Railway Association of Canada

RIGHT TRACK

LOCOMOTIVE EMISSIONS MONITORING REPORT 2018

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Review Notice

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

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Executive Summary

Introduction

The Locomotive Emissions Monitoring Program (LEM) data filing for 2018 has been completed in accordance with the terms of the 2018–2022 Memorandum of Understanding (the MOU) signed on March 21, 2019, between the Railway Association of Canada (RAC) and Transport Canada (TC) concerning the emissions of greenhouse gases (GHGs) and criteria air contaminants (CACs) from locomotives operating in Canada. This is the first report prepared under the MOU, though it is based on reporting for the LEM program governed by MOUs dating back to 1995.

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

2018 - 2022 MOU Targets

Railway Operation	Percent Reduction Target (by 2022)	Base Year	Productivity Unit
Class 1 Freight	6% reduction from 2017	2017 reported GHG intensity	kg CO_2e per 1,000 revenue tonne kilometres
Intercity Passenger	6% reduction from 2017	2017 reported GHG intensity	kg CO_2e per passenger kilometre
Regional & Shortlines	3% reduction from 2017	2017 reported GHG intensity	kg CO_2e per 1,000 revenue tonne kilometres

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

2018–2022 MOU Progress

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

Class 1 Freight GHG emissions intensity decreased by 0.80%, representing 13% progress towards the MOU target of a 6% reduction. Intercity Passenger GHG emissions intensity decreased by 0.66%,

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

resulting in 11% progress towards the MOU target of a 6% reduction. Regional and Shortline GHG intensity increased by 6.69% in 2018, as the decrease in RTKs was greater than the reduction in fuel usage (and emissions).

The following table presents the GHG emission intensity targets for 2018–2022 and railway emission performance for baseline (2017) and reporting (2018) years, as expressed in kilograms (kg) of carbon dioxide equivalent (CO_2e) per productivity unit:

2018 Railway Performance Relative to GHG Reduction Targets

Railway Operation	Productivity Unit	2017	2018	2022 Target	Change from 2017–2018
Class 1 Freight	kg CO_2e per 1,000 revenue tonne kilometres	13.53	13.42	12.71	0.80% decrease
Intercity Passenger	kg CO_2e per passenger kilometre	0.097	0.097	0.092	0.66% decrease
Regional & Shortlines	kg CO_2e per 1,000 revenue tonne kilometres	14.04	14.98	13.62	6.69% increase

LEM 2018 Additional Key Findings

Railway Traffic

Freight Traffic

- **Gross Tonne-Kilometres (GTK):**
  In 2018, the railways handled 864.66 billion GTK of traffic as compared to 823.45 billion GTK in 2017, representing an increase of 5.0%. GTK traffic was 99.8% higher than it was in 1990, the reference year, having increased by a compound annual growth rate (CAGR) of 2.5%. Class 1 GTK traffic accounted for 94.9% of the total GTK hauled in 2018.
- **Revenue Tonne-Kilometres (RTK):**

  In 2018, the railways handled 455.72 billion RTK of traffic as compared to 435.46 billion RTK in 2017, representing an increase of 4.7%. RTK traffic was 95.2% higher than it was in 1990, the reference year, having risen by a CAGR of 2.4%. Of the freight RTK traffic handled in 2018, Class 1 freight railways were responsible for 95.1% of the total traffic.
- **Intermodal Traffic**

  Intermodal tonnage increased by 0.2% to 39.22 million tonnes in 2018 from 39.13 million tonnes in 2017. Overall, intermodal tonnage comprising both container-on-flat-car and trailer-on-flat-car traffic for railways in Canada has risen 77% since 1999, equating to an CAGR of 3.1%.

Passenger Traffic

- Intercity passenger traffic in 2018 by all carriers totalled 5.03 million passengers compared to 4.65 million in 2017, an increase of 8.2%.

- Commuter rail traffic increased from 79.35 million passengers in 2017 to 82.79 million in 2018, an increase of 4.3%. This represents an increase of 102% from 1997, the first year RAC collected commuter railway statistics in Canada.
- In 2018, six RAC member railways reported Tourist and Excursion traffic totalling 321 thousand passengers, an increase of 4.0% above the 309 thousand passengers transported in 2017.

Fuel Consumption Data

Fuel Consumption:

- Fuel consumed by railway operations in Canada increased by 3.9% from 2,157.98 million litres in 2017 to 2,242.19 million litres in 2018.
- Of the total fuel consumed by all railway operations, Class 1 freight train operations consumed 87.0% and Regional and Short Lines consumed 5.0%. Yard switching and work train operations consumed 2.6%, and passenger operations accounted for 5.4%.
- For freight operations, the overall fuel consumption in 2018 was 2,120.46 million litres, 4.0% above the 2017 level of 2,039.28.
- For total freight operations, fuel consumption per productivity unit (litres per 1,000 RTK) in 2018 was 4.65 litres per 1,000 RTK, representing an improvement of 0.6% from 2017. This is down from 8.40 litres per 1,000 RTK in 1990, an improvement of 44.6%.
- For total passenger operations, the overall fuel consumption in 2018 was 121.72 million litres, 2.5% above the 2017 level of 118.70.

Diesel Fuel Properties:

- The sulphur content of railway diesel fuel in Canada is regulated at 15 parts per million (ppm). Renewable fuel content for diesel fuel sold and imported in Canada is also regulated, mandating at least 2% biodiesel and/or HDRD (hydrogenation-derived renewable diesel) content. Some provinces, such as Ontario and British Columbia, require a minimum renewable fuel content of 4%.

Locomotive Inventory

Locomotive Fleet:

- The reported number of diesel-powered locomotives and diesel multiple units (DMUs) in active service in Canada belonging to RAC member railways totalled 3,782 in 2018 versus 3,177 in 2017.[2] Significant new acquisitions of Tier 3 and 4 locomotives occurred in 2018.
- For freight operations in 2018, 3,521 locomotives were in service, of which 2,531 were on Class 1 Mainline, 195 were on Class 1 Road Switching service, 130 were owned by regional railways and

2 The active fleet is reported as it existed on December 31st of each year. As the data represents the fleet on one particular day in the calendar year, significant year-over-year fluctuations are possible.

166 were owned by Short Lines. A further 499 were in Switching and Work Train operations, of which 409 were in Class 1 service and 90 in Regional and Short lines. A total of 261 locomotives and DMUs were used in 2018 to support passenger railway operations in Canada, of which 75 were for intercity-passenger services, 144 for Commuter railway services, and 39 for Tourist and Excursion services. There were 3 locomotives in Passenger Switching operations in 2018, all by Tourist and Excursion Services railways.

Locomotives Compliant with USEPA Emission Limits:

In 2018, 92.6% of the total regulated fleet met emission standards (as set out under the *Locomotive Emissions Regulations* or the United States Environmental Protection Agency (USEPA) Regulations). 30 Tier 3 and 30 Tier 4 high-horsepower locomotives were added to the Class 1 freight line-haul fleet; a total of 93 Class 1 freight line-haul locomotives were upgraded to Tier 1+; and 108 medium-horsepower locomotives manufactured between 1973 and 1999 were retired from Class 1s and four non-tiered locomotive were retired from other railways.

Locomotives Equipped with Anti-Idling Devices:

The number of locomotives in 2018 equipped with a device to minimize unnecessary idling, such as an AESS system or APU, was 2,168, which represents 57.3% of the fleet, compared with 2,195 in 2017.[3]

Tropospheric Ozone Management Areas (TOMA):

Of the total GHGs emitted by the railway sector in 2018, 2.3% occurred in the Lower Fraser Valley of British Columbia, 13.0% in the Windsor-Québec City Corridor, and 0.1% in the Saint John area of New Brunswick. NO_X emissions for each TOMA were at the same ratios as GHGs.

Emissions Reduction Initiatives by Railways:

Railways continue to implement a number of initiatives outlined in the *Locomotive Emissions Monitoring Program Action Plan for Reducing GHG Emissions*. This action plan presents a variety of initiatives for railways, governments, and the RAC to implement to reduce GHGs produced by the railway sector in Canada.

3 The active fleet is reported as it existed on December 31st of each year. As the data represents the fleet on one particular day in the calendar year, significant year-over-year fluctuations are possible.

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Appendices

1 Introduction

This report contains the Locomotive Emissions Monitoring (LEM) data filing for 2018 in accordance with the terms of the memorandum of understanding (MOU) signed on March 21, 2019, between the Railway Association of Canada (RAC) and Transport Canada (TC) concerning voluntary arrangements to limit greenhouse gas (GHG) emissions and criteria air contaminant (CAC) emissions from locomotives operating in Canada. This fourth MOU signed by RAC and the federal government since 1995 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, which can be found on the RAC website, includes measures, targets, and actions that will further reduce GHG and CAC emission intensities from rail operations to help protect the health and environment for Canadians and address climate change. This is the first report prepared under this MOU.

GHG Commitments:

As stated in the MOU, the RAC will encourage its members to improve their GHG emissions intensity from railway operations. The 2017 baseline data, the GHG emission targets for 2022 and the actual emissions from 2018, expressed as kilograms (kg) of carbon dioxide equivalent (CO_2e) per productivity unit, for the rail industry are outlined in the following table:

2018 Railway Performance Relative to GHG Reduction Targets

Railway Operation	Baseline-2017	2018	2022 Target	Change from 2017–2018	Productivity Unit
Class 1 Freight	13.53	13.42	12.71	0.80% decrease	kg CO_2e per 1,000 revenue tonne kilometres
Intercity Passenger	0.097	0.097	0.092	0.66% decrease	kg CO_2e per passenger kilometre
Regional & Shortlines	14.04	14.98	13.62	6.69% increase	kg CO_2e per 1,000 revenue tonne kilometres

Note: All values above, including the revised 2017 baselines and 2022 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 has developed regulations to control CAC emissions under the *Railway Safety Act*. The *Locomotive Emissions Regulations* came into force on June 9, 2017 and apply to railway companies that the federal government regulates.[4] The Canadian regulations are aligned with the United States Environmental Protection Agency (US EPA) emission regulations *(Title 40 of the Code of Federal Regulations of the United States, Part 1033).*

4 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, RAC encouraged all members to conform to the US EPA emission standards and to adopt operating practices aimed at reducing CAC emissions. RAC continues to encourage its members, including those not covered by the *Locomotive Emissions Regulations* (LER), to improve their CAC emissions performance, specifically nitrogen oxides (NO_X), particulate matter (PM), carbon monoxide (CO), hydrocarbons (HC), and sulphur oxides (SO_X). Through this Memorandum, the RAC will continue to report on annual CAC emissions, in a manner and format that is agreeable to all parties, with a view to leverage the data railways provide under the regulations. CAC reporting under the MOU does not fulfill reporting requirements under the LER.

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 2018 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 2017 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 the number of significant digits reflected in the table. To facilitate comparison with American railway operations, traffic, fuel consumption, and emissions data in US (imperial) units are available upon request to the RAC.

2 Traffic Data

2.1 Freight Traffic Handled

As shown in **Table 1** and **Figure 1**, traffic in 2018 handled by Canadian railways totalled 864.66 billion gross tonne-kilometres (GTK) compared with 823.45 billion GTK in 2017, an increase of 5.0%, and 432.74 billion GTK for 1990 (the reference year) for an increase of 99.8%. Revenue traffic in 2018 increased to 455.72 billion revenue tonne-kilometres (RTK) from 435.46 billion RTK in 2017 and is up from 233.45 billion RTK in 1990—an increase of 4.7% and 95.2%, respectively. Since 1990, the compound annual growth rate (CAGR) was 2.5% for GTK and 2.4% for RTK.

