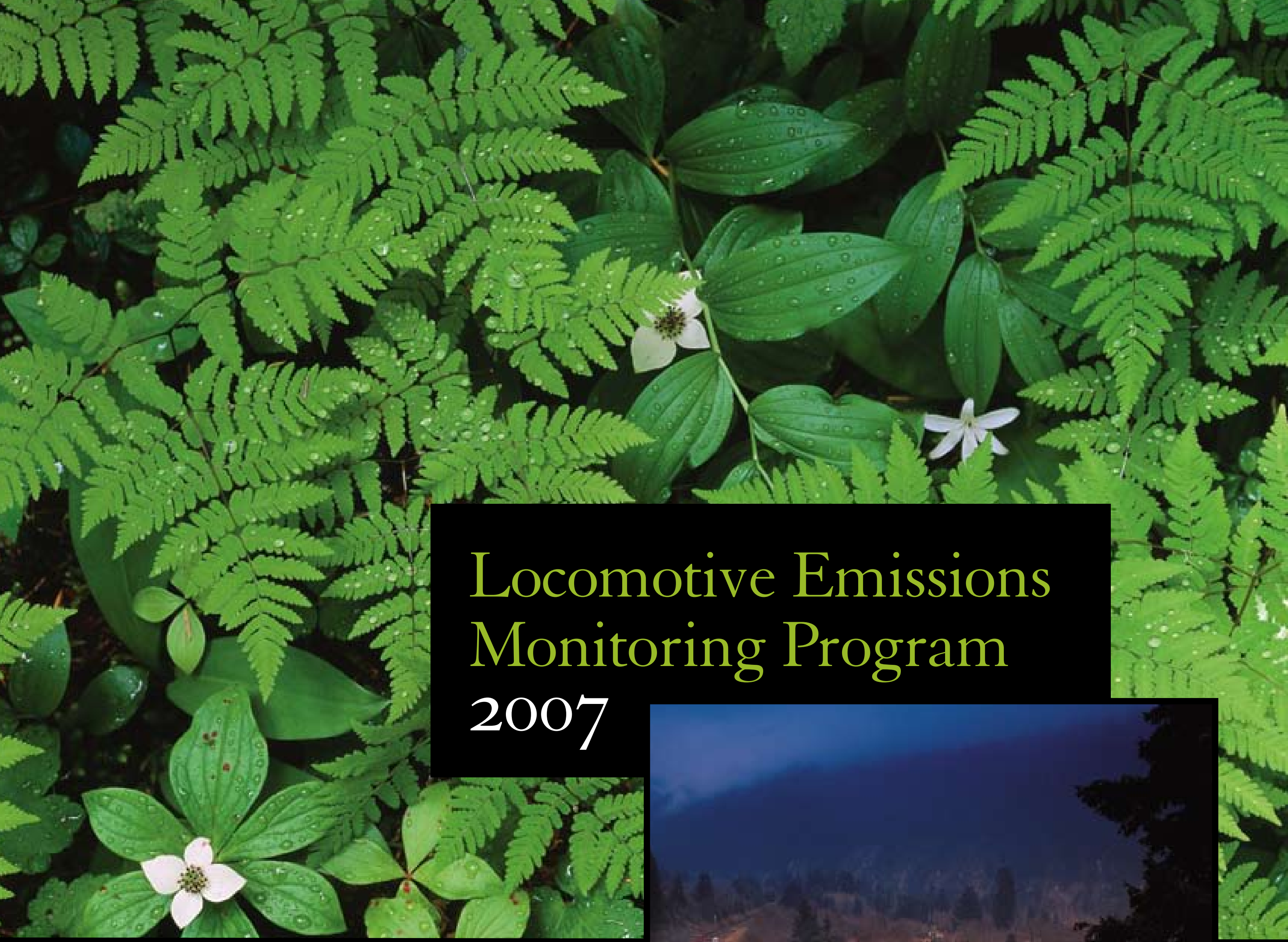

Locomotive Emissions Monitoring Program 2007

RAC

Locomotive Emissions Monitoring Program

2007

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Review Notice

This report has been reviewed by members of Transportation System Branch, Environment Canada; Environmental Initiatives Branch, Transport Canada, and Pollution Probe, and approved for publication. Approval does not necessarily signify that the contents reflect the views and policies of Environment Canada, Transport Canada and Pollution Probe. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

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Executive Summary

The annual Locomotive Emissions Monitoring (LEM) data filing has been completed for 2007 in accordance with the terms of the Memorandum of Understanding (MOU) signed on May 15, 2007, between the Railway Association of Canada (RAC), Environment Canada and Transport Canada concerning the emissions of greenhouse gases (GHG) and criteria air contaminants (CAC) from locomotives operating in Canada. The MOU is in force from 2006 to 2010 and identifies specific commitments on the part of the major railway companies to achieve during this period:

i. CAC Commitments:
- acquire only new and freshly manufactured locomotives that meet applicable U.S. Environmental Protection Agency (EPA) emissions standards;
- retire from service 130 medium-horsepower locomotives built between 1973 and 1999; and
- upgrade, upon remanufacturing, all high-horsepower locomotives to EPA emissions standards.

ii. GHG Commitments:
- achieve by 2010 targeted aggregate GHG emissions intensity levels.

In regard to the above-listed commitments, analysis of railway data for 2007 shows that GHG emissions intensities (as $CO_{2\ equivalent}$ per productivity unit) compared to the target levels by category of railway operation set out in the MOU for 2010 were:

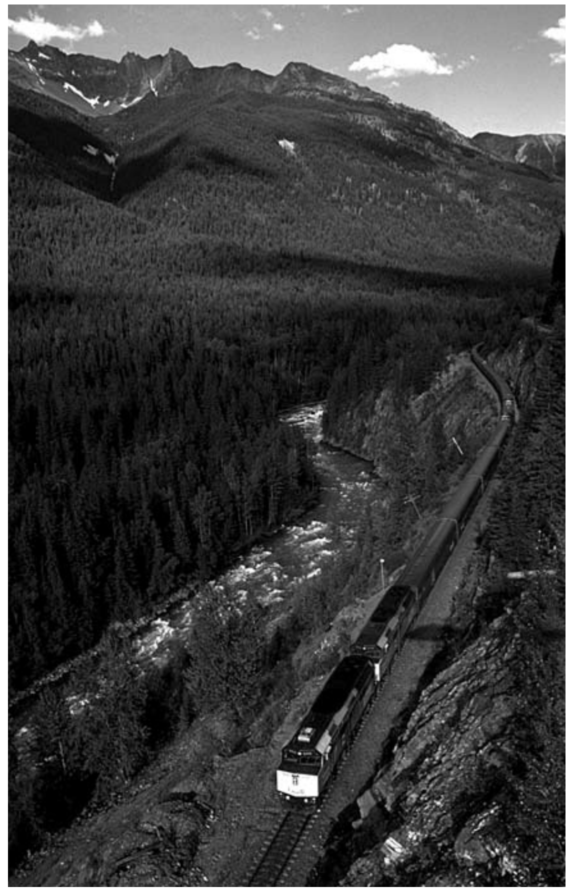

Photo courtesy of VIA Rail / Matthew G. Wheeler

Railway Operation	Units	MOU 2010 target	2006 level	2007 level
Class I Freight	kg / 1,000 RTK	16.98	17.79	17.32
Regional and Short Lines	kg / 1,000 RTK	15.38	15.10	15.21
Intercity Passenger	kg / passenger-km	0.12	0.13	0.13
Commuter Rail	kg / passenger	1.46	1.74	1.71

The fleet change actions, which primarily contributed to reductions in GHG intensities and CAC emissions in 2007, are listed on the following page. The new locomotives acquired meet the stringent U.S. EPA Tier 2 emissions standard and, as well, consume less fuel for the power produced. Older, less efficient locomotives continue to be retired.

Actions Taken in 2007	Class I Mainline Freight	Intercity Passenger	Commuter Service
New EPA Tier 2 Locomotives Acquired	85	0	2
High-horsepower Units Upgraded to EPA Tier 0	92	0	0
Medium-horsepower Units Upgraded to EPA Tier 0	10	0	0
Retire 1973-99 era Medium-horsepower Units	50	0	0

Oxides of nitrogen (NO_x), the baseline CAC emission, from all rail operations in 2007 totalled 104.46 kilotonnes, as compared to 112.22 kilotonnes in 2006.

Summarized below are the data collection process, input data and calculated emissions from all diesel locomotives operating in Canada during 2007 on RAC member railways. Also summarized are the emissions reduction initiatives of the railways and the RAC's awareness generation actions to improve the environmental performance of the sector.

Data Collection: The cumulative emissions reported in the annual LEM reports are calculated from data in a RAC LEM protocol collected from each of the 54 RAC member railways. The data include traffic volumes, diesel fuel consumption and locomotive fleet inventories for freight, yard switching, work train and passenger operations. Freight data are differentiated between Class I, Regional and Short Line operations. Passenger data are differentiated between Intercity, Commuter, and Tourist and Excursion operations.

Emissions Calculations: GHG emissions are calculated according to the amount of diesel fuel consumed and expressed as equivalents to carbon dioxide ($CO_{2\ equivalent}$). Similarly CACs, namely, NO_x, carbon monoxide (CO), hydrocarbons (HC), particulate matter (PM) and oxides of sulphur (SO_x, but expressed as SO_2) are calculated based on the amount of diesel fuel consumed, the locomotives' duty cycle and characteristics of their diesel engine. The amount of SO_x emitted varies mostly according to the sulphur content of the diesel fuel, while the other CACs are a function of the emissions factors and duty cycles specific to individual locomotive types and their operational service. Emission metrics are expressed in terms of absolute weight as well as intensity, that is, a ratio relating emissions to productivity or operational efficiency.

Freight Traffic: In 2007, the railways handled 361.62 billion revenue tonne-kilometres (RTK) of traffic as compared to 355.83 billion RTK in 2006, an increase of 1.6 percent. Of the total, the Class I railways (CN and CP) were responsible for 93.6 percent of the traffic. Since 1990, railway freight RTK has risen by an average annual rate of 2.6 percent.

Intermodal Traffic: Of the total freight carried in 2007, intermodal carloadings dominated at 21 percent. Class I intermodal traffic increased from 82.62 billion RTK in 2006 to 84.73 billion RTK in 2007, a rise of 2.6 percent. Since 1990, container-on-flat car traffic has increased 247.9 percent while trailer-on-flat car has decreased 69.2 percent.

Passenger Traffic: Intercity traffic in 2007 by all operators totalled 4.48 million passengers compared to 4.32 million in 2006. The carriers were VIA Rail Canada, CN / Algoma Central, Ontario Northland Railway and Tshiuetin Rail Transportation. VIA Rail Canada carried 93.3 percent of the intercity traffic.

Commuter rail traffic increased from 60.63 million passengers in 2006 to 63.39 million in 2007, an increase of 4.5 percent. This is up from 41.00 million passengers in 1997, when the RAC first started collecting commuter passenger statistics, an increase of 54.6 percent.

Fuel Consumption: Overall, the fuel consumed by railway operations in Canada increased from 2,210.38 million litres (L) in 2006 to 2,237.22 million L in 2007 to, a rise of 1.12 percent. Of this amount, Class I freight train operations consumed 87.1 percent and Regional and Short Lines consumed 5.3 percent. Yard switching and work train operations consumed 3.1 percent and passenger operations accounted for 4.6 percent (of which 2.6 percent was for VIA Rail Canada, 1.6 percent for commuter, 0.3 percent for tourist and excursion operations and 0.1 percent for Amtrak operations in Canada).

Fuel Consumption Per Productivity Unit: For total freight operations, fuel consumption per productivity unit, (L per 1,000 RTK) in 2007 was 5.90 L per 1,000 RTK as compared to 5.93 L in 2006. This is down from 7.83 L per 1,000 RTK in 1990, a reduction of 24.6 percent.

For total passenger operations, the overall fuel consumption in 2007 was 1.1 percent above corresponding figures for 2006. In terms of consumption per unit of productivity, the values were 41.93 L per 1,000 passenger-km for VIA Rail Canada intercity operations and 566.97 L per 1,000 passengers for the Commuter Rail operations.

Locomotive Fleet Inventory: In 2007, the number of in-service diesel-powered locomotives and diesel mobile units (DMUs) in operation in Canada belonging to RAC member railways totalled 3,027. For line-haul freight operations, 2,389 are in service. On Class I railways there were 2,058, with 283 on Regional and Short Lines. A further 450 are in Switching and Work Train operations, of which 374 are in Class I service and 76 in Regional and Short lines. A total of 188 locomotives and DMUs are in passenger operations, of which 77 are in VIA Rail Canada intercity services, 75 in Commuter and 36 are in Tourist and Excursion services.

In 2007, there were 1,065 locomotives meeting the stringent U.S. EPA Tier 0, Tier 1 and Tier 2 emissions standards, up from 956 in 2006. In addition to adding 87 new high-horsepower locomotives that meet Tier 2 standards and upgrading 92 high-horsepower and 10 medium-horsepower locomotives to Tier 0, the railways retired 50 medium-horsepower locomotives manufactured between 1973 and 1999.

Emissions Factors (EF): The EF used to calculate total GHG emissions was 3.00715 kilograms / litre (kg/L) and expressed as $CO_{2\ equivalent}$, the constituents of which for diesel cycle combustion are CO_2, methane (CH_4) and nitrous oxide (N_2O). The $CO_{2\ equivalent}$ EF has been revised downward from the previously-used value of 3.07415 to be in-line with the *National Inventory Report 1990 – 2006* submitted by Environment Canada to the United Nations Framework Convention on Climate Change. The revision stems from studies updating the carbon content, density and oxidation rates of Canadian liquid fuels.

The EF used to calculate NO_x emitted from freight train locomotives was re-calculated to 44.90 grams / litre (g/L) of diesel fuel consumed for 2007 versus 49.53 g/L in 2006. This lowering reflects the acquisition of new locomotives manufactured to U.S. EPA Tier 1 emissions standards during 2002 to 2004 and to Tier 2 standards from 2005 onwards. Upon remanufacture, high-horsepower in-service locomotives were upgraded to Tier 0.

Emissions: Reflecting the lower EF for 2007, total GHG emissions were 6,727.65 kt as compared to 6,795.04 kt in 2006 and 6,288.00 kt in 1990. NO_x emissions from all rail operations totalled 104.46 kilotonnes (kt), as compared to 112.22 kt reported in 2006; a 6.9 percent reduction. Total HC emissions were 3.93 kt, CO totalled 11.86 kt and PM totalled 3.57 kt. Emissions of SO_x in 2007 were 1.91 kt compared to 4.80 kt in 2006, a 60.2 percent reduction reflecting regulations effective June 2007 limiting railway diesel fuel sulphur content in Canada to 500 ppm.

Emissions Intensity: For total freight train operations, emissions per 1,000 RTK continue to decline. GHG emissions intensity in 2007 was 25.7 percent below the 1990 baseline; declining from 23.88 kg to 17.75 kg per 1,000 RTK. By category of operation, the 2007 level for Class I freight was 17.32 kg per 1,000 RTK, for Regional and Short Lines was 15.21 kg per 1,000 RTK, for Intercity Passenger was 0.13 kg per passenger-km and for Commuter Rail was 1.71 kg per passenger. Similarly, the NO_x emission intensity in 2007 was 37.2 percent below the 1990 baseline. It declined from 0.43 kilograms (kg) per 1,000 RTK in 1990 to 0.27 kg in 2007.

Tropospheric Ozone Management Areas (TOMA): Of the total Canadian rail sector fuel consumed in 2007, 2.97 percent was used in the Lower Fraser Valley of British Columbia, 17.34 percent in the Windsor-Quebec City Corridor and 0.20 percent in the Saint John area of New Brunswick. Similarly, NO_x emissions for the three TOMA were, respectively, 2.8 percent, 16.6 percent and 0.2 percent.

Emissions Reduction Initiatives by Railways: During 2007, the railways continued to acquire new locomotives compliant with U.S. EPA Tier 2 emissions standards (which came into force January 1st, 2005) as well as to upgrade to Tier 0 in-service high-horsepower locomotives upon remanufacture. The outfitting of locomotives with engine automatic stop/start devices and low-idle settings has been accelerated. In 2007, ultra-low sulphur diesel fuel was standardized on VIA Rail Canada and commuter operations.

Staff training and incentives focussing on fuel conserving train-handling procedures were accelerated. Non-locomotive initiatives to reduce fuel consumption and, hence, emissions included acquisition of additional higher-capacity freight cars and lower-weight aluminium gondola units. Further, operational fluidity improvements were implemented which included infrastructure upgrades, wheel-flange lubrication, top-of-rail friction control and the benefits of co-production arrangements between the Class I freight railways, Canadian National and Canadian Pacific for shared operation on mainline segments. The Canadian railways are monitoring field testing on U.S. railway locomotives of prototype diesel oxidation catalysts and diesel particulate filters to reduce CAC emissions. Such devices may become part of the locomotive technology needed to meet future more stringent U.S. EPA emissions limits.

RAC Awareness Generation Actions Aimed at Emissions Reduction: The RAC provides a venue for the railway companies to exchange ideas and best operating practices for reducing emissions associated with railway activities. The RAC is in frequent communication with its members, through newsletters, E-mail distribution, working committees, RAC member events, the RAC Annual General Meeting and through the RAC website. As such, the RAC distributes relevant information within its membership regarding technologies and operating practices that reduce emissions, particularly GHGs, on an activity basis. Similarly, to assist shippers and other concerned parties to know difference in emissions level, on a shipment-by-shipment basis, between choosing the rail versus truck mode, the RAC initiated development of an on-line Rail Freight Greenhouse Gas Calculator. The Calculator is now available by accessing ghg.railcan.ca.

To further emphasize awareness about environmental concerns, the RAC sponsors an annual Environmental Award Program for both passenger and freight railways operating in Canada. The objective of the program is to share and assess initiatives undertaken by railways to improve their environmental performance. Also, in 2007 the RAC participated in a two-day symposium convened by the Railway Research Advisory Board to identify needs and priorities for railway research in Canada, an element of which dealt with emissions reduction.

Photo courtesy of VIA Rail

Glossary of Terms

Terminology Pertaining to Railway Operations

Class I 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 US $250 million annually in 1991 dollars for the provision of Canadian railway services. The three Canadian Class I 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 Utilization Profile: This is the breakdown of locomotive activity within a 24-hour day (based on yearly averages).

```
|←——————————————— 24-hour day ———————————————→|
|←——————— Locomotive Available ———————→| Unavailable |
|←—— Engine Operating Time ——→|←Engine Shutdown→|
|←Low-Idle, Idle →|←DB, N1 to N8 →|
|←———— Duty Cycle ————→|
```

The elements in the above diagram constitute, respectively:

Locomotive Available: This is the time, expressed in percent 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, re-built or in storage. Locomotive available time plus unavailable time equals 100 percent;

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 percent 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.

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

Medium-speed Diesel Engine: This engine, having an operating speed of 800 to 1,100 RPM, is the power source of choice for locomotives in operation on Canadian railways. It has found its niche as a result of its fuel-efficiency, ruggedness, reliability and installation flexibility. Combustion takes place in a diesel engine by compressing the fuel and air mixture until auto-ignition occurs.

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, that is, the average of all revenue passenger kilometres travelled divided by the average of all train kilometres operated.

Revenue Passenger-Kilometres (RPK): 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 Factor (EF): 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 respective constituent emissions from a specific locomotive type are calculated based on data from test measurements, the operational duty cycle and engine specific fuel consumption. 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 and impact on human health and the environment. The principal CAC emissions are:

NO_x (Oxides of Nitrogen): these are the products of nitrogen and oxygen that 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 to contribute to smog formation.

CO (Carbon Monoxide): 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.

HC (Hydrocarbons): these are the result of incomplete combustion of diesel fuel and lubricating oil.

PM (Particulate Matter): 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; that is, technologies that control NO_x (such as retarding injection timing) result in higher PM emissions. Conversely, technologies that control PM often result in increased NO_x emissions

SO_x (Oxides of Sulphur): these emissions are the result of burning fuels containing sulphur compounds. For the 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:

CO_2 (Carbon Dioxide): this gas is by far the largest by-product of combustion emitted from engines and is the principal 'greenhouse gas' 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. The only way to reduce CO_2 emissions is to reduce the consumption of fossil fuels.

CH_4 (Methane): this is a colourless, odourless and inflammable gas that is a bi-product of incomplete diesel combustion. Relative to CO_2, it has a Global Warming Potential of 21.

N_2O (Nitrous Oxide): this is a colourless gas produced during combustion that has a Global Warming Potential of 310 (relative to CO_2).

The sum of the constituent greenhouse gases expressed in terms of their equivalents to the Global Warming Potential of CO_2 is depicted as $CO_{2\ equivalent}$. This is calculated by multiplying the volume of fuel consumed by the Emission Factor of each constituent then, in turn, multiplying the product by the respective Global Warming Potential, and then summing them. See page ix for conversion values pertaining to diesel fuel combustion.

Terminology Related to Locomotive Emissions Monitoring and Control

Canada: the **Memorandum of Understanding (MOU)** is a document signed by the Railway Association of Canada, Environment Canada and Transport Canada which sets out measures on a voluntary basis to address CAC and GHG emissions from all railway operations in Canada. The MOU calls for a *Locomotive Emissions Monitoring* (LEM) report to be published annually containing the respective cumulative data on CAC and GHG emissions, and information related to emissions reduction actions taken by the railways. The previous MOU covered the period 1995 to 2005; the current MOU covers the period 2006 to 2010, as exhibited in Appendix A. Once the MOU expires, the voluntary approach will be replaced with a regulatory regime implemented under the Railway Safety Act to take effect in 2011.

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

Compliance Schedule for U.S. EPA Locomotive-Specific Emissions Limits (g/bhp-hr)

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

In 2007, for locomotives operating in the U.S.A., the EPA promulgated a revision to the level of Tier 0 and Tier 1 standards, the year of manufacture for which the limits apply and the outlook for yet more stringent Tier 3 and Tier 4 emissions standards, as on the following page.

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

Tier	MY*	Date	HC	CO	NO_x	PM
Tier 0[a]	1973-1992[c]	2010[d]	1.00	5.0	8.0	0.22
Tier 1[a]	1993[c]-2004	2010[d]	0.55	2.2	7.4	0.22
Tier 2[a]	2005-2011	2010[d]	0.30	1.5	5.5	0.10[e]
Tier 3[b]	2012-2014	2012	0.30	1.5	5.5	0.10
Tier 4	2015 or later	2015	0.14[f]	1.5	1.3[f]	0.03

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

Switch Locomotive Emission Standards (g/bhp-hr)

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

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

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 these data are systematically stored for various RAC applications). Data from the RAC's database 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 I railways' *Annual Reports* and *Financial* and *Related Data* submissions to Transport Canada also list much of these data.

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) are specific to individual engine and locomotive types, and are obtained from test measurements.

Emission Factor for Sulphur Dioxide	(SO_2)	0.00085 kg / L

(based on 500 ppm sulphur in diesel fuel)

Emission Factors for Greenhouse Gases:

Carbon Dioxide	CO_2	2.66300 kg / L
Methane	CH_4	0.00015 kg / L
Nitrous Oxide	N_2O	0.00110 kg / L
Hydrofluorocarbons	HFC	)
Perfluorocarbons	PFC	) not present in diesel fuel
Sulphur hexafluoride	SF_6	)

$CO_{2\ equivalent}$† of all six GHGs		3.00715 kg / L
Global Warming Potential for	CO_2	1
Global Warming Potential for	CH_4	21
Global Warming Potential for	N_2O	310

† Sum of constituent Emissions Factors multiplied by their Global Warming Potentials

Conversion Factors Related to Railway Operations

Imperial gallons to litres	4.5461
U.S. gallons to litres	3.7853
Litres to Imperial gallons	0.2200
Litres to U.S. 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', that is, as 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*; that is, the weight in kilograms of NO_x emitted per 1,000 revenue tonne-kilometres of freight hauled.

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
$CO_{2\ equivalent}$	Carbon Dioxide equivalent of all six Greenhouse Gases
CO	Carbon Monoxide
EF	Emissions Factor
GHG	Greenhouse Gas
HC	Hydrocarbons
NO_x	Oxides of Nitrogen
PM	Particulate Matter
SO_x	Oxides of Sulphur
SO_2	Sulphur Dioxide
TOMA	Tropospheric Ozone Management Areas

Abbreviations used in Railway Operations

COFC	Container-on-Flat-Car
DB	Dynamic Brake
DMU	Diesel Multiple Unit
EMU	Electric Multiple Unit
GTK	Gross tonne-kilometres
HEP	Head End Power
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

Acronyms of Organizations

ALCO	American Locomotive Company
AAR	Association of American Railroads
CCME	Canadian Council of the Ministers of the Environment
CN	Canadian National Railway
CP	Canadian Pacific
EC	Environment Canada
EMCC	Electro Motive Canada Company
ESDC	Engine Systems Development Centre
GE	General Electric Transportation Systems
GM/EMD	General Motors Corporation Electro-Motive Division.
MLW	Montreal Locomotive Works
MPI	MotivePower Industries
OEM	Original Equipment Manufacturer
RAC	Railway Association of Canada
SwRI	Southwest Research Institute
TC	Transport Canada
UNFCCC	United Nations Framework Convention on Climate Change
U.S. EPA	United States Environmental Protection Agency
VIA	VIA Rail Canada

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1 Introduction

This report contains the Locomotive Emissions Monitoring (LEM) data filing for 2007 in accordance with the terms of the Memorandum of Understanding (MOU) signed on May 15, 2007, between the Railway Association of Canada (RAC), Environment Canada and Transport Canada concerning voluntary arrangements to limit greenhouse gases (GHG) and criteria air contaminants (CAC) emitted from locomotives operating in Canada. The MOU, in force for the 2006 to 2010 timeframe, is contained in Appendix A. It identifies specific commitments for the major railway companies to achieve during this period:

i. CAC Commitments:

- acquire only new and freshly manufactured locomotives that meet applicable U.S. Environmental Protection Agency (EPA) emissions standards;
- retire from service 130 medium-horsepower locomotives built between 1973 and 1999; and
- upgrade, upon remanufacturing, all high-horsepower locomotives to EPA emissions standards.

ii. GHG Commitments:

- achieve, by 2010, targeted aggregate operations-specific GHG emissions intensities (expressed as $CO_{2\ equivalent}$ per productivity unit), as listed below:

Railway Operation	**Units**	**MOU 2010 target**	**2006 level**	**2007 level**
Class I Freight	kg / 1,000 RTK	16.98	17.79	17.32
Regional and Short Lines	kg / 1,000 RTK	15.38	15.10	15.21
Intercity Passenger	kg / passenger-km	0.12	0.13	0.13
Commuter Rail	kg / passenger	1.46	1.74	1.71

Data for this report were collected, according to a RAC LEM protocol, via a survey sent to each member railway, as done annually. The data assembled include calendar year traffic volumes, diesel fuel consumption and sulphur content, and in-service locomotive inventory (as contained in Appendix B) for all freight train, yard switching, work train and passenger train operations. Based on these data, calculated were the GHG and CAC emissions produced by in-service locomotives in Canada. The GHG in this report are expressed as $CO_{2\ equivalent}$, the constituents of which are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). CAC emissions include oxides of nitrogen (NO_x), carbon monoxide (CO), hydrocarbons (HC), particulate matter (PM) and oxides of sulphur (SO_x). The SO_x emitted is a function of the sulphur content of the diesel fuel and is expressed as SO_2.

Separate sections of the report highlight the particulars for 2007 regarding traffic, fuel consumption and composition, GHG and CAC emissions and status of the locomotive fleet. Also included is a section on initiatives being taken or examined by the sector to reduce fuel consumption and, consequently, all emissions, particularly GHG.

In addition, the 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 - Quebec City Corridor and the Saint John area in New Brunswick. Data for winter and summer operations have also been segregated. The railways operating in the different TOMA are listed in Appendix C.

Data and statistics by year for traffic, fuel consumption and emissions are listed for the ten-year period starting with 1997. For historical comparison purposes, the year 1990 has been set as the baseline reference year. LEM statistics for the Canadian railway sector dating from 1975 can be found in the respective Environment Protection Series reports published by Environment Canada[1].

Unless otherwise specified, metric units are used and quantities and percentages are expressed to two and one significant figures, respectively. To facilitate comparison with American railway operations, Appendices D and E display traffic, fuel consumption and emissions data in U.S. units. Appendix F lists the 54 RAC member railways surveyed.

1 1995 LEM – EPS 2/TS/10 – November 1997; 1996 and 1997 LEM – EPS 2/TS/11 – May 1999; 1998 LEM – EPS 2/TS/13 – October 2000; 1999 and 2000 LEM – EPS 2/TS/15 – April 2002; 2001 LEM – EPS 2/TS/16 – December 2002; 2002 LEM – EPS 2/TS/17 – December 2003; 2003 LEM – EPS 2/TS/11 – December 2004; 2004 LEM– EPS 2/TS/19 – December 2005; 2005 LEM – EPA 2/TS/20 – December 2006; 2006 LEM –Published by RAC – December 2007

2 Traffic and Fuel Consumption Data

2.1 Freight Traffic Handled

As shown in Table 1 and Figure 1, traffic in 2007 handled by Canadian railways increased to 676.43 billion gross tonne-kilometres (GTK) from 671.00 billion GTK in 2006. For the 1990 reference year, the value was 454.94 billion GTK. Similarly, revenue traffic in 2007 rose to 361.62 billion revenue tonne-kilometres (RTK) from 355.83 billion RTK in 2006, and up from 250.13 billion RTK in 1990. As a percentage, the traffic in GTK in 2007 was 0.4 percent over the 2006 level, and is now 47.5 percent over the 1990 level. RTK in 2007 increased by 1.6 percent compared to 2006 and 44.6 percent compared to 1990. Since 1990, the average annual growth was, respectively, 2.8 percent for GTK and 2.6 percent for RTK.

In 2007, Class I GTK traffic increased by 1.4 percent to 638.66 billion from 629.93 billion in 2006. This was 94.4 percent of the total GTK hauled. Class I RTK traffic increased 2.2 percent in 2007 to 338.32 billion from 330.96 billion in 2006. Class I railways accounted for 93.6 percent of the total RTK. Of the total freight traffic, Regional and Short Lines were responsible for 37.77 billion GTK (or 5.6 percent) and 23.30 billion RTK (or 6.4 percent). In 2007, the Regional and Short Lines experienced a 6.3 percent decrease in RTK compared to 2006.

Table 1
Total Freight Traffic
tonne-kilometres (billion)

	1990	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
GTK											
Class I							569.75	608.51	628.09	629.93	638.66
Regional + Short Line							36.57	35.97	40.45	41.07	37.77
Total	454.94	529.72	554.82	586.56	583.2	582.06	606.26	644.48	668.54	671.00	676.43
RTK											
Class I							300.51	320.27	328.24	330.96	338.32
Regional + Short Line							23.07	22.96	24.67	24.87	23.3
Total	250.13	296.96	301.96	322.38	321.74	308.76	323.58	343.23	352.91	355.83	361.62
Ratio of RTK/GTK	0.550	0.561	0.544	0.550	0.552	0.531	0.534	0.533	0.528	0.530	0.535

Note: No data are available for the years 1990 to 2002 separating Class I and Short Line traffic.

Figure 1
Total Freight Traffic (1990-2007)
tonne-kilometres (billion)

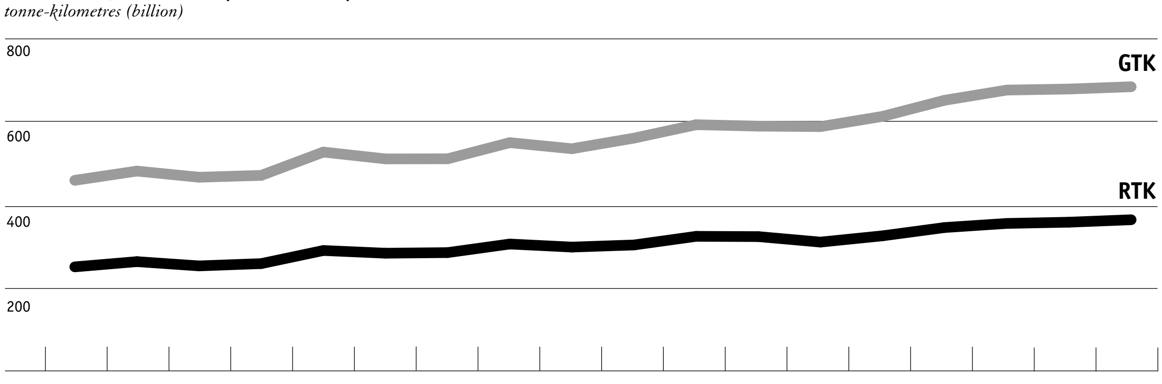
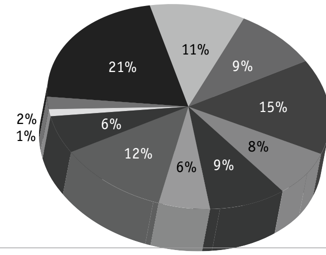


Figure 2

Canadian Rail Originated Freight Carloads by Commodity Grouping - 2007



11% Agriculture
9% Coal
15% Minerals
8% Forest Products
9% Metals
6% Machinery & Auto
12% Fuels & Chemicals
6% Paper Products
1% Food Products
2% Manufactured & Miscellaneous
21% Intermodal

2.1 Freight Traffic Handled

2.1.1 Freight Carloads by Commodity Grouping

2.1.2 Class I Intermodal Traffic

The number of intermodal carloads handled by the Class I railways in Canada in 2007 rose to 828,020 from 816,132 in 2006, an increase of 1.46 percent. Intermodal tonnage rose 3.8 percent to 32.70 million tonnes from 31.50 million tonnes in 2006. Overall, since 1990 intermodal tonnage comprising both container-on-flat-car and trailer-on-flat-car traffic has risen 155.7 percent equating to an average annual growth of 9.2 percent.

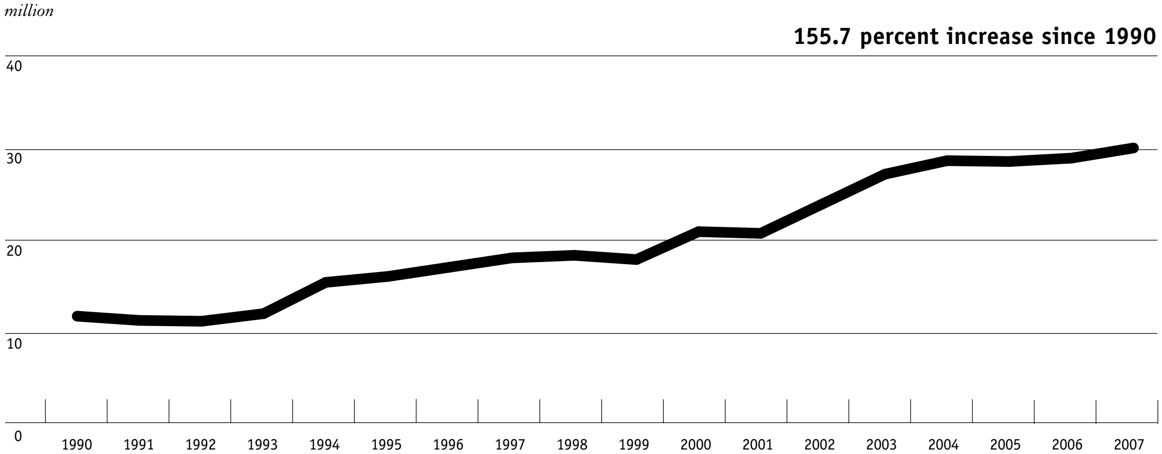
Class I intermodal RTK totalled 84.73 billion in 2007 versus 82.62 billion for 2006, an increase of 2.6 percent. Of the 338.32 billion RTK transported by the Class I railways in 2007, intermodal accounted for 25.0 percent of their RTK[2].

Intermodal service growth is an indication that the Canadian railways have been effective in partnering with shippers and the trucking industry to affect a modal shift in the transportation of goods. According to railway sector analysts, each intermodal carload displaces about 2.8 trucks from Canada's highways[3].

Figure 3

Class I Intermodal Tonnage

million



2 *2008 Railway Trends*, Railway Association of Canada

3 RAC / AAR

2.2 Passenger Traffic Handled

2.2.1 Intercity Passenger Services

Intercity passenger traffic in 2007 in Canada totalled 4.48 million, as compared to 4.32 million in 2006. The carriers were VIA Rail Canada, CN / Algoma Central, Ontario Northland Railway and Tshiuetin Rail Transportation. Of the total, VIA Rail Canada transported 93.3 percent, representing 4.18 million passengers. This was a 2.2 percent increase from the 4.09 million transported in 2006, and an increase of 20.8 percent from 3.46 million in 1990. In terms of revenue passenger-kilometres (RPK), the figure for 2007 was 1,407 million, the same as for 2006. It is up from 1,235 million in 1990, a rise of 13.9 percent. The annual statistics since 1990 for VIA's traffic and RPK are displayed in Figures 4 and 5.

The parameter to express intercity train efficiency is 'average passenger-kilometres (km) per train-kilometre (km)'. As shown in Figure 6, VIA's train efficiency in 2007 was 131 passenger-km per train-km, the same as in 2006, but above the 1990 baseline of 123. As a percentage, train efficiency in 2007 was 6.5 percent over that in 1990.

Figure 4
VIA Rail Canada Passenger Traffic
million

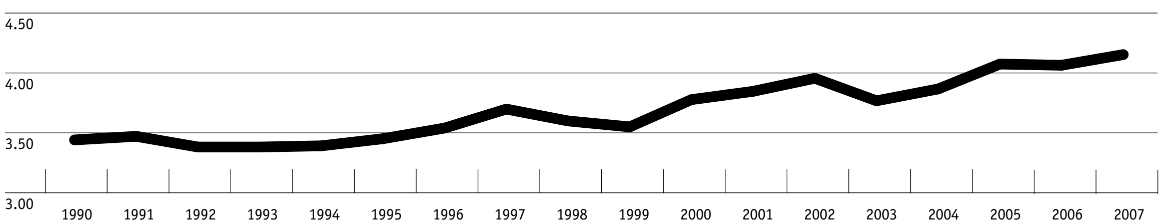


Figure 5
VIA Rail Canada Revenue Passenger-Kilometres
million

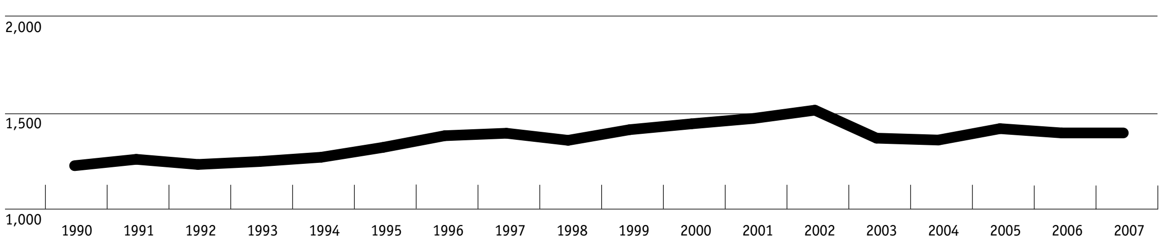
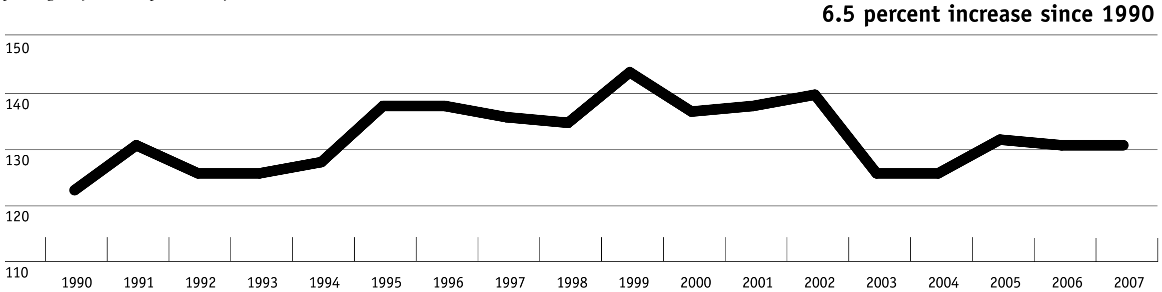


Figure 6
VIA Rail Canada Train Efficiency
passenger-kilometres per train-kilometre

6.5 percent increase since 1990

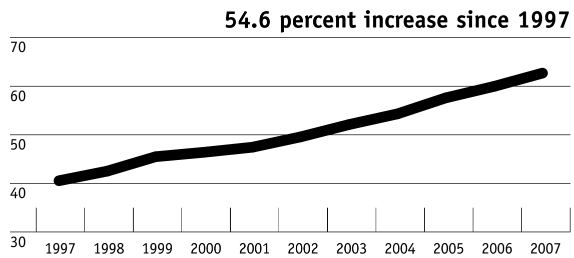


2.2 Passenger Traffic Handled

2.2.2 Commuter Rail

Commuter rail passengers in 2007 totalled 63.39 million. This is up from 60.63 million in 2006, an increase of 4.5 percent. As shown in Figure 7, by 2007, commuter traffic has increased 54.6 percent over the 1997 baseline of 41.00 million passengers when the RAC first started to collect commuter rail statistics. This is an average annual rate of 5.5 percent since 1997. The four commuter operations in Canada using diesel prime movers are Agence métropolitaine de transport (serving the Montreal-centred region), Capital Railway (Ottawa), GO Transit (serving the Toronto-centred region) and West Coast Express (serving the Vancouver-centred region).

Figure 7
Commuter Rail Passengers
million



2.2.3 Tourist and Excursion Services

In 2007, the eleven railways offering tourist and excursion services transported 378 thousand passengers as contrasted to 360 thousand in 2006, an increase of 5.0 percent. The railways reporting these services were: Agence métropolitaine de transport , Alberta Prairie Railway Excursions, Barrie-Collingwood Railway, CN / Algoma Central (also operates a scheduled passenger service), CP / Royal Canadian Pacific, Great Canadian Railtour Company, Hudson Bay Railway, Ontario Northland Railway (also operates a scheduled passenger service), South Simcoe Railway, Tshiuetin Rail Transportation (which also operates a scheduled passenger service) and White Pass & Yukon Route.

2.3 Fuel Consumption

As shown in Table 2, total rail sector fuel consumption increased to 2,237.22 million L in 2007 from 2,210.38 million L in 2006 and from 2,060.66 million L in 1990. As a percentage, fuel consumption increased 1.2 percent over 2006 and 8.6 percent over 1990.

2.3.1 Freight Operations

Fuel consumption for all freight train, yard switching and work train operations in 2007 was 2,134.92 million litres, up from 2,109.21 million L in 2006 and 1,957.96 million L in 1990. This is an increase of 1.2 percent over 2006 and 9.0 percent over 1990. The trend in overall freight operations fuel consumption is shown in Table 2 and Figure 8.

A measure of freight traffic fuel efficiency is the amount of fuel consumed per 1,000 RTK. As shown in Figure 9, freight traffic fuel consumption decreased to 5.90 L per 1,000 RTK in 2007 from 5.93 L per 1,000 RTK in 2006 and has decreased from 7.83 L per 1,000 RTK in 1990.

As a percentage, freight traffic fuel consumption per 1,000 RTK in 2007 was 0.5 percent below the 2006 level and is 24.6 percent lower than in 1990. Overall, this shows the ability of the Canadian freight railways to accommodate traffic growth while reducing fuel consumption per unit of work.

Table 2
Canadian Rail Operations Fuel Consumption
litres (million)

	1990	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Freight Train	1,822.60	1,881.46	1,799.72	1,836.37	1,823.21	1,870.44	1,909.40	2,009.50	2,033.33	2,037.05	2,066.64
Yard Switching	119.36	118.35	86.85	86.63	89.86	73.79	69.20	70.79	67.85	64.67	62.20
Work Train	16.00	7.00	5.00	4.00	4.86	5.70	4.90	4.17	6.73	7.49	6.09
Total Freight Operations	1,957.96	2,006.81	1,891.57	1,927.00	1,917.93	1,949.93	1,983.50	2,084.46	2,107.91	2,109.21	2,134.92
Total Passenger Operations	102.70	58.51	58.29	60.87	99.20	100.75	99.18	99.93	101.10	101.17	102.30
Total Rail Operations	2,060.66	2,065.32	1,949.86	1,987.87	2,017.13	2,050.68	2,082.68	2,184.39	2,209.01	2,210.38	2,237.22

Figure 8
Freight Operations Fuel Consumption
litres (million)

9.0 percent increase over 1990

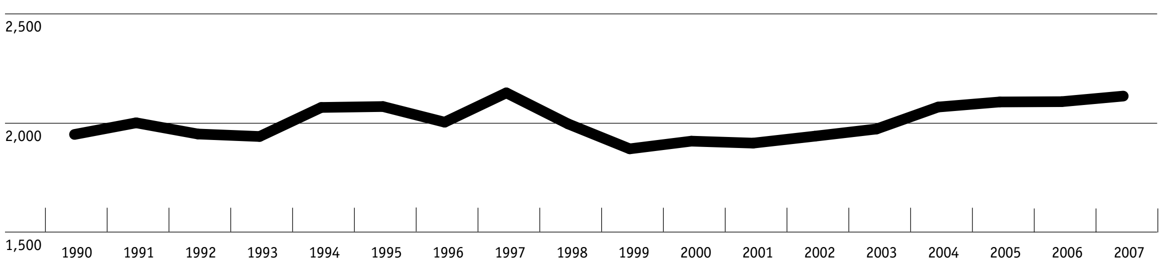
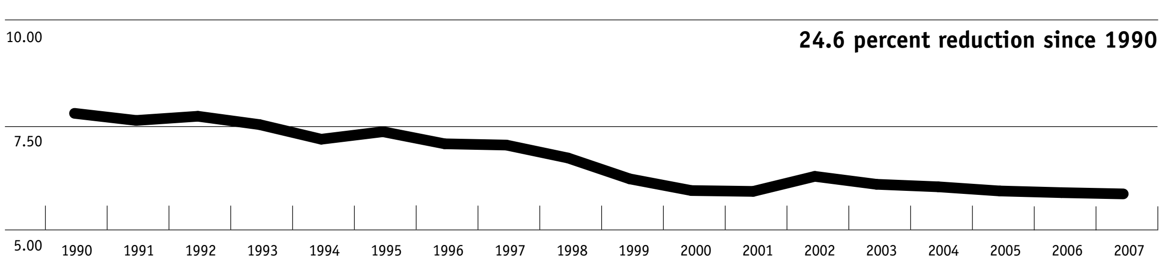


Figure 9
Freight Fuel Consumption per 1,000 RTK
litres

24.6 percent reduction since 1990



This improved fuel efficiency by Canadian freight railways has been achieved primarily by replacing older locomotives with modern fuel-efficient EPA compliant locomotives. As well, operating practices that reduce fuel consumption are being evaluated and implemented. The fuel consumption reduction initiatives implemented or under examination in 2007 are discussed in Section 7.

Table 3 shows the freight operations fuel consumption by service type for 2007 compared to years 2006, 2005, 2004 and 2003. Of the total diesel fuel consumed in freight operations in 2007, Class I freight trains accounted for 91.3 percent, Regional and Short Lines 5.5 percent and Yard Switching and Work Train 3.2 percent.

Table 3
Freight Operations Fuel Consumption
litres (million)

	2003	2004	2005	2006	2007
Freight Train Operations					
Freight: Class I	1,775.80	1,870.60	1,893.19	1,914.92	1,948.75
Freight: Regional and Short Line	133.60	138.90	140.14	122.13	117.89
Sub-total	**1,909.40**	**2,009.50**	**2,033.33**	**2,037.05**	**2,066.64**
Yard Switching	69.20	70.79	67.85	64.67	62.20
Work Train	4.90	4.17	6.73	7.49	6.09
Sub-total	**74.10**	**75.0**	**74.58**	**72.16**	**68.29**
Total	**1,983.50**	**2,084.46**	**2,107.91**	**2,109.21**	**2,134.92**

2.3 Fuel Consumption

2.3.2 Passenger Services

Overall rail passenger fuel consumption, that is, the sum of intercity, commuter and tourist and excursion train operations, was 102.30 million L in 2007, slightly up from 101.17 million L in 2006, a rise of 1.1 percent. The breakdown and comparison with previous years are shown on Table 4.

VIA's fuel consumption in 2007 increased 0.4 percent over that of 2006. Commuter rail fuel consumption in 2007 increased 5.0 percent over the 2006 level.

Table 4
Passenger Services Fuel Consumption
litres (million)

	2003	2004	2005	2006	2007
Via Rail Canada	60.99	60.37	60.09	*58.63	58.97
Amtrak	n/a	0.65	0.64	0.64	0.64
Commuter	31.54	33.79	35.31	34.23	35.94
Tourist Train and Excursion	6.65	5.12	5.06	7.67	6.75
Total	**99.18**	**99.93**	**101.10**	**101.17**	**102.30**

* Corrected to 58.75 following 2007 audit

3 Locomotive Inventory

The active fleet of diesel locomotives and DMUs in-service in Canada in 2007 totalled 3,027. Locomotives assigned to line-haul freight train operations in 2007 totalled 2,389, up from 2,252 in 2006. Passenger train motive power (locomotives and DMUs) totalled 188 and yard switching and work train locomotives totalled 450, down from 529 in 2006. Excluded from the 2007 reporting were steam locomotives, non-powered slug units and EMUs as they do not contribute diesel combustion emissions. The detailed inventory is shown in Appendix B. Only locomotives powered by diesel engines have been included in the 2007 inventory.

Table 5

NO_x Emissions Reduction Schedule for Line-Haul Locomotives

U.S. EPA Compliance Level	Year in effect	NO_x (g/bhp-hr)	Percent Reduction
Non-compliant Locomotives	Pre- 2000	13.5	
Tier 0	2000 - 2001	9.5	29.6
Tier 1	2002 - 2004	7.4	45.2
Tier 2	2005 -	5.5	59.3

3.1 Locomotives Compliant with U.S. EPA Emissions Limits

The MOU indicates that the member railways of the RAC are encouraged to conform to all applicable emission standards, including any updated U.S. EPA emissions standards respecting new and in-service locomotives manufactured after 1972.

Table 5 shows the U.S. EPA compliance schedule in effect in 2007 for the reduction of NO_x emissions according to the year a locomotive was freshly manufactured. Those now complying with Tier 2 limits will have NO_x emissions 59.3 percent lower than locomotives manufactured prior to 2000. The NO_x emissions intensity for the Canadian fleet, therefore, is projected to decrease as the railways continue to introduce new locomotives, plus retrofit high-horsepower in-service locomotives to U.S. EPA Tier 0.

Since the early 1990s, Canadian railways have been upgrading their fleets with new fuel-efficient, high horsepower locomotives. Of note, locomotives manufactured by the U.S. original equipment manufacturers (OEMs) during 2000 and 2001 met the U.S. EPA Tier 0 emissions limits; those manufactured during 2002 to 2004 met Tier 1 and those after January 1, 2005, meet Tier 2. Also, since 2000, in-service high-horsepower locomotives manufactured prior to 2000 are being voluntarily upgraded at overhaul to Tier 0 limits. Table 6 shows the progressive number of mainline locomotives meeting Tier 0, Tier 1 or Tier 2 compared to the total number of freight and passenger train locomotives.

Table 6

Locomotives in Canadian Fleet Meeting U.S. EPA Emissions Limits

	2000	2001	2002	2003	2004	2005	2006	2007
Total number of freight train and passenger train locomotives*	1,991	2,048	2,069	2,129	2,300	2,363	2,425	2,565
Number of freight train and passenger train locomotives* meeting EPA Tier 0, Tier 1 and Tier 2 emissions limits	80	179	189	634	842	870	956	1,065

* Does not include DMUs, EMUs, RDCs, switchers, slugs, historic or steam locomotives.

4 Diesel Fuel Properties

Of significance regarding diesel fuel properties is that the Environment Canada regulation limiting sulphur content to 500 ppm (or 0.05 percent) came into force on June 1, 2007. This precedes a further reduction to come into effect June 1, 2012 to 15 ppm (or 0,0015 percent) referred to as ultra-low sulphur fuel. Of note is that in 2007 VIA Rail Canada and the commuter railways standardized on the use of ultra-low sulphur fuel.

The RAC survey showed that in 2007 the weighted average sulphur content of the diesel fuel used by Canadian railways was 500 ppm. This is down from the average in 2006 of 1,275 ppm and, accordingly, resulted in a lower emission factor as noted in Section 5 used to calculate the emitted amount of oxides of sulphur (SO_x, but expressed as SO_2).

Photo: Courtesy of Rick Robinson/CP

5 Locomotive Emissions

5.1 Emissions Factors

The emission factors (EF) used to calculate the three greenhouse gases (GHG) emitted from diesel locomotive engines, that is, CO_2, CH_4 and N_2O are those used in Environment Canada's *National Inventory Report* submitted annually to the United Nations Framework Convention on Climate Change (UNFCCC). Of note is that the EF for the total of the three GHG emissions (expressed as $CO_{2\ equivalent}$) was adjusted downwards in 2007 from 3.07415 to 3.00715 kilograms per litre (kg/L) of diesel fuel consumed to correspond with updated UNFCCC worldwide reporting guidelines. The revision stems from more recent studies of the carbon content, density and oxidation rates of Canadian liquid fuels.

Similarly, EFs for the Criteria Air Contaminants (CAC), that is, NO_x, CO, HC, PM and SO_x, emitted from locomotive diesel engines have been calculated in grams per litre (g/L) of fuel consumed. Except for SO_x which is mostly a function of the sulphur content of the diesel fuel, CAC EFs are based on emissions data from the different engines in the various throttle notch settings applied to the duty cycle for the locomotives operating in Canadian railway fleets[4]. Emissions factors were derived originally from test measurements performed in the early 1990s by the Association of American Railroads (AAR), Southwest Research Institute (SwRI) and the locomotive manufacturers. The EFs were reviewed in 2001 and revised accordingly to reflect changes in the Canadian fleet[5]. Additional data have become available as a result of Transport Canada commissioning laboratory tests at SwRI[6] and Engine Systems Development Centre, Division of CAD Railway Services to measure emissions from locomotives types in service in Canada[7,8,9]. In 2007, data were also obtained from in-service emissions testing of locomotives operating in the U.S.A. to ensure their compliance with the stringent U.S. EPA Tier 0, Tier 1 and Tier 2 emissions standards[10]. The locomotives tested were types similar to those in Canadian railway service.

Since 2003, the EFs of CACs have been revised annually. The revisions reflect the evolving composition of the locomotive fleet, primarily the rising number of locomotives now meeting the stringent U.S. EPA Tier 0, Tier 1 and Tier 2 emissions standards. As can be seen from Table 7, a consolidated EF was calculated for NO_x emitted from all freight train locomotives. It was re-calculated to 44.90 g/L for 2007 versus 49.53 g/L for 2006. The progressive lowering of the NO_x EF shows the impact of the acquisition since 2005 of new locomotives manufactured to Tier 2 emissions standards as well as the upgrading to Tier 0, at overhaul, of in-service locomotives.

Table 7 also shows that the EF used to calculate CO emitted from freight train locomotives was re-calculated downwards to 5.39 g/L for 2007 versus 7.30 g/L for 2006. This stems from the receipt of additional emissions test results during 2007 that permitted a more confident curve-fitting of the data spread. Similarly, when updated emissions test data obtained in 2007 were added to the database spread for locomotive types used in switching and passenger operations, the EFs for CO were modified downward significantly. As these data were deemed to be more representative and accurate, they were used for the 2007 calculations which also contributed to the variance in NO_x and CO EFs between the time period 1990 - 2003 and subsequent years. Adjustments were also made to the EFs used to calculate HC and PM for 2007.

4 See Tables 10 and 12 in Environment Canada document EPS 2/TS/8, *Recommended Reporting Requirements for the Locomotive Emissions Monitoring (LEM) Program* – September 1994

5 *Review of Memorandum of Understanding Between Environment Canada and the Railway Association of Canada Regarding Railway Locomotive Emissions*, Environment Canada – June 2001

6 *Locomotive Exhaust Emissions Test Report: BNSF 9476,* undertaken for Transport Canada by Southwest Research Institute, San Antonio, Texas – May 2004

7 *Locomotive Emissions Testing Program - Fiscal Year 2005-6,* Report No. ETR-0339-R3 undertaken for Transport Canada by Engine Systems Development Centre, Inc., Lachine, Quebec – March 2006

8 *Locomotive Emissions Testing Program – Fiscal Year 2006-7,* Report No. ETR-0356 undertaken for Transport Canada by Engine Systems Development Centre, Inc., Lachine, Quebec – April 2007

9 *Locomotive Emissions Testing Program – Fiscal Year 2007-8,* Report No. ETR-0391 undertaken for Transport Canada by Engine Systems Development Centre, Inc., Lachine, Quebec – April 2007

10 *Locomotive Emissions Testing 2006 – Summary report for emissions testing of in-use locomotives conducted by the North American Class I Railroads to the Environmental Protection Agency Federal Test Procedure LA-023*, prepared by Steve Fritz, SwRI and Brian Smith, Transportation Technology Center, (a subsidiary of the Association of American Railroads), Pueblo, Colorado – April 2007

For 2007, the passenger trains EFs were based on a consolidation of locomotive data from both intercity and commuter train operations. Prior to 2007, EFs were only available from commuter train locomotives.

The EFs to calculate emissions of SO_x (expressed as SO_2) are based on the sulphur content of the diesel fuel. As noted in Section 4 of this report, new regulations in 2007 have reduced the sulphur content of railway diesel fuel in Canada to 500 ppm maximum.

Table 7

Railway Operations CAC Emissions Factors

grams / litre

	NO_x	CO	HC	PM	SO_x
Freight Train					
Consolidated 1990-2000	54.69	10.51	2.73	1.30	2.54
2001-2002	58.81	10.51	2.73	1.30	2.54
2003	53.17	10.81	2.34	1.19	2.37
2004	52.54	7.22	2.99	1.85	2.30
2005	50.48	7.17	3.01	1.83	2.33
2006	49.53	7.30	1.96	1.24	2.17
2007	44.90	5.39	1.71	1.61	0.85
Passenger Train					
1990-2000	54.69	10.51	2.73	1.30	2.54
2001-2002	54.69	10.51	2.73	1.30	2.54
2003	54.59	10.81	2.73	1.30	2.37
2004	61.04	9.25	2.34	1.36	2.30
2005	68.34	9.24	2.34	1.36	2.33
2006	65.58	5.18	2.01	1.27	2.17
Consolidated 2007	61.89	3.92	0.93	0.76	0.85
Switching					
1990-2000	61.01	10.42	3.61	1.48	2.54
2001-2002	61.01	10.42	3.61	1.48	2.54
2003	61.01	10.42	2.34	1.48	2.37
2004	71.69	12.77	4.12	1.72	2.30
2005	71.55	12.77	4.11	1.72	2.33
2006	64.63	5.34	3.16	1.52	2.17
2007	78.11	4.53	4.52	2.28	0.85

* 2007 EF for SO_x calculated for a diesel fuel sulphur content of 500 ppm

5.2 Locomotive Duty Cycle

The duty cycle is an element of the daily locomotive utilization profile. An explanation of what constitutes the Locomotive Utilization Profile and where the duty cycle fits in the profile is given in the Glossary of Terms. Duty cycles are determined by evaluating the time spent at each power notch level for a statistically significant sample of locomotives. Shown in Table 8 below are duty cycle values for the various freight services as of 2007, that is, Class I mainline, road switching, yard switching, regional lines and short lines, plus intercity and commuter rail passenger services. For comparison purposes, included are freight operations duty cycles established in 2001 and 1990. Of note is that the percentage of time at idle of Class I mainline locomotives has reduced. This has been due primarily to the installation of automatic stop/start devices and a strict manual shutdown policy. The increased use of such engine shutdown procedures has led to lower fuel consumption and emissions generated.

Table 8
Duty Cycle by Locomotive Service – 2007, 2001, 1990
Percent of Engine Operating Time

	Idle	N1	N2	N3	N4	N5	N6	N7	N8	DB
2007 Update										
2007 Class I Mainline Freight	51.3	4.7	5.7	4.7	3.8	3.2	3.0	1.6	14.0	8.0
2007 Class I Road Switching	77.6	4.3	4.4	2.8	2.2	1.4	1.1	0.6	3.2	2.4
2007 Regional Mainline Freight	45.0	3.0	7.4	7.4	7.4	4.6	5.2	3.2	16.8	0.0
2007 Short Line (Assumed equivalent to Road Switching)	77.6	4.3	4.4	2.8	2.2	1.4	1.1	0.6	3.2	2.4
2007 Yard Switching	84.9	5.4	4.2	2.2	1.4	0.6	0.3	0.2	0.6	0.2
2007 Intercity Passenger	49.7	16.5	4.9	3.4	2.2	1.3	1.2	0.3	18.3	2.2
2007 Commuter	30.5	31.0	2.5	2.1	2.5	1.2	1.7	1.1	25.8	1.6
2001 Update										
2001 Freight Class I	58.1	3.9	5.0	4.4	3.7	3.3	3.0	1.5	12.0	5.1
2001 Freight Train	61.6	3.8	4.7	4.1	3.5	3.1	2.8	1.5	10.9	4.0
2001 Passenger	69.5	0.5	4.8	2.1	1.4	1.2	0.8	0.2	19.5	0.0
2001 Switching	83.0	4.1	4.0	3.6	2.0	1.0	0.5	0.3	1.5	0.0
1990 Update										
1990 Freight	60.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	12.0	0.0
1990 Branch/Yard	81.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	5.0	0.0

5.3 Emissions Generated

5.3.1 Greenhouse Gases (GHG)

As reported in the *National Inventory Report 1990 – 2006* submitted by Environment Canada in 2008 to the UNFCCC, the transportation sector produces almost 27.0 percent of all Canadian GHG emissions and rail accounts for 3.0 percent of the transportation contribution[11]. It also reported an adjustment to the emission factor for $CO_{2\ equivalent}$, lowering it from 3.07415 kg/L to 3.00715 kg/L.

As shown in Table 9 and Figure 10, between 1998 and 2002 the Canadian railway sector did manage to reduce its GHG emissions to 1990 levels. However, its levels have since increased with the rise in annual traffic and concomitant fuel consumption. In 2007, GHG emissions produced by the railway sector as a whole (expressed as $CO_{2\ equivalent}$) were 6,727.65 kt, as compared to 6,795.04 kt in 2006 and 6,288.00 kt in 1990. This is a rise of 7.0 percent since 1990, with a corresponding rise of 44.6 percent in RTK traffic. Of note is that due to the effect of the adjusted $CO_{2\ equivalent}$ emission factor, the calculated GHG emissions are lower in 2007 compared to 2006 despite a higher fuel consumption in 2007.

Figure 11 shows the GHG emissions intensities trend line for freight traffic which decreased in 2007 to 17.75 kg per 1,000 RTK from 18.22 in 2006 and from 23.88 in 1990. The yearly values are listed in Table 9. As a percentage, the 2007 GHG emissions intensity for total freight was 2.5 percent below 2006 and 25.7 percent below 1990 levels. It is expected that this trend will continue as Canadian railways progressively acquire new locomotives, retire older locomotives and continue to implement fuel consumption reduction strategies. The initiatives to accomplish the latter are discussed further in Section 7.

Figure 10

Total Railway GHG Emissions

kilotonnes of $CO_{2\ equivalent}$

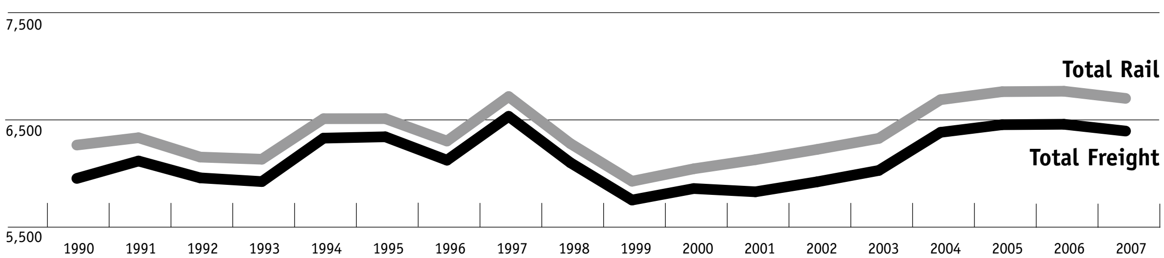
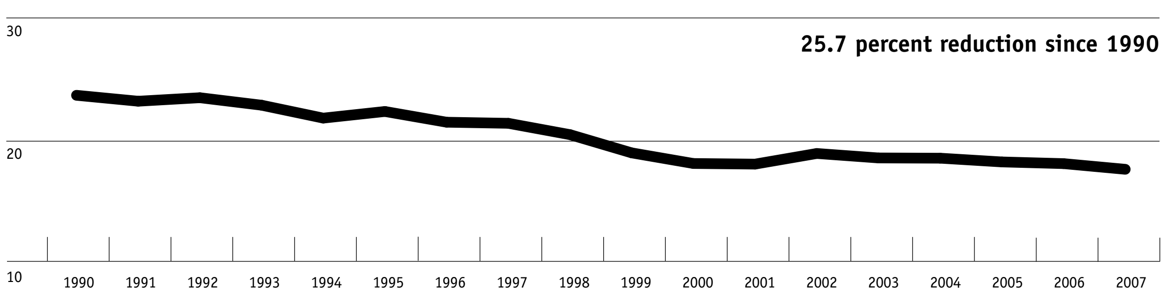


Figure 11

Total Freight GHG Emissions Intensity

kg of $CO_{2\ equivalent}$ / 1,000 RTK



11 *National Inventory Report, 1990- 2006 – Greenhouse Gas Sources and Sinks in Canada.* The Canadian Government's Submission to the UN Framework Convention on Climate Change, Environment Canada, April 2008 http://www.ec.gc.ca/pdb/ghg/inventory_e.cfm

Table 9

Locomotive GHG Emissions

in kilotonnes

	1990	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Freight Train											
$CO_{2\ equivalent}$	5,560.36	5,739.50	5,489.97	5,602.05	5,560.83	5,697.87	5,822.86	6,177.50	6,250.73	6,262.19	6,214.67
CO_2	4,937.88	5,096.97	4,875.37	4,974.91	4,938.30	5,060.00	5,171.00	5,485.93	5,550.97	5,561.13	5,503.42
CH_4	5.70	5.88	5.63	5.74	5.70	5.84	5.97	6.33	6.40	6.42	6.51
N_2O	616.78	636.65	608.97	621.40	616.83	632.03	645.90	685.24	693.36	694.64	704.74
Yard Switching and Work Train											
$CO_{2\ equivalent}$	413.76	382.86	280.78	276.81	287.52	244.35	226.34	230.56	229.25	221.84	205.36
CO_2	367.44	340.00	249.35	245.82	255.33	217.00	201.00	204.75	203.59	197.00	181.85
CH_4	0.42	0.39	0.29	0.28	0.29	0.25	0.23	0.24	0.23	0.23	0.22
N_2O	45.90	42.47	31.15	30.70	31.89	27.10	25.11	25.57	25.43	24.61	23.29
Freight Operations											
$CO_{2\ equivalent}$	5,974.12	6,122.36	5,770.75	5,878.86	5,848.35	5,942.23	6,049.20	6,408.06	6,479.99	6,484.03	6,420.03
CO_2	5,305.32	5,436.97	5,124.72	5,220.73	5,193.63	5,277.00	5,372.00	5,690.68	5,754.56	5,758.13	5,685.27
CH_4	6.12	6.27	5.91	6.02	5.99	6.09	6.20	6.57	6.64	6.65	6.73
N_2O	662.67	679.12	640.12	652.11	648.72	659.14	671.01	710.81	718.79	719.25	728.03
Passenger											
$CO_{2\ equivalent}$	314.23	179.99	176.95	186.10	302.03	305.16	301.78	307.11	310.79	311.01	307.62
CO_2	279.05	159.84	157.14	165.27	268.22	271.00	268.00	272.73	276.00	276.19	272.42
CH_4	0.32	0.18	0.18	0.19	0.31	0.31	0.31	0.31	0.32	0.32	0.32
N_2O	34.85	19.96	19.63	20.64	33.50	33.85	33.47	34.07	34.47	34.50	34.88
Total – Rail Operations											
$CO_{2\ equivalent}$	6,288.34	6,302.35	5,947.70	6,064.96	6,150.38	6,247.39	6,350.99	6,715.17	6,790.78	6,795.04	6,727.65
CO_2	5,584.37	5,596.81	5,281.86	5,386.00	5,461.85	5,548.00	5,640.00	5,963.41	6,030.56	6,034.32	5,957.69
CH_4	6.44	6.46	6.09	6.21	6.30	6.40	6.51	6.88	6.96	6.97	7.05
N_2O	697.53	699.08	659.74	672.75	682.23	692.99	704.48	744.88	753.26	753.75	762.91
Freight Operations Emissions Intensity *kg / 1,000 RTK*											
$CO_{2\ equivalent}$	23.88	20.62	19.11	18.23	18.18	19.06	18.69	18.67	18.37	18.22	17.75
CO_2	21.21	18.31	16.97	16.19	16.14	16.93	16.60	16.58	16.31	16.18	15.72
CH_4	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
N_2O	2.65	2.29	2.12	2.02	2.02	2.11	2.07	2.07	2.04	2.02	2.01

The MOU signed on May 15, 2007, between the Railway Association of Canada (RAC), Environment Canada and Transport Canada (attached as Appendix A) sets out targets to be achieved by 2010 for GHG emissions intensities by category of railway operation. Vis-à-vis the 2010 target, Table 10 shows the emissions intensity levels for the years 2003 to 2007 for, respectively, Class I freight, Regional and Short Lines, Intercity Passenger and Commuter Rail. The emissions reduction trend continues towards the 2010 target. At present, the reason for the steeper decline in the Regional and Short Lines data trend cannot be pinpointed.

Table 10

GHG Emissions Intensities by Category of Operation

Railway Operation	Units	2003	2004	2005	2006	2007	2010 Target
Class I Freight	kg / 1,000 RTK	18.16	17.62	17.73	17.79	17.32	16.98
Regional and Short Lines	kg / 1,000 RTK	17.81	18.59	17.46	15.10	15.21	15.38
Intercity Passenger	kg / passenger-km	0.14	0.14	0.13	0.13	0.13	0.12
Commuter Rail	kg / passenger	1.82	1.89	1.87	1.74	1.71	1.46

To illustrate the significance of the data in Table 10, Figures 12, 13, 14 and 15 display, for the four categories of railway operation, the intensity trend lines of GHG emissions (expressed as $CO_{2\ equivalent}$). The 2010 target identified in the MOU is denoted as the bold horizontal line.

Figure 12

Class I Freight GHG Emissions Intensity

kg / 1,000 RTK

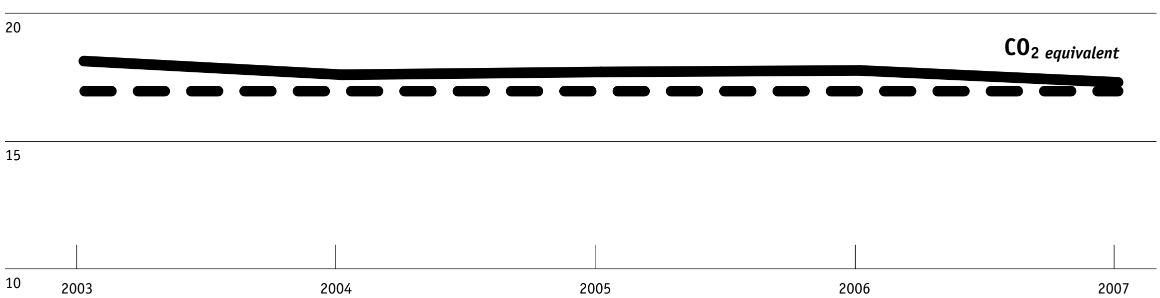


Figure 13

Regional and Short Lines GHG Emissions Intensity

kg / 1,000 RTK

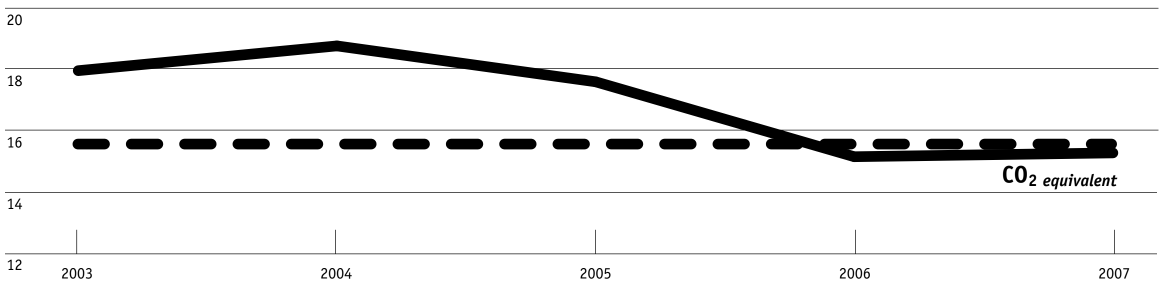


Figure 14

Intercity Passenger GHG Emissions Intensity

kg / passenger-km

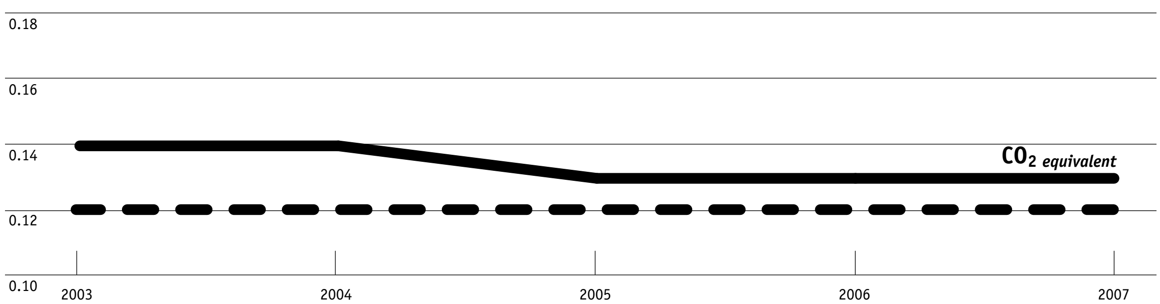
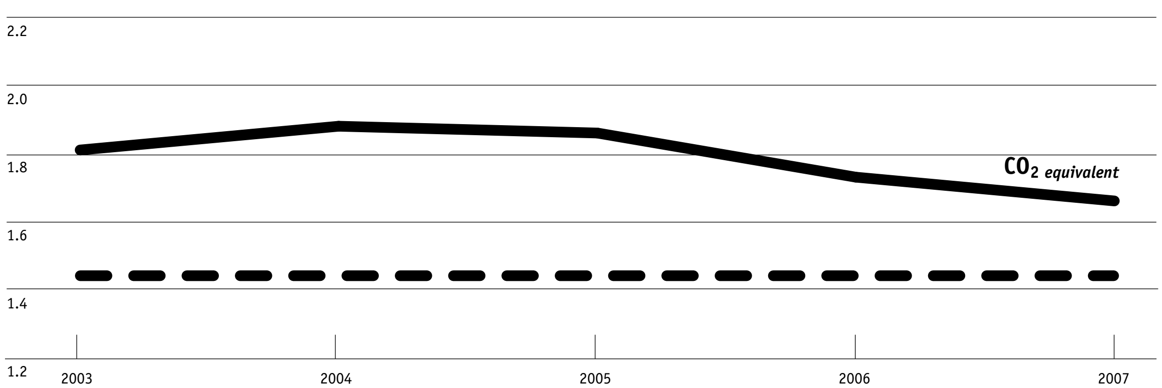


Figure 15

Commuter Rail GHG Emissions Intensity

kg / passenger



5.3.2 Criteria Air Contaminants (CAC)

Table 11 displays the CAC emissions produced annually by locomotives in operation in Canada, namely NO_x, CO, HC, PM and SO_x. The values are for both absolute amounts and intensities per productivity unit.

The CAC of key concern in the railway sector is oxides of nitrogen (NO_x). As shown in Table 11, railway-generated NO_x emissions in 2007 totalled 104.46 kt, as compared to 112.22 kt in 2006 and 113.59 kt for 1990, the baseline year. Total rail NO_x emissions in 2007 were 6.9 percent lower than in 2006 and 8.0 percent lower than in 1990. Freight operations accounted for 93.5 percent of railway-generated NO_x emissions in Canada.

NO_x emissions intensity, that is, the quantity of NO_x emitted per unit of productivity, decreased in 2007 to 0.27 kg per 1,000 RTK from 0.30 in 2006. This is down from 0.43 kg per 1,000 RTK in 1990. Figure 16 is indicative of the historical trend in NO_x emissions per 1,000 RTK for freight operations since 1990. The reduction since 2003 shows the impact of the acquisition of locomotives meeting U.S. EPA emissions limits as well as upgrading, upon remanufacture, high-horsepower locomotives freshly manufactured prior to 2000.

Figure 16

Total Freight NO_x Emissions Intensity
kg / 1,000 RTK

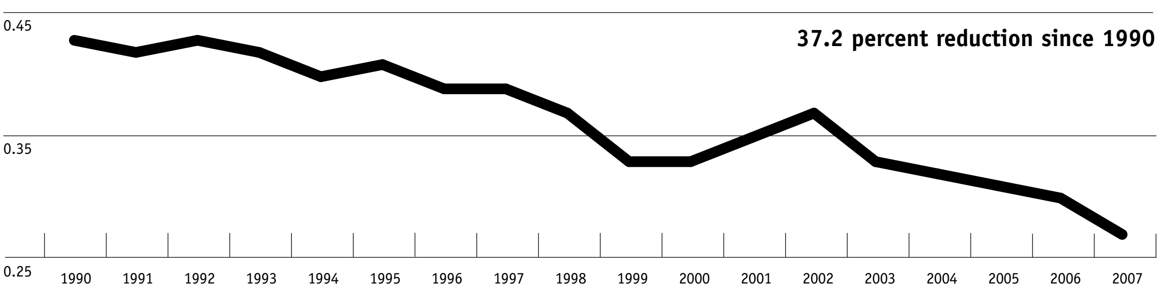


Table 11

Locomotive CAC Emissions

in kilotonnes

		1990	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Freight Train	NO_x	99.68	102.90	94.43	100.43	107.21	109.86	101.50	105.57	102.64	100.89	92.80
	CO	19.15	19.77	18.91	19.29	19.15	19.63	20.85	14.40	14.59	14.87	11.15
	HC	4.98	5.14	4.92	5.02	4.98	5.10	4.60	6.05	6.12	3.99	3.53
	PM	2.37	2.45	2.34	2.39	2.37	2.43	2.31	4.53	3.73	2.53	3.33
	SO_x	4.62	4.77	4.57	4.66	4.62	4.74	4.52	3.83	4.71	4.42	1.76
Yard Switching + Work Train	NO_x	8.27	7.65	5.60	5.53	5.74	4.88	4.51	5.38	5.34	4.70	5.33
	CO	1.41	1.31	0.96	0.94	0.98	0.83	0.77	0.96	0.95	0.39	0.31
	HC	0.49	0.45	0.33	0.33	0.34	0.29	0.27	0.31	0.31	0.23	0.31
	PM	0.20	0.18	0.14	0.13	0.14	0.12	0.11	0.13	0.13	0.11	0.16
	SO_x	0.34	0.32	0.23	0.23	0.24	0.20	0.18	0.17	0.17	0.16	0.06
Freight Operations	NO_x	107.95	110.55	100.03	105.96	112.95	114.74	106.01	110.95	107.98	105.59	98.13
	CO	20.56	21.08	19.87	20.23	20.13	20.46	21.62	15.36	15.54	15.26	11.46
	HC	5.47	5.59	5.25	5.35	5.32	5.39	4.89	6.36	6.43	4.22	3.84
	PM	2.57	2.63	2.48	2.52	2.51	2.55	2.42	4.66	3.86	2.64	3.49
	SO_x	4.96	5.09	4.80	4.89	4.86	4.94	4.70	4.00	4.88	4.58	1.82
Passenger Operations	NO_x	5.63	3.23	3.17	3.34	5.41	5.47	5.31	6.10	6.88	6.63	6.33
	CO	1.08	0.62	0.61	0.64	1.04	1.05	1.04	0.92	0.93	0.52	0.40
	HC	0.28	0.16	0.16	0.17	0.27	0.27	0.27	0.23	0.24	0.20	0.09
	PM	0.13	0.08	0.08	0.08	0.13	0.13	0.13	0.14	0.14	0.13	0.08
	SO_x	0.26	0.15	0.15	0.15	0.25	0.25	0.23	0.23	0.23	0.22	0.09
Total - Rail Operations	NO_x	113.59	113.78	103.21	109.30	118.36	120.21	111.32	117.05	114.86	112.22	104.46
	CO	21.64	21.70	20.48	20.87	21.17	20.46	22.66	16.28	16.47	15.78	11.86
	HC	5.75	5.75	5.41	5.52	5.59	5.66	5.14	6.59	6.67	4.42	3.93
	PM	2.70	2.71	2.56	2.60	2.64	2.68	2.55	4.80	3.99	2.77	3.57
	SO_x	5.22	5.24	4.95	5.04	5.11	5.19	4.93	4.23	5.09	4.80	1.91
Freight Operations	NO_x	0.43	0.37	0.33	0.33	0.35	0.37	0.33	0.32	0.31	0.30	0.27
Emissions Intensity	CO	0.08	0.07	0.07	0.06	0.06	0.07	0.07	0.05	0.04	0.04	0.03
kg / 1,000 RTK	HC	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01
	PM	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	SO_x	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01

6 Fuel Consumption and Emissions in Tropospheric Ozone Management Areas

6.1 Data Derivation

Three Tropospheric Ozone Management Areas (TOMA) have been designated as being of particular interest for railway emissions. These are areas of concern regarding air quality. The TOMA are the Lower Fraser Valley in British Columbia, the Windsor-Quebec City Corridor and the Saint John area in New Brunswick. Railway operations that traverse the TOMA are shown in Appendix C.

The fuel consumption in each of the TOMA is derived from the total traffic in the areas. Table 13 shows the fuel consumption and, hence, the GHG emissions in the TOMA regions as a percentage of the total fuel consumption for all rail operations. The emissions of GHGs and CACs are then calculated using the respective emissions factors as established in Section 5.1. Table 14 shows NO_x emissions in the TOMAs as a percentage of the total NO_x emissions for all rail operations. This illustrates the relative concentration of railway operations in the TOMA.

6.2 Seasonal Data

The emissions during 2007 in the TOMA have been split according to two seasonal periods:

- Winter (7 months) January to April and October to December, inclusively;
- Summer (5 months) May to September, inclusively.

The division of traffic in the TOMA in the seasonal periods was then 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, except in the case of GO Transit in the Windsor-Quebec City TOMA where the actual seasonal fuel consumption data was available. The emissions in the seasonal periods were then calculated as per Section 6.1. The results are shown in Tables 15 to 17.

Table 12
TOMA Percentages of Total Fuel Consumption and GHG Emissions

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Lower Fraser Valley, B.C.	4.9	4.6	4.3	4.6	4.1	3.8	4.0	3.7	3.1	3.0
Windsor-Quebec City Corridor	18.5	18.4	18.4	18.7	20.7	21.9	21.9	20.6	19.5	17.4
Saint John, N.B.	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.2	0.2	0.2

Table 13
TOMA Percentages of Total NO_x Emissions

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Lower Fraser Valley, B.C.	4.3	4.4	3.9	3.9	3.4	3.4	3.4	3.2	2.8	2.9
Windsor-Quebec City Corridor	16.3	17.8	16.8	15.8	17.2	19.7	18.7	17.9	17.4	16.6
Saint John, N.B.	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2

Table 14

TOMA No. 1 – Lower Fraser Valley, B.C.
Traffic, Fuel and Emissions Data, 2007

	TOMA Region No. 1 LOWER FRASER VALLEY, B.C. Seasonal Split		
	2007	**Winter**	**Summer**
	Total	**58%**	**42%**
TRAFFIC	*(million GTK)*		
Freight Operations			
CN	7,575	4,394	3,182
CP	10,921	6,334	4,587
Burlington Northern Santa Fe	584	339	245
Southern Railway of BC	353	205	148
Total Freight Traffic	**19,433**	**11,271**	**8,162**
FUEL CONSUMPTION	*(million litres)*		
Freight Operations			
Freight Fuel Rate: 3.16 litres/1,000 GTK			
Total Freight Fuel Consumption	**61.41**	**35.62**	**25.79**
Passenger Operations			
VIA Rail Canada	0.42	0.24	0.18
Great Canadian Railtour Company	2.06	1.19	0.87
Westcoast Express	1.16	0.67	0.49
Total Passenger Fuel Consumption	**3.64**	**2.10**	**1.54**
Total Rail Fuel Consumption	**65.05**	**37.72**	**27.33**
EMISSIONS	*(kilotonnes)*		
Emissions Factors: NO_x 45.75 g/L	2.98	1.73	1.25
CO 5.30 g/L	0.34	0.20	0.14
HC 1.66 g/L	0.11	0.06	0.05
PM 1.56 g/L	0.10	0.06	0.04
SO_x 0.85 g/L	0.06	0.03	0.03
CO_2 2663 g/L	173.23	100.47	72.76
CH_4 3.15 g/l	0.20	0.12	0.08
N_2O 341 g/L	22.18	12.86	9.32
$CO_{2\ equivalent}$ 3007.15 g/L	195.61	113.45	82.16

Note: EFs adjusted for mix of Freight and Passenger traffic.

Table 15

TOMA No. 2 – Windsor - Quebec City Corridor
Traffic, Fuel and Emissions Data, 2007

	TOMA Region No. 2 WINDSOR–QUEBEC CITY CORRIDOR Seasonal Split		
	2007	**Winter**	**Summer**
	Total	**58%**	**42%**
TRAFFIC		***(million GTK)***	
Freight Operations			
CN	56,927	33,018	23,909
CP	37,036	21,481	15,555
CSX	296	172	124
Essex Terminal Railway	49	28	20
Goderich – Exeter Railway	438	254	184
Montreal, Maine & Atlantic	848	492	356
Norfolk Southern	10	6	4
Ottawa Central	230	133	97
Ottawa Valley – Railink *(Note 1)*	-	-	-
Quebec Gatineau	1,677	973	704
St. Lawrence & Atlantic	416	241	175
Total Freight Traffic	**97,926**	**56,798**	**41,128**
FUEL CONSUMPTION		***(million litres)***	
Freight Operations			
Freight Fuel Rate: 3.143 litres/1,000 GTK			
Total Freight Fuel Consumption	**309.45**	**179.48**	**129.97**
Passenger Operations			
VIA Rail Canada	35.44	20.56	14.88
Commuter Rail	34.29	19.89	14.40
Total Passenger Fuel Consumption	**69.73**	**40.45**	**29.28**
Total Rail Fuel Consumption	**379.18**	**219.93**	**159.25**
EMISSIONS		***(kilotonnes)***	
Emissions Factors: NO_x 45.75 g/L	17.35	10.06	7.29
CO 5.30 g/L	2.01	1.17	0.84
HC 1.66 g/L	0.63	0.37	0.26
PM 1.56 g/L	0.59	0.34	0.25
SO_x 0.85 g/L	0.32	0.19	0.13
CO_2 2663 g/L	1,009.76	585.66	424.10
CH_4 3.15 g/l	1.19	0.69	0.50
N_2O 341 g/L	129.30	74.99	54.31
$CO_{2\ equivalent}$ 3007.15 g/L	1,140.25	661.34	478.91

Note 1: Ottawa Valley - RaiLink data is included in CP data.
Note: EFs adjusted for mix of Freight and Passenger traffic.

Table 16

TOMA No. 3 – Saint John Area, New Brunswick
Traffic, Fuel and Emissions Data, 2007

	TOMA Region No. 3 SAINT JOHN, NB Seasonal Split		
	2007	**Winter**	**Summer**
	Total	**58%**	**42%**
TRAFFIC	*(million GTK)*		
Freight Operations			
CN	744	431	313
New Brunswick Southern Railway	555	322	233
Total Freight Traffic	**1,299**	**753**	**546**
FUEL CONSUMPTION	*(million litres)*		
Freight Operations			
Freight Fuel Rate: 3.143 litres/1,000 GTK			
Total Freight Fuel Consumption	**4.32**	**2.51**	**1.81**
Passenger Operations	**0**	**0**	**0**
Total Rail Fuel Consumption	**4.32**	**2.51**	**1.81**
EMISSIONS	*(kilotonnes)*		
Emissions Factors: NO_x 45.75 g/L	0.20	0.12	0.08
CO 5.30 g/L	0.02	0.01	0.01
HC 1.66 g/L	0.01	0.01	0.00
PM 1.56 g/L	0.01	0.01	0.00
SO_x 0.85 g/L	0.00	0.00	0.00
CO_2 2663 g/L	11.50	6.67	4.83
CH_4 3.15 g/l	0.01	0.01	0.00
N_2O 341 g/L	1.47	0.85	0.62
$CO_{2\ equivalent}$ 3007.15 g/L	12.98	7.53	5.45

7 Emissions Reductions Initiatives

Locomotive exhaust emissions, both in terms of intensity per unit of work performed and overall, can be reduced. This objective can be achieved not only through improved diesel engine technology but also by introducing a variety of new rolling stock equipment designs, train handling improvements and infrastructure upgrades to increase operational fluidity that reduce fuel consumption and, hence, emissions. In this regard, described herein are various initiatives underway in 2007. Section 7.1 describes the awareness generation actions of the RAC, while Sections 7.2, 7.3, 7.4 and 7.5 list initiatives pursued, or being explored, by the railways or equipment supply companies regarding new technology, operating procedures, infrastructure enhancements and governmental support aimed at fuel consumption and emissions reductions.

7.1 RAC Awareness Generation Actions

The RAC provides a venue for the railway companies to exchange ideas and best operating practices for reducing emissions associated with railway activities. The RAC represents virtually all of the railways operating in Canada. Its 54 members include Class I freight, regional and short Lines, intercity passenger, commuter passenger and tourist railways.

The RAC is in frequent communication with its members, through newsletters, E-mail distribution, working committees, RAC member events, the RAC Annual General Meeting and through the RAC website. For example, RAC coordinates the Canadian railway officer participation in annual meetings of fuel conservation teams wherein North American Class I railways share information on 'best practice' solutions, technologies and related information. As such, the RAC distributes relevant information within its membership regarding technologies and operating practices that reduce the emissions of GHGs on an activity basis.

Furthermore, the RAC has an annual Environmental Award Program for both passenger and freight railways operating in Canada. The objective of the program is to share and assess initiatives undertaken by railways to improve their environmental performance. To date, this program has proven very useful in sharing various projects and initiatives within the RAC membership by recognizing, on a yearly basis, the efforts that individual railways have made in developing new environmental programs and initiatives.

In 2007, the RAC began developing an on-line Rail Freight Greenhouse Gas (GHG) Calculator, a web-based user-friendly tool for calculating the GHG emissions associated with specific shipments. This tool allows shippers and others to better understand, on a shipment by shipment basis, the difference in emissions levels by choosing the rail as compared to truck mode. The RAC will continually update the "input" factors employed as new data becomes available. The Calculator is now available by accessing ghg.railcan.ca.

7.2 Equipment-related Initiatives

7.2.1 Locomotive Fleet Renewal

Canadian freight and passenger railways are progressively renewing their fleets by acquiring new locomotives that are compliant with U.S. EPA emissions standards. As of the end of 2007, a total of 207 locomotives have entered the Canadian fleet meeting the stringent EPA Tier 2 standard. Their diesel engines emit 62% less NO_x than those in locomotives without emission control technologies. As these new locomotives also have higher-power and higher-adhesion capabilities, fewer locomotives are needed to pull the same train weight. This results in a more optimum matching of motive power to train operations, i.e., more time at high notch power levels, resulting in economies in fuel consumption and reduction in emissions intensities. Also, the railways are exploring options such as retrofitting existing locomotive bodies with new Tier-compliant diesel engines. One such strategy for switchers is to replace the large conventional medium-speed diesel engine with multiple smaller industrial diesel engines packaged as individual generator sets (known as 'GenSets') resulting in lower fuel consumption and emissions. Compared to a conventional Tier 0 switcher locomotive, the GenSets have demonstrated a three-fold improvement in HC, CO and PM and less than half the NO_x emissions[12].

12 *Fuel Consumption and Exhaust Emissions from a 1,125 kW Multiple GenSet Switcher Hybrid Locomotive,* Paper No.41 presented by Southwest Research Institute (S. Fritz) and Railpower Hybrid Technologies (M. Schell) at the Conseil International des Machines à Combustion (CIMAC) Congress, Vienna – April 2007

7.2.2 Fleet Upgrading and Maintenance

Upon remanufacture, the Class I freight railways are upgrading to EPA Tier 0 limits those high-horsepower locomotives manufactured prior to 2000, a commitment under the MOU. Also, the Canadian railways are introducing maintenance programs aimed at realizing fuel conservation gains and emissions reduction, such as a scheduled three-year fuel injector change-out on certain locomotives. Such measures ensure emissions intensities, particularly for NO_x, and PM, will continue to be reduced.

7.2.3 Low Idle

The railways are extending the application of the 'Low Idle' feature to more locomotives. This feature allows the diesel engine to idle at a reduced speed with a consequently reduced load from cooling fans and other parasitic equipment. The reduction in fuel consumption can be as much as 10 L/hr and, on the accepted duty cycles, can be up to 1.0 percent of the fleet annual fuel consumption. The use of the low idle feature is limited in some cases, particularly in cold weather, by the need to supply sufficient power for battery charging and crew comfort equipment.

7.2.4 Automatic Stop/Start Systems

Railways are installing devices on locomotives for both line-haul and yard switching services that will automatically shut down and restart the diesel engine when the restart the engine to idle for a time to prevent freezing and to charge the batteries. Automatic stop/start systems will extend the time during the warmer seasons when the locomotive engine can be shut down. Monitoring of line-haul locomotives equipped with a properly operating automatic stop/start system has shown annual savings per locomotive on average of 30,000 L[13]. Analyses of fleet operations indicate that the capital and installation costs of a unit to supply auxiliary power for a shut-down locomotive can be recouped within 2.2 years[14].

Photo: Courtesy of CN

7.2.5 Low and Ultra-Low Sulphur Diesel Fuel

Sulphur in diesel fuel influences emissions both directly in the amount of SO_x produced and indirectly by enabling exhaust emissions reduction technologies such as diesel particulate filters and oxidation catalysts to function and not become contaminated[15].

In harmony with standards introduced in the U.S.A., as of June 2007 Canadian refineries are required to limit diesel fuel sulphur content to a maximum of 500 ppm (0.05 percent), referred to a low sulphur diesel fuel. As of 2012, ultra-low sulphur diesel fuel (ULSF) having a sulphur content limited to 15 ppm (0.0015 percent) will be the only diesel fuel marketed in Canada available to the railways. In view of the environmental benefits of ULSF, in 2007 ahead of this deadline VIA Rail Canada and the commuter passenger railways standardized on its use.

7.2.6 Freight Car Technology Improvements

The maximum allowable axle load has been increased from 119,545 to 130,000 kg (263,000 to 286,000 lbs)

13 *Reduction of Impacts from Locomotive Idling,* presentation by Linda Gaines, Center for Transportation Research, Argonne National Laboratory, to Society of Automotive Engineers International Truck and Bus Meeting, Fort Worth, Texas – November 2003

14 *Locomotive Emission and Engine Idle Reduction Technology Demonstration Project,* report CSXT A29312 authored by J.R.Archer (TECHSVCTRAIN) for CSX Transportation for Maryland Energy Administration and U.S. Department of Energy – March 2005

15 *Operational Effects of Low Sulfur Diesel Fuel in Locomotives,* report by Fred Girshick, Infineum USA, published in Proceedings of the 70th Annual Meeting of the Locomotive Maintenance Officers Association (LMOA), Chicago, Illinois – September 21-24, 2008

on many lines in Canada. This means the needed gross tonne-kilometres of train consist to move a given amount of freight is reduced. The gross-to-tare ratio of such freight cars is increased permitting the railways to reduce the number of railcars without losing capacity. Similarly, to improve gross-to-tare weight ratios, the railways have invested in lighter-weight aluminum railcars. Also, freight car rolling friction has been reduced through the use of steerable-axle trucks and the universal use of roller bearings on running gear.

Double-stack container cars permit a higher container cargo volume for a specific train length, thus lowering the fuel consumption and emissions per RTK of intermodal trains. However, on intermodal trains attention is required to avoid unfilled slots, that is, flat cars without containers. Analyses have shown that improving slot utilization from 90 to 100 percent reduced the aerodynamic resistance coefficient sufficient to save up to 2.4 L/km of fuel[16].

7.2.7 Longer Trains

Trains up to 2.5 kilometres in length are now operating as a result of lengthened passing tracks and sidings. Longer trains permit improved utilization of the locomotive power. In its long trains, CN is deploying Distributed Braking Cars (DBC) which are placed at the end of trains to maintain airbrake pipe pressure at a certain operational level. The DBC were developed to assist in the operation of long trains in cold weather conditions, particularly between Winnipeg and Edmonton. The concept is based on the older-design air repeater car, which utilized an air compressor installed in a box car that was placed in the middle of the train. DBC obviate the need for additional locomotives used primarily in long trains to supply additional air for the braking system and, hence, avoiding the concomitant fuel consumption and emissions. DBC are monitored by a suite of proprietary Wi-Tronix software that link CN managers via the internet to provide data on: GPS tracking, fuel levels, refuel alerts, engine monitoring (running state, overload, oil temperature, and coolant temperature), main reservoir pressure, battery voltage monitoring and the ability to receive emailed alerts[17].

7.2.8 Remote Power

Distributing a remote-controlled locomotive within a freight train permits better handling of long trains, especially in undulating terrain, so as to provide more optimum locomotive power assignment and better air distribution for braking. As well, distributing a locomotive within the train helps remove energy-dissipating slack action

7.2.9 Passenger Train Layover Systems

Commuter and intercity passenger railways shut down locomotives during layover, such as overnight and during off-peak periods. To maintain suitable passenger comfort levels when the locomotive is shut down, wayside electrical power for coach heating or cooling is drawn from the local utility. As well, locomotive layover heating systems have been installed that keep the engine coolant and crankcase oil warm and the batteries charged. This allows the engines to be shut down anytime during the year, resulting in significant fuel savings and reductions of emissions and noise.

7.2.10 Intercity Passenger Train Equipment Initiatives

Emissions reduction initiatives underway or planned for VIA Rail Canada's intercity operations include locomotive low-idle settings, upgrading the engines of FP40 units upon overhaul to Tier 0, installing separate head-end power (HEP) low-emissions diesel generators in FP40s and promoting the use of dynamic braking. Similarly, under test and evaluation on a P42 locomotive are Layover Heat and Auto-Start-Stop systems. The use of 15 ppm ultra-low sulphur fuel (ULSF) has been standardized for VIA's operations. Not only does ULSF reduce SO_x emissions but also sulphur-based PM formed during diesel combustion. Also, use of ULSF facilitates VIA's initiative to evaluate oxidation catalyst converter exhaust after-treatment systems to further reduce engine-out emissions, particularly HC and PM. ULSF avoids contamination of such after-treatment systems.

16 *Options for Improving the Energy Efficiency of Intermodal Freight Trains,* Paper No.1916 by Y.C. Lai and C.P.L. Barkan, University of Illinois Urbana-Champaign, published in the Journal of the Transportation Research Board – 2005

17 *Wi-Tronix WiPUs to be Installed on CN Distributed Braking Cars,* Press Release, Wi-Tronics LLC, Bolingbrook, Illinois – October 18, 2008

Initiatives to reduce coach energy requirements (which result in a lower power draw from the HEP, hence lower emissions generated) include installation of light-emitting diode (LED) and low-mercury fluorescent tube lighting, lowering air conditioning demand by raising the set point and weight reduction by removal of redundant electrical equipment.

7.2.11 Commuter Rail Equipment Modifications

The GO Transit coach fleet is being retrofitted with reflective windows which reduce solar gain significantly, thus reducing air conditioning requirements in summer. To further reduce energy loss, new and refurbished coaches are being fitted with upgraded insulation and LED lighting (to replace incandescent lighting). GO Transit has also retrofitted the locomotives with an energy management switch which reduces the heating and cooling requirements of the coaches when the train is not in revenue service but not on wayside power and, therefore, does not require full heating or cooling. GO Transit is now operating on ultra-low sulphur diesel fuel.

7.2.12 Fuel Additives

The supply sector offers additives to diesel fuel that claim to improve combustion and reduce emissions. The railways undertake on-going assessments and testing in this regard to determine whether the claimed improvements are applicable for railway operations, whether there are potential negative effects and if opting for the additive would be cost-effective and operationally feasible. For example, GO Transit uses the proprietary FPC fuel additive and reported advantages for fuel consumption (confirmed in tests at Engine Systems Development Centre, Inc., Lachine) which showed a 2.5 to 7.0 percent reduction (depending on notch and load) with concomitant reductions in CO and smoke emissions of 2.8 to 5.8 percent, but a slight increase in NO_x emissions[18].

7.3 Operations-related Initiatives

7.3.1 Crew Training and Incentives

The railways have on-going training programs that focus on awareness of the importance of fuel conservation practices. Also, the railways aim to overcome variations in the manner engineers operate and handle a train, which can have a significant impact on fuel consumption and emissions generated. The Class I railways conduct regular training reviews and have introduced incentives to reduce driver variance.

7.3.2 Manual Shut-down of Locomotive Engines

For those locomotives that are not equipped with automatic start / stop systems, the Class I railways have policies in place when trains are not moving to shut down locomotive engines when ambient temperatures and other operational conditions permit.

The railways concentrate on matching locomotive horsepower with train resistance. In this regard, when there is excess power available in a consist of locomotives, some are shut down or isolated[19]. Railways are conducting audits to ensure compliance with shutdown policies and system procedures.

7.3.3 Consolidation of Cars with Similar Destination into Blocks

This operational tactic reduces delays at intermediate locations and increases fluidity at rail yards and terminals. The reduction of delays reduces fuel consumption and emissions.

7.3.4 Train Pacing and Braking Strategies

Pacing is the use of better track / train management by the network management personnel to ensure trains are not rushing to meets. Also, where operations permit, coasting to a stop rather than using heavy braking requiring engine power, is being practised more and

18 *Evaluation of Performance of FPC Fuel Additive in an EMD F59PH Locomotive,* Report No. ETR-0260 prepared for GO Transit by Engine Systems Development Centre Inc., Lachine, Quebec – February 2003

19 *Locomotive Shutdown – A Fuel Conservation Project,* CSX Corporation information presentation – 2005

more. Effectively all mainline locomotives are now fitted with dynamic brake equipment. This allows the use of the dynamic brake to control train speed variations rather than the use of the air brake system. As the latter does not allow the locomotive engineer to reduce the severity of a brake application already in force, it is frequently necessary to apply power at the same time as the brakes to maintain speed over variable track grades. This causes a significant increase in fuel consumption. When the dynamic brake is used to control speed, the severity of the application can be varied at will and the fuel consumption is reduced.

The above-mentioned practices are audited to ensure conformance to pacing and use of dynamic braking objectives.

7.3.5 Commuter Train Coach Door Management

Initiatives being implemented in GO Transit's commuter rail operations include eliminating the practice of opening all doors at long dwell-time station stops so as to avoid warm coach air being evacuated and replaced by colder ambient air (or warmer ambient air in summer) which wastes energy and over-taxes the HEP generator. GO Transit has also interlocked the fresh air input fan with the door open interlock to prevent fresh air being forced into the coach while the doors are open so as to limit the warmed, or cooled, air being forced out while the doors are open.

7.4 Infrastructure-related Initiatives

7.4.1 Improved Track Structures

Improved track structures facilitate train handling and reduce the dynamics that impede smooth train operation. The railways are investing in improvements aimed at reducing friction on a train caused by such track features as sharp curves, grades, uneven roadbeds, track flexing and jointed rail. Under assessment is laser glazing of the railhead, as testing at the Facility for Accelerated Service Testing of the Transportation Test Center, Inc, Pueblo, Colorado and using Instrumented Wheel Set of the Wheel, Bearing and Brake Facility of the National Research Council of Canada has shown improved fuel consumption by reducing wheel flange / rail friction of up to 13 percent on curved track and 3 percent on tangent track[20].

To eliminate the structural fuel penalty of single line trackage, investment in double tracking and siding extensions of heavily trafficked sections is underway. Double tracking permits operational efficiencies (such as eliminating meets and avoiding idling and day-to-day variability) that yield reductions in fuel consumption and emissions.

7.4.2. Rail Lubrication

Efficient rail gauge-face lubrication has been shown in many tests to reduce fuel consumption. In this regard, railways have in place, system wide, trackside flange lubricators and locomotive-mounted wheel flange lubricators. As well, the railways have an on-going program to ensure that the track mounted rail lubricators are maintained in good operating condition.

7.4.3 Top-of-Rail Friction Control

Top-of-rail friction control is being deployed in selected Canadian railway regions as it has shown to reduce the wheel-rail drag friction of freight cars; hence, lowering the fuel consumption and emissions generated to haul them. Top-of-rail friction control involves applying a proprietary liquid having a specific coefficient of friction of 0.30 to 0.35 to the railhead, that is, the top of the steel rail. The liquid is dispersed both from wayside applicators as well as from the trailing unit of a locomotive consist just sufficient to lubricate the wheel-rail interface of all the trailing railcars. Measurements on a railway line having curve densities of 34, 42 and 51 percent over its length exhibited fuel consumption savings (and hence emissions reductions), respectively, 2.3, 2.5 and 10.5 percent[21].

20 *Laser Glazing of Rails, WBB/IWS Tests at NRCC,* report to Argonne National Laboratories by S. Aldajah, et al of Wheel, Bearing and Brake Facility (WBB) of National Research of Canada– January 2005

21 *Top-of-Rail Friction Control with Locomotive Delivery on BC Rail: Reduction in Fuel and Greenhouse Gas Emissions*, presented by team of BC Rail, Kelsan Technologies Corp. and National Research Council Canada to the American Railway Engineering and Maintenance of Way Association Conference and Expo, Nashville, Tennessee – September 2004

7.4.4 Co-production

Co-production is when one railway shares its tracks with another to deliver freight, or move a train more expeditiously and efficiently than by sticking to its own line. An example is the agreement between Canada's two Class I railways to share track in the Fraser Canyon region of B.C This agreement allows the railways to eliminate meets and concomitant idling as well as to haul heavily loaded trains over lighter grade (less steep) track sections of one railway and light loads (empty cars) on heavier grade sections on the other. This agreement should lower fuel consumption, hence emissions, on both railways. Co-production is also being implemented on other sites in Canada[22].

7.5 Monitoring and Evaluation of Technological Developments

7.5.1 Government Programs

The railways have taken advantage of Transport Canada's Freight Technology Demonstration Program and Freight Technology Incentive Program which cost-share the deployment and evaluation of various fuel conservation and emissions reduction schemes. Examples are top-of-rail lubrication, electronic fuel injection, automatic stop/start systems, auxiliary power units for idling avoidance, upgraded governor controls and switchers having hybrid battery / diesel motive power. For details view: http://www.tc.gc.ca/programs/environment/ecofreight/programincentiveguide-eng.htm.

Sustainable Development Technology Canada also operates funding programs for which railway technology development and demonstration projects could be eligible for support. The programs are the Sustainable Development Technology Fund launched in 2002 and the NextGen Biofuels Fund launched in 2007. Railway-related technology demonstration projects supported include the Railpower Technologies Corporation's hybrid switcher locomotive and the GE Canada Clean Diesel Locomotive, the Aboriginal Cogeneration Corp.'s Biomass-to-Energy Demonstration to dispose of creosote railway ties and ARC Resins Corp. composite material for longer-life railway ties. For details view: http://www.sdtc.ca/en/funding/index.htm.

7.5.2 Monitoring Emissions Reduction Technologies under Development

The railways are monitoring technologies and procedures under development worldwide aimed at reducing emissions from diesel locomotives. Many of those technologies are envisaged to enable the OEMs to supply locomotives meeting the next levels of emissions standards that the U.S. EPA will bring into force[23]. For example, being followed with interest is the testing under the California Emissions Program to evaluate oxidation catalysts and diesel particulate filter technologies retrofitted onto conventional diesel line-haul and switching locomotives. In-service testing of a Union Pacific (UP) GM/EMD SD60M locomotive equipped with a diesel exhaust oxidation catalyst exhibited reductions in PM of 60 percent at power notches N1 to N4 and, over the line-haul and switch cycles respectively, PM reductions of 52 and 50 percent, CO reductions of 82 and 81 percent and HC reductions of 38 and 34 percent, but with some increase in NO_x and smoke emissions[24].

Similarly, comparative in-service testing of a UP and a Burlington Northern Santa-Fe (BNSF) GM/EMD M15DC switcher each fitted with diesel particulate filters exhibited reductions in PM of 80 percent and in HC of 30 percent[25]. Of note is that the engine of the BNSF unit was fitted with low oil consumption rings and liners that yielded an engine-out PM average of 0.33 g/KW-hr versus 0.53 g/KW-hr for the UP unit.

Several types of locomotives incorporating non-traditional motive power technology are entering railway service or are under development. The aim of all such developments is to realize a step-wise improvement in fuel consumption and significantly lower emissions, primarily by the avoidance of idling.

22 *CN, CP Push Co-production,* article in Interchange – Official Publication of the Railway Association of Canada, Pages 20-25, Ottawa – Spring 2006

23 *Exhaust Aftertreatment Technologies Definitions and Maintenance,* report by Ted E. Stewart, Advanced Global Engineering, published in Proceedings of the 70th Annual Meeting of the Locomotive Maintenance Officers Association (LMOA), Chicago, Illinois – September 21-24, 2008

24 *Exhaust Emissions from a 2,850 kW EMD SD60M Locomotive Equipped with a Diesel Oxidation Catalyst,* Paper No. JRCICE 2007-40060 presented at the ASME/IEEE Joint Rail Conference and Internal Combustion Engine Technical Conference, Pueblo, Colorado – March 2007

25 *Experimental Application of Diesel Particulate Filters to EMD Switcher Locomotives,* Paper No. ICEF2007-1626 presented at the ASME Internal Combustion Engine 2007 Technical Conference, Charleston, South Carolina – October 2007

The pioneer development of this nature was the Railpower Technologies' hybrid switcher locomotive that, in place of a conventional 16-cylinder diesel engine, has a battery pack kept charged by a 250 kW diesel generator set The battery pack has the capacity to supply 2,000 horsepower-hours of energy[26]. The battery pack also permits the recoupment and storage of braking energy.

Entering into service on a test basis in 2007 were switcher locomotives having as motive power three 'stand alone' diesel generator sets (GenSets) to collectively produce the power equivalent to a conventional switcher locomotive. The most common arrangement consists of three 700 horsepower truck engines, each powering separate alternators. The advantage of this arrangement is that individual GenSet engines can be started or stopped according to the power required. As truck-type engines use antifreeze in their cooling systems rather than water, the necessity to idle in cold weather is further reduced[27].

A longer term technology development being monitored is a proof-of-concept hydrogen-fueled fuel cell-battery hybrid switcher locomotive under construction in the U.S.A. by a consortium of Vehicle Projects LLC, the BNSF railway and the U.S. Department of Defense. The test vehicle will be the most powerful fuel cell land vehicle yet built. The objective is to ultimately realize technology for a locomotive not requiring fossil fuel and, hence, obviating GHG and CAC emissions[28].

The U.S. Department of Energy (DOE) 21st Century Locomotive Technology program is also stimulating several initiatives, one of note being a Tier 2+ compliant GE Evolution-series freight locomotive fitted with regenerative braking battery storage, advanced fuel injection, advanced turbocharger and real-time consist fuel trip optimizer[29]. Target fuel consumption reduction is 20 percent (with a concomitant 10 percent CAC reduction) contributed 15 percent from regenerating captured braking energy, 1 to 3 percent from the trip optimizer and 2 to 4 percent from diesel engine combustion advancements. This project is one of several initiated following a joint foresight established with the North American railway sector for a technology development roadmap to reduce fuel consumption and emissions from railway and locomotive operations[30].

The initial operations of Electronically Controlled Pneumatic (ECP) brake systems are being monitored to understand their attributes and limitations. They are in operational evaluation in single-product unit train consists such as those operated by the Quebec North Share and Labrador railway. ECP brakes use an electronic signal from the locomotive to direct compressed air from each railcar's reservoir to the brake cylinder or to release air from the brake cylinder to de-activate the brakes.

Also, in 2007 the RAC supported a two-day symposium convