	3	3	3
SD35		645	3000	1964	0	0	1	1	1
SD38-2		16V-645E	2000	1973-1979	1	0	0	0	1
SD50-3		645E3B	3000	1970-1979	0	4	0	4	4

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2019 LOCOMOTIVE FLEET - FREIGHT YARD SWITCHING & WORK TRAIN OPERATIONS - PART 2

Model	US EPA Tier Level	Engine	HP	Year of Manufacture	Class 1	Regional	Shortlines	Total Regional & Shortlines	Total Freight Fleet
GM/EMD									
SW1000		645	1000	1967-1969	0	0	2	2	2
SW1200		567	1200	1960-1062	0	0	2	2	2
SW1200		567	1200	1960-1969	0	1	0	1	1
SW14		567	1400	1950-1959	0	0	1	1	1
SW1500		567	1500	1973	0	0	1	1	1
SW1500		567	1500	1970-1974	0	0	4	4	4
SW900		8-567C	900	1950-1959	1	0	0	0	1
SW900		567	900	1960-1969	0	0	1	1	1
SW900		567	900	1950-1959	0	0	9	9	9
GP38-2	Tier 0	16V-645E	2000	1973-1979	2	0	0	0	2
GP38-2	Tier 0	16-645E	2000	1980-1989	1	0	0	0	1
GP38-2	Tier 0	16-645E	2000	1980-1989	1	0	0	0	1
GP38-2	Tier 0	16-645E	2000	1980-1989	8	0	0	0	8
GP38-2	Tier 0	16-645E	2000	1973-1979	5	0	0	0	5
GP38-2	Tier 0	16-645E	2000	1973-1979	26	0	0	0	26
GP39-2	Tier 0	16-645E	2000	1980-1989	2	0	0	0	2
GP40-2	Tier 0	16-645E	2000	1960-1969	1	0	0	0	1
GMD1	Tier 0+	12V-645C	1200	1950-1959	2	0	0	0	2
GP20ECO	Tier 0+	8-710	2150	1950-1959	22	0	0	0	22
GP20ECO	Tier 0+	8-710	2150	1950-1959	6	0	0	0	6
GP20ECO	Tier 0+	8-710	2150	1950-1959	30	0	0	0	30
GP20ECO	Tier 0+	8-710	2150	2010-2019	60	0	0	0	60
GP20ECO	Tier 0+	8-710	2150	1950-1959	11	0	0	0	11
GP20ECO	Tier 0+	GP20C	2000	1950-1959	1	0	0	0	1
GP38-2	Tier 0+	16-645E	2000	1980-1989	35	0	0	0	35
GP38-2	Tier 0+	16-645E	2000	1970-1972	5	0	0	0	5
GP38-2	Tier 0+	16-645E	2000	1973-1979	18	0	0	0	18
GP38-2	Tier 0+	16V-645E	2000	1973-1979	26	0	0	0	26
GP38-2	Tier 0+	16-645E	2000	1970-1972	1	0	0	0	1
GP38-2	Tier 0+	16V-645E	2000	1970-1972	1	0	0	0	1
GP38-2	Tier 0+	16-645E	2000	1980-1989	7	0	0	0	7
GP38-3	Tier 0+	16-645E	2000	1970-1972	1	0	0	0	1
GP38-3	Tier 0+	16-645E	2000	1970-1972	1	0	0	0	1
GP38-3	Tier 0+	16-645E	2000	1980-1989	1	0	0	0	1
GP38AC	Tier 0+	16-645E	2000	1970-1972	1	0	0	0	1
GP38AC	Tier 0+	16-645E	2000	1970-1972	5	0	0	0	5
GP40-3	Tier 0+	16-645E3	3000	1960-1969	1	0	0	0	1
GP9-RM	Tier 0+	16V-645C	1800	1950-1959	1	0	0	0	1
SD38-2	Tier 0+	16V-645E	2000	1973-1979	2	0	0	0	2
GM/EMD SUB-TOTAL					**539**	**11**	**51**	**62**	**601**

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2019 LOCOMOTIVE FLEET - FREIGHT YARD SWITCHING & WORK TRAIN OPERATIONS - PART 3

Model	US EPA Tier Level	Engine	HP	Year of Manufacture	Class 1	Regional	Shortlines	Total Regional & Shortlines	Total Freight Fleet
MLW									
RS-18		251	1800	1954-1958	0	0	3	3	3
RS-23		251	1000	1959-1960	0	0	3	3	3
S-13		251	900	1959-1960	0	0	2	2	2
MLW SUB-TOTAL					**0**	**0**	**8**	**8**	**8**
ALCO									
S-13		251	1000	1959-1960	0	0	1	1	1
S-6		251	900	1953	0	0	1	1	1
ALCO SUB-TOTAL					**0**	**0**	**2**	**2**	**2**
Other									
Slug	Elec/Steam/ Other		0	1956-1957	0	0	2	2	2
Slug	Elec/Steam/ Other		0	1986	0	0	1	1	1
Slug	Elec/Steam/ Other		0	2005	0	0	1	1	1
Slug	Elec/Steam/ Other		0		0	0	4	4	4
OTHER SUB-TOTAL					**0**	**0**	**8**	**8**	**8**
YARD SWITCHING & WORK TRAIN TOTAL					**539**	**11**	**69**	**80**	**619**

Locomotive's year of manufacture may not be 100% accurate as locomotives may be ordered in batches that are manufactured across more than one year.