Table 1. Total Freight Traffic, 1990, 2006–2018*
Tonne-kilometres (billion)

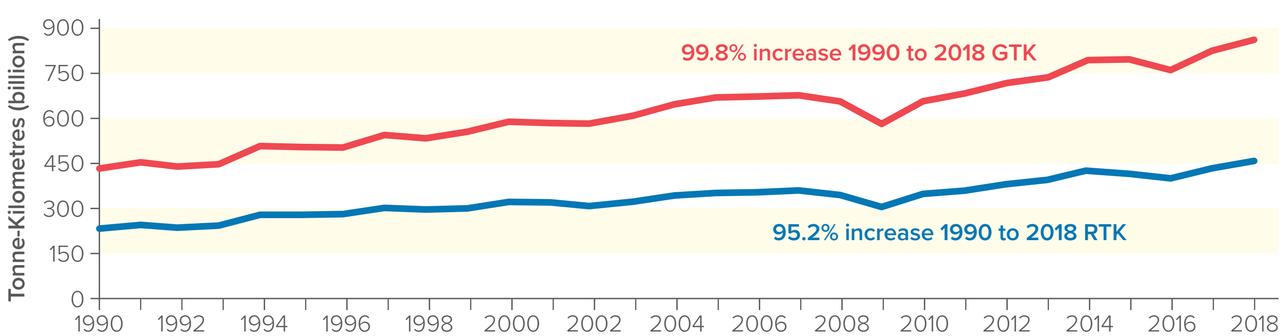
	1990	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
GTK														
Class I		629.93	638.66	621.90	549.17	620.16	644.75	674.62	695.58	754.24	752.30	722.33	778.86	820.67
Regional + Short Line		41.07	37.77	34.92	30.82	32.57	34.79	37.32	39.62	39.19	42.09	44.07	44.59	43.98
Total	**432.74**	**671.00**	**676.43**	**656.82**	**579.99**	**652.73**	**679.54**	**711.94**	**735.19**	**793.43**	**794.39**	**766.40**	**823.45**	**864.66**
RTK														
Class I		330.96	338.32	324.99	288.82	327.81	337.91	356.92	371.77	399.47	394.10	383.47	411.22	433.45
Regional + Short Line		24.87	23.30	21.46	19.06	21.44	22.25	23.08	24.23	23.01	23.98	25.05	24.25	22.27
Total	**233.45**	**355.83**	**361.62**	**346.46**	**307.88**	**349.24**	**360.16**	**380.00**	**396.00**	**422.49**	**418.08**	**408.53**	**435.46**	**455.72**
Ratio of RTK/GTK(1)	**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**	**0.53**

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

* GTK and RTK figures have been revised for the period from 2010 to 2017 where necessary to address findings of internal data quality reviews and more accurately reflect historical variances in freight traffic by RAC members. Please see **Appendix I** for further details.

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

Figure 1. Total Freight Traffic, 1990–2018



In 2018, Class 1 GTK traffic increased by 5.4% to 820.67 billion from 778.86 billion in 2017 (**Table 1**) and accounted for 94.9% of the total GTK hauled. Class 1 RTK traffic increased by 5.4% in 2018 to 433.45 billion from 411.22 billion in 2017 and accounted for 95.1% of the total RTK. Of the total freight traffic in 2018, regional and shortlines were responsible for 43.98 billion GTK (or 5.1%) and 22.27 billion RTK (or 4.9%). In 2018, regional and shortlines traffic experienced an 8.1% decrease in RTK compared to 2017 and a decrease of 1.3% of their GTK traffic.

2.1.1 Freight Carloads by Commodity Grouping

The total 2018 freight carloads for 11 commodity groups are shown in **Figure 2** and **Table 2** below.

Figure 2. Canadian Rail Originated Carloads by Commodity Grouping, 2018

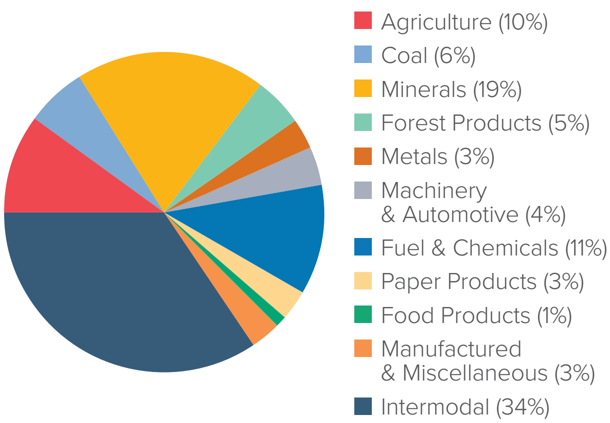


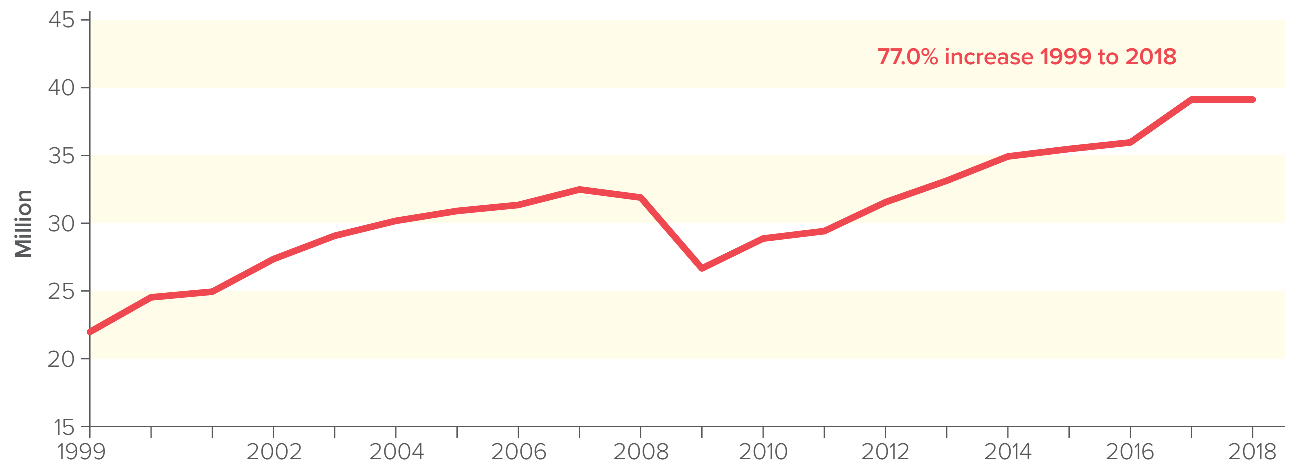
Table 2. Canadian Rail Originated Carloads by Commodity Grouping, 2018
Carloads

Agriculture	542,722
Coal	337,323
Minerals	1,060,395
Forest Products	260,377
Metals	178,784
Machinery & Automotive	214,592
Fuel & Chemicals	622,769
Paper Products	140,822
Food Products	78,864
Manufactured & Miscellaneous	181,935
Intermodal	1,878,392
Total	**5,496,976**

2.1.2 Intermodal Traffic

Of the total freight carloads in 2018, intermodal made up the largest share at 34.2%, as illustrated by **Figure 2** and **Table 2** above. The number of intermodal carloads handled by railways in Canada increased to 1,878,392 from 1,828,225 in 2017, an increase of 2.7%. Intermodal tonnage increased slightly by 0.2% to 39.22 million tonnes from 39.13 million tonnes in 2017. Overall, since 1999, intermodal tonnage, comprising both container-on-flat-car and trailer-on-flat-car traffic, has risen 77.0%, equating to an average annual growth of 3.1%, as illustrated in **Figure 3**.

Figure 3. Intermodal Tonnage, 1999–2018



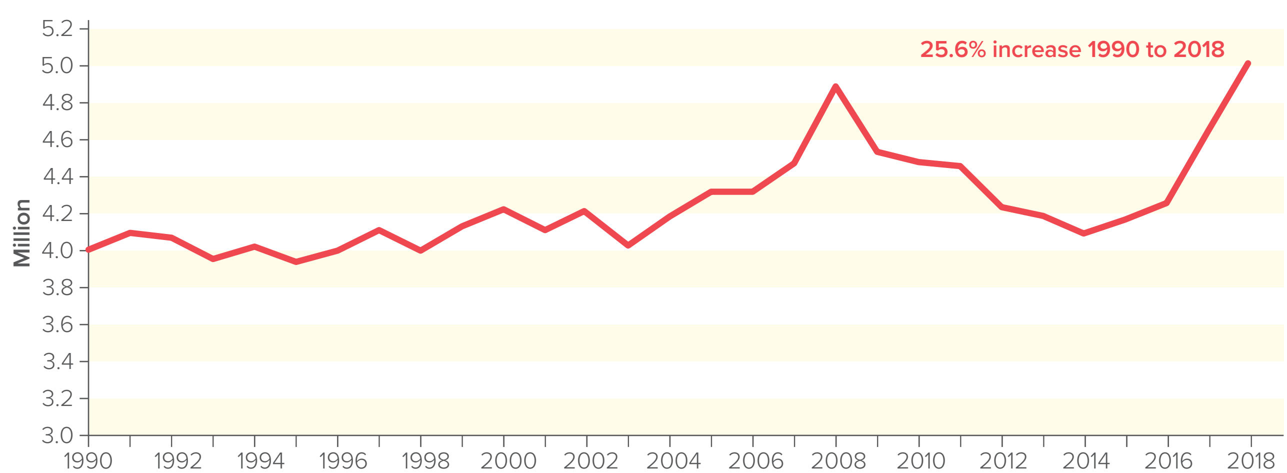
Intermodal service growth is an indication that the Canadian railways have been effective in partnering with shippers and other elements of the transportation supply chain, such as trucking, to move more goods by rail. Full accounting of the growth in intermodal traffic across the transportation supply chain would be required to assess the full impact of this shift.

2.2 Passenger Traffic Handled

2.2.1 Intercity Passenger Services

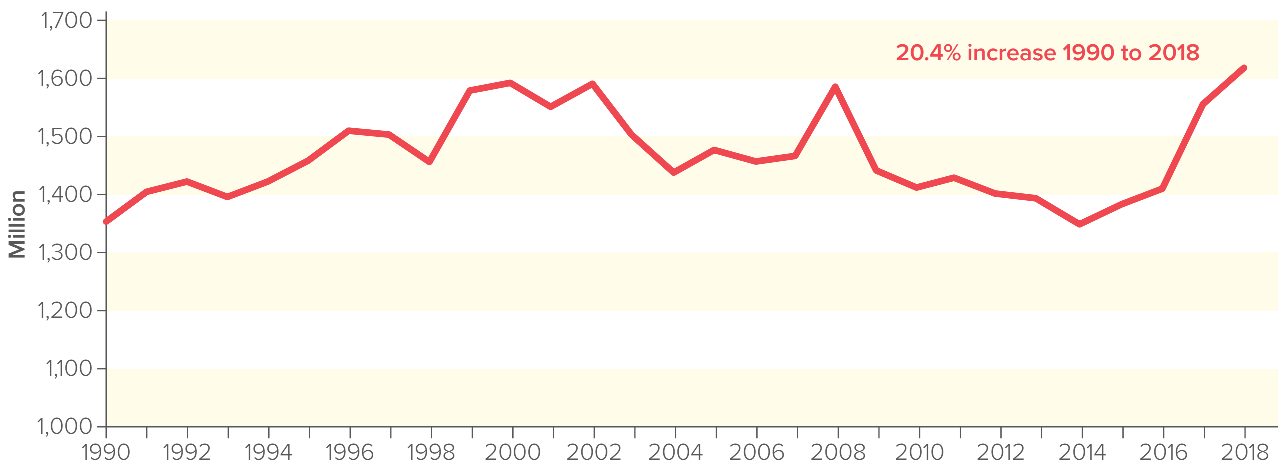
Intercity passenger traffic in 2018 totalled 5.03 million passengers, as compared to 4.65 million passengers in 2017, an increase of 8.2%, and a 25.6% increase from 4.00 million passengers in 1990 (**Figure 4**).

Figure 4. Intercity Rail Passenger Traffic, 1990–2018



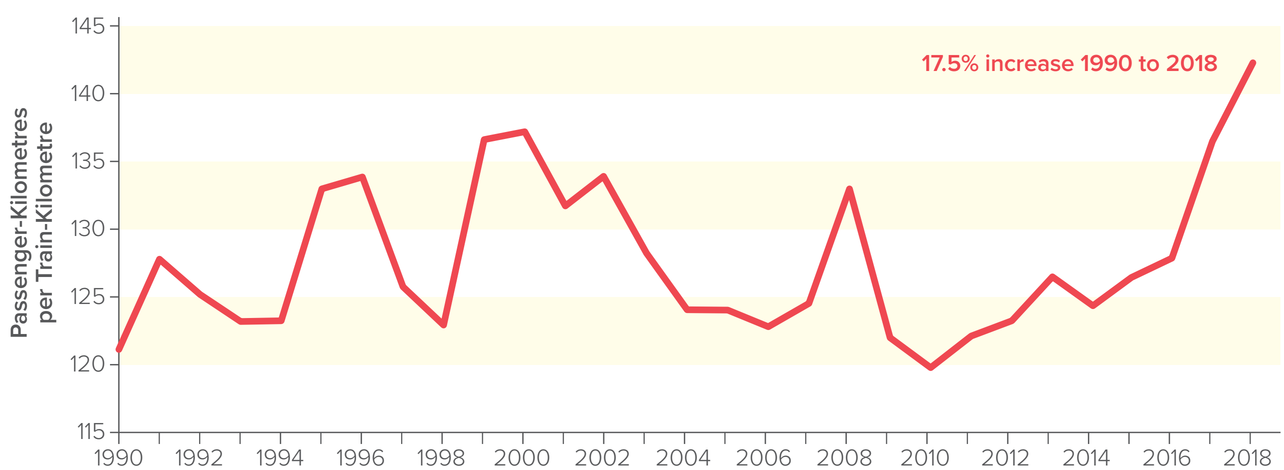
The total revenue passenger-kilometres (RPK) for intercity passenger traffic totalled 1,626.36 million. This is an increase of 4.1% as compared to 1,562.13 million in 2017 and 20.4% increase from 1,350.71 million in 1990 (**Figure 5**).

