Railway Association of Canada

RIGHT TRACK

LOCOMOTIVE EMISSIONS MONITORING REPORT | 2017

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Acknowledgements

In preparing this document, the Railway Association of Canada wishes to acknowledge appreciation for the services, information, and perspectives provided by members of the following organizations:

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ISBN: 978-1-927520-10-9
Originally published December 2019. Edited January 2020.

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Review Notice

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

This report has been prepared with funding support from the Railway Association of Canada and Transport Canada. Results may not add up due to rounding.

Executive Summary

Introduction

The Locomotive Emissions Monitoring Program (LEM) data filing for 2017 was completed in December 2019, in accordance with the terms of the Memorandum of Understanding (MOU) between the Railway Association of Canada (RAC) and Transport Canada (TC) concerning greenhouse gases (GHGs) and criteria air contaminants (CACs) emissions from locomotives operating in Canada. This is the final report under that MOU, which covered all operations from 2011–2017. A new MOU has been signed for 2018–2022.

The MOU establishes a framework for railways to report on voluntary emission reduction targets for their operations. As stated in the MOU, the RAC encouraged its members to reduce GHG emission intensity from railway operations for the duration of the MOU. The GHG emission intensity targets for 2017 were as follows:

Railway Operation	2017 Target	Productivity Unit
Class 1 Freight	14.93	kg CO_{2e} per 1,000 revenue tonne kilometres
Intercity Passenger	0.112	kg CO_{2e} per passenger kilometre
Regional & Short Lines	14.45	kg CO_{2e} per 1,000 revenue tonne kilometres

Regarding CAC emissions, as stated in the MOU, until the implementation of the *Locomotive Emissions Regulations*, the RAC encouraged its members to conform to the United States Environmental Protection Agency (US EPA) emission standards and to adopt operating practices aimed at reducing CAC emissions. The RAC continues to encourage its members to reduce CAC emissions and conform with the *Locomotive Emissions Regulations*, which came into force on June 9, 2017. This is the seventh and final report prepared under this MOU.

2011 – 2017 MOU Results

This report highlights that Canadian railways met their 2017 GHG emission intensity reduction targets for Class 1 freight and intercity passenger rail. However, the GHG emission intensity for regional and shortlines was more than 25% higher than the 2017 target. The following table presents the 2010 baseline emission intensity figures, the 2017 performance figures, and the 2017 emissions intensity targets, as expressed in kilograms (kg) of carbon dioxide equivalent (CO_{2e}) per productivity unit:

Railway Operation	Productivity Unit	2010	2017	2017 Target	Change from 2010–2017	Difference from Target	Target Achieved?
Class 1 Freight	kg CO_{2e} per 1,000 revenue tonne kilometres	16.30	13.53	14.93	16.99% decrease	9.4% lower	✓
Intercity Passenger	kg CO_{2e} per passenger kilometre	0.123	0.098	0.112	20.33% decrease	13.27% lower	✓
Regional & Shortlines	kg CO_{2e} per 1,000 revenue tonne kilometres	15.09	18.19	14.45	20.54% increase	25.8% higher	✗

Achieving GHG Intensity Reductions

The rail sector continues to reduce its GHG and CAC emissions intensity. **Figures 1** and **2** below highlight that overall freight and intercity passenger performance is improving.

Figure 1 Freight Emissions Intensity (2011–2017)

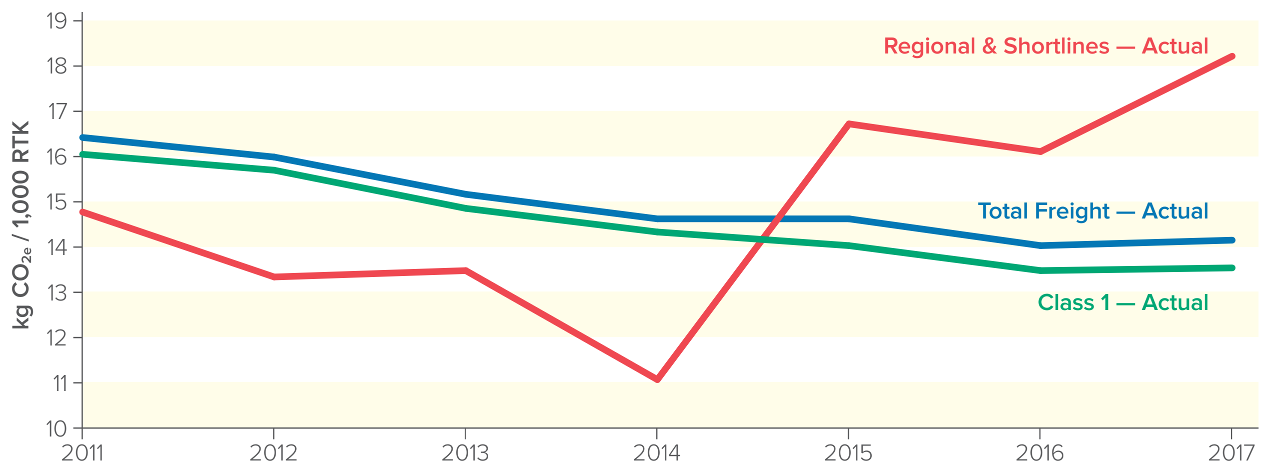
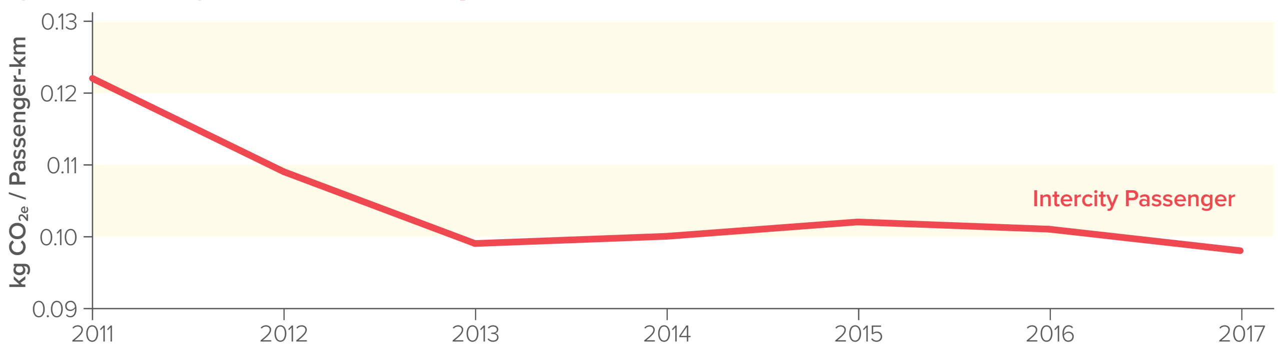


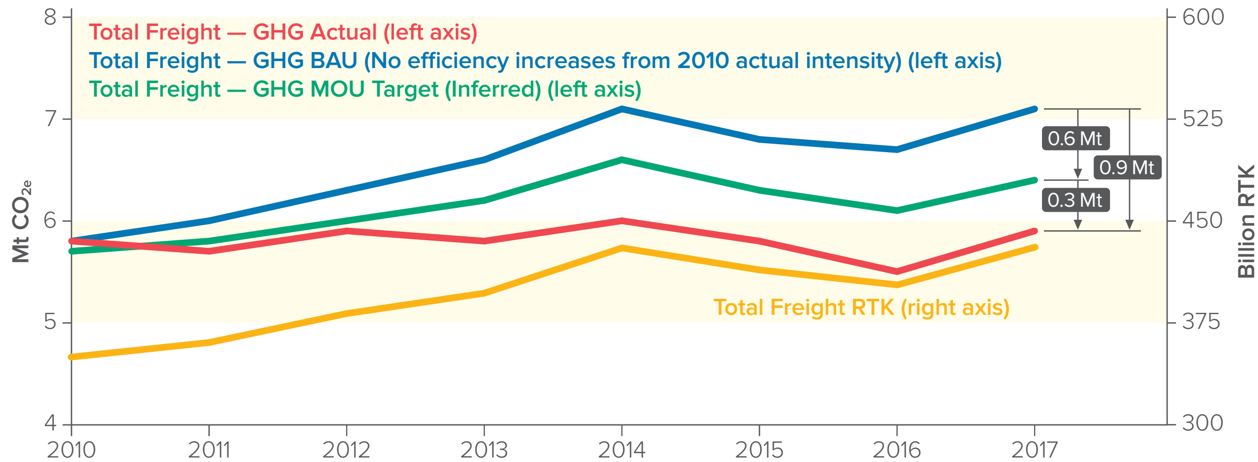
Figure 2 Passenger Emissions Intensity (2011–2017)



As Canada's economy and population grows, so does the movement of goods and people. Over the MOU period, freight traffic increased from 359.69 to 429.51 billion revenue tonne-kilometres (RTK), while intercity passengers increased from 4.46 to 4.65 million and commuter passengers from 68.43 to 79.35 million.

Industry and Government investments and efforts to support fuel efficiency improvements limited GHG emissions growth to only 0.2 Mt CO_{2e} during the MOU period, representing a 0.9 Mt CO_{2e} reduction against business as usual GHG reductions using 2010 GHG intensities and a 0.3 Mt CO_{2e} reduction compared to the target MOU GHG intensities while RTKs increase by 23% during the same period (**Figure 3**).

Figure 3 Freight Emissions and Revenue-Tonne Kilometres (2010–2017)



A number of industry and government GHG reduction initiatives also supported improvements in 2017:

- **CN — Fuel Efficiency Technologies and HPTA (Horse Power Tonnage Analyzer)**
  CN maintains a longstanding commitment to reducing its emissions by investing in innovative fuel efficiency technologies and programs such as the Horse Power Tonnage Analyzer (HPTA) and Energy Management Systems. In 2017, CN continued investing in HPTA (a system which works to optimize a locomotive's horsepower to tonnage ratio) and through its fleet renewal strategy acquired 34 new high horsepower locomotives equipped with Energy Management Systems.
- **CP — Locomotive Fleet Renewal and Energy Efficiencies**
  As part of its annual capital expenditure program for 2017, CP Invested $60 million to modernize 30 locomotives as part of a multi-year fleet renewal partnership with General Electric. Upgrades included advanced diesel engines, enhanced cooling systems, improved traction, and technological enhancements to fuel trip optimizer and distributed power systems. Beyond operational efficiency, each renewed locomotive is expected to reduce fuel consumption by greater than 2.7 percent. Work is underway to complete similar upgrades to an additional 140 locomotives by the end of 2019.
- **VIA — Enhanced Training Program**
  In 2017, VIA enhanced its locomotive engineer simulator training program. By adding a new feature to the simulator, VIA is now training its locomotive engineers on how to better operate locomotives for lower fuel consumption.

- **Transport Canada — Innovation Centre**
  The Innovation Centre runs the Clean Rail RD&D program which spurs the development of technologies that reduce emissions from the rail sector. This program emphasizes technologies that are on the pathway to commercialization; industry leadership plays a key role informing the technologies that are selected and advanced. The main themes for 2017 projects were:
  - electrical energy storage for commuter train operations,
  - development of stronger, lighter construction materials for railcars, and
  - distillation of renewable diesel fuel from lignin, which is biological waste from forestry and agriculture industries.

  The ideas and innovation at universities are an important part of technology development. Transport Canada supplied $250,000 as grant funding to universities across Canada that are working on clean rail technologies. The projects that received grants were about improving anti-idling devices, enhancing hydrogen fuel cell durability and energy output, optimizing train marshalling for fuel efficiency, developing better railcar construction materials and understanding train aerodynamics.

CAC Emission Reductions

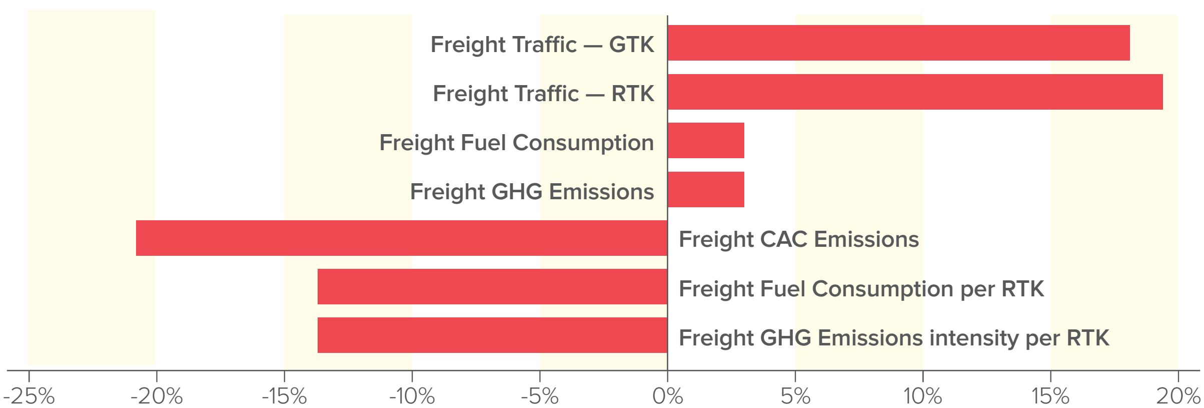
There are no targets for CAC emissions or emissions intensity, but progress is being made toward reducing overall railway CAC emissions intensity. The total freight nitrogen oxides (NO_X) emissions intensity (i.e., the quantity of NO_X emitted per unit of productivity) was 0.17 kg per 1,000 revenue tonne kilometres (RTK) in 2017. This was 5.5% lower than the 2016 figure (0.18 kg per 1,000 RTK) and is a 34.6% decrease from 2011 (0.26 kg per 1,000 RTK) and a 67.3% reduction from 1990 (0.52 kg per 1,000 RTK).

Additional Key Results and Summary

For the period of the MOU (2011 to 2017), the following additional key performance metrics were achieved.