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APPENDIX B-3

2019 LOCOMOTIVE AND DMU FLEET - PASSENGER TRAIN OPERATIONS - PART 1

Model	US EPA Tier Level	Engine	HP	Year of Manufacture	Intercity Rail	Commuter	Tourist & Excursion	Total
GM/EMD								
F40-PH		645	3000	1977-1978	2	0	0	2
F59-PH		710	3000	1988-1994	0	8	0	8
F59-PHI		710	3000	1990-1999	0	5	0	5
FP40-PH2		645	3000	1987-1989	52	0	0	52
GMD-1		567	1200	1958	0	0	1	1
GP40		645	3000	1970-1979	0	0	9	9
GP9		567	1750	1951-1963	0	0	1	1
GP9		645	1800	1957	0	0	2	2
MP36PH-3C		645	3600	2000-2009	0	1	0	1
SD40		645	3000	1971	0	0	1	1
F59-PH	Tier 2	710	3000	1980-1989	0	10	0	10
F59-PHI	Tier 2	710	3000	1980-1989	0	11	0	11
GM/EMD SUB-TOTAL					**54**	**35**	**14**	**103**
GE								
LL162/162		251	990	1954-1966	0	0	11	11
P42DC		7FDL16	4250	2001	21	0	0	21
70-ton	Elec/Steam/Other	FWL-6T	600	1948	0	0	1	1
GE SUB-TOTAL					**21**	**0**	**12**	**33**
Motive Power								
MP40PH-3C	Tier 2	710	4000	2007-2013	0	56	0	56
MP40PH-3C	Tier 3	710	4000	2007-2013	0	10	0	10
MP40PHT-T4-AC	Tier 4	Cummins QSK-60	4000	2017-2018	0	16	0	16
MP40PHTC-T4-DC	Tier 4	Cummins QSK-60	4000	2010-2014	0	1	0	1
MOTIVE POWER SUB-TOTAL					**0**	**83**	**0**	**83**
Bombardier								
ALP45-DP	Tier 3	3512C HD	4200	2010-2012	0	19	0	19
BOMBARDIER SUB-TOTAL					**0**	**19**	**0**	**19**
Alstom								
Coradia LINT 41	Elec/Steam/Other	DMU	780	2013	0	6	0	6
ALSTOM SUB-TOTAL					**0**	**6**	**0**	**6**

2019 LOCOMOTIVE AND DMU FLEET - PASSENGER TRAIN OPERATIONS - PART 2

Model	US EPA Tier Level	Engine	HP	Year of Manufacture	Intercity Rail	Commuter	Tourist & Excursion	Total
CLC								
44-ton	Elec/Steam/Other	H44A3	400	1960	0	0	1	1
MLW								
DL535		251	1200	1960-1969	0	0	8	8
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
Dubbs								
Dubbs 440	Elec/Steam/Other	0	0	1882	0	0	1	1
Budd								
RDC-1		Cummins	600	1950-1959	1	0	0	1
RDC-2		Cummins	600	1950-1959	3	0	0	3
RDC-4		Cummins	600	1950-1959	2	0	0	2
CLC/MLW/CUMMINS/DUBBS/BUDD SUB-TOTAL					**6**	**18**	**10**	**34**
Baldwin								
Baldwin 280	Elec/Steam/Other		0	1920	0	0	1	1
BALDWIN STEAM ENGINES SUB-TOTAL					**0**	**0**	**1**	**1**
Other Steam Engines								
MLW 4-6-0 steam	Elec/Steam/ Other		0	1912	0	0	1	1
Rogers 4-4-0 steam	Elec/Steam/ Other		0	1883	0	0	1	1
OTHER STEAM ENGINES SUB-TOTAL					**0**	**0**	**2**	**2**

Yard Switching Passenger Operations								
ALCO								
DQS18		251	1800	1950-1959	0	0	2	2
GE								
35-Ton	Elec/Steam/Other		236		0	0	1	1
GM/EMD								
SW1000		8-695E	1000	1960-1969	2	0	0	2
YARD SWITCHING PASSENGER OPERATIONS SUB-TOTAL					**2**	**0**	**3**	**5**
PASSENGER OPERATIONS TOTAL					**83**	**161**	**42**	**286**

Locomotive's year of manufacture may not be 100% accurate as locomotives may be ordered in batches that are manufactured across more than one year.

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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

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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:	MONTRÉAL
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

TOMA REGION NO. 3: SAINT JOHN AREA, NEW BRUNSWICK

CN	
District:	Champlain
Subdivisions:	Denison, Sussex
Other	
New Brunswick Southern	All

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.

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.govinfo.gov/content/pkg/CFR-2002-title40-vol17/xml/CFR-2002-title40-vol17-sec92-8.xml.

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.

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

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.

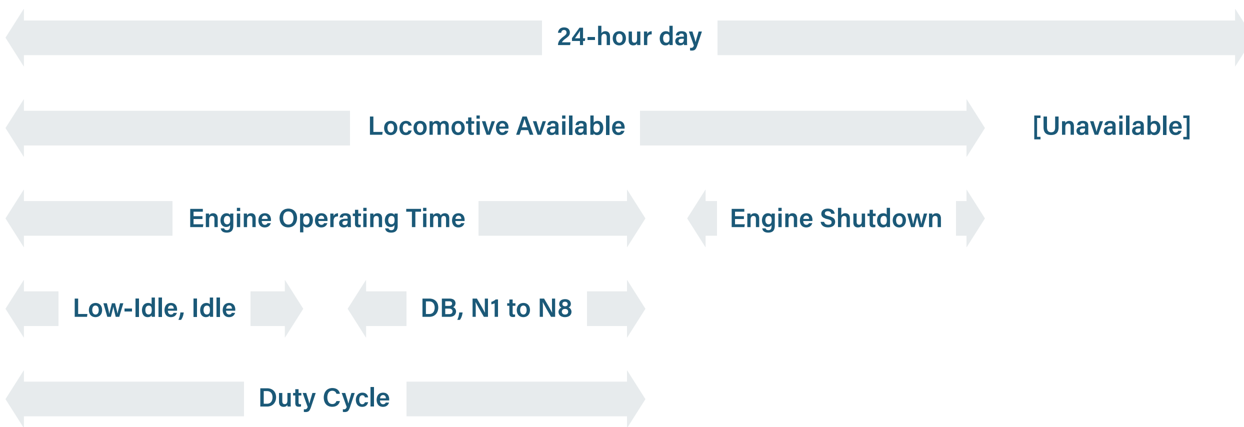
Locomotive Power Ranges: Locomotives are categorized as high horsepower (having engines greater than 3,000 hp), medium horsepower (2,000 to 3,000 hp) or low horsepower (less than 2,000 hp).

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*).

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.

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.

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

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

METHODOLOGICAL CHANGE - FREIGHT LOCOMOTIVE CATEGORY ASSIGNMENT

To calculate CAC emissions, locomotives must be assigned into a category of service. In 2018 and earlier LEM Reports, each freight locomotive was assigned into one of three categories: line haul, road switching, or yard switching. CAC emissions from line haul and road switching locomotives were assigned to the “Freight: Line Haul” category in the table below, and CAC emissions from yard switching locomotives were assigned to the “Yard Switching” category in the table below.

Under the LER reporting requirements, there are only two categories or types of locomotives that are defined: line haul or switch, which are determined based on the locomotive’s total rated horsepower. Beginning in 2019, each locomotive is assigned into one of two categories: line haul or switch. The CAC emissions from the line haul locomotives are assigned to “Freight: Line Haul” in the table below, and the CAC emissions from the switch locomotives are assigned to “Yard Switching” in the table below.

The methodological change was tested on the 2018 data, and it appears to have only a very negligible impact on calculated CACs (as seen in the table below).

The change in methodology has no impact on GHG emissions, which are based on fuel usage and GHG emissions factors.

This new methodology, of having locomotives assigned into only two categories (line haul and switch) as opposed to three, will be applied in future LEM reports.

2018 CAC EMISSIONS BY RAILWAY OPERATION IN CANADA (KILOTONNES)

	ORIGINAL 2018 LEM REPORT					NEW METHODOLOGY APPLIED TO 2018				
Operation	**PM_{10}**	**HC**	**NO_x**	**CO**	**SO_2**	**PM_{10}**	**HC**	**NO_x**	**CO**	**SO_2**
Freight: Line Haul	1.61	3.18	71.25	14.48	0.05	1.62	3.16	71.54	14.40	0.05
Yard Switching	0.07	0.20	3.32	0.43	0.00	0.06	0.18	3.15	0.43	0.00
Passenger	0.13	0.25	6.56	0.85	0.00	0.13	0.25	6.56	0.85	0.00
TOTAL RAILWAY OPERATIONS	**1.81**	**3.63**	**81.14**	**15.76**	**0.06**	**1.81**	**3.59**	**81.24**	**15.68**	**0.06**

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