Figure 5. Intercity Rail Revenue Passenger-Kilometres, 1990–2018



Intercity train efficiency is expressed in terms of average passenger-kilometres (km) per train-km. As shown in **Figure 6**, intercity rail train efficiency in 2018 was 142.19 passenger-km per train-km, 136.71 in 2017, and 121.04 in 1990. As a percentage, train efficiency in 2018 was 17.5% above that in 1990.

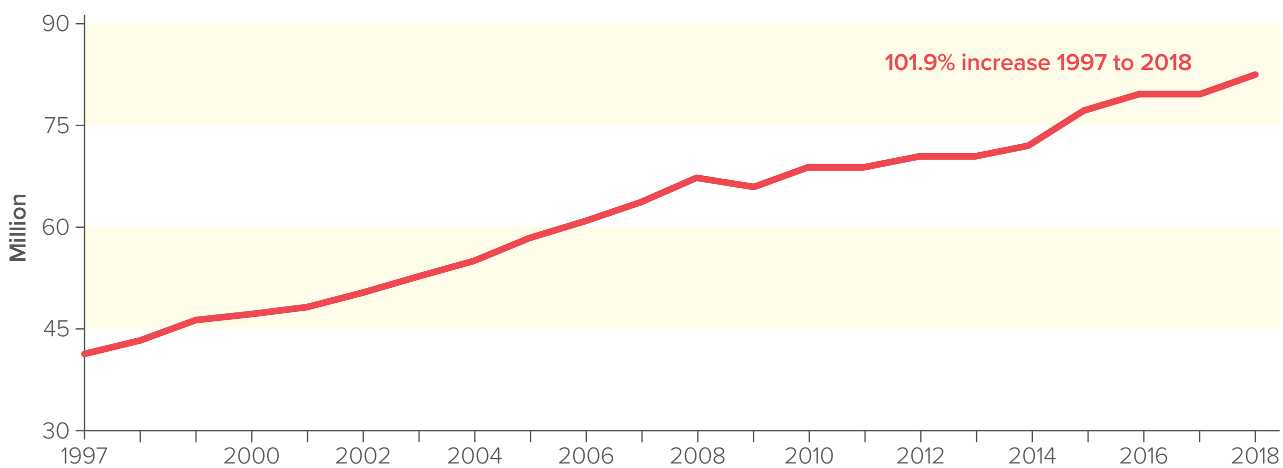
Figure 6. Intercity Train Efficiency, 1990–2018



2.2.2 Commuter Rail

In 2018, commuter rail passengers totalled 82.79 million (**Figure 7**). This is up from 79.35 million in 2017, an increase of 4.3%. As shown in **Figure 7**, by 2018, commuter traffic increased 102% over the 1997 base year of 41.00 million passengers when the RAC first started to collect commuter rail statistics. This is a CAGR of 3.4% since 1997. The four commuter operations in Canada using diesel locomotives and/or Diesel Multiple Units (DMUs) are exo serving the Montréal-centred region (previously Réseau de transport métropolitain), Capital Railway serving Ottawa, Metrolinx serving the Greater Toronto Area, and West Coast Express serving the Vancouver-Lower Fraser Valley region.

Figure 7. Commuter Rail Passengers, 1997–2018



2.2.3 Tourist and Excursion Services

In 2018, the six RAC member railways offering tourist and excursion services transported 321 thousand passengers compared to 309 thousand in 2017, an increase of 4.0%. The railways reporting these services were Alberta Prairie Railway Excursions, Great Canadian Railtour Company, Prairie Dog Central Railway, South Simcoe Railway, Train Touristique de Charlevoix and White Pass & Yukon.

3 Fuel Consumption Data

As shown in **Table 3**, total rail sector fuel consumption increased to 2,242.19 million litres in 2018 from 2,157.98 million litres in 2017 and 2,063.55 million litres in 1990. As a percentage, fuel consumption in 2018 was 3.9% higher than in 2017 and 8.7% higher than the 1990 level. The higher fuel consumption reflects an increase in total freight traffic in 2018. Of the total fuel consumed by all railway operations, freight train operations consumed 92.0%, yard switching and work train operations consumed 2.6%, and passenger operations accounted for 5.4%. For total freight train operations fuel consumption, Class 1 railways accounted for 92.0%, regional and shortlines 5.3%, and yard switching and work trains 2.8%.

Table 3. Canadian Rail Operations Fuel Consumption, 1990, 2006–2018*
Litres (million)

	1990	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Class 1	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	1,949.92
Regional & Shortline	n/a*	122.13	117.89	113.12	90.01	104.65	107.91	96.55	101.72	108.91	105.45	101.83	114.15	111.88
Total Freight Train	**1825.05**	**2,037.05**	**2,066.64**	**2,016.00**	**1,716.48**	**1,895.76**	**1,924.35**	**1,972.39**	**1,951.29**	**2,027.18**	**1,958.43**	**1,834.03**	**1,978.98**	**2,061.80**
Yard Switching	120.13	64.67	62.20	55.52	40.73	34.47	44.79	46.85	41.77	62.02	52.97	46.95	50.29	51.56
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	7.10
Total Yard Switching and Work Train	**135.80**	**72.16**	**68.29**	**63.13**	**46.70**	**41.53**	**52.51**	**55.62**	**52.07**	**72.82**	**64.32**	**57.79**	**60.30**	**58.66**
TOTAL FREIGHT OPERATIONS	**1,960.85**	**2,109.21**	**2,134.92**	**2,079.13**	**1,763.18**	**1,937.28**	**1,976.86**	**2,028.01**	**2,003.36**	**2,100.00**	**2,022.75**	**1,891.82**	**2,039.28**	**2,120.46**
Intercity – Total	n/a*	64.25	64.03	64.27	63.50	58.11	58.63	50.99	46.17	44.89	46.98	47.93	51.02	52.77
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	65.74
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	3.22
Total Passenger Operations	**102.70**	**101.29**	**102.30**	**105.99**	**108.00**	**107.08**	**110.63**	**103.48**	**97.03**	**97.16**	**110.13**	**110.15**	**118.70**	**121.72**
TOTAL RAIL OPERATIONS	**2,063.55**	**2,210.50**	**2,237.24**	**2,185.12**	**1,871.18**	**2,044.37**	**2,087.50**	**2,131.49**	**2,100.39**	**2,197.17**	**2,132.88**	**2,001.97**	**2,157.98**	**2,242.19**

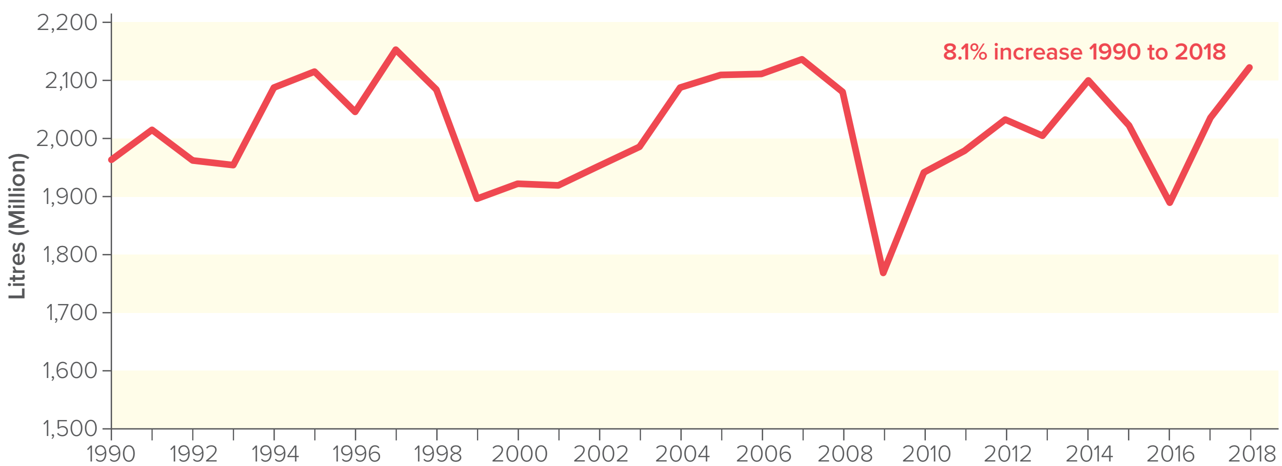
n/a* = not available

* Fuel figures have been revised for the period from 2010 to 2017 where necessary to address findings of internal data quality reviews and more accurately reflect historical variances in fuel use by RAC members. Please see **Appendix I** for further details.

3.1 Freight Operations

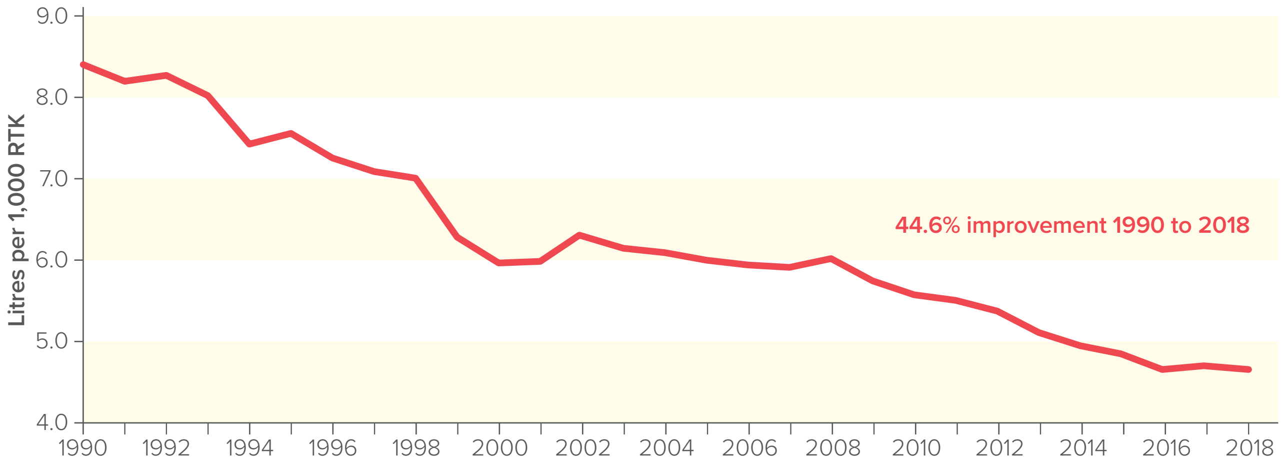
The volume of fuel consumption since 1990 in overall freight operations is shown in **Figure 8**. Fuel consumption in 2018 for all freight train, yard switching, and work train operations was 2,120.46 million litres, an increase of 4.0% from the 2,039.28 million litres consumed in 2017 and an increase of 8.1% 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 215 kilometres on just one litre of fuel.

Figure 8. Freight Operations Fuel Consumption, 1990–2018



The amount of fuel consumed per 1,000 RTK can be used as a measure of freight traffic fuel efficiency. As shown in **Figure 9**, the value in 2018 for overall rail freight traffic was 4.65 litres per 1,000 RTK. This value is a 0.6% decrease (an improvement) from the 4.68 litres per 1,000 RTK in 2017 and is 44.6% 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 9. Freight Fuel Consumption per 1,000 RTK, 1990–2018



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 2018 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 121.72 million litres in 2018, an increase of 2.5% from the 118.70 million litres consumed in 2017. The breakdown and comparison with previous years is shown in **Table 3**.

Intercity passenger's fuel consumption increased by 3.4% from 51.02 million litres in 2017 to 52.77 million litres in 2018. Fuel consumption for commuter rail increased by 2.0% from 64.46 million litres in 2017 to 65.74 million litres in 2018. Finally, tourist rail excursion fuel consumption remained steady at 3.22 million litres in 2017 and 2018.

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 (Fatty Acid Methyl Ester – FAME) and hydrogenation-derived renewable diesel (HDRD), which Canadian railways have been actively using. HDRD 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 HDRD in their locomotives but there have been some challenges regarding performance and concerns over exceeding OEM warranties.

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 blends of lignin-derived diesel fuel with petroleum diesel. As of 2018, this work has produced the goal of producing a 5% blend of lignin in diesel that meets CGSB 3.18 locomotive fuel specifications.[5] This work continues as a part of Transport Canada's 2019-2021 rail research work plan; the next target is a 10% lignin in diesel blend that meets CGSB 3.18 specifications. Following that, blends greater than 10% will be explored.

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 and manufacturers are working through issues stemming from higher blend rates. Currently, blend rates higher than 5% may cause adverse operational impacts and void some OEM warranties.

5 Lignin-derived "drop-in" renewable diesel fuels for rail applications, Canmet (NRCan) for the Innovation Centre Transport Canada), 2019 https://tcdocs.ingeniumcanada.org/sites/default/files/2020-02/Lignin-derived%20drop-in%20renewable%20diesel%20fuels%20for%20rail%20applications.PDF

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 hydrotreating 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.

4 Locomotive Inventory

4.1 Fleet Overview

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

Table 4. Canadian Locomotive Fleet Summary, 2018

Freight Operations	
Locomotives for Line Haul Freight	
Class I Mainline	2,531
Regional	130
Short line	166
Locomotives for Freight Switching Operations	
Yard	499
Road Switching	195
Total — Freight Operations	**3,521**
Passenger Operations	
Passenger Train	234
DMUs	24
Yard Switching	3
Total — Passenger Operations	**261**
TOTAL — PASSENGER & FREIGHT OPERATIONS	**3,782**

4.2 Locomotives Meeting Emission Standards

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

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

Table 5 shows the total number of in-service locomotives meeting emission standards[6] 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.

6 The emission standards include the following Tier levels: Tier 0, Tier 0+, Tier 1, Tier 1+, Tier 2, Tier 2+, Tier 3 and Tier 4

Table 5. Locomotives in Canadian Fleet Meeting US EPA Emissions Limits, 2000, 2006–2018

	2000	2006	2007	2008	2009	2010[c]	2011[c]	2012[c]	2013[c]	2014[c]	2015[c]	2016[c]	2017	2018
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	3,233
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	549
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	2,995

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 2018, 92.6% of the total line-haul fleet subject to regulation (2,995 locomotives of 3,233) met emissions standards (set-out under the LER or the US EPA regulations). The LER and US EPA emission standards have been phased in over time and are applicable only to "new" locomotives (i.e., originally manufactured and remanufactured locomotives). Locomotives manufactured prior to 1973 and that have not been upgraded and locomotives below 1,006 horsepower (hp) are not required to meet the LER and US EPA emission regulations. The remaining locomotive fleet is not required to meet the emission standards until the time of its next remanufacture.

Table 6 provides an overview of the 2018 locomotive fleet and includes details about the number of locomotives meeting each tier level.

Table 6. Locomotive Fleet Breakdown by US EPA Tier Level, 2018

Not required to meet regulation[a]	549
Meeting regulation – Non Tier-Level Locomotives	175
Tier 0	364
Tier 0+	954
Tier 1	208
Tier 1+	470
Tier 2	334
Tier 2+	279
Tier 3	246
Tier 4	203
TOTAL	**3,782**

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 2018, 30 Tier 3 and 30 Tier 4 high-horsepower locomotives were added to the Class 1 freight line-haul fleet. A total of 93 Class 1 freight line-haul locomotives were upgraded to Tier 1+, 108 medium-horsepower locomotives manufactured between 1973 and 1999 were retired from Class 1s, and four non-tiered locomotives were retired from other railways.

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 2018 equipped with a device to minimize unnecessary idling such as an Automatic Engine Stop-Start (AESS) system or Auxiliary Power Unit (APU) was 2,168 compared with 2,195 in 2017. This represents 57.3% of the total in-service fleet in 2018.

Table 7. Changes in Locomotive Fleet by Tier Level, 2018[a]

	Added	Retired	Remanufactured	Locomotives with anti-idling devices
Not upgraded		11(7)		77(0)
Tier 0		72(72)		455(453)
Tier 0+		3(3)		0(0)
Tier 1				568(547)
Tier 1+		26(26)	93(93)	110(110)
Tier 2				538(534)
Tier 2+				0(0)
Tier 3	30(30)			236(236)
Tier 4	30(30)			184(184)
TOTAL	**60(60)**	**112(108)**	**93(93)**	**2,168(2,064)**

a The figures in parenthesis represent the Class 1 freight 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 1990–2018: Greenhouse Gas Sources and Sinks in Canada*, which is submitted annually to the United Nations Framework Convention on Climate Change (UNFCCC).[7]

Emission Factors for Criteria Air Contaminant Emissions:

CAC EFs for 2018 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). PM, and HC EFs for freight operations increased in 2018 compared to 2017. This was due to the make-up of the locomotive fleet. EFs for passenger and yard operations stayed the same or decreased in 2018 compared to 2017. The CAC EFs are estimated based on the active fleet on December 31.

The EFs to calculate emissions of SO_X (calculated as SO_2) are based on the sulphur content of the diesel fuel. 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.

7 National Inventory Report 1990–2018: Greenhouse Gas Sources and Sinks in Canada, Environment and Climate Change Canada, 2020 http://publications.gc.ca/collections/collection_2020/eccc/En81-4-2018-2-eng.pdf

The CAC EFs are listed in **Table 8** for 1990 and 2006–2018. EFs for years prior to 2006 are available upon request to the RAC.

Table 8. CAC Emissions Factors for Diesel Locomotives 1990, 2006–2018 (g/L)

	Year	NO_X	PM	CO	HC	SO_2
Freight: Line haul	2018	34.56	0.78	7.02	1.54	0.02
	2017	34.79	0.72	7.04	1.46	0.02
	2016	38.17	0.78	7.05	1.54	0.02
	2015	39.50	0.81	7.13	1.68	0.02
	2014	41.40	0.90	7.07	1.81	0.02
	2013	44.41	1.01	7.05	2.00	0.02
	2012	46.09	1.09	7.05	2.13	0.07
	2011	47.50	1.15	7.03	2.21	0.17
	2010	49.23	1.23	7.06	2.38	0.21
	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	2018	56.67	1.18	7.35	3.33	0.02
	2017	69.14	1.50	7.35	4.01	0.02
	2016	65.68	1.46	7.35	3.92	0.02
	2015	68.38	1.48	7.35	3.96	0.02
	2014	68.93	1.50	7.35	3.99	0.02
	2013	68.79	1.50	7.35	4.01	0.02
	2012	69.19	1.52	7.35	4.03	0.07
	2011	69.64	1.53	7.35	4.06	0.17
	2010	69.65	1.54	7.35	4.06	0.21
	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	2018	54.37	1.11	7.03	2.10	0.02
	2017	56.34	1.15	7.03	2.19	0.02
	2016	54.05	1.11	7.03	2.12	0.02
	2015	48.96	1.00	7.03	1.91	0.02
	2014	54.58	1.14	7.03	2.18	0.02
	2013	51.64	1.06	7.03	2.03	0.02
	2012	54.04	1.13	7.03	2.17	0.07
	2011	54.94	1.16	7.02	2.19	0.18
	2010	56.23	1.18	7.03	2.23	0.21
	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

5.2.1 Greenhouse Gases

In 2018, GHG emissions produced by the railway sector (expressed as CO_2e) were 6,687.88 kt, an increase of 3.9% as compared to 6,436.72 kt in 2017. The 2018 emissions have increased by 8.7% from 6,155.06 kt in 1990 (with a rise in RTK traffic of 95.2% over the same period). The GHG emissions intensities for freight traffic decreased in 2018 to 13.88 kg per 1,000 RTK from 13.97 kg in 2017, and 25.05 kg in 1990. As a percentage, the GHG emissions intensity for total freight in 2018 was 44.6% 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, 2006–2018*
(in kilotonnes unless otherwise specified)

	1990	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Total Railway														
CO_2e	6,155.06	6,593.38	6,673.12	6,517.67	5,581.27	6,097.84	6,226.47	6,357.71	6,264.94	6,553.60	6,361.85	5,971.37	6,436.72	6,687.88
CO_2	5,532.38	5,926.36	5,998.03	5,858.31	5,016.64	5,480.95	5,596.57	5,714.54	5,631.15	5,890.61	5,718.25	5,367.28	5,785.55	6,011.30
CH_4	7.74	8.29	8.39	8.19	7.02	7.67	7.83	7.99	7.88	8.24	8.00	7.51	8.09	8.41
N_2O	614.94	658.73	666.70	651.17	557.61	609.22	622.07	635.19	625.92	654.76	635.60	596.59	643.08	668.17
Passenger — Intercity, Commuter, Tourist/Excursion														
CO_2e	306.33	302.12	305.14	316.14	322.13	319.40	329.99	308.66	289.42	289.82	328.49	328.54	354.05	363.07
CO_2	275.34	271.56	274.27	284.16	289.55	287.09	296.60	277.43	260.14	260.50	295.26	295.31	318.23	326.34
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	0.46
N_2O	30.60	30.18	30.49	31.59	32.18	31.91	32.97	30.84	28.92	28.95	32.82	32.82	35.37	36.27
Freight-Line Haul														
CO_2e	5,443.66	6,076.01	6,164.28	6,013.23	5,119.82	5,654.57	5,739.86	5,883.16	5,820.20	6,046.57	5,841.51	5,470.45	5,902.80	6,149.83
CO_2	4,892.95	5,461.33	5,540.67	5,404.90	4,601.88	5,082.52	5,159.18	5,287.99	5,231.40	5,434.87	5,250.55	4,917.03	5,305.65	5,527.69
CH_4	6.84	7.64	7.75	7.56	6.44	7.11	7.22	7.40	7.32	7.60	7.34	6.88	7.42	7.73
N_2O	543.86	607.04	615.86	600.77	511.51	564.94	573.46	587.77	581.48	604.10	583.61	546.54	589.74	614.42
Yard Switching and Work Train														
CO_2e	405.08	215.24	203.70	188.30	139.31	123.87	156.63	165.90	155.32	217.21	191.85	172.38	179.87	174.98
CO_2	364.10	193.47	183.09	169.25	125.21	111.34	140.78	149.11	139.61	195.24	172.44	154.94	161.67	157.27
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	0.22
N_2O	40.47	21.50	20.35	18.81	13.92	12.38	15.65	16.57	15.52	21.70	19.17	17.22	17.97	17.48
Total Freight Operations														
CO_2e	5,848.73	6,291.25	6,367.98	6,201.52	5,259.13	5,778.43	5,896.49	6,049.06	5,975.52	6,263.79	6,033.36	5,642.83	6,082.67	6,324.81
CO_2	5,257.05	5,654.80	5,723.76	5,574.15	4,727.09	5,193.86	5,299.97	5,437.10	5,371.01	5,630.11	5,423.00	5,071.97	5,467.32	5,684.96
CH_4	7.35	7.91	8.01	7.80	6.61	7.26	7.41	7.61	7.51	7.88	7.59	7.09	7.65	7.95
N_2O	584.33	628.55	636.21	619.58	525.43	577.31	589.10	604.35	597.00	625.80	602.78	563.76	607.71	631.90
Emissions Intensity — Total Freight (kg/1,000 RTK)														
CO_2e	25.05	17.68	17.61	17.90	17.08	16.55	16.37	15.92	15.09	14.83	14.43	13.81	13.97	13.88
CO_2	22.52	15.89	15.83	16.09	15.35	14.87	14.72	14.31	13.56	13.33	12.97	12.42	12.56	12.47
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	0.02
N_2O	2.50	1.77	1.76	1.79	1.71	1.65	1.64	1.59	1.51	1.48	1.44	1.38	1.40	1.39

Table 9. GHG Emissions and Emission Intensities by Railway Service in Canada 1990, 2006–2018*
(in kilotonnes unless otherwise specified) *(continued)*

	1990	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
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	13.42
Emissions Intensity — Regional and Short Line Freight (kg/1,000 RTK)														
CO_2e	n/a*	14.65	15.09	15.72	14.08	14.56	14.47	12.48	12.52	14.12	13.11	12.12	14.04	14.98
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	0.097	0.097
Emissions Intensity — Commuter Rail (kg/Passenger)														
CO_2e	n/a*	1.68	1.69	1.68	1.93	2.04	2.17	2.09	2.01	1.95	2.34	2.23	2.42	2.37

* GHG emissions and emissions intensities have been revised for the period from 2010 to 2017 based on revisions to fuel usage and RTKs. Please see **Appendix I** for further details.

n/a* = indicates not available

The MOU sets out targets to be achieved in 2022 for GHG emissions intensities by category of railway operation. In relation to the 2022 targets, **Table 10** shows the GHG emissions intensity levels for Class 1 freight, intercity passenger, and regional and shortlines for 2018.

Table 10. GHG Emissions Intensities by Category of Operation

Railway Operation	Units	Baseline – 2017	2018	2022 Target	Change from 2017–2018
Class I Freight	kg CO_2e/1,000 RTK	13.53	13.42	12.71	0.80% decrease
Intercity Passenger	kg CO_2e/passenger-km	0.097	0.097	0.092	0.66% decrease
Regional and Shortlines	kg CO_2e/1,000 RTK	14.04	14.98	13.62	6.69% increase

Note: All values above, including the revised 2017 baselines and 2022 targets, have been calculated based on the new emission factors and global warming potentials. Historical values have been updated from previous reports where necessary.

In 2018, Class 1 freight railways were able to better match locomotive power to freight traffic compared to 2017 with a decrease in emissions intensity of 0.80% below the 2017 value for line haul operations.

Intercity saw a 0.66% decrease in emissions intensity relative to 2017. As previously stated, commuter railways do not have a GHG emissions intensity target under the MOU.

Regional and shortlines saw a 6.69% increase in GHG intensity relative to 2017, as their reduction in RTKs was greater than the reduction in fuel usage.

5.2.2 Criteria Air Contaminants[8]

Table 11 displays the CAC emissions produced annually by locomotives in operation in Canada for the reference year (1990) and annually from 2006 to 2018, 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 2018 totalled 81.14 kt. Freight operations accounted for 91.9% of railway-generated NO_X emissions in Canada.

The total freight NO_X emissions intensity (i.e., the quantity of NO_X emitted per unit of productivity) was 0.16 kg per 1,000 RTK in 2018. This represents a 2.4% decrease from the 2017 figure and is down from 0.52 kg per 1,000 RTK in 1990, a 68.6% reduction.

Table 11. Locomotive CAC Emissions, 1990, 2006–2018*
(in kilotonnes, unless otherwise noted)

Operation	Year	NO_X	PM	CO	HC	SO_2 (tonnes)
Freight: Line haul	2018	71.25	1.61	14.48	3.18	50.81
	2017	68.84	1.43	13.93	2.89	48.77
	2016	70.01	1.42	12.94	2.82	45.20
	2015	77.35	1.59	13.96	3.28	48.27
	2014	83.92	1.82	14.34	3.66	49.96
	2013	86.65	1.98	13.76	3.90	48.09
	2012	90.91	2.14	13.91	4.20	129.97
	2011	91.41	2.21	13.53	4.25	327.14
	2010	93.32	2.32	13.38	4.51	402.39
	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	2018	3.32	0.07	0.43	0.20	1.45
	2017	4.17	0.09	0.44	0.24	1.49
	2016	3.80	0.08	0.42	0.23	1.42
	2015	4.40	0.10	0.47	0.25	1.59
	2014	5.02	0.11	0.54	0.29	1.79
	2013	3.58	0.08	0.38	0.21	1.28
	2012	3.85	0.08	0.41	0.22	3.66
	2011	3.66	0.08	0.39	0.21	8.93
	2010	2.89	0.06	0.31	0.17	8.81
	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
Total Passenger	2018	6.56	0.13	0.85	0.25	2.97
	2017	6.63	0.14	0.83	0.26	2.90
	2016	5.89	0.12	0.77	0.23	2.69

8 In previous years, it was noted that there were some inconsistencies among member datasets regarding the application of rated horsepower of various locomotives. RAC is working with members to confirm hp ratings for their fleets, but there may still be some inconsistencies in the locomotive inventory used to calculate CACs. Additionally, emissions figures have been revised for the period from 2010 – 2017 to reflect revisions to historical fuel consumption as noted in **Table 3**. Further evaluations of CAC methodology are ongoing.

Table 11. Locomotive CAC Emissions, 1990, 2006–2018*
(in kilotonnes, unless otherwise noted) *(continued)*

Operation	Year	NO_x	PM	CO	HC	SO_2 (tonnes)
	2015	5.33	0.11	0.77	0.21	2.69
	2014	5.24	0.11	0.68	0.21	2.37
	2013	4.95	0.10	0.67	0.19	2.12
	2012	5.51	0.12	0.72	0.22	6.72
	2011	5.99	0.13	0.77	0.24	19.17
	2010	5.94	0.12	0.74	0.24	22.43
	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(1)	2018	74.58	1.68	14.91	3.38	52.26
	2017	73.01	1.52	14.37	3.13	50.26
	2016	73.80	1.51	13.36	3.05	46.63
	2015	81.75	1.69	14.43	3.54	49.85
	2014	88.94	1.93	14.87	3.95	51.76
	2013	90.23	2.05	14.14	4.11	49.37
	2012	94.75	2.23	14.32	4.42	133.63
	2011	95.06	2.29	13.91	4.47	336.07
	2010	96.22	2.39	13.68	4.68	411.20
	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(2)	2018	81.14	1.81	15.76	3.63	55.23
	2017	79.64	1.66	15.20	3.38	53.16
	2016	79.70	1.63	14.13	3.28	49.31
	2015	87.08	1.80	15.20	3.75	52.54
	2014	94.18	2.04	15.55	4.16	54.12
	2013	95.19	2.16	14.82	4.30	51.50
	2012	100.26	2.34	15.03	4.64	140.35
	2011	101.06	2.42	14.68	4.71	355.24
	2010	102.16	2.51	14.43	4.92	433.63
	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)	2018	0.16	0.0037	0.033	0.0074	0.00011
	2017	0.17	0.0035	0.033	0.0072	0.00012
	2016	0.18	0.0037	0.033	0.0075	0.00011
	2015	0.20	0.0040	0.035	0.0085	0.00012
	2014	0.21	0.0046	0.035	0.0094	0.00012
	2013	0.23	0.0052	0.036	0.0104	0.00012
	2012	0.25	0.0059	0.038	0.0116	0.00035
	2011	0.26	0.0064	0.039	0.0124	0.00093
	2010	0.28	0.0068	0.039	0.0134	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

* CAC emissions have been revised for the period from 2010 to 2017 based on revisions to fuel usage. Please see **Appendix I** for further details.

(1) Total Freight Operations = Freight: Line Haul + Total Yard Switching
(2) Total Railway Operations = Total Freight Operations + Total 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, 2006–2018*

	1999	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Lower Fraser Valley, B.C.	4.2	2.8	3.0	2.8	3.0	3.1	2.8	2.9	2.9	2.2	2.3	2.5	2.4	2.3
Windsor–Québec City Corridor	17.1	16.8	17.4	17.1	15.7	15.3	14.8	14.3	14.2	14.1	14.1	14.0	13.8	13.0
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	0.2	0.1

Table 13. TOMA Total NO_X Emissions as Percentage of All Rail Operations in Canada, 1999, 2006–2018

	1999	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Lower Fraser Valley, B.C.	4.4	2.8	2.9	2.8	2.9	3.1	2.8	2.9	2.9	2.3	2.3	2.5	2.4	2.3
Windsor–Québec City Corridor	17.8	17.4	16.6	16.8	15.1	15.3	14.8	14.4	14.2	14.1	14.1	14.0	13.8	13.0
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	0.2	0.1

* TOMA Fuel, GHG, and CAC shares have been revised for the period from 2010 to 2017 based on revisions to fuel usage and GTK. Please see **Appendix I** for further details.

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.

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 2018 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 2018

		Seasonal Split	
	Total 100%	Winter 58%	Summer 42%
TRAFFIC		Million GTK	
CN	10,632	6,167	4,466
CP	8,608	4,993	3,615
Southern Rail of BC	263	153	111
TOTAL FREIGHT TRAFFIC	**19,504**	**11,312**	**8,192**
FUEL CONSUMPTION		Million Litres	
Freight operations			
Freight Fuel Rate (L/1,000 GTK) = 2.45(1)			
Total Freight Fuel Consumption	**47.83**	**27.74**	**20.09**
Passenger Fuel Consumption			
VIA Rail Canada	0.44	0.26	0.19
Great Canadian Railtours	2.92	1.69	1.23
West Coast Express	1.32	0.76	0.55
Total Passenger Fuel Consumption	**4.68**	**2.71**	**1.96**
TOTAL RAIL FUEL CONSUMPTION	**52.51**	**30.45**	**22.05**
EMISSIONS		Kilotonnes/Year	
Emission Factors (g/L)(2)			
NO_X: 36.20	1.90	1.10	0.80
PM: 0.81	0.04	0.02	0.02
CO: 7.03	0.37	0.21	0.16
HC: 1.62	0.09	0.05	0.04
SO_2: 0.02	0.00	0.00	0.00
CO_2: 2,681(3)	140.78	81.65	59.13
CH_4: 3.75(3)	0.20	0.11	0.08
N_2O: 298(3)	15.65	9.08	6.57
CO_2e: 2,982.75(3)	156.62	90.84	65.78

(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 2018

		Seasonal Split	
	Total 100%	Winter 58%	Summer 42%
TRAFFIC		**Million GTK**	
CN	58,434	33,892	24,542
CP	18,051	10,470	7,582
Essex Terminals	35	20	15
Goderich & Exeter	396	229	166
Québec Gatineau	1,053	611	442
Southern Ontario	171	99	72
St-Lawrence & Atlantic (Canada)	271	157	114
TOTAL FREIGHT TRAFFIC	**78,411**	**45,478**	**32,933**
FUEL CONSUMPTION		**Million Litres**	
Freight operations			
Freight Fuel Rate (L/1,000 GTK) = 2.45[1]			
Total Freight Fuel Consumption	**192.29**	**111.53**	**80.76**
Passenger Fuel Consumption			
VIA Rail Canada	33.73	19.57	14.17
Commuter Rail	64.42	37.37	27.06
Total Passenger Fuel Consumption	**98.16**	**56.93**	**41.23**
TOTAL RAIL FUEL CONSUMPTION	**290.45**	**168.46**	**121.99**
EMISSIONS		**Kilotonnes/Year**	
Emission Factors (g/L)[2]			
NO_X: 36.20	10.52	6.10	4.42
PM: 0.81	0.23	0.14	0.10
CO: 7.03	2.04	1.18	0.86
HC: 1.62	0.47	0.27	0.20
SO_2: 0.02	0.01	0.00	0.00
CO_2: 2,681[3]	778.70	451.64	327.05
CH_4: 3.75[3]	1.09	0.63	0.46
N_2O: 298[3]	86.55	50.20	36.35
CO_2e: 2,982.75[3]	866.34	502.48	363.86

(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 16. TOMA No. 3 — Saint John Area, New Brunswick Traffic, Fuel and Emissions Data 2018

	Total 100%	Seasonal Split Winter 58%	Summer 42%
TRAFFIC		Million GTK	
CN	647	375	272
New Brunswick Southern Railway	650	377	273
Total Freight Traffic	**1,297**	**752**	**545**
FUEL CONSUMPTION		Million Litres	
Freight Operations			
Freight Fuel Rate (L/1,000 GTK) = 2.45[1]			
Total Freight Fuel Consumption	**3.18**	**1.84**	**1.34**
Passenger Fuel Consumption			
Total Passenger Fuel Consumption	**0**	**0**	**0**
Total Rail Fuel Consumption	**3.18**	**1.84**	**1.34**
EMISSIONS		Kilotonnes/Year	
Emission Factors (g/L)[2]			
NO_X: 36.20	0.12	0.07	0.05
PM: 0.81	0.00	0.00	0.00
CO: 7.03	0.02	0.01	0.01
HC: 1.62	0.01	0.00	0.00
SO_2: 0.02	0.00	0.00	0.00
CO_2: 2,681[3]	8.53	4.95	3.58
CH_4: 3.75[3]	0.01	0.01	0.01
N_2O: 298[3]	0.95	0.55	0.40
CO_2e: 2,982.75[3]	9.49	5.50	3.98

(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

Canadian National Railway — 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 2018, CN continued investing in HPTA (a system which works to optimize a locomotive's horsepower to tonnage ratio) and through their fleet renewal strategy, they acquired 200 new high horsepower locomotives equipped with Energy Management Systems. The growth of the renewable fuel market has also presented an important opportunity for CN to further reduce our emissions by using biodiesel blends in their locomotive fleet. In 2018, the use of renewable fuels in their fleet saved almost 100,000 tonnes of carbon.

Transport Canada — Innovation Centre

The Innovation Centre has a RD&D branch dedicated to advancing rail technologies in the areas of Safety, Ground hazards, Human Factors, and Clean Air. The Clean Air RD&D program's goal is to advance the readiness of technologies that would enable the rail industry to reduce its emissions, and to carry out the research needed to support industry's ability to use them safely. Because this program is designed to enable industry's opportunity to use new technologies, they play a leading role informing the technologies that are advanced. Notable updates for 2018 are:

- **Research on lignin-derived drop-in diesel replacement fuel:** Research on the production of renewable diesel fuel from lignin, a waste product from forestry and agriculture industries, continued this year. This project achieved a 5% lignin in diesel blend that met all CGSB 3.18 fuel specifications. Work continues to produce a 10% blend that meets these specifications.
- **Scan of Rail Technologies for Reducing Emissions:** A project to consult with the broad spectrum of rail industry; rail operators, OEMs, transit operators, academia, and technology consultants was launched this year. This project, in partnership with CUTRIC, will highlight the most promising technologies for reducing rail emissions that warrant further research and development in an effort to make them commercially ready.

The ideas and innovation at universities are an important part of technology development. Transport Canada supplied grant funding to universities across Canada that are working on clean rail technologies. The projects that received grants conducted research in the following areas:

- Hydrogen as a locomotive fuel, including the preparation of a rail speeder to be used to test various configurations of hydrogen fuel cells, batteries, and the power control systems, and other projects to model fuel cell temperature and explore hydrogen as a hybrid powertrain
- Research into the design, and durability of, materials that could be used to create lighter weight railcars, and coatings to reduce friction

Canadian Pacific Railway Company – Trip Optimizer and Locomotive Modernization Program

Since 2009, CP has actively installed Trip Optimizer (TO) technology on high-horsepower road haul locomotives. Effectively a sophisticated locomotive cruise control optimized for fuel economy, TO equipped locomotives enable trip planning to significantly reduce fuel and energy consumption. TO takes into account factors such as train length, weight, and track grade to determine the optimal speed profile for a given portion of track. TO systems have been demonstrated to effectively reduce locomotive fuel consumption and corresponding GHG emissions by an average 5%. As of 2019, CP estimates that TO technology will result in an annual GHG emissions savings of over 70,000 tonnes of carbon.

The Locomotive Modernization program is a multi-year fleet renewal program at CP. Starting in 2017 through 2019 CP upgraded and retrofitted 171 locomotives to meet operational needs. Locomotive modernization includes technology upgrades, advanced EPA diesel engines, enhanced cooling and improved traction systems. All units will be equipped with GE Trip Optimizer and Distributed Power which are both EPA certified fuel/emissions reduction technologies. By the end of 2019, approximately 25 percent of CP's active line haul fleet was upgraded as part of modernization program, having a direct and positive impact on CP's fuel efficiency and corresponding GHG and air pollutant emissions. A conservative estimate of emissions reductions associated with this project have been calculated based on a fuel efficiency guarantee of 2.7% as provided by our equipment vendor. It is anticipated that the combined effect of locomotive upgrades coupled with installed fuel saving technology will result in a realized fuel savings beyond 2.7%. Modernized locomotives currently in service through 2019 were estimated to have reduced GHG emissions by over 11,000 tonnes of carbon annually.

Genesee and Wyoming Canada – Smart Start

In 2018, GW Canada installed approximately 20 APU's and two Smart Start systems.

VIA Rail Canada – Improved Energy Efficiency and Reduced Fuel Consumption

In 2018, VIA has improved energy and carbon efficiency by training and coaching their Locomotive Engineers (LEs) to reduce train idling and improve fuel efficiency. They have also invested in energy efficiency of buildings, by upgrading lighting fixtures, air conditioning and boiler systems. Through their Automatic Engine Start-Stop project, VIA is reducing the amount of fuel consumed as well as the exhaust emissions. Overall fuel consumption during idling times was reduced by 21.7% since 2012.

8 Summary and Conclusions

The 2018 Locomotive Emissions Monitoring Report highlights that Canadian railways are continuing to reduce their GHG emissions intensities. Reductions in year 1 of the MOU have demonstrated progress towards MOU targets. Class 1 Freight GHG emissions intensities decreased by 0.80%, representing 13% progress towards target; and Intercity Passenger emissions intensities decreased by 0.66%, representing 11% progress towards target. Regional & shortline GHG emissions intensities increased by 6.69%. GHG emissions from all railway operations in Canada totalled 6,687.88 kt in 2018, which is an increase of 3.9% from 6,436.72 kt in 2017. This increase primarily reflects an increase in traffic in both the freight and passenger sectors.

For total freight operations, the GHG emissions intensity (in kg CO_2e per 1,000 RTK) decreased by 0.6% from 13.97 in 2017 to 13.88 in 2018. Compared to 25.05 in 1990, 2018 performance reflects a 44.6% improvement.

CAC emissions from all railway operations increased, with total locomotive NO_X emissions increasing to 81.14 kt in 2018 from 79.64 kt in 2017. However, the total freight NO_X emissions intensity decreased by 2.4% to 0.16 kg/1,000RTK, and 68.6% from 1990 levels (at 0.52 kg/1,000 RTK).

In 2018, Canadian railways made substantive investments and added 30 Tier 3 locomotives to Class 1 freight and 30 Tier 4 high-horsepower locomotives to Class 1 freight. 93 Class 1 locomotives were upgraded to Tier 1+. Older and lower-horsepower locomotives continued to be retired, and in 2018, 108 locomotives were taken out of active duty by Class 1 railways.

The Canadian fleet totalled 3,782 units in 2018, of which 3,233 locomotives were subject to the emissions standards. Of the locomotives subject to the emissions standards, 92.6% (2,995) met them. Not all locomotives in Canada are required to meet emission standards. The number of locomotives equipped with APUs or AESS systems to minimize unnecessary idling totalled 2,168 or 57.3% of the in-service fleet.

Through implementation of the *Locomotive Emissions Monitoring Program Action Plan for Reducing GHG Emissions*, along with federal initiatives (e.g., Pan Canadian Framework on Clean Growth and Climate Change, Clean Fuel 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 has been replaced by the 2018–2022 MOU with new GHG intensity targets based on a 2017 baseline for Canadian-owned Class 1 freight, regional & 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.

GHG Emissions Intensities by Category of Operation

Railway Operation	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	12.71
Intercity Passenger	CO_2e per passenger-kilometre	2017 reported GHG intensity (0.097 kg CO_2e / passenger-km)	6% reduction from 2017	0.092
Regional & Shortlines	CO_2e per 1,000 revenue tonne kilometres	2017 reported GHG intensity (14.04 kg CO_2e / 1,000 RTK)	3% reduction from 2017	13.62

As with previous MOUs, CAC emissions will be reported and 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 2018.

Appendix A

RAC Member Railways Participating in the 2018–2022 MOU by Province

Railway	Provinces of Operation
Alberta Prairie Railway Excursions	Alberta
Arcelor Mittal Infrastructure Canada s.e.n.c.	Québec
Barrie-Collingwood Railway	Ontario
Battle River Railway	Alberta
BCR Properties	British Columbia
Big Sky Rail Corp.	Saskatchewan
Boundary Trail Railway Co.	Manitoba
Canadian Pacific	British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Québec
Cape Breton & Central Nova Scotia Railway	Nova Scotia
Capital Railway	Ontario
Carlton Trail Railway	Saskatchewan
Central Maine & Québec Railway Canada Inc.	Québec
Central Manitoba Railway Inc.	Manitoba
Chemin de fer Arnaud Québec	Québec
Compagnie du Chemin de Fer Lanaudiere Inc.	Québec
CN	British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Québec, New Brunswick, Nova Scotia
Essex Terminal Railway Company	Ontario
Exo	Québec
Goderich-Exeter Railway Company Ltd.	Ontario
Great Canadian Railtour Company Ltd.	British Columbia
Great Western Railway Ltd.	Saskatchewan
Hudson Bay Railway	Manitoba, Saskatchewan
Huron Central Railway Inc.	Ontario
Keewatin Railway Company	Manitoba
Kettle Falls International Railway, LLC	British Columbia
Knob Lake and Timmins Railway	Québec

Railway	Provinces of Operation
Last Mountain Railway	Saskatchewan
Metrolinx	Ontario
New Brunswick Southern Railway Company Ltd.	New Brunswick
Nipissing Central Railway Company	Ontario, Québec
Ontario Northland Transportation Commission	Ontario, Québec
Ontario Southland Railway Inc.	Ontario
Orangeville Brampton Railway	Ontario
Ottawa Valley Railway	Ontario, Québec
Prairie Dog Central Railway	Manitoba
Québec Gatineau Railway Inc.	Québec
Québec Iron Ore Inc.	Québec
Québec North Shore and Labrador Railway Company Inc.	Québec, Newfoundland and Labrador
Roberval and Saguenay Railway Company, 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
St. Lawrence & Atlantic Railroad (Québec) Inc.	Québec
Toronto Terminals Railway Company Limited, The	Ontario
Train Touritique de Charlevoix Inc.	Québec
Trillium Railway Co. Ltd.	Ontario
Tshiuetin Rail Transportation Inc.	Québec, Newfoundland and Labrador
VIA Rail Canada Inc.	British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Québec, New Brunswick, Nova Scotia
West Coast Express Ltd.	British Columbia
White Pass and Yukon Route Railroad	Yukon, British Columbia

Appendix B-1

2018 Locomotive Fleet — Freight Train Line-Haul Operations

OEM	Model	USEPA Tier Level	Engine	hp	Year of Manufacture	Class 1	Shortlines	Regional	Total Regional and Short Lines	Total Freight Fleet
MAINLINE LOCOMOTIVES										
GM/EMD	GP10		567	1800	1967–1977	0	3	0	3	3
	GP35-3		645	2500	1963–1966	0	3	0	3	3
	GP38		645	2000	1970–1979	0	1	3	4	4
	GP38-2		645	2000	1972–1986	0	14	8	22	22
	GP38-2		645	2000	1972–1973	0	7	0	7	7
	GP38-2		645	2000	1974–1979	0	1	0	1	1
	GP38-2/QEG		645	2000	1974–1986	0	2	0	2	2
	GP38-3		645	2000	1968–1973	0	8	0	8	8
	GP38-3		645	2000	1980–1989	0	15	0	15	15
	GP39-2		645	2300	1974–1979	0	2	0	2	2
	GP39-2		645	2300	1970–1973	0	2	0	2	2
	GP40		645	3000	1970–1979	0	1	0	1	1
	GP40-2		645	3000	1972–1979	0	26	0	26	26
	GP40-2		645	3000	1972–1986	0	4	0	4	4
	GP40-2		645	3000	1980–1986	0	0	3	3	3
	GP40-2R		645	3000	1966–1969	0	1	0	1	1
	GP40-3		645	3000	1966–1968	0	7	0	7	7
	GP40-3		567	3000	1966–1968	0	2	0	2	2
	GP9		645	1800	1974–1981	0	9	0	9	9
	GP9		645	1800	1954–1960	0	6	0	6	6
	SD38		645	2000	1971–1974	0	1	0	1	1
	SD38-2		645	2000	1973–1979	0	2	0	2	2
	SD40		645	3200	1973–1979	0	1	0	1	1
	SD40-2		645	3000	1970–1972	0	8	0	8	8
	SD40-2		645	3000	1973–1979	0	9	5	14	14
	SD40-2		645	3000	1972–1990	0	1	0	1	1
	SD40-2		645	3000	1978–1985	0	3	0	3	3
	SD40-2		645	3000	1980–1990	0	1	8	9	9
	SD40-2/QEG		645	3000	1978–1985	0	2	0	2	2
	SD40-3		645	3000	1966–1972	0	9	7	16	16
	SD70-ACE		710	4000	1995–2000	0	0	28	28	28
	SD75-I		710	4300	1996–1999	0	0	5	5	5
	GP40	Tier 0	645	2300	1960–1969	11	0	0	0	11
	GP40-2	Tier 0	645	2300	1960–1969	1	0	0	0	1
	GP40-2	Tier 0	645	3000	1972–1979	19	0	0	0	19
	GP40-2	Tier 0	645	2300	1973–1979	1	0	0	0	1
	GP40-2	Tier 0	645	2300	1980–1989	2	0	0	0	2
	SD40-2	Tier 0	645	3000	1973–1979	68	0	0	0	68
	SD40-2	Tier 0	645	3000	1980–1989	90	0	0	0	90
	SD60	Tier 0	710	3800	1980–1989	31	0	0	0	31
	SD70I	Tier 0	710	4000	1990–1999	4	0	0	0	4
	SD75-I	Tier 0	710	4300	1990–1999	30	0	0	0	30
	SD90-MAC	Tier 0	710	4300	1990–1999	0	0	2	2	2
	GP40	Tier 0+	645	2300	1970–1972	3	0	0	0	3
	GP40-2	Tier 0+	645	3000	1972–1979	15	0	0	0	15
	SD30	Tier 0+	710	3000	1980–1989	23	0	0	0	23
	SD30	Tier 0+	710	3000	1970–1972	2	0	0	0	2
	SD30	Tier 0+	710	3000	1973–1979	25	0	0	0	25
	SD40-2	Tier 0+	645	3000	1980–1989	10	0	0	0	10
	SD40-2	Tier 0+	645	3000	1978–1979	0	0	4	4	4
	SD40-2	Tier 0+	645	3000	1980–1985	0	0	2	2	2
	SD40-2	Tier 0+	645	3000	1973–1979	22	0	0	0	22
	SD40-3	Tier 0+	645	3000	1960–1969	14	0	0	0	14
	SD40-3	Tier 0+	645	3000	1980–1989	8	0	0	0	8
	SD40-3	Tier 0+	645	3000	1970–1972	3	0	0	0	3
	SD60	Tier 0+	710	3800	1980–1989	74	0	0	0	74
	SD60-3	Tier 0+	710	3800	1980–1989	10	0	0	0	10
	SD70I	Tier 0+	710	4000	1995–1999	21	0	0	0	21
	SD75-I	Tier 0+	710	4300	1996–1999	125	0	0	0	125
	SD90-MAC	Tier 0+	710	3800	1990–1999	61	0	0	0	61
	SD70-ACE	Tier 2	710	4400	2010–2018	0	0	5	5	5
	SD70-M2	Tier 2	710	4300	2000–2009	20	0	0	0	20
	SD70-M2	Tier 2	710	4300	2010–2018	34	0	0	0	34
	SD70-M2	Tier 2+	710	4300	2010–2018	49	0	0	0	49
	SD70-M2	Tier 2+	710	4300	2000–2009	72	0	0	0	72
	SD70-ACE	Tier 3	710	4300	2010–2018	4	0	0	0	4
GM/EMD Sub–Total						852	151	80	231	1083

OEM	Model	USEPA Tier Level	Engine	hp	Year of Manufacture	Class 1	Shortlines	Regional	Total Regional and Short Lines	Total Freight Fleet
MAINLINE LOCOMOTIVES										
GE	B23-7		7FDL12	2000	1979	0	3	0	3	3
	Dash 8-40CM		7FDL16	4000	1990–1992	0	3	0	3	3
	AC4400CW	Tier 0	7FDL16	4400	1990–1999	19	0	0	0	19
	AC4400CW	Tier 0	7FDL16	4400	2000–2009	1	2	0	2	3
	C44-9W	Tier 0	7FDL16	4400	2000–2009	1	0	0	0	1
	Dash 9-44CW	Tier 0	7FDL16	4400	1990–1999	0	0	11	11	11
	ES44AC	Tier 0	GEVO12	4500	2000–2009	23	0	0	0	23
	C40-8	Tier 0+	7FDL16	4000	1990–1999	44	0	0	0	44
	C40-8	Tier 0+	7FDL16	4000	1980–1989	24	0	0	0	24
	C40-8M	Tier 0+	7FDL16	4000	1990–1999	73	0	0	0	73
	C44-8W	Tier 0+	7FDL16	4400	1990–1999	62	0	0	0	62
	AC4400CW	Tier 1	7FDL16	4400	2000–2009	187	0	21	21	208
	AC4400CW	Tier 1+	7FDL16	4400	1990–1999	135	0	0	0	135
	AC4400CW	Tier 1+	7FDL16	4400	2000–2009	17	0	0	0	17
	AC4400CWM	Tier 1+	7FDL16	4400	1997–1998	110	0	0	0	110
	C40-8M	Tier 1+	7FDL16	4000	1990–1999	5	0	0	0	5
	C44-9W	Tier 1+	7FDL16	4400	2000–2009	103	0	0	0	103
	C44-9W	Tier 1+	7FDL16	4400	1990–1999	100	0	0	0	100
	AC4400CW	Tier 2	7FDL16	4400	2005–2007	0	0	12	12	12
	ES44AC	Tier 2	GEVO12	4500	2000–2009	177	0	0	0	177
	ES44AC	Tier 2	GEVO12	4400	2010–2018	0	0	6	6	6
	ES44DC	Tier 2	GEVO12	4400	2010–2018	3	0	0	0	3
	ES44DC	Tier 2	GEVO12	4400	2000–2009	21	0	0	0	21
	ES44AC	Tier 2+	GEVO12	4500	2010–2018	61	0	0	0	61
	ES44DC	Tier 2+	GEVO12	4400	2010–2018	31	0	0	0	31
	ES44DC	Tier 2+	GEVO12	4400	2000–2009	66	0	0	0	66
	ES44AC	Tier 3	GEVO12	4400	2010–2018	202	0	0	0	202
	ES44AC	Tier 3	GEVO12	4500	2010–2018	30	0	0	0	30
	ES44AC	Tier 4	GEVO12	4400	2010–2018	34	0	0	0	34
	ET44AC	Tier 4	GEVO12	4400	2010–2018	150	0	0	0	150
GE Sub–Total						**1679**	**8**	**50**	**58**	**1737**
MLW	M420 (W)		251	2000	1971–1975	0	1	0	1	1
	RS-18		251	1800	1954–1958	0	6	0	6	6
MLW Sub–Total						**0**	**7**	**0**	**7**	**7**
FREIGHT MAINLINE SUB–TOTAL						**2531**	**166**	**130**	**296**	**2827**
ROAD SWITCHERS										
GM/EMD	FP9A		645	3000	1950-1959	2	0	0	0	2
	GP40-2		645	3000	1972-1979	23	0	0	0	23
	SD40-2		645	3000	1972-1990	20	0	0	0	20
	SD40-2		645	3000	1980-1990	12	0	0	0	12
	SD40-3		645	3000	1966-1972	9	0	0	0	9
	GP20-C	Tier 0+	710	2150	2010-2018	60	0	0	0	60
	GP20-C	Tier 0+	710	2150	1950-1959	69	0	0	0	69
GM/EMD Road Switchers Sub–Total						**195**	**0**	**0**	**0**	**195**
ROAD SWITCHERS SUB–TOTAL						**195**	**0**	**0**	**0**	**195**
TOTAL MAINLINE FREIGHT						**2726**	**166**	**130**	**296**	**3022**

Appendix B-2

2018 Locomotive Fleet — Freight Yard Switching & Work Train Operations

OEM	Model	USEPA Tier Level	Engine	HP	Year of Manufacture	Class 1	Shortlines	Regional	Total Regional and Short Lines	Total Freight Fleet
GM/ EMD	GMD-1		567	1200	1958–1960	9	0	0	0	9
	GP15		645	1500	1981–1984	0	3	0	3	3
	GP38-2		645	2000	1974–1979	4	0	0	0	4
	GP38-2		645	2000	1972–1973	60	10	0	10	70
	GP9		645	1750	1960–1973	0	2	1	3	3
	GP9		645	1750	1950–1959	0	3	0	3	3
	GP9		567	1700	1960–1969	0	1	0	1	1
	GP9		567	1750	1951–1959	0	10	2	12	12
	GP9		567	1750	1960–1973	0	1	0	1	1
	GP9-RM		645	1800	1950–1959	84	0	0	0	84
	MP15		645	1500	1973–1979	0	3	0	3	3
	MP15		645	1500	1970–1972	0	1	0	1	1
	MP15-AC		645	1500	1972–1976	0	2	0	2	2
	MP1500		567	1500	1973–1979	0	3	0	3	3
	SD35		645	3000	1960–1969	0	1	0	1	1
	SD38-2		645	2000	1973–1979	1	0	0	0	1
	SW1000		645	1000	1960–1969	0	2	0	2	2
	SW1200		567	1200	1960–1969	0	2	0	2	2
	SW14		567	1400	1950–1959	0	1	0	1	1
	SW1500		567	1500	1970–1974	0	4	0	4	4
	SW1500		567	1500	1966–1974	0	1	0	1	1
	SW900		567	900	1960–1969	0	1	0	1	1
	SW900		567	900	1954–1959	1	9	0	9	10
	GP38-2	Tier 0	645	2000	1973–1979	32	0	0	0	32
	GP38-2	Tier 0	645	2000	1972–1986	2	0	0	0	2
	GP38-2	Tier 0	645	2000	1980–1989	11	0	0	0	11
	GP39-2	Tier 0	645	2000	1980–1989	2	0	0	0	2
	GP40	Tier 0	645	2000	1960–1969	2	0	0	0	2
	GP40-2	Tier 0	645	2000	1960–1969	1	0	0	0	1
	GMD-1	Tier 0+	645	1200	1950–1959	2	0	0	0	2
	GP20-C	Tier 0+	710	2000	1950–1959	1	0	0	0	1
	GP38	Tier 0+	645	2000	1980–1989	2	0	0	0	2
	GP38	Tier 0+	645	2000	1970–1972	13	0	0	0	13
	GP38	Tier 0+	645	2000	1960–1969	2	0	0	0	2
	GP38-2	Tier 0+	645	2000	1972–1986	25	0	0	0	25
	GP38-2	Tier 0+	645	2000	1980–1989	118	0	0	0	118
	GP38-2	Tier 0+	645	2000	1970–1972	10	0	0	0	10
	GP38-2	Tier 0+	645	2000	1973–1979	17	0	0	0	17
	GP38AC	Tier 0+	645	2000	1970–1972	5	0	0	0	5
	GP40	Tier 0+	645	2000	1960–1969	0	0	0	0	0
	GP40-3	Tier 0+	645	3000	1960–1969	2	0	0	0	2
	GP9-RM	Tier 0+	645	1800	1972–1979	1	0	0	0	1
	SD38-2	Tier 0+	645	2000	1973–1979	2	0	0	0	2
GM/EMD Sub-Total						**409**	**60**	**3**	**63**	**472**

OEM	Model	USEPA Tier Level	Engine	HP	Year of Manufacture	Class 1	Shortlines	Regional	Total Regional and Short Lines	Total Freight Fleet
MLW	RS-18		251	1800	1954–1958	0	3	0	3	3
	RS-23		251	1000	1959–1960	0	3	0	3	3
	S-13		251	900	1959–1960	0	2	0	2	2
	S-13		251	1000	1959–1960	0	1	0	1	1
MLW Sub-Total						**0**	**9**	**0**	**9**	**9**
ALCO	S-6		251	900	1953	0	1	0	1	1
ALCO Sub-Total						**0**	**1**	**0**	**1**	**1**
Other	GR35-2		645	2000		0	4	0	4	4
	Modesto Empire	Elec/Steam/Other		600		0	0	5	5	5
	Slug	Elec/Steam/Other		0		0	8	0	8	8
Other Sub-Total						**0**	**12**	**5**	**17**	**17**
YARD SWITCHING & WORK TRAIN TOTAL						**409**	**82**	**8**	**90**	**499**

Appendix B-3
2018 Locomotive and DMU Fleet — Passenger Train Operations

OEM	Model	USEPA Tier Level	Engine	HP	Year of Manufacture	Intercity Rail	Commuter	Tourist & Excursion	Total
PASSENGER TRAIN LOCOMOTIVES									
GM/EMD	F40-PH		645	3000	1977–1978	2	0	0	2
	F59-PH		710	3000	1988–1994	0	16	0	16
	F59-PHI		710	3000	1990–1999	0	16	0	16
	FP40-PH2		645	3000	1987–1989	52	0	0	52
	GMD-1		567	1200	1958	0	0	1	1
	GP40		645	3000	1970–1979	0	0	9	9
	GP9		567	1750	1951–1963	0	0	1	1
	GP9		645	1750	1950–1959	0	0	1	1
	MP36PH-3C		645	3600	2000–2009	0	1	0	1
GM/EMD Sub-Total						**54**	**33**	**12**	**99**
GE	LL162/162		251	990	1954–1966	0	0	11	11
	P42DC		7FDL16	4250	2001	21	0	0	21
	70-ton	Elec/Steam/Other	FWL-6T	600	1948	0	0	1	1
GE Sub-Total						**21**	**0**	**12**	**33**
Motive Power	MP40PH-3C	Tier 2	710	4000	2008–2011	0	56	0	56
	MP40PH-3C	Tier 3	710	4000	2013–2014	0	10	0	10
	MP40PHTC-T4 (DC)	Tier 4	QSK60	4000	2015–2016	0	1	0	1
Motive Power Sub-Total						**0**	**67**	**0**	**67**
Bombardier	ALP45-DP		MITRAC-TC 3360	3600	2010–2012	0	20	0	20
Bombardier Sub-Total						**0**	**20**	**0**	**20**
Alstom	Coradia LINT 41	Elec/Steam/Other	DMU	780	2013	0	6	0	6
Alstom Sub-Total						**0**	**6**	**0**	**6**
R&H	28-ton	Elec/Steam/Other		165	1950	0	0	1	1
CLC	44-ton	Elec/Steam/Other	H44A3	400	1960	0	0	1	1
MLW	DL535		251	1200	1960–1969	0	0	8	8
Cummins	DMU A-Car	Tier 4	QSK19R	760	2011–2014	0	12	0	12
	DMU C-Car	Tier 4	QSK19R	760	2011–2014	0	6	0	6
Other Sub-Total						**0**	**18**	**10**	**28**
MLW	MLW Hudson	Elec/Steam/Other		2500	1912	0	0	1	1
Baldwin	Baldwin 280	Elec/Steam/Other		0	1920	0	0	2	2
Baldwin Steam Engines Sub-Total						**0**	**0**	**3**	**3**
Other Steam Engines	Other	Elec/Steam/Other		0		0	0	2	2
Other Steam Engines Sub-Total						**0**	**0**	**2**	**2**
PASSENGER TRAIN LOCOMOTIVES SUB-TOTAL						**75**	**144**	**39**	**258**
YARD SWITCHING PASSENGER OPERATIONS									
ALCO	DQS18		251	1800	1950–1959	0	0	2	2
R&H	35-Ton	Elec/Steam/Other		236		0	0	1	1
Yard Switching Passenger Operations Sub-Total						**0**	**0**	**3**	**3**
PASSENGER OPERATIONS TOTAL						**75**	**144**	**42**	**261**

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	Rawlison
	Yale

CP

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

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	Talbot
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
Québec Gatineau Railway	All
Southern Ontario Railway	All
St-Lawrence & Atlantic (Canada)	All

Appendix D
Locomotive Emissions Standards

Locomotive Emissions Regulations:

The *Locomotive Emissions Regulations*:

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

The *Locomotive Emissions Regulations* require railways companies to:

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

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

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

Emission Standards:

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

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

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

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

The *Locomotive Emissions Regulations* incorporate by reference specific tables, footnotes and paragraphs of 40 CFR Part 1033, which set out the emission standards and can be found online at: https://www.ecfr.gov/cgi-bin/text-idx?SID=4fb15ae65d78e6ebd7a202e45cf19081&mc=true&node=pt40.36.1033&rgn=div5#se40.36.1033_1101.

The older emission standards, under the U.S. regulations 40 CFR Part 92, typically no longer apply, unless a locomotive is covered by an EPA certificate that sets out family emission limits (FELs), as family emission limits (FELs) are valid for the locomotive's service life. The older emission standards, are set out in section 92.8 of 40 CFR Part 92 and can be found online at: https://www.ecfr.gov/cgi-bin/text-idx?SID=9833dcbb71d68fe073c49c29b2bec6d0&mc=true&node=pt40.22.92&rgn=div5#se40.22.92_18.

A railway company's fleet can contain locomotives that:

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

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

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

Appendix E
Glossary of Terms

Terminology Pertaining to Railway Operations

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

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

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

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

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

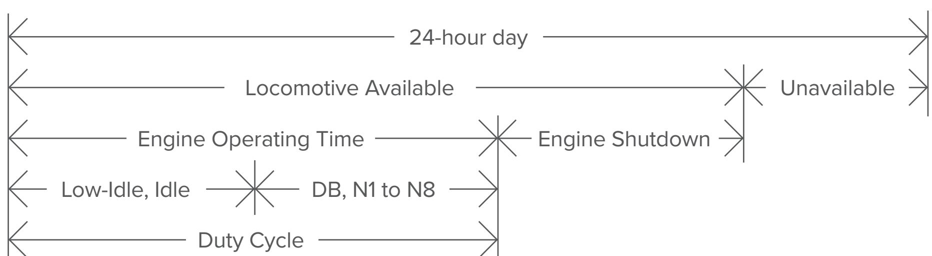
Medium-speed diesel engine: This engine is installed in versions from 8 to 16 cylinders at up to 4,400 hp, with an operating speed of 800 to 1,100 rpm.

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
OEM	Original Equipment Manufacturer
RAC	Railway Association of Canada
TC	Transport Canada
UNFCCC	United Nations Framework Convention on Climate Change
US EPA	United States Environmental Protection Agency
VIA	VIA Rail Canada

Appendix H
Calculations Methodology

Data Collection

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

- **Traffic Data:**
  - Freight railways: revenue tonne-kilometres; gross tonne-kilometres; carloads by commodity.
  - Passenger railways: number of passengers; passenger-kilometres; train kilometres; average length of journey; average number of passengers per train.
- **Fuel Consumption Data:**
  - Fuel consumed across four service categories: mainline service; yard switching service; work train service; and passenger service.
- **Locomotive Inventory:**
  - For each locomotive in the railway's fleet, details on: manufacturer, model, EPA tier level, engine, horsepower, year of original manufacture, anti-idle devices, and service type (mainline; yard).

Data Analysis

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

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

Data Review

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

Appendix I

Statistical Revisions

In the spirit of the MOU between the RAC and Transport Canada, the RAC strives to maintain accurate data regarding locomotive emissions monitoring, therefore, revisions are periodically carried out in order to incorporate the most accurate and up-to-date information.

In 2018, there were three types of revisions to historical data:

1. **Revised Estimates:** As new data becomes available, historical estimates may be revised. For example, if a data point in 2017 was estimated based on historical data (2016–earlier), the 2017 estimate may be revised based on the newly acquired 2018 data. These types of revisions affect the fuel usage, revenue tonne-kilometre and gross tonne-kilometre figures.
2. **Measurement System (Metric vs Imperial):** It was identified that in some cases, data had been reported using the incorrect measurement system (e.g., misreported as gallons as opposed to litres; kilometres as opposed to miles; or vice versa). These types of revisions affect the fuel usage, revenue tonne-kilometre and gross tonne-kilometre figures.
3. **Orders of Magnitude:** In RAC's database, many data points are recorded in thousands (000). It was identified that in some cases, the recorded value did not properly account for this. The misreported values have been corrected. These types of revisions affect the revenue tonne-kilometres and gross tonne-kilometres figures.

Impact of Data Revisions, 2010–2017

			2010	2011	2012	2013	2014	2015	2016	2017
Class I	Data in 2017 LEM	Fuel (Litres, million)	1,791.11	1,816.44	1,875.85	1,849.57	1,918.27	1,852.98	1,732.20	1,864.83
		RTK (billion)	327.81	337.90	356.91	371.77	399.47	394.10	383.47	411.22
		kg CO_2e per 1,000 RTK	16.30	16.03	15.68	14.84	14.32	14.02	13.47	13.53
	Revised data (2018 LEM)	Fuel (Litres, million)	1,791.11	1,816.44	1,875.85	1,849.57	1,918.27	1,852.98	1,732.20	1,864.83
		RTK (billion)	327.81	337.91	356.92	371.77	399.47	394.10	383.47	411.22
		kg CO_2e per 1,000 RTK	16.30	16.03	15.68	14.84	14.32	14.02	13.47	13.53
	Difference	Fuel (Litres, million)	0%	0%	0%	0%	0%	0%	0%	0%
		RTK (billion)	0%	0%	0%	0%	0%	0%	0%	0%
		kg CO_2e per 1,000 RTK	0%	0%	0%	0%	0%	0%	0%	0%
Intercity Passenger	Data in 2017 LEM	Fuel (Litres, million)	58.09	58.32	50.99	46.17	44.89	46.98	47.93	51.02
		RTK (billion)	1,411,755	1,428,414	1,401,553	1,386,019	1,342,959	1,379,660	1,409,012	1,560,726
		kg CO_2e per 1,000 RTK	0.123	0.122	0.109	0.099	0.100	0.102	0.101	0.098
	Revised data (2018 LEM)	Fuel (Litres, million)	58.11	58.63	50.99	46.17	44.89	46.98	47.93	51.02
		RTK (billion)	1,411,755	1,428,414	1,401,553	1,386,019	1,342,959	1,379,660	1,409,012	1,562,132
		kg CO_2e per 1,000 RTK	0.123	0.122	0.109	0.099	0.100	0.102	0.101	0.097
	Difference	Fuel (Litres, million)	0%	1%	0%	0%	0%	0%	0%	0%
		RTK (billion)	0%	0%	0%	0%	0%	0%	0%	0%
		kg CO_2e per 1,000 RTK	0%	1%	0%	0%	0%	0%	0%	0%
Regional & Shortlines	Data in 2017 LEM	Fuel (Litres, million)	107.88	107.78	107.08	108.58	109.36	104.82	99.34	111.51
		RTK (billion)	21.33	21.79	23.96	24.04	29.46	18.72	18.42	18.29
		kg CO_2e per 1,000 RTK	15.09	14.76	13.33	13.47	11.07	16.70	16.09	18.19
	Revised data (2018 LEM)	Fuel (Litres, million)	104.65	107.91	96.55	101.72	108.91	105.45	101.83	114.15
		RTK (billion)	21.44	22.25	23.08	24.23	23.01	23.98	25.05	24.25
		kg CO_2e per 1,000 RTK	14.56	14.47	12.48	12.52	14.12	13.11	12.12	14.04
	Difference	Fuel (Litres, million)	-3%	0%	-10%	-6%	0%	1%	2%	2%
		RTK (billion)	1%	2%	-4%	1%	-22%	28%	36%	33%
		kg CO_2e per 1,000 RTK	-3%	-2%	-6%	-7%	27%	-21%	-25%	-23%

Impact of revisions on 2011–2017 MOU

Revisions have materially impacted the GHG emissions intensities over the 2011–2017 MOU period. The tables below compare the 2011–2017 MOU results that were in the 2017 LEM Report against the 2010–2017 MOU results using the revised data included in the 2018 LEM Report.

The revisions to Class 1 Freight and Intercity Passenger Railways were minor. The revisions to Regional & Shortline railways were more significant. Revised figures for RTKs and fuel usage show that the GHG emissions intensity of Regional & Shortline railways in 2010 was 14.56 kg CO_2e per 1,000 RTKs, as opposed to the previously reported value of 15.09.[9] The revised GHG emissions intensity in 2017 was 14.04 kg CO_2e per 1,000 RTKs, as opposed to the previously reported value of 18.19. As a result, Regional & Shortline railways decreased their GHG emissions intensities by 3.5% from 2010 to 2017 (as opposed to increasing by 20.54%), narrowly missing the 2017 target.

2011–2017 MOU Results in the 2017 LEM Report, Executive Summary

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	yes
Intercity Passenger	kg CO_2e per passenger kilometre	0.123	0.098	0.112	**20.33% decrease**	13.3% lower	yes
Regional & Shortlines	kg CO_2e per 1,000 revenue tonne kilometres	15.09	18.19	14.45	**20.54% decrease**	25.8% higher	no

Source: 2017 LEM, Executive Summary

2011–2017 MOU Results based on revised data

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	**17.00% decrease**	9.4% lower	yes
Intercity Passenger	kg CO_2e per passenger kilometre	0.123	0.097	0.112	**20.66% decrease**	13.4% lower	yes
Regional & Shortlines	kg CO_2e per 1,000 revenue tonne kilometres	14.56	14.04	13.95	**3.55% decrease**	0.7% higher	no

9 Note that the revisions to 2010 emissions intensities impact the 2017 targets.

Impact of Revisions on 2018–2022 MOU

Revisions to the 2017 GHG emissions intensities impact the 2022 targets under the current MOU. For regional and shortlines, the 2022 target is more stringent based on the revised data (target of 13.62 as opposed to 17.64).

2022 Targets based on data in 2017 LEM Report

Railway Operation	Productivity Unit	2017	2022 target
Class 1 Freight	kg CO_2e per 1,000 revenue tonne kilometres	13.53	12.71
Intercity Passenger	kg CO_2e per passenger kilometre	0.098	0.092
Regional & Shortlines	kg CO_2e per 1,000 revenue tonne kilometres	18.19	17.64

Source: 2017 LEM, Executive Summary

2022 Targets based on revised data (2018 LEM Report)

Railway Operation	Productivity Unit	2017	2022 target
Class 1 Freight	kg CO_2e per 1,000 revenue tonne kilometres	13.53	12.71
Intercity Passenger	kg CO_2e per passenger kilometre	0.097	0.092
Regional & Shortlines	kg CO_2e per 1,000 revenue tonne kilometres	14.04	13.62