Performance Metric	2011	2017	Increase (Decrease)
Total Railway GHG Emissions	6,226.21 kilotonnes (kt) CO_{2e}	6,428.84 kt CO_{2e}	**3.2%**
Total Railway CAC Emissions	101.06 kt NO_x 2.43 kt PM	79.55 kt NO_x 1.65 kt PM	**(21.3%)** **(31.9%)**
Total Freight Traffic	689.69 billion gross tonne kilometres (GTK) 359.69 billion RTK	814.56 billion GTK 429.50 billion RTK	**18.1% GTK** **19.4% RTK**
Total Intermodal Traffic	32.24 million tonnes	41.21 million tonnes	**27.8%**
Total Passenger Traffic	4.46 million intercity passengers 68.43 million commuter passengers	4.64 million intercity passengers 79.35 million commuter passengers	**4.1% intercity** **16.0% commuter**
Total Fuel Consumption	2,087.41 million litres (L)	2,155.34 million L	**3.2%**
Total Freight Fuel Consumption	1,977.09 million L	2,036.64 million L	**3.0%**
Freight Fuel Consumption per RTK	5.50 L/1,000 RTK	4.74 L/1,000 RTK	**(13.8%)**
Locomotive Inventory	2,978 locomotives	3,177 locomotives	**6.7%**

Figure 4 Percent Change of Key Total Freight Performance Metrics (2011–2017)



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1 Introduction/Background

This report contains the LEM data filing for 2017 in accordance with the terms of the memorandum of understanding (MOU) signed on April 30, 2013, between the RAC and TC concerning voluntary arrangements to limit greenhouse gas (GHG) emissions and criteria air contaminant (CAC) emissions from locomotives operating in Canada. Originally signed as an MOU to address performance from 2011 to 2015, the MOU was extended to the end of 2017.

This MOU establishes a framework through which the RAC, its member companies (as listed in **Appendix A**), and TC address GHG and CAC emissions produced by locomotives in Canada. The MOU includes measures, targets, and actions that will further reduce GHG and CAC emission intensities from rail operations to help protect the health and environment for Canadians and address climate change and can be found on the RAC Website. This is the seventh and last report prepared under this MOU.

GHG Commitments:

As stated in the MOU, the RAC encourages its members to reduce the GHG emission intensity from their operations. The GHG emission targets for 2017 and the actual emissions from 2010 to 2017, expressed as kilograms (kg) of carbon dioxide equivalent (CO_{2e}) per productivity unit, for the rail industry are outlined in the following table:

Railway Operation	2010	2011	2012	2013	2014	2015	2016	2017	2017 Target	Change from 2010–2017	Productivity Unit
Class 1 Freight	16.30	16.03	15.68	14.84	14.32	14.02	13.47	13.53	14.93	16.99% decrease	kg CO_{2e} per 1,000 revenue tonne kilometres
Intercity Passenger	0.123	0.122	0.109	0.099	0.100	0.102	0.101	0.098	0.112	20.33% decrease	kg CO_{2e} per passenger kilometre
Regional & Shortlines	15.09	14.76	13.33	13.47	11.07	16.70	16.09	18.19	14.45	20.54% increase	kg CO_{2e} per 1,000 revenue tonne kilometres

Note: All values above, including the revised 2017 targets, have been calculated based on the most recent versions of the emission factors and global warming potentials. Historical values have been updated from previous reports.

CAC Commitments:

As stated in the MOU, Transport Canada was simultaneously developing regulations to control CAC emissions under the *Railway Safety Act*. The *Locomotive Emissions Regulations* came into force on June 9, 2017 and applies to railway companies that the federal government regulates and only apply to locomotives placed into service on or after the day the regulations came into force. The regulations are aligned with the United States Environmental Protection Agency (US EPA) emission standards (Title 40 of the Code of Federal Regulations of the United States, Part 1033[1]).

1 Most CAC performance reflected in this report predates the Locomotive Emission Regulations (LER) for CACs. The Locomotive Emissions Regulations came into force on June 9, 2017. https://laws-lois.justice.gc.ca/PDF/SOR-2017-121.pdf

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 CAC emission reductions and conformance with appropriate CAC emission standards for those locomotives not covered by the new *Locomotive Emissions Regulations*. As the new regulations came into force, TC undertook compliance promotion activities with affected stakeholders, including education and outreach related to the regulatory requirements.

Data for this report was collected via a survey sent to each RAC member by the RAC. 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 CO_{2e}, the constituents of which are CO_2, CH_4, and N_2O. CAC emissions include NO_X, PM, CO, HC, and SO_X. The SO_X emitted is a function of the sulphur content of the diesel fuel and is expressed as SO_2. The survey and calculation methodology are available upon request to the RAC.

This report provides an overview of 2017 rail performance including traffic, fuel consumption, fleet inventory, and GHG and CAC emissions. Also included is a section on initiatives being taken or examined by the sector to reduce fuel consumption and, consequently, all emissions, particularly GHGs. In addition, this report contains 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 for winter and summer operations have been segregated. For the most part, data and statistics by year for traffic, fuel consumption, and emissions are listed for the period starting with 2006. For historical comparison purposes, the year 1990 has been set as the reference year and has also been included. 1990 was chosen as the reference year because it is the first year of available locomotive data and it was set as the reference year in the first MOU between the RAC and the Federal Government. LEM statistics from 1990 to 2010 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 (intercity passenger emissions intensity was shown to the fourth significant digit to demonstrate year to year differences), while percentages are expressed to one significant figure. To facilitate comparison with American railway operations, traffic, fuel consumption, and emissions data in US (imperial) units are available upon request to the RAC.

2 Traffic Data

2.1 Freight Traffic Handled

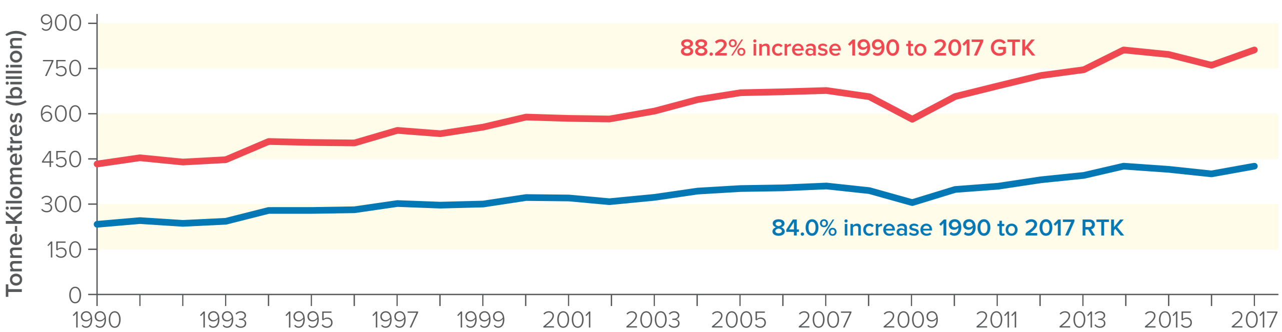
As shown in **Table 1** and **Figure 5**, traffic in 2017 handled by Canadian railways totalled 814.56 billion gross tonne-kilometres (GTK) compared with 762.86 billion GTK in 2016, an increase of 6.8%, and 432.74 billion GTK for 1990 (the reference year) for an increase of 88.2%. Revenue traffic in 2017 increased to 429.5 billion revenue tonne-kilometres (RTK) from 401.89 billion RTK in 2016 and is up from 233.45 billion RTK in 1990—an increase of 6.9% and 84%, respectively. Since 1990, the average annual growth was 3.3% for GTK and 3.1% for RTK.

Table 1. Total Freight Traffic, 1990, 2006–2017
Tonne-kilometres (billion)

	1990	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
GTK													
Class I		629.93	638.66	621.90	549.17	620.16	644.75	674.62	695.58	754.24	752.30	722.33	778.86
Regional + Short Line		41.07	37.77	34.92	30.82	32.47	44.94	47.74	47.59	58.02	41.83	40.54	35.70
Total	**432.74**	**671.00**	**676.43**	**656.82**	**579.99**	**652.63**	**689.69**	**722.35**	**743.17**	**812.25**	**794.13**	**762.86**	**814.56**
RTK													
Class I		330.96	338.32	324.99	288.82	327.81	337.90	356.91	371.77	399.47	394.10	383.47	411.22
Regional + Short Line		24.87	23.30	21.46	19.06	21.33	21.79	23.96	24.04	29.46	18.72	18.42	18.29
Total	**233.45**	**355.83**	**361.62**	**346.46**	**307.88**	**349.14**	**359.69**	**380.87**	**395.81**	**428.93**	**412.82**	**401.89**	**429.51**
Ratio of RTK/GTK	**0.54**	**0.53**	**0.53**	**0.53**	**0.53**	**0.53**	**0.52**	**0.53**	**0.53**	**0.53**	**0.52**	**0.53**	**0.53**

Note: No data is available separating Class 1 and shortline traffic for the reference year, 1990.

Figure 5. Total Freight Traffic, 1990–2017



In 2017, Class 1 GTK traffic increased by 7.3% to 778.86 billion from 722.33 billion in 2016 (**Table 1**) and accounted for 95.6% of the total GTK hauled. Class 1 RTK traffic increased by 6.7% in 2017 to 411.22 billion from 383.47 billion in 2016 and accounted for 95.7% of the total RTK. Of the total freight traffic in 2017, regional and shortlines were responsible for 35.7 billion GTK (or 4.4%) and 18.29 billion RTK (or 4.3%).

In 2017, regional and shortlines traffic experienced a 0.7% decrease in RTK compared to 2016 and a decrease of 11.9% of their GTK traffic. The main driver behind the decrease in regional and shortline activity is the washout of the Hudson Bay Railway (HBR) main line in 2017. Regional railways such as the HBR have an outsized impact on the performance of regional and shortline railways because they move, on average, larger quantities of goods over longer distances.

2.1.1 Freight Carloads by Commodity Grouping

The total 2017 freight carloads for 11 commodity groups are shown in **Figure 6** and **Table 2** below.

Figure 6. Canadian Rail Originated Carloads by Commodity Grouping, 2017

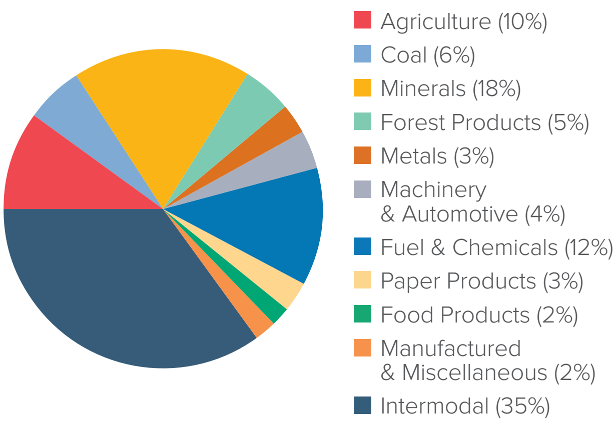


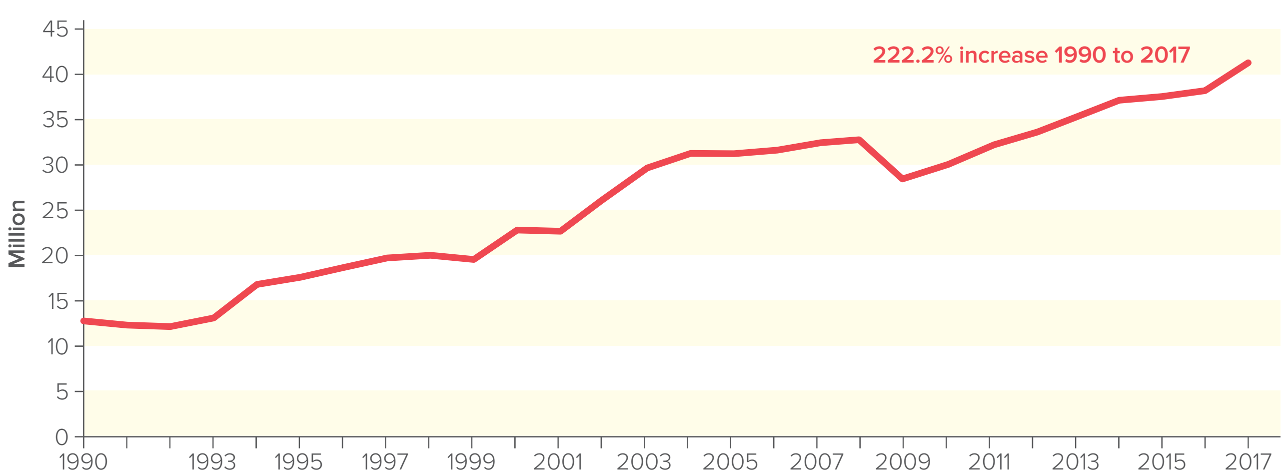
Table 2. Canadian Rail Originated Carloads by Commodity Grouping, 2017
Carloads

Agriculture	527,271
Coal	326,228
Minerals	937,737
Forest Products	251,273
Metals	165,404
Machinery & Automotive	189,632
Fuel & Chemicals	617,792
Paper Products	129,675
Food Products	79,041
Manufactured & Miscellaneous	118,651
Intermodal	1,828,225
Total	**5,170,929**

2.1.2 Class 1 Intermodal Traffic

Of the total freight carloads in 2017, intermodal led at 35.4%, as illustrated by **Figure 6** and **Table 2** above. The number of intermodal carloads handled by the Class 1 railways in Canada increased to 1,828,225 from 1,669,892 in 2016, an increase of 9.5%. Intermodal tonnage rose 8% to 41.21 million tonnes from 38.13 million tonnes in 2016. Overall since 1990, intermodal tonnage, comprising both container-on-flat-car and trailer-on-flat-car traffic, has risen 222.2%, equating to an average annual growth of 8.2%, as illustrated in **Figure 7**.

Figure 7. Class 1 Intermodal Tonnage, 1990–2017



Class 1 intermodal RTK totalled 122.13 billion in 2017 versus 113.74 billion for 2016, an increase of 7.4%. Of the 411.22 billion RTK transported by the Class 1 railways in 2017, intermodal accounted for 29.7%.

Intermodal service growth is an indication that the Canadian railways have been effective in partnering with shippers and other elements of the transportation supply chain, such as trucking, to move more goods by rail.

2.2 Passenger Traffic Handled

2.2.1 Intercity Passenger Services

Intercity passenger traffic in 2017 totalled 4.64 million passengers, as compared to 4.24 million passengers in 2016, an increase of 9.5% and a 16.1% increase from 4.00 million passengers in 1990 (**Figure 8**). The carriers were VIA Rail Canada, CN/Algoma Central, Amtrak, and Tshiuetin Rail Transportation.

The total revenue passenger-kilometres (RPK) for intercity passenger traffic totalled 1,560.73 million. This is an increase of 10.8% as compared to 1,409.01 million in 2016 and 15.5% increase from 1,350.71 million in 1990 (**Figure 9**).

Figure 8. Intercity Rail Passenger Traffic, 1990–2017

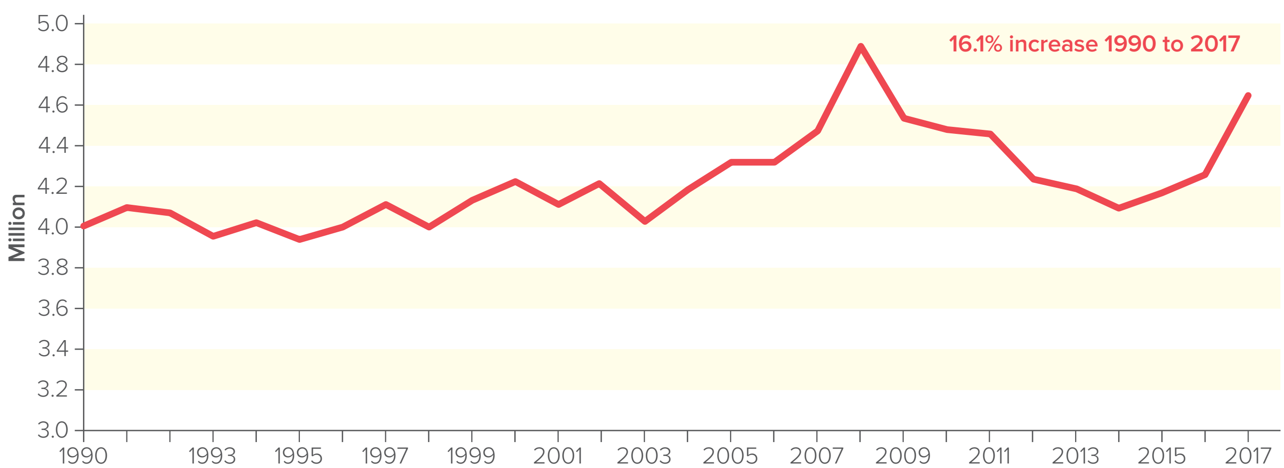
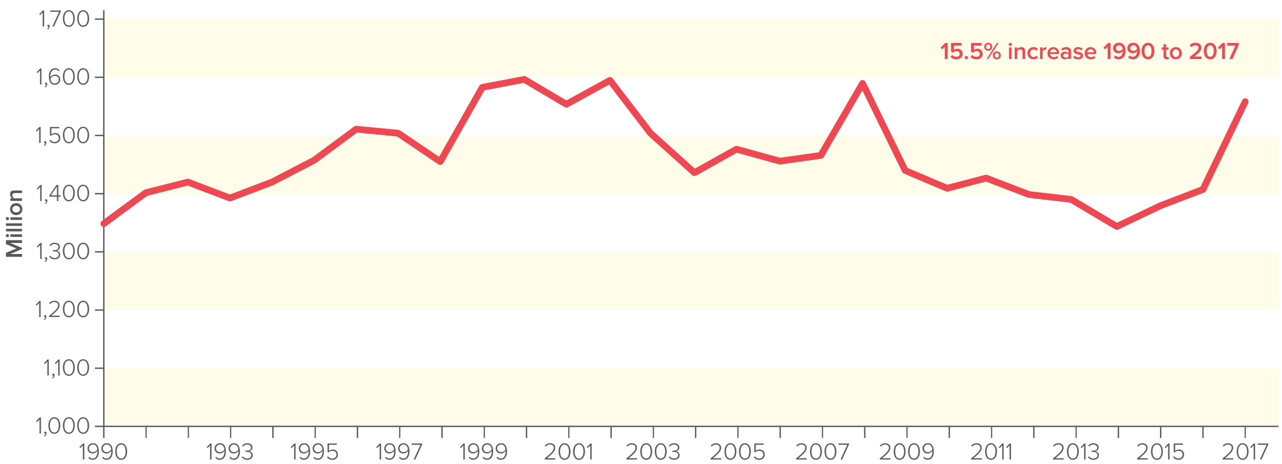
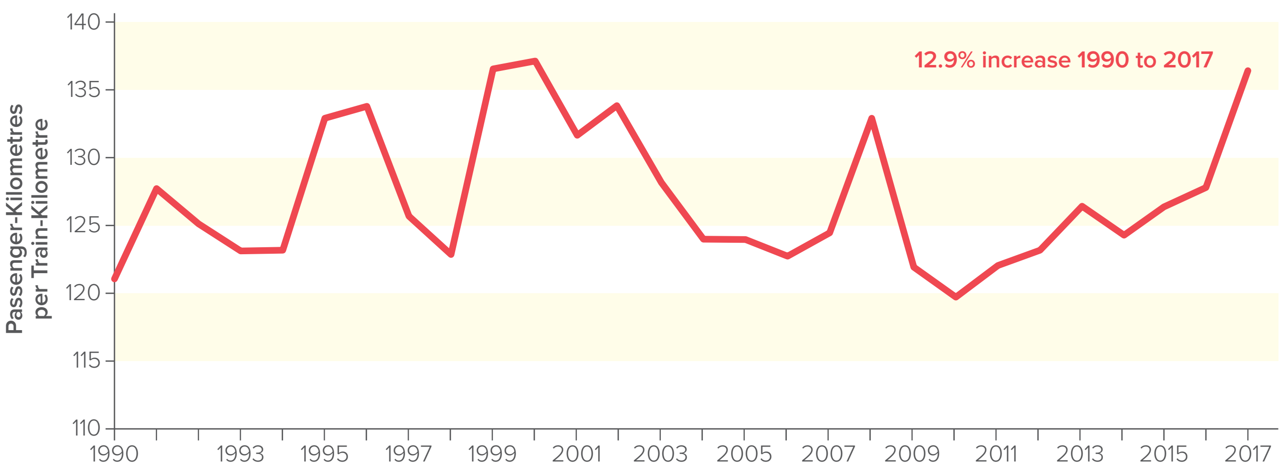


Figure 9. Intercity Rail Revenue Passenger-Kilometres, 1990–2017



Intercity train efficiency is expressed in terms of average passenger-kilometres (km) per train-km. As shown in **Figure 10**, intercity rail train efficiency in 2017 was 136.71 passenger-km per train-km, 127.81 in 2016, and 121.04 in 1990. As a percentage, train efficiency in 2017 was 12.9% above that in 1990.

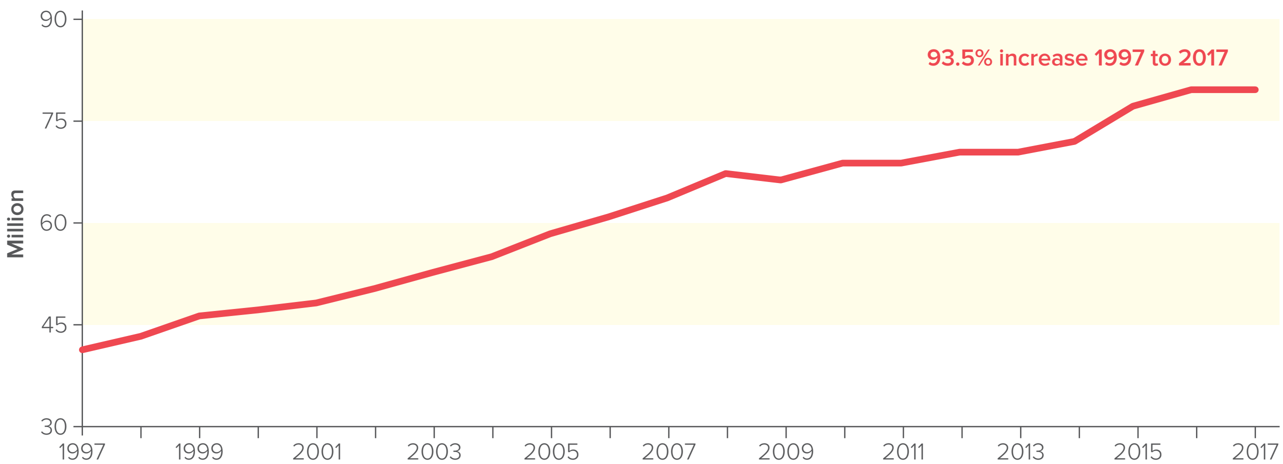
Figure 10. Intercity Rail Train Efficiency, 1990–2017



2.2.2 Commuter Rail

In 2017, commuter rail passengers totalled 79.35 million (**Figure 11**). This is down from 79.63 million in 2016, a decrease of 0.3%. As shown in **Figure 11**, by 2017, commuter traffic increased 93.5% over the 1997 base year of 41.00 million passengers when the RAC first started to collect commuter rail statistics. This is an average annual growth rate of 4.7% since 1997. The four commuter operations in Canada using diesel locomotives 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.

Figure 11. Commuter Rail Passengers, 1997–2017



2.2.3 Tourist and Excursion Services

In 2017, the six RAC member railways offering tourist and excursion services transported 309 thousand passengers compared to 318 thousand in 2016, a decrease of 2.8%, largely due to a decrease in ridership in Ontario. The railways reporting these services were Alberta Prairie Railway Excursions, Great Canadian Railtour Company, Ontario Northland Transportation Commission, Prairie Dog Central Railway, South Simcoe Railway, Train Touristique de Charlevoix and White Pass & Yukon[2].

2 White Pass and Yukon joined the RAC in 2014 — the passenger and fuel data from this railway was not included in previous LEM reports.

3 Fuel Consumption Data

As shown in **Table 3**, total rail sector fuel consumption increased to 2,155.34 million litres in 2017 from 1,999.60 million litres in 2016 and increased from 2,063.55 million litres in 1990. As a percentage, fuel consumption in 2017 was 7.8% higher than in 2016 and 4.4% higher than the 1990 level. The higher fuel consumption reflects an increase in total freight traffic in 2017. Of the total fuel consumed by all railway operations, freight train operations consumed 94.5% and passenger operations accounted for 5.5%. For total freight train operations fuel consumption, Class 1 railways accounted for 91.6%, regional and shortlines 5.5%, and yard switching and work trains 3.0%.

Table 3. Canadian Rail Operations Fuel Consumption, 1990, 2006–2017
Litres (million)

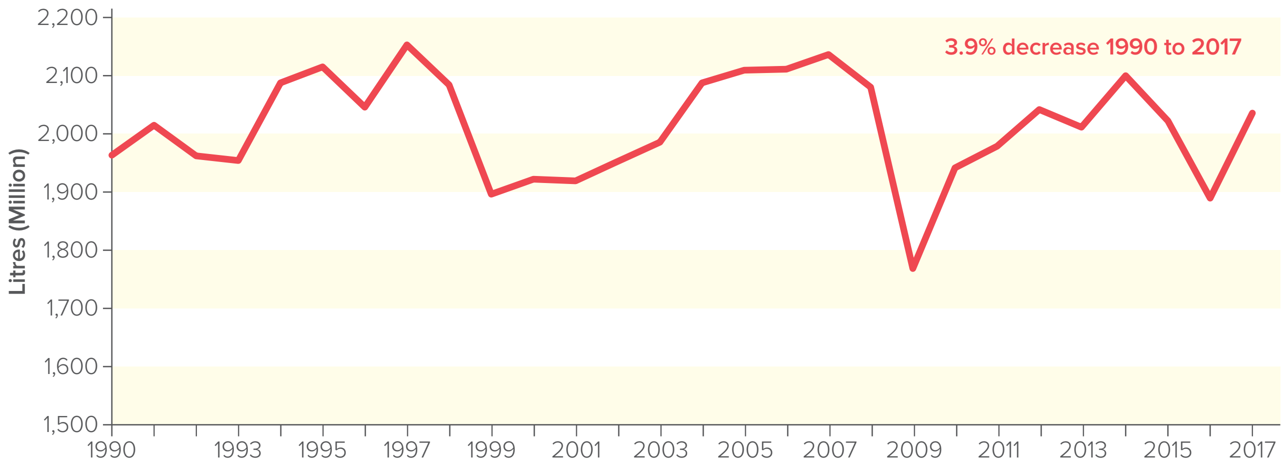
	1990	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Class I	1,825.05	1,914.92	1,948.75	1,902.88	1,626.47	1,791.11	1,816.44	1,875.85	1,849.57	1,918.27	1,852.98	1,732.20	1,864.83
Regional and Short Line	n/a*	122.13	117.89	113.12	90.01	107.88	107.78	107.08	108.58	109.36	104.82	99.34	111.51
Total Freight Train	**1,825.05**	**2,037.05**	**2,066.64**	**2,016.00**	**1,716.48**	**1,898.99**	**1,924.22**	**1,982.93**	**1,958.15**	**2,027.63**	**1,957.80**	**1,831.55**	**1,976.34**
Yard Switching	120.13	64.67	62.20	55.52	40.73	35.70	45.15	47.05	41.94	62.28	53.23	47.06	50.29
Work Train	15.67	7.49	6.09	7.60	5.97	7.06	7.72	8.77	10.30	10.80	11.35	10.84	10.01
Total Yard Switching and Work Train	**135.80**	**72.16**	**68.29**	**63.13**	**46.70**	**42.76**	**52.87**	**55.81**	**52.24**	**73.08**	**64.58**	**57.91**	**60.30**
TOTAL FREIGHT OPERATIONS	**1,960.85**	**2,109.21**	**2,134.92**	**2,079.13**	**1,763.18**	**1,941.76**	**1,977.09**	**2,038.74**	**2,010.39**	**2,100.71**	**2,022.38**	**1,889.45**	**2,036.64**
VIA Rail Canada	n/a*	58.75	58.97	59.70	57.43	52.16							
Intercity – Non-VIA Rail Canada	n/a*	5.50	5.06	4.57	6.07	5.93							
Intercity – Total	n/a*	64.25	64.03	64.27	63.50	58.09	58.32	50.99	46.17	44.89	46.98	47.93	51.02
Commuter	n/a*	34.23	35.94	37.85	42.68	46.92	49.81	50.22	48.61	49.67	60.50	59.43	64.46
Tourist Train & Excursion	n/a*	2.81	2.33	3.87	1.82	2.05	2.19	2.27	2.25	2.61	2.65	2.79	3.22
Total Passenger Operations	**102.70**	**101.29**	**102.30**	**105.99**	**108.00**	**107.06**	**110.32**	**103.48**	**97.03**	**97.16**	**110.13**	**110.15**	**118.70**
TOTAL RAIL OPERATIONS	**2,063.55**	**2,210.50**	**2,237.24**	**2,185.12**	**1,871.18**	**2,048.82**	**2,087.41**	**2,142.22**	**2,107.42**	**2,197.87**	**2,132.51**	**1,999.60**	**2,155.34**

n/a* = not available

3.1 Freight Operations

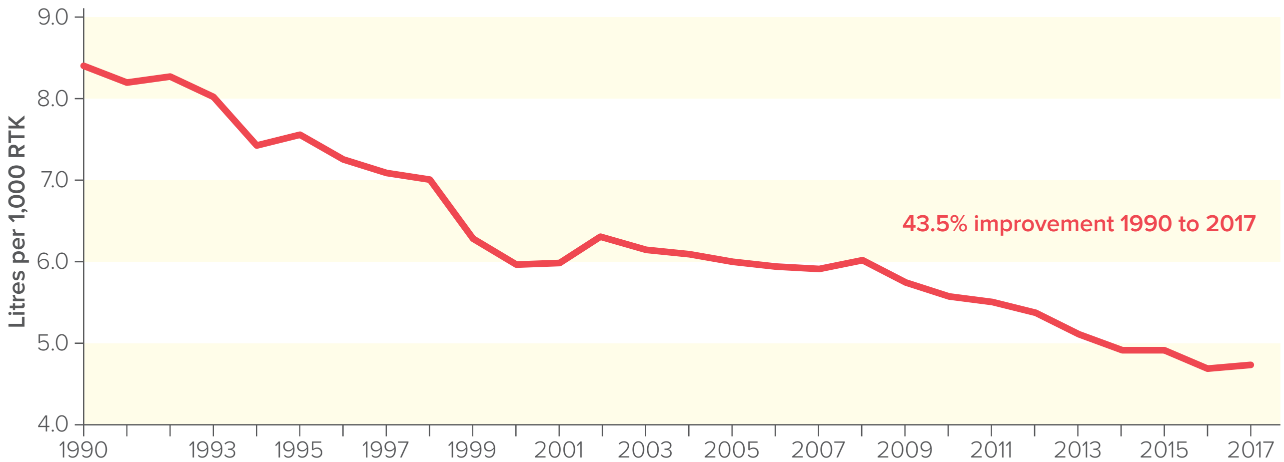
The volume of fuel consumption since 1990 in overall freight operations is shown in **Figure 12**. Fuel consumption in 2017 for all freight train, yard switching, and work train operations was 2,036.64 million litres, an increase of 7.8% from the 1,889.45 million litres consumed in 2016 and an increase of 3.9% from the 1990 level of 1,960.85 million litres. Given total traffic moved by railways in Canada, measured in revenue tonne-kilometres, railways can move one tonne of freight over 200 kilometres on just one litre of fuel.

Figure 12. Freight Operations Fuel Consumption, 1990–2017



The amount of fuel consumed per 1,000 RTK can be used as a measure of freight traffic fuel efficiency. As shown in **Figure 13**, the value in 2017 for overall rail freight traffic was 4.74 litres per 1,000 RTK. This value is a 0.86% increase from the 4.70 litres per 1,000 RTK in 2016 and is 43.5% below the 1990 level of 8.40 litres per 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 13. Freight Fuel Consumption per 1,000 RTK, 1990–2017



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 US EPA 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 7 provides details on a number of initiatives that the railways implemented in 2017 to reduce their fuel consumption. 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.

3.2 Passenger Services

Overall rail passenger fuel consumption—that is the sum of intercity, commuter, and tourist and excursion train operations—was 118.70 million litres in 2017, an increase of 7.8% from the 110.15 million litres consumed in 2016. The breakdown and comparison with previous years is shown in **Table 3**.

Intercity passenger's fuel consumption increased by 6.4% from 47.93 million litres in 2016 to 51.02 million litres in 2017. Fuel consumption for commuter rail increased by 8.5% from 59.43 million litres in 2016 to 64.46 million litres in 2017. Finally, tourist rail excursion fuel consumption increased by 15.5% to 3.22 million litres in 2017 from 2.79 million litres in 2016.

3.3 Diesel Fuel Properties

Effective June 1, 2007, amendments to Environment and Climate Change Canada's (ECCC's) *Sulphur in Diesel Fuel Regulations* came into force limiting the sulphur content of railway diesel fuel to 500 ppm (or 0.05%). A further reduction came into force June 1, 2013, limiting sulphur content in diesel fuel produced or imported for use in locomotives to 15 ppm (or 0.0015%)—referred to as ultra-low sulphur diesel (ULSD) fuel. Canadian railways have standardized the use of ULSD since 2013. This shift has further reduced railway diesel fuel sulphur content from an average of 1,275 ppm in 2006, 500 ppm in 2007, and 40.1 ppm in 2012. At this point in time, the use of diesel fuel meeting the 15ppm sulphur content requirement for ULSD has been standardized across Canada's railways.

Since July 2011, the Canadian *Renewable Fuel Regulations* require producers and importers of diesel fuel to blend a minimum of 2% renewable content into the total annual production or imported volume in Canada. It includes fuels such as biodiesel (Fathyl Athyl Methyl Ester – FAME) and renewable hydrocarbon diesel (hydrotreated derived renewable diesel). Canadian railways have been using renewable fuels in the form of biodiesel and renewable hydrocarbon diesel (RHD). RHD has very similar chemical properties to petroleum diesel and its blends are considered a drop-in replacement. Canadian railways are exploring the use of greater blend rates of biodiesel and RHD in their locomotives but there have been some challenges.

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. It can be converted into a drop-in replacement for diesel. The Government of Canada is working on developing a process to produce the lignin-derived diesel fuel with the goal of producing a 5% blend in diesel that meets CGSB 3.18 locomotive fuel specifications.

Biodiesel is derived from vegetable oils or animal fats. Biodiesel is produced in stand-alone facilities and can be blended with other diesel fuels for use in any compression ignition engine or burner application. Blends up to five percent (5%) by volume can be sold as "diesel fuel" without any required disclosure or labeling. Blends up to twenty percent (20%) are common throughout the marketplace. Pure biodiesel, designated B100, meets both the ASTM D6751 and CGSB 3.5.24 fuel specifications. Biodiesel blends up to B5 are covered within CAN/CGSB 3.520, while B6-B20 blends are covered within CAN/CGSB 3.522. Railways are working through issues with the accelerated deterioration of engines using high blends of biodiesel before adopting high blend rates.

RHD (or Hydrocarbon vegetable oil – HVO) employs many of the same feedstocks as biodiesel. Produced in stand-alone facilities, it uses more typical petroleum refining techniques such as hydro treating to convert the renewable feedstocks into hydrocarbons. These hydrocarbons are chemically identical to some of the molecules found in petroleum diesel fuel. RHD typically meets the same diesel fuel requirements found in ASTM D975 and CAN/CGSB 3.517 for petroleum diesel fuel and biodiesel blends up to B5. Although it meets the same specifications as petroleum diesel fuel, some original equipment manufacturers (OEMs) have placed limits on the amount of RHD that can be included when blended with petroleum diesel fuels.

While the standards and specifications cited above for RHD imply that it has identical properties and limits as petroleum diesel, blending high content of renewable feedstock can cause the final properties to fluctuate greatly within those limits. The fluctuations in RHD properties can be greater than for petroleum diesel.

4 Locomotive Inventory

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, 2017

Freight Operations	
Locomotives for Line Haul Freight	
Class I Mainline	2,064
Regional	117
Short line	168
Locomotives for Freight Switching Operations	
Yard	287
Road Switching	289
Total — Freight Operations	**2,925**
Passenger Operations	
Passenger Train	241
DMUs	6
Yard Switching	5
Total — Passenger Operations	**252**
TOTAL — PASSENGER & FREIGHT OPERATIONS	**3,177**

4.1 Locomotives Meeting US EPA Emissions Limits

The MOU indicates that the RAC member railways are encouraged to conform to all applicable emission standards, which includes the current US EPA emission standards for locomotives that are listed in **Appendix D**. Locomotives operated by federally regulated railways will be subject to the *Locomotive Emissions Regulations* which came into force on June 9, 2017.

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 US EPA tier level standards 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.

3 The US EPA tier levels include Tier 0, Tier 0+, Tier 1, Tier 1+, Tier 2, Tier 2+, Tier 3 and Tier 4

Table 5. Locomotives in Canadian Fleet Meeting US EPA Emissions Limits, 2000, 2006–2017

	2000	2006	2007	2008	2009	2010[c]	2011[c]	2012[c]	2013[c]	2014[c]	2015[c]	2016[c]	2017
Total number of freight train and passenger train line-haul locomotives subject to regulation[a]	1,498	2,319	2,216	2,051	1,898	2,196	2,112	2,290	2,293	1,925	1,828	1,674	2,742
Total number of freight train and passenger train locomotives not subject to regulation[b]	1,578	680	811	772	829	752	866	802	770	775	572	644	435
Number of freight train and passenger train locomotives meeting US EPA emissions limits	80	914	1,023	1,042	1,094	1,209	1,317	1,512	1,631	1,538	1,266	1,267	2,157

a Includes locomotives which are meeting Title 40 of the United States Code of Federal Regulations, part 1033, “Control of Emissions from Locomotives.”

b Includes locomotives which are not meeting Title 40 of the United States Code of Federal Regulations, part 1033, “Control of Emissions from Locomotives.”

c. Table was revised to include commuter and non-Class 1 intercity passenger rail

In 2017, 78.7% of the total line-haul fleet (2,157 locomotives) met the US EPA Tier Level emissions standards. The US EPA emission standards are phased in over time and are applicable only to “new” locomotives (i.e., originally manufactured and remanufactured locomotives). Locomotives manufactured prior to 1973 and that have not been upgraded and locomotives below 1,006 horsepower (hp) are not required to meet the US EPA emission standards. The remaining locomotive fleet is not required to meet the standards until the time of its next remanufacture. **Table 6** provides an overview of the 2017 locomotive fleet and includes details about the number of locomotives meeting each tier level.

Table 6. Locomotive Fleet Breakdown by US EPA Tier Level, 2017

Not required to meet regulation[a]	435
Meeting regulation – Non Tier-Level Locomotives	583
Tier 0	144
Tier 0+	621
Tier 1	1
Tier 1+	438
Tier 2	310
Tier 2+	239
Tier 3	165
Tier 4	241
TOTAL	**3,177**

a Includes locomotives which are not meeting the regulations because of exceptions. Regulations refer to Title 40 of the United States Code of Federal Regulations, part 1033, “Control of Emissions from Locomotives.”

Table 7 provides a summary of the fleet changes by emissions tier level for the overall fleet with the Class 1 freight line-haul fleet noted in parenthesis.

In 2017, 30 Tier 3 and 30 Tier 4 high-horsepower locomotives were added to the Class 1 freight line-haul fleet; a total of 11 Class 1 freight line-haul locomotives were upgraded to Tier 1+; and 70 medium-horsepower locomotives manufactured between 1973 and 1999 were retired from Class 1 and one additional locomotive was retired.

Anti-idling devices on locomotives reduce emissions by ensuring that locomotive engines are shut down after extended periods of inactivity, reducing engine activity and therefore emissions. The number of locomotives in 2017 equipped with a device to minimize unnecessary idling such as an Automatic Engine Stop-Start (AESS) system or Auxiliary Power Unit (APU) was 2,195 compared with 1,392 in 2016. This represents 69.1% of the total in-service fleet in 2017 versus 60.1% in 2016.

Table 7. Changes in Locomotive Fleet by Tier Level, 2017[a]

	Added	Retired	Remanufactured	Locomotives with anti-idling devices
Not upgraded		7(6)		165(92)
Tier 0		64(64)		80(73)
Tier 0+				612(612)
Tier 1				10(1)
Tier 1+			11(11)	438(438)
Tier 2				256(254)
Tier 2+				239(239)
Tier 3	30(30)			155(155)
Tier 4	30(30)			240(240)
TOTAL	**60(60)**	**71(70)**	**11(11)**	**2,195(2,104)**

a The figures in parenthesis represent the Class 1 freight line-haul absolute figures

5 Locomotive Emissions

5.1 Emission Factors

The methodology document describing the calculation of GHG and CAC emission factors referenced in the sections below is available upon request to the RAC. The emission factors (EFs) for GHGs and CACs can be found in **Appendix F**, "Conversion Factors Related to Railway Emissions."

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 Environment and Climate Change Canada to create the *National Inventory Report 1990–2017: Greenhouse Gas Sources and Sinks in Canada*, which is submitted annually to the United Nations Framework Convention on Climate Change (UNFCCC).[4]

Emission Factors for Criteria Air Contaminant Emissions:

CAC EFs for 2017 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). NO_X, PM, and HC EFs for passenger and yard operations increased in 2017 compared to 2016. This was due to the make-up of the locomotive fleet. The CAC EFs are estimated based on the active fleet on December 31. Since a higher percentage of the active fleet on December 31, 2017 was made-up of locomotives of lower Tier level than in the active fleet on December 31, 2016, the 2017 CAC EFs are higher than the 2016 CAC EFs.

The EFs to calculate emissions of SO_X (calculated as SO_2) are based on the sulphur content of the diesel fuel. As noted in Section 3.3 of this report, the Sulphur in Diesel Fuel Regulations have contributed to the widespread use of ULSD fuel in the Canadian locomotive fleet.

4 *National Inventory Report 1990–2017: Greenhouse Gas Sources and Sinks in Canada,* Environment and Climate Change Canada, 2019 http://www.publications.gc.ca/site/eng/9.506002/publication.html

The CAC EFs are listed in **Table 8** for 1990 and 2006–2017. EFs for years prior to 2006 are available upon request to the RAC.

Table 8. CAC Emissions Factors for Diesel Locomotives 1990, 2006–2017 (g/L)

	Year	NO_X	PM	CO	HC	SO_2
Total Freight	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
	2009	50.41	1.31	7.07	2.47	0.18
	2008	51.19	1.38	7.32	2.74	0.24
	2007	52.74	1.44	7.35	2.79	0.82
	2006	55.39	1.50	6.98	2.53	2.10
	1990	71.44	1.59	7.03	2.64	2.47
Total Yard Switching	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
	2009	69.42	1.53	7.35	4.04	0.18
	2008	69.88	1.54	7.35	4.06	0.24
	2007	69.88	1.57	7.35	4.06	0.82
	2006	69.88	1.63	7.35	4.06	2.10
	1990	69.88	1.65	7.35	4.06	2.47
Total Passenger	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
	2009	62.60	1.29	7.03	2.40	0.18
	2008	62.37	1.29	7.03	2.39	0.24
	2007	70.69	1.47	7.03	2.62	0.82
	2006	71.44	1.57	7.03	2.64	2.10
	1990	71.44	1.59	7.03	2.64	2.47

5.2 Emissions Generated[5]

5.2.1 Greenhouse Gases

In 2017, GHG emissions produced by the railway sector (expressed as CO_{2e}) were 6,428.84 kt, an increase of 7.8% as compared to 5,964.31 kt in 2016. The 2017 emissions have increased by 4.4% from 6,155.06 kt in 1990 (with a rise in RTK traffic of 84.0% over the same period). The GHG emissions intensities for freight traffic increased in 2017 to 14.14 kg per 1,000 RTK from 14.02 kg in 2016. As a percentage, the GHG emissions intensity for total freight in 2017 was 43.5% below 1990 levels. **Table 9** displays the GHG emissions produced in 1990 and annually since 2006. The GHG emissions for years prior to 2006 are available upon request to the RAC.

Table 9. GHG Emissions and Emission Intensities by Railway Service in Canada 1990, 2006–2017 *(in kilotonnes unless otherwise specified)*

	1990	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total Railway													
CO_{2e}	6,155.06	6,593.38	6,673.12	6,517.67	5,581.27	6,111.11	6,226.21	6,389.71	6,285.91	6,555.70	6,360.73	5,964.31	6,428.84
CO_2	5,532.38	5,926.36	5,998.03	5,858.31	5,016.64	5,492.88	5,596.34	5,743.30	5,650.00	5,892.49	5,717.25	5,360.93	5,778.46
CH_4	7.74	8.29	8.39	8.19	7.02	7.68	7.83	8.03	7.90	8.24	8.00	7.50	8.08
N_2O	614.94	658.73	666.70	651.17	557.61	610.55	622.05	638.38	628.01	654.97	635.49	595.88	642.29
Passenger — Intercity, Commuter, Tourist/Excursion													
CO_{2e}	306.33	302.12	305.14	316.14	322.13	319.33	329.06	308.66	289.42	289.82	328.49	328.54	354.05
CO_2	275.34	271.56	274.27	284.16	289.55	287.03	295.77	277.43	260.14	260.50	295.26	295.31	318.23
CH_4	0.39	0.38	0.38	0.40	0.40	0.40	0.41	0.39	0.36	0.36	0.41	0.41	0.45
N_2O	30.60	30.18	30.49	31.59	32.18	31.90	32.88	30.84	28.92	28.95	32.82	32.82	35.37
Freight-Line Haul													
CO_{2e}	5,443.66	6,076.01	6,164.28	6,013.23	5,119.82	5,664.22	5,739.47	5,914.58	5,840.67	6,047.90	5,839.63	5,463.04	5,894.92
CO_2	4,892.95	5,461.33	5,540.67	5,404.90	4,601.88	5,091.20	5,158.84	5,316.23	5,249.79	5,436.07	5,248.86	4,910.38	5,298.56
CH_4	6.84	7.64	7.75	7.56	6.44	7.12	7.22	7.44	7.34	7.60	7.34	6.87	7.41
N_2O	543.86	607.04	615.86	600.77	511.51	565.90	573.42	590.91	583.53	604.23	583.42	545.80	588.95
Yard Switching and Work Train													
CO_{2e}	405.08	215.24	203.70	188.30	139.31	127.56	157.69	166.48	155.83	217.98	192.62	172.72	179.87
CO_2	364.10	193.47	183.09	169.25	125.21	114.65	141.73	149.64	140.06	195.93	173.13	155.24	161.67
CH_4	0.51	0.27	0.26	0.24	0.18	0.16	0.20	0.21	0.20	0.27	0.24	0.22	0.23
N_2O	40.47	21.50	20.35	18.81	13.92	12.74	15.75	16.63	15.57	21.78	19.24	17.26	17.97
Total Freight Operations													
CO_{2e}	5,848.73	6,291.25	6,367.98	6,201.52	5,259.13	5,791.78	5,897.16	6,081.06	5,996.49	6,265.88	6,032.24	5,635.76	6,074.79
CO_2	5,257.05	5,654.80	5,723.76	5,574.15	4,727.09	5,205.85	5,300.57	5,465.87	5,389.86	5,631.99	5,421.99	5,065.62	5,460.23
CH_4	7.35	7.91	8.01	7.80	6.61	7.28	7.41	7.65	7.54	7.88	7.58	7.09	7.64
N_2O	584.33	628.55	636.21	619.58	525.43	578.64	589.17	607.54	599.10	626.01	602.67	563.06	606.92
Emissions Intensity — Total Freight (kg/1,000 RTK)													
CO_{2e}	25.05	17.68	17.61	17.90	17.08	16.59	16.40	15.97	15.15	14.61	14.61	14.02	14.14
CO_2	22.52	15.89	15.83	16.09	15.35	14.91	14.74	14.35	13.62	13.13	13.13	12.60	12.71
CH_4	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
N_2O	2.50	1.77	1.76	1.79	1.71	1.66	1.64	1.60	1.51	1.46	1.46	1.40	1.41

5 Note Amtrak is excluded from the CAC emissions calculations due to a lack of information on the Amtrak locomotive fleet (the fleet is not captured by the Rail Trends Survey). However, Amtrak is included in the GHG emissions calculations.

Table 9. GHG Emissions and Emission Intensities by Railway Service in Canada 1990, 2006–2017 *(in kilotonnes unless otherwise specified)* *(continued)*

	1990	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Emissions Intensity — Class 1 Freight Line-Haul (kg/1,000 RTK)													
CO_{2e}	n/a*	17.26	17.18	17.46	16.80	16.30	16.03	15.68	14.84	14.32	14.02	13.47	13.53
Emissions Intensity — Regional and Short Line Freight (kg/1,000 RTK)													
CO_{2e}	n/a*	14.65	15.09	15.72	14.08	15.09	14.76	13.33	13.47	11.07	16.70	16.09	18.19
Emissions Intensity — Intercity Passenger (kg/Passenger-km)													
CO_{2e}	n/a*	0.131	0.130	0.121	0.132	0.123	0.122	0.109	0.099	0.100	0.102	0.101	0.098
Emissions Intensity — Commuter Rail (kg/Passenger)													
CO_{2e}	1.68	1.68	1.69	1.68	1.93	2.04	2.17	2.14	2.06	2.06	2.34	2.23	2.42

n/a* = indicates not available

The MOU sets out targets to be achieved by 2017 for GHG emissions intensities by category of railway operation. In relation to the 2017 targets, **Table 10** shows the GHG emissions intensity levels for Class 1 freight, intercity passenger, and regional and shortlines for 2017.

Table 10. GHG Emissions Intensities by Category of Operation

Railway Operation	Units	2010	2011	2012	2013	2014	2015	2016	2017	2017 Target	Change from 2010–2017
Class I Freight	kg CO_{2e}/1,000 RTK	16.30	16.03	15.68	14.84	14.32	14.02	13.47	13.53	14.93	16.99% decrease
Intercity Passenger	kg CO_{2e}/passenger-km	0.123	0.122	0.109	0.099	0.100	0.102	0.101	0.098	0.112	20.33% decrease
Regional and Short Lines	kg CO_{2e}/1,000 RTK	15.09	14.76	13.33	13.47	11.07	16.70	16.09	18.19	14.45	20.54% increase

Note: All values above, including the revised 2017 targets, have been calculated based on the new emission factors and global warming potentials. Historical values have been updated from previous reports.

In 2017, Class 1 freight railways were able to similarly match locomotive power to freight traffic compared to 2016 with a modest increase in emissions intensity of 0.4% above the 2016 value.

Intercity passenger operations were able to optimize locomotive power with fluctuating traffic levels, resulting in decreased emissions intensity relative to 2016 by 3.9%. As previously stated, commuter railways do not have a GHG emissions intensity target under the MOU.

Regional and shortlines saw an increase in the GHG intensity relative to the 2016 value of 13.0%; the emissions intensity is above the 2017 target. The volatility in regional and shortlines GHG emissions intensity is primarily attributed to variations in economic demand for certain bulk commodities which tend to be more fuel efficient on average.

5.2.2 Criteria Air Contaminants[6]

Table 11 displays the CAC emissions produced annually by locomotives in operation in Canada for the reference year (1990) and annually from 2006 to 2017, namely NO_X, PM, CO, HC, and SO_X. The values presented are for both absolute amounts and intensities per productivity unit. The emissions and intensities for years previous to 2006 are available upon request to the RAC.

The CAC of key concern for the railway sector is NO_X. As shown in **Table 11**, NO_X emissions in 2017 totalled 79.55 kt. Freight operations accounted for 91.7% 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 0.17 kg per 1,000 RTK in 2017. This was 5.5% lower than the 2016 figure (0.18 kg per 1,000 RTK) and is down from 0.52 kg per 1,000 RTK in 1990, a 67.3% reduction.

Table 11. Locomotive CAC Emissions, 1990, 2006–2017
in kilotonnes, unless otherwise noted

Operation	Year	NO_X	PM	CO	HC	SO_2 (tonnes)
Total Freight	2017	68.75	1.43	13.91	2.88	48.71
	2016	69.28	1.41	12.11	2.79	42.28
	2015	77.33	1.59	13.96	3.28	48.25
	2014	83.94	1.82	14.34	3.66	49.97
	2013	86.96	1.98	13.81	3.91	48.26
	2012	89.88	2.13	13.59	4.18	126.97
	2011	91.40	2.22	13.52	4.26	336.10
	2010	93.49	2.34	13.40	4.52	403.08
	2009	86.52	2.25	12.13	4.24	310.67
	2008	103.15	2.78	14.76	5.51	487.40
	2007	109.00	2.97	15.20	5.76	1,700.23
	2006	112.83	3.06	14.22	5.15	4,273.51
	1990	130.38	2.91	12.84	4.81	4,504.32
Total Yard Switching	2017	4.17	0.09	0.44	0.24	1.49
	2016	3.49	0.08	0.38	0.20	1.28
	2015	4.42	0.10	0.47	0.26	1.59
	2014	5.04	0.11	0.54	0.29	1.80
	2013	3.59	0.08	0.38	0.21	1.29
	2012	3.86	0.08	0.41	0.22	3.68
	2011	3.68	0.08	0.39	0.21	7.67
	2010	2.98	0.07	0.31	0.17	9.08
	2009	3.24	0.07	0.34	0.19	8.45
	2008	4.39	0.10	0.46	0.26	15.21
	2007	4.77	0.11	0.50	0.28	56.18
	2006	5.04	0.12	0.53	0.29	151.38
	1990	9.49	0.22	1.00	0.55	335.18

6 Two potential issues were raised during the QA/QC of the 2017 LEM data. In calculating CAC emissions, it appears that the terms brake horsepower (bhp) and horsepower (hp) were used interchangeably. Brake horsepower is the measurement of an engine's power without any power losses, while hp is bhp less the power losses. The RAC is aware of the potential issue and this will be addressed for future reporting. Secondly, the weighted notch percentage for the OEM GE was applied to other OEMs where this data was unavailable, including MLW, Bombardier, and ALCO. It is unknown at this time if the weighted notch percentage is comparable (transferrable) between these OEMs. No changes have been made to the CAC calculations to address either of these potential issues.

Table 11. Locomotive CAC Emissions, 1990, 2006–2017
in kilotonnes, unless otherwise noted *(continued)*

Operation	Year	NO_x	PM	CO	HC	SO_2 (tonnes)
Total Passenger[1]	2017	6.63	0.14	0.83	0.26	2.90
	2016	5.72	0.12	0.72	0.23	2.52
	2015	4.84	0.10	0.64	0.19	2.23
	2014	5.24	0.11	0.68	0.21	2.37
	2013	4.88	0.10	0.67	0.19	2.36
	2012	5.51	0.12	0.72	0.22	6.72
	2011	5.98	0.13	0.76	0.24	19.12
	2010	5.94	0.12	0.74	0.24	22.43
	2009	6.65	0.14	0.75	0.25	19.24
	2008	6.56	0.14	0.74	0.25	25.45
	2007	7.19	0.15	0.72	0.27	83.64
	2006	7.18	0.16	0.71	0.27	210.90
	1990	7.35	0.16	0.72	0.27	253.80
Total Freight Operations[2]	2017	72.92	1.52	14.35	3.12	50.19
	2016	72.77	1.49	12.49	3.00	43.56
	2015	81.74	1.69	14.43	3.54	49.84
	2014	88.98	1.93	14.88	3.95	51.77
	2013	90.55	2.06	14.19	4.12	49.55
	2012	93.71	2.22	14.00	4.40	130.57
	2011	95.08	2.30	13.91	4.47	343.78
	2010	96.47	2.40	13.27	4.69	412.15
	2009	89.76	2.32	12.47	4.43	315.85
	2008	107.54	2.88	15.22	5.77	502.60
	2007	113.78	3.08	15.70	6.03	1,756.41
	2006	117.88	3.18	14.75	5.44	4,424.89
	1990	139.87	3.13	13.84	5.36	4,839.50
Total Railway Operations[3]	2017	79.55	1.65	15.18	3.38	53.09
	2016	78.49	1.61	13.21	3.22	46.08
	2015	86.58	1.79	15.07	3.73	52.08
	2014	94.21	2.04	15.55	4.16	54.14
	2013	95.43	2.16	14.86	4.31	51.91
	2012	99.22	2.33	14.71	4.62	137.28
	2011	101.06	2.43	14.67	4.71	363.16
	2010	102.41	2.53	14.46	4.92	434.58
	2009	96.41	2.46	13.22	4.68	338.36
	2008	114.10	3.01	15.96	6.02	528.05
	2007	120.96	3.23	16.41	6.30	1,840.05
	2006	125.06	3.34	15.46	5.71	4,635.79
	1990	147.21	3.30	14.56	5.64	5,093.30
Total Freight Emissions Intensity (kg/1000 RTK)	2017	0.17	0.0035	0.033	0.0073	0.00012
	2016	0.18	0.0037	0.031	0.0075	0.00001
	2015	0.20	0.0041	0.035	0.0086	0.00001
	2014	0.21	0.0045	0.035	0.0092	0.00001
	2013	0.23	0.052	0.036	0.0104	0.00001
	2012	0.25	0.058	0.037	0.0116	0.00003
	2011	0.26	0.064	0.039	0.0124	0.00010
	2010	0.28	0.070	0.039	0.0136	0.00118
	2009	0.29	0.075	0.041	0.0144	0.00104
	2008	0.31	0.083	0.044	0.0167	0.00145
	2007	0.31	0.085	0.043	0.0167	0.00486
	2006	0.33	0.089	0.041	0.0153	0.01244
	1990	0.52	0.0116	0.051	0.0192	0.01801

(1) Passenger data does not take into account Amtrak due to the definition of active locomotive fleet used to calculate CAC emissions.

(2) Freight Operations = Freight + Yard Switching

(3) Total Railway Operations = Freight + Yard Switching + Passenger

6 Tropospheric Ozone Management Areas

6.1 Data Derivation

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.

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 Total Fuel Consumption and GHG Emissions as Percentage of All Rail Operations in Canada, 1999, 2006–2017

	1999	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016[7]	2017
Lower Fraser Valley, B.C.	4.2	2.8	3.0	2.8	3.0	3.1	3.0	2.8	2.9	2.2	2.3	2.5	3.1
Windsor-Québec City Corridor	17.1	16.8	17.4	17.1	15.7	15.3	14.8	14.2	14.1	14.6	14.1	15.1	14.6
Saint John, N.B.	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3

Table 13. TOMA Total NO_X Emissions as Percentage of All Rail Operations in Canada, 1999, 2006–2017

	1999	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Lower Fraser Valley, B.C.	4.4	2.8	2.9	2.8	2.9	3.1	3.0	3.1	2.9	2.2	2.3	2.3	3.1
Windsor-Québec City Corridor	17.8	17.4	16.6	16.8	15.1	15.3	14.8	15.7	14.1	14.6	14.1	14.1	14.6
Saint John, N.B.	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.3

The emissions of GHGs for the TOMA regions were calculated using the respective GHG emissions factors as discussed in **Section 5.1** 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 5.1**, 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 The 2016 data was incorrectly listed in the 2016 LEM Report. It has been corrected in this 2017 LEM Report.

6.2 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. The 2017 traffic, fuel consumption, and emissions data in the seasonal periods for each railway are summarized in **Tables 14 to 16**.

Table 14. TOMA No. 1 — Lower Fraser Valley, B.C. Traffic, Fuel and Emissions Data 2017

	Total 100%	Seasonal Split Winter 58%	Summer 42%
TRAFFIC		**Million GTK**	
CN	10,494	6,087	4,408
CP	7,945	4,608	3,337
Southern Rail of BC	260	151	109
TOTAL FREIGHT TRAFFIC	**18,699**	**10,845**	**7,853**
FUEL CONSUMPTION		**Million Litres**	
Freight operations			
Freight Fuel Rate (L/1,000 GTK) = 3.31(1)			
Total Freight Fuel Consumption	**61.92**	**35.91**	**26.01**
Passenger Fuel Consumption			
VIA Rail Canada	0.44	0.26	0.19
Great Canadian Railtours	2.92	1.69	1.23
West Coast Express	1.30	0.76	0.55
Total Passenger Fuel Consumption	**4.67**	**2.71**	**1.96**
TOTAL RAIL FUEL CONSUMPTION	**66.58**	**38.62**	**27.97**
EMISSIONS		**Kilotonnes/Year**	
Emission Factors (g/L)(2)			
NO_X: 36.93	2.46	1.43	1.03
PM: 0.77	0.05	0.03	0.02
CO: 7.05	0.47	0.27	0.20
HC: 1.57	0.10	0.06	0.04
SO_2: 0.02	0.00	0.00	0.00
CO_2: 2,681(3)	178.51	103.54	74.97
CH_4: 3.75(3)	0.25	0.14	0.10
N_2O: 298(3)	19.84	11.51	8.33
CO_{2e}: 2,982.75(3)	198.60	115.19	83.41

(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).

(2) The emission factor used in the emissions calculations is a weighted average of the overall freight, switching, 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.

Table 15. TOMA No. 2 — Windsor-Québec City Corridor Traffic, Fuel and Emissions Data 2017

		Seasonal Split	
	Total 100%	Winter 58%	Summer 42%
TRAFFIC		Million GTK	
CN	59,322	34,407	24,915
CP	4,455	2,584	1,871
Essex Terminals	28	16	12
Goderich & Exeter	479	278	201
Ottawa Valley Railway(1)	0	0	0
Québec Gatineau Railway	1,033	599	434
Southern Ontario Railway	154	89	65
St-Lawrence & Atlantic (Canada)	256	148	107
TOTAL FREIGHT TRAFFIC	**65,726**	**38,121**	**27,605**
FUEL CONSUMPTION		Million Litres	
Freight operations			
Freight Fuel Rate (L/1,000 GTK) = 3.31(2)			
Total Freight Fuel Consumption	**217.64**	**126.23**	**91.41**
Passenger Fuel Consumption			
VIA Rail Canada	33.73	19.57	14.17
Commuter Rail	63.16	36.63	26.53
Total Passenger Fuel Consumption	**96.89**	**56.20**	**40.69**
TOTAL RAIL FUEL CONSUMPTION	**314.53**	**182.43**	**132.10**
EMISSIONS		Kilotonnes/Year	
Emission Factors (g/L)(3)			
NO_x: 36.93	11.61	6.74	4.88
PM: 0.77	0.24	0.14	0.10
CO: 7.05	2.22	1.29	0.93
HC: 1.57	0.49	0.29	0.21
SO_2: 0.02	0.01	0.00	0.00
CO_2: 2,681(4)	843.26	489.09	354.17
CH_4: 3.75(4)	1.18	0.68	0.50
N_2O: 298(4)	93.73	54.36	39.37
CO_{2e}: 2,982.75(4)	938.17	544.14	394.03

(1) Ottawa Valley Railway data are included in CP data.

(2) 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).

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

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

Table 16. TOMA No. 3 — Saint John Area, New Brunswick Traffic, Fuel and Emissions Data 2017

	Total 100%	Seasonal Split Winter 58%	Summer 42%
TRAFFIC		Million GTK	
CN	867	503	364
New Brunswick Southern Railway	1,080	626	453
Total Freight Traffic	**1,946**	**1,129**	**817**
FUEL CONSUMPTION		Million Litres	
Freight Operations			
Freight Fuel Rate (L/1,000 GTK) = 3.31[1]			
Total Freight Fuel Consumption	**6.45**	**3.74**	**2.71**
Passenger Fuel Consumption			
Total Passenger Fuel Consumption	**0.00**	**0.00**	**0.00**
Total Rail Fuel Consumption	**6.45**	**3.74**	**2.71**
EMISSIONS		Kilotonnes/Year	
Emission Factors (g/L)[2]			
NO_X: 36.93	0.24	0.14	0.10
PM: 0.77	0.00	0.00	0.00
CO: 7.05	0.05	0.03	0.02
HC: 1.57	0.01	0.01	0.00
SO_2: 0.02	0.00	0.00	0.00
CO_2: 2,681[3]	17.28	10.02	7.26
CH_4: 3.75[3]	0.02	0.01	0.01
N_2O: 298[3]	1.92	1.11	0.81
CO_{2e}: 2,982.75[3]	19.22	11.15	8.07

(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).

(2) The emission factor used in the emissions calculations is a weighted average of the overall freight, switching, 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.

7 Emissions Reductions Initiatives

CN — Fuel Efficiency Technologies and HPTA (Horse Power Tonnage Analyzer)

CN maintains a longstanding commitment to reducing its emissions by investing in innovative fuel efficiency technologies and programs such as the Horse Power Tonnage Analyzer (HPTA) and Energy Management Systems. In 2017 CN continued investing in HPTA (a system which works to optimize a locomotive's horsepower to tonnage ratio) and through our fleet renewal strategy, we acquired 34 new high horsepower locomotives equipped with Energy Management Systems.

Transport Canada — Innovation Centre

The Innovation Centre runs the Clean Rail RD&D program which spurs the development of technologies that reduce emissions from the rail sector. This program emphasizes technologies that are on the pathway to commercialization; industry leadership plays a key role informing the technologies that are selected and advanced. The main themes for 2017 projects were:

- electrical energy storage for commuter train operations,
- development of stronger, lighter construction materials for railcars, and
- distillation of renewable diesel fuel from lignin, which is biological waste from forestry and agriculture industries.

The ideas and innovation at universities are an important part of technology development. Transport Canada supplied $250,000 as grant funding to universities across Canada that are working on clean rail technologies. The projects that received grants were about improving anti-idling devices, enhancing hydrogen fuel cell durability and energy output, optimizing train marshalling for fuel efficiency, developing better railcar construction materials and understanding train aerodynamics.

CP — Locomotive Fleet Renewal and Energy Efficiencies

As part of its annual capital expenditure program for 2017, CP Invested $60 million to modernize 30 locomotives as part of a multi-year fleet renewal partnership with General Electric. Upgrades included advanced diesel engines, enhanced cooling systems, improved traction, and technological enhancements to fuel trip optimizer and distributed power systems. Beyond operational efficiency, each renewed locomotive is expected to reduce fuel consumption by greater than 2.7 percent. Work is underway to complete similar upgrades to an additional 140 locomotives by the end of 2019.

VIA — Enhanced Training Program

In 2017, VIA enhanced its locomotive engineer simulator training program. By adding a new feature to the simulator, VIA is now training its locomotive engineers on how to better operate locomotives for lower fuel consumption.

8 Summary and Conclusions

The 2017 Locomotive Emissions Monitoring Report highlights that Canadian railways met their 2017 GHG emission intensity reduction targets for freight and intercity passenger rail. GHG emissions intensity for regional and shortlines was 25.8% higher than the 2017 target. GHG emissions from all railway operations in Canada totalled 6,428.84 kt in 2017, which is an increase of 7.8% from 5,964.31 kt in 2016. This increase primarily reflects an increase in traffic in both the freight and passenger sectors. **Overall, the railway sector has reduced its GHG and CAC emission intensity during the MOU period.**

For total freight operations, the GHG emissions intensity (in kg CO_{2e} per 1,000 RTK) increased by 0.8% from 14.02 in 2016 to 14.14 in 2017. Compared in 1990, 2017 performance reflects a 43.5% improvement. Class 1 freight GHG emission intensity (in kg CO_{2e} per 1,000 RTK) increased by 0.4% from 2016 levels while intercity passenger operations GHG emissions intensity (in kg CO_{2e} per passenger kilometre) decreased by 3% over the same period. Regional and shortlines increased their GHG emission intensity (in kg CO_{2e} per 1,000 RTK) by 13.0% from 16.09 in 2016 to 18.19 in 2017.

CAC emissions from all railway operations increased, with total locomotive NO_X emissions increasing to 79.55 kt in 2017 from 78.49 kt in 2016. However, the total freight NO_X emissions intensity decreased slightly from 0.18 kg/1,000 RTK in 2016 to 0.17 kg/1,000 RTK in 2017, and 67.3% from 1990 levels (at 0.52 kg/1,000 RTK).

In 2017, Canadian railways made substantive investments and added 30 Tier 3 locomotives and 30 Tier 4 high-horsepower locomotives to the Class 1 freight. Eleven Class 1 locomotives were upgraded to Tier 1+. Older and lower-horsepower locomotives continued to be retired, and in 2017, 71 locomotives were taken out of active duty.

The Canadian fleet totalled 3,177 units in 2017, of which 2,742 locomotives were subject to the US EPA emissions regulations. Of the locomotives subject to the US EPA emissions regulations, 78.7% (2,157) met the emission standards. The number of locomotives equipped with APUs or AESS systems to minimize unnecessary idling totalled 2,195 or 69.1% (up from 60% in 2016) 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 Standard, carbon pricing, etc.), Canadian railways and the Government of Canada will continue their efforts to reduce GHG emissions intensity in the railway sector.

The 2011 – 2017 MOU will be replaced by the 2018 – 2022 MOU with new GHG intensity targets based on a 2017 baseline for Canadian-owned Class 1 freight, shortlines, and intercity passenger railways. As with the previous MOU, commuter railways do not have an intensity target, but will continue to report on performance and efforts to reduce GHG emissions intensity. The new targets are as defined in the table below.

Carrier Class	Productivity Unit	Base Year	Percent Reduction Target (by 2022)	2022 Target
Class 1 Freight	CO_{2e} per 1,000 revenue tonne kilometres	2017 reported GHG intensity (13.53 kg CO_{2e} / 1,000 RTK)	6% reduction from 2017	12.72
Intercity Passenger	CO_{2e} per passenger-kilometre	2017 reported GHG intensity (0.098 kg CO_{2e} / passenger-km)	6% reduction from 2017	0.092
Shortlines	CO_{2e} per 1,000 revenue tonne kilometres	2017 reported GHG intensity (18.19 kg CO_{2e} / 1,000 RTK)	3% reduction from 2017	17.64

As with previous MOUs, CAC emissions will be reported and the RAC will continue to encourage its members (including those not covered by the new *Locomotive Emissions Regulations*) to improve their CAC emission performance.

This report meets the filing requirements for 2017.

Appendix A

RAC Member Railways Participating in the MOU by Province

Railway	Provinces of Operation
6970184 Canada Ltd	Saskatchewan
Réseau de transport métropolitain	Québec
Alberta Prairie Railway Excursions	Alberta
Amtrak	British Columbia, Ontario, Québec
ArcelorMittal Mines Canada	Québec
Arnaud Railway Company	Québec
Barrie-Collingwood Railway	Ontario
Battle River Railway	Alberta
BCR Properties	British Columbia
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
Charlevoix Railway Company Inc.	Québec
Canadian National	British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Québec, New Brunswick, Nova Scotia
CSX Transportation Inc.	Ontario, Québec
Eastern Maine Railway Company	(Maine)
Essex Terminal Railway Company	Ontario
Goderich-Exeter Railway Company Ltd.	Ontario
Great Canadian Railtour Company Ltd.	British Columbia
Great Sandhills Railway Ltd.	Saskatchewan
Great Western Railway Ltd.	Saskatchewan
Huron Central Railway Inc.	Ontario
Keewatin Railway Company	Manitoba
Kettle Falls International Railway, LLC	British Columbia
Labrador Iron Mines	Newfoundland and Labrador
Metrolinx	Ontario

Railway	Provinces of Operation
New Brunswick Southern Railway Company Ltd.	New Brunswick
Nipissing Central Railway Company	Ontario, Québec
Norfolk Southern Railway	Ontario
Ontario Northland Transportation Commission	Ontario, Québec
Ontario Southland Railway Inc.	Ontario
Ottawa Valley Railway	Ontario, Québec
Prairie Dog Central Railway	Manitoba
Québec Gatineau Railway Inc.	Québec
Québec North Shore and Labrador Railway Company Inc.	Québec, Newfoundland and Labrador
Roberval and Saguenay Railway Company, The	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
Southern Railway of Vancouver Island	British Columbia
St. Lawrence & Atlantic Railroad (Québec) Inc.	Québec
Sydney Coal Railway	Nova Scotia
Toronto Terminals Railway Company Limited, The	Ontario
Trillium Railway Co. Ltd.	Ontario
Tshiuetin Rail Transportation Inc.	Québec
VIA Rail Canada Inc.	British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Québec, New Brunswick, Nova Scotia
Wabush Lake Railway Company, Limited	Newfoundland and Labrador
West Coast Express Ltd.	British Columbia

Appendix B-1
2017 Locomotive Fleet — Freight Train Line-Haul Operations

OEM	Model	USEPA Tier Level	Engine	Cylinders	hp	Year of Manufacture	Year of Remanufacture	Total Class 1	Regional	Short Lines	Total Regional and Short Lines	Total Freight Fleet
MAINLINE LOCOMOTIVES												
GM/EMD	GP10		567	16V	1800	1967–1977				3	3	3
	GP9		645C	16V	1800	1954–1960				7	7	7
	GP9		645C	16V	1800	1974–1981				9	9	9
	SD38-2		645E	16V	2000	1974–1976				3	3	3
	SD38		645	16V	2000	1971–1974				1	1	1
	GP38		645	16V	2000	1970–1986			3	1	4	4
	GP38-AC/QEG		645	16V	2000	1970–1971		4				4
	GP35-2		645	16V	2000	1963–1966				1	1	1
	GP38-2		645	16V	2000	1972–1986			8	17	25	25
	GP38-2		645E	16V	2000	1970–1972				3	3	3
	GP38-2		645E	16V	2000	1974–1979				2	2	2
	GP38-2/QEG		645E	16V	2000	1973–1986				1	1	1
	GP38-2/ZTR		645E	16V	2000	1986		1				1
	GP38-3		645E	16V	2000	1971–1973		3		6	6	9
	GP38-3		645E	16V	2000	1981–1986		5		17	17	22
	GP39-2		645	16V	2300	1974–1984				4	4	4
	GP35-3		645	16V	2500	1963–1966				3	3	3
	GP40		645	16V	3000	1975–1987				1	1	1
	GP40-2		645	16V	3000	1972–1986		27	3	16	19	46
	GP40-2R		645E3B	16V	3000	1966–1969				1	1	1
	GP40-3		645	16V	3000	1966–1968				6	6	6
	GP40-3		645	16V	3100	1966–1968				2	2	2
	SD40-2		645E3	16V	3000	1972–1990	1994–1995	43	13	35	48	91
	SD40-2/QEG		645E3	16V	3000	1978–1985		2		1	1	3
	SD40-3		645E3B	16V	3000	1966–1972		9	7	8	15	24
	SD40		645	16V	3200	1966–1972				1	1	1
	SD45-T2		645E3	20V	3600	1972–1975				1	1	1
	SD60		710	16V	3800	1985–1989		43				43
	SD70-ACE		710	16V	4000	1995–2000			21		21	21
	SD75-I		710G3C	16V	4300	1996–1999			5		5	5
	GP38-2	Tier 0	645E	16V	2000	1972–1986		10				10
	GP40-2	Tier 0	645	16V	3000	1972–1979		21				21
	SD40-2	Tier 0	645E3	16V	3000	1978–1990		16				16
	SD60	Tier 0	710	16V	3800	1985–1989	2002–2005	1				1
	SD70-I	Tier 0	710	16V	4000	1996–1999		7				7
	SD75-I	Tier 0	710	16V	4300	1996–1999	2002–2005	63				63
	SD90-MAC	Tier 0	710	16V	4300	1998			5		5	5
	GP38-AC	Tier 0+	645	16V	2000	1970–1971		1				1
	GP38-AC/QEG	Tier 0+	645	16V	2000	1970–1971		1				1
	SD40-3	Tier 0+	645	16V	3000	1966–1972	2012	17				17
	SD40-3	Tier 0+	645	16V	3000	1981–1984		6				6
	SD40-2	Tier 0+	645E3	16V	3000	1978–1985	2012		6		6	6
	SD40-2	Tier 0+	645E3	16V	3000	1990–1999	2012	30				30
	GP40-2	Tier 0+	645	16V	3000	1972–1986	2012	11				11
	GP40-3	Tier 0+	645E3	16V	3000	1969		1				1
	SD60	Tier 0+	710	16V	3800	1985–1989	2002–2012	46				46
	SD70-I	Tier 0+	710G3B	16V	4000	1995–1999		19				19
	SD75-I	Tier 0+	710	16V	4300	1996–1999	2002–2012	108				108
	SD70-ACE	Tier 2	710	16V	4000	2010–2018		4				4
	SD70-M2	Tier 2	710G3C	16V	4300	2005–2007		115				115
	SD70-M2	Tier 2+	710	16V	4300	2005–2011	2013	75				75
GM/EMD Sub–Total								**689**	**71**	**150**	**221**	**910**

OEM	Model	USEPA Tier Level	Engine	Cylinders	hp	Year of Manufacture	Year of Remanufacture	Total Class 1	Regional	Short Lines	Total Regional and Short Lines	Total Freight Fleet
MAINLINE LOCOMOTIVES												
GE	B23-7		7FDL12	12V	2000	1979				2	2	2
	B23-7		7FDL12	12V	2250	1979–1980				2	2	2
	Dash 8-40CM		7FDL16	16V	4000	1990–1992				3	3	3
	Dash 8-40CM	Tier 0	7FDL16	16V	4000	1990–1992		1				1
	Dash 9-44CW	Tier 0	7FDL16	16V	4400	1994–1999	2001–2003	8	11		11	19
	AC4400CW	Tier 0	7FDL16	16V	4400	1995–1999		8	12		12	20
	AC4400CW	Tier 0	7FDL16	16V	4400	2000–2001				2	2	2
	Dash 8-40CM	Tier 0+	7FDL16	16V	4400	1990–1992	2011–2012	81				81
	C40-8	Tier 0	7FDL16	16V	4000	1989–1991		10				10
	C40-8	Tier 0+	7FDL16	16V	4000	1989–1991		134				134
	AC4400CW	Tier 1	7FDL16	16V	4400	2002–2004		1	9		9	10
	Dash 9-44CW	Tier 1+	7FDL16	16V	4400	1994–2004	2011–2012	204				204
	AC4400CW	Tier 1+	7FDL16	16V	4400	1995–2001		121				121
	AC4400CW	Tier 1+	7FDL16	16V	4400	2002–2004		113				113
	AC4400CW	Tier 2	7FDL16	16V	4400	2005–2007			12		12	12
	ES44AC	Tier 2	GEVO12	16V	4360	2005–2011		79	2		2	81
	ES44DC	Tier 2	GEVO12	16V	4400	2005–2008		56				56
	ES44AC	Tier 2+	GEVO12	16V	4360	2005–2011	2012	95				95
	ES44DC	Tier 2+	GEVO12	16V	4400	2005–2008		69				69
	ES44AC	Tier 3	GEVO12	16V	4365	2012		30				30
	EA4400AC	Tier 3	GEVO12	16V	4400	2012		125				125
	ES44AC	Tier 4	GEVO12	16V	4400	2015–2016		81				81
	ET44AC	Tier 4	GEVO12	16V	4400	2015–2016		159				159
GE Sub–Total								**1375**	**46**	**9**	**55**	**1430**
MLW	RS-18		251	12V	1800	1954–1958				4	4	4
	M420(W)		251	12V	2000	1971–1975				3	3	3
	M420R (W)		251	12V	2000	1971–1975				2	2	2
MLW Sub–Total								**0**	**0**	**9**	**9**	**9**
FREIGHT MAINLINE SUB–TOTAL								**2064**	**117**	**168**	**285**	**2349**
ROAD SWITCHERS												
	GMD-1		645	12V	1200	1958–1960		17				17
	GP9-RM		645	16V	1800	1950–1959		20				20
	SD38-2		645E	16V	2000	1975		1				1
	GP38-2		645E	16V	2000	1974–1986		58				58
	GP38-2-QEG		645	16V	2000	1973–1986		35				35
	GMD-1	Tier 0+	645	12V	1200	1958–1960		1				1
	GP38-2	Tier 0	645E	16V	2000	1972–1986	2010–2011	1				1
	GP9-RM	Tier 0+	645	16V	1800	1950–1959		1				1
	GP20	Tier 0+	710	8V	2000	2013–2014		86				86
	GP38	Tier 0+	645	16V	2000	1970–1986		29				29
	GP38-2-QEG	Tier 0+	645	16V	2000	1974–1986		38				38
	SD38-2	Tier 0+	645	16V	2000	1975	2012	2				2
GM/EMD Road Switchers Sub–Total								**289**	**0**	**0**	**0**	**289**
ROAD SWITCHERS SUB–TOTAL								**289**	**0**	**0**	**0**	**289**
TOTAL MAINLINE FREIGHT								**2353**	**117**	**168**	**285**	**2638**

Appendix B-2
2017 Locomotive Fleet — Freight Yard Switching & Work Train Operations

OEM	Model	USEPA Tier Level	Engine	Cylinders	HP	Year of Manufacture	Year of Remanufacture	Total Class 1	Regional	Short Lines	Total Regional and Short Lines	Total Freight Fleet
GM/ EMD	SW900		567	8V	900	1954–1965				13	13	13
	SW1200		567	12V	1200	1955–1962				2	2	2
	SW1200-RB		645	12V	1200	1957		1				1
	SW1500		567	12V	1500	1966–1974				8	8	8
	MP15		645	16V	1500	1976				5	5	5
	GP7		567	16V	1500	1949–1954	1980–1988			2	2	2
	SW14		567	12V	1400	1950				1	1	1
	GP15		645	16V	1500	1973–1979				3	3	3
	GP9		645	16V	1700	1960	1980–1981			1	1	1
	GP9		645	16V	1750	1951–1959		88	2	4	6	94
	GP9		645	16V	1750	1960–1973			1	7	8	8
	GR35-2		645	16V	2000					4	4	4
	GP38-2		645	16V	2000	1972–1973				11	11	11
	SD38-2		645	16V	2000	1974–1976		27				27
	SD40-2/QEG		645E3	16V	3000	1979–1985		3				3
	GP20-ECO	Tier 0+	710	8V	2000	2000–2001	2011	4				4
	GP38-2	Tier 0+	645	16V	2000	1972–1986	2012	1				1
GM/EMD Sub-Total								**124**	**3**	**61**	**64**	**188**
GE	44T		Cummins		300	1947				1	1	1
GE Sub-Total								**0**	**0**	**1**	**1**	**1**
MLW	S-13		251	6V	900	1959–1960				2	2	2
	S-13		251	6V	1000	1959–1960	1978			1	1	1
	RS-18		251	12V	1800	1954–1958				3	3	3
	RS-23		251	18V	1000	1959–1960				3	3	3
MLW Sub-Total								**0**	**0**	**9**	**9**	**9**
ALCO	S-6		251	6V	900	1953				1	1	1
ALCO Sub-Total								**0**	**0**	**1**	**1**	**1**
Other	YBU					1980–1983		57				31
	HBU					1978–1980		22				12
	Modesto Empire								5		5	5
	Slug									4	4	4
Other Sub-Total								**79**	**5**	**4**	**9**	**88**
YARD SWITCHING & WORK TRAIN TOTAL								**203**	**8**	**76**	**84**	**287**

Appendix B-3
2017 Locomotive and DMU Fleet — Passenger Train Operations

OEM	Model	USEPA Tier Level	Engine	Cylinders	HP	Year of Manufacture	Year of Remanufacture	Intercity Rail	Commuter	Tourist & Excursion	Total
PASSENGER TRAIN LOCOMOTIVES											
GM/EMD	GMD-1		567	12V	1200	1958				1	1
	GP9		567	16V	1750	1950-1960				1	1
	GP9		645	16V	1800	1954-1972				1	1
	FP40-PH2		645	16V	3000	1987-1989		52			52
	GP40		645	16V	3000	1970-1979				9	9
	F40-PHR		645	16V	3000	1977-1978		3			3
	F59-PH		710	12V	3000	1988-1994			16		16
	F59-PHI		710	12V	3000	1995	2000-2001		16		16
GM/EMD Sub-Total								**55**	**32**	**12**	**99**
GE	LL162/162		251		990	1954–1966				11	11
	P42DC		7FDL16	16V	4250	2001		21			21
GE Sub-Total								**21**	**0**	**12**	**33**
Motive Power	MP36PH-3C		645	16V	3600	2006			1		1
	MP40PH-3C	Tier 2	710	16V	4000	2007–2013			56		56
	MP40PH-3C	Tier 3	710	16V	4000	2013–2014			10		10
	MP40PHTC-T4	Tier 4	Cummins QSK60	16V	5400	2015			1		1
Motive Power Sub-Total								**0**	**68**	**0**	**68**
Bombardier	ALP 45DP	Tier 3	MITRAC TC	12V	3600	2012			20		20
Bombardier Sub-Total								**0**	**20**	**0**	**20**
Alstom	Coradia LINT 4		Electric DMU		780	2013			6		6
Alstom Sub-Total								**0**	**6**	**0**	**6**
R&H	28-ton				165	1950				1	1
CLC	44-ton		H44A3		400	1960				1	1
GE	70-ton		FWL-6T		600	1948				1	1
BUDD	RDC-1		Cummins		600	1956–1958		1			1
BUDD	RDC-2		Cummins		600	1956–1958		3			3
BUDD	RDC-4		Cummins		600	1956–1958		2			2
ALCO	DL535		251		1200	1969				8	8
Other Sub-Total								**6**	**0**	**11**	**17**
MLW	MLW Hudson		Class H1b			1912				1	1
Baldwin	B280					1920				2	2
Baldwin Steam Engines Sub-Total								**0**	**0**	**3**	**3**
Other										2	2
Other Steam Engines Sub-Total								**0**	**0**	**2**	**2**
PASSENGER TRAIN LOCOMOTIVES SUB-TOTAL								**82**	**126**	**39**	**247**
YARD SWITCHING PASSENGER OPERATIONS											
GM/EMD	SW1000		645	8V	1000	1966–1967		2			2
Cummins	35-ton			6V	236					1	1
ALCO	DQS18		251		1800	1957				2	2
Yard Switching Passenger Operations Sub-Total								**2**	**0**	**3**	**5**
PASSENGER OPERATIONS TOTAL								**84**	**126**	**42**	**252**

Appendix C
Railways Operating in Tropospheric Ozone Management Areas

Railway Lines Included in Tropospheric Ozone Management Areas

TOMA Region No. 1: LOWER FRASER VALLEY, BRITISH COLUMBIA

CN

Division	**Subdivision**
Pacific	Squamish
	Yale

CP

Operations Service Area	**Subdivision**
Vancouver	Cascade
	Mission
	Page
	Westminster

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

TOMA Region No. 3: SAINT JOHN AREA, NEW BRUNSWICK

CN

District	**Subdivision**
Champlain	Denison
	Sussex

New Brunswick Southern	All

TOMA Region No. 2: WINDSOR-QUÉBEC CITY CORRIDOR, ONTARIO AND QUÉBEC

CN

District — **Champlain**

Subdivisions

Becancour	Rouses Point	Bridge
Sorel	Deux-Montagnes	St. Hyacinthe
Drummondville	St. Laurent	Joliette
Valleyfield	Montréal	

District — **Great Lakes**

Subdivisions

Alexandria	Grimsby	Strathroy
Caso	Halton	Talbot
Chatham	Kingston	Uxbridge
Dundas	Oakville	Weston
Guelph	Paynes	York

CP

Operations Service Area — **Montréal**

Subdivisions — All

Operations Service Area — **Southern Ontario**

Subdivisions

Belleville	Hamilton	North Toronto
Canpa	MacTier	St. Thomas
Galt	Montrose	Waterloo
Windsor		

Réseau de transport métropolitain	All
Capital Railway	All
GO Transit	All
VIA Rail Canada	Part
Essex Terminal Railway	All
Goderich – Exeter Railway	All
Ottawa Valley Railway	Part
Québec Gatineau Railway	All
Southern Ontario Railway	All
St-Lawrence & Atlantic (Canada)	All

Appendix D
Locomotive Emissions Standards in the United States

The **US Environmental Protection Agency (US EPA)** rulemaking promulgated in 1998 contains three levels of locomotive-specific emissions limits corresponding to the date of a locomotive's original manufacture – Tier 0, Tier 1, and Tier 2 (as listed below). The significance of the US EPA regulations for Canadian railways is that the new locomotives they traditionally acquire from the American locomotive original equipment manufacturers (OEM) are manufactured to meet the latest US EPA emissions limits. Hence, emissions in Canada are reduced as these new locomotives are acquired.

Compliance Schedule for US EPA Locomotive-Specific Emissions Limits *(g/bhp-hr)*[8]

Duty Cycle	HC	CO	NO_x	PM
		Tier 0 (1973–2001)		
Line-haul	1.0	5.0	9.5	0.60
Switching	2.1	8.0	14.0	0.72
		Tier 1 (2002–2004)		
Line-haul	0.55	2.2	7.4	0.45
Switching	1.2	2.5	11.0	0.54
		Tier 2 (2005 and later)		
Line-haul	0.3	1.5	5.5	0.20
Switching	0.6	2.4	8.1	0.24
		Estimated Pre-Regulation (1997) Locomotive Emissions Rates		
Line-haul	0.5	1.5	13.5	0.34
Switching	1.1	2.4	19.8	0.41

Referencing the above-listed limits for locomotives operating in the US, the US EPA in 2008 put into force revisions that tighten the existing Tier 0 to Tier 2 standards. The revisions are now referred to as Tier 0+, Tier 1+, and Tier 2+ standards. As indicated in the tables below, the revised standards also consider the year of original manufacture of the locomotive. Also, two new, more stringent standards levels were introduced, designated as Tier 3 and Tier 4. The revised and new standards are to be phased in between 2011 and 2015 for locomotives as they become new (new in this case includes both when locomotives are originally manufactured and when remanufactured). Tier 3 standards have since been implemented for the 2013 reporting year, and Tier 4 standards were implemented for the 2015 reporting year. Elaboration on the US EPA locomotive emissions regulations can be viewed on the website: https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-emissions-locomotives.

8 US EPA. Regulatory Announcement. Final Emissions Standards for Locomotives. December 1997. https://nepis.epa.gov/Exe/ZyPDF.cgi/700004EQ.PDF?Dockey=700004EQ.PDF

Line-Haul Locomotive Emission Standards (g/bhp-hr)[9]

Tier	*MY	Date	HC	CO	NO_x	PM
Tier 0+[a]	1973–1992	2011[c]	1.00	5.0	8.0	0.22
Tier 1+[a]	1993–2004[b]	2011[c]	0.55	2.2	7.4	0.22
Tier 2+[a]	2005–2011	2013[c]	0.30	1.5	5.5	0.10[d]
Tier 3[e]	2013–2014	2013	0.30	1.5	5.5	0.10
Tier 4	2015 or later	2015	0.14[f]	1.5	1.3f	0.03

a Tier 0+ to Tier 2+ line-haul locomotives must also meet switch standards of the same Tier.
b 1993–2001 locomotives that were not equipped with an intake air coolant system are subject to Tier 0+ rather than Tier 1+ standards.
c As early as 2008 if approved engine upgrade kits become available.
d 0.20 g/bhp-hr until January 1, 2013 (with some exceptions).
e Tier 3 line-haul locomotives must also meet Tier 2+ switching standards.
f Manufacturers may elect to meet a combined NO_x + HC standard of 1.4 g/bhp-hr.
* MY—Year of original manufacture

Switching Locomotive Emission Standards (g/bhp-hr)[10]

Tier	*MY	Date	HC	CO	NO_x	PM
Tier 0+	1973–2001	2011[b]	2.10	8.0	11.8	0.26
Tier 1+[a]	2002–2004	2011[b]	1.20	2.5	11.0	0.26
Tier 2+[a]	2005–2010	2013[b]	0.60	2.4	8.1	0.13[c]
Tier 3	2011–2014	2011	0.60	2.4	5.0	0.10
Tier 4	2015 or later	2015	0.14[d]	2.4	1.3[d]	0.03

a Tier 1+ and Tier 2+ switching locomotives must also meet line-haul standards of the same Tier.
b As early as 2008 if approved engine upgrade kits become available.
c 0.24 g/bhp-hr until January 1, 2013 (with some exceptions).
d Manufacturers may elect to meet a combined NO_x + HC standard of 1.3 g/bhp-hr.
* MY—Year of original manufacture

9 Part IV Environmental Protection Agency. 40 CFR Parts 9, 85, et al. Control of Emissions of Air Pollution From Locomotive Engines and Marine Compression-Ignition Engines Less Than 30 Liters per Cylinder; Republication; Final Rule. June 30, 2008. https://www.govinfo.gov/content/pkg/FR-2008-06-30/pdf/R8-7999.pdf

10 Part IV Environmental Protection Agency. 40 CFR Parts 9, 85, et al. Control of Emissions of Air Pollution From Locomotive Engines and Marine Compression-Ignition Engines Less Than 30 Liters per Cylinder; Republication; Final Rule. June 30, 2008. https://www.govinfo.gov/content/pkg/FR-2008-06-30/pdf/R8-7999.pdf

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).

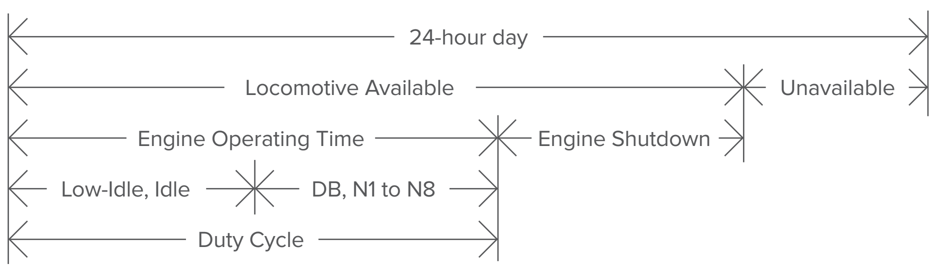
Locomotive Prime Movers: The diesel engine is the prime mover of choice for locomotives in operation on Canadian railways. Combustion takes place in a diesel engine by compressing the fuel and air mixture until auto-ignition occurs. It has found its niche as a result of its fuel-efficiency, reliability, ruggedness, and installation flexibility. Two diesel prime mover installation arrangements are currently in use:

Medium-speed diesel engine: This engine is installed in versions from 8 to 16 cylinders at up to 4,400 hp, with an operating speed of 800 to 1,100 rpm.

Multiple 'GenSet' diesel engines: This "stand alone" generating set (GenSet) is each powered by a 700 hp industrial diesel engine driving separate generators, which are linked electronically to produce up to 2,100 traction horsepower, with an operating speed up to 1,800 rpm. For switching locomotive applications, the advantage of this arrangement is that individual GenSet engines can be started or stopped according to the power required.

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).

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 Emissions

Emission Factors (in grams or kilograms per litre of diesel fuel consumed)

Emission Factors for the Criteria Air Contaminants (NO_X, CO, HC, PM, SO_X) in g/L are found in **Table 10**.

Emission Factors for Sulphur Dioxide (SO_2) for 2015:

Freight Railways (15.0 ppm sulphur in fuel)	0.000025 kg / L

Emission Factors for Greenhouse Gases:

Carbon Dioxide	CO_2	2.68100 kg / L[1]
Methane	CH_4	0.00015 kg / L
Nitrous Oxide	N_2O	0.00100 kg / L
Hydrofluorocarbons[2]	HFC	
Perfluorocarbons[2]	PFC	
Sulphur hexafluoride[2]	SF_6	
CO_{2e}[3] of all six GHGs		2.98275 kg / L
Global Warming Potential for	CO_2	1
Global Warming Potential for	CH_4	25
Global Warming Potential for	N_2O	298

(1) CO_2 emission factor was updated in 2016

(2) Not present in diesel fuel

(3) Sum of constituent Emissions Factors multiplied by their Global Warming Potentials

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

Metrics Relating Railway Emissions and Operations

Emissions in this report are displayed both as an absolute amount and as 'intensity,' which is either a ratio that relates a specific emission to productivity or units of work performed. An example of emissions intensity metrics is the ratio NO_X per 1,000 RTK; which is the mass in kilograms of NO_X emitted per 1,000 revenue tonne-kilometres of freight hauled.

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 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

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
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

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
NRCAN	Natural Resources Canada.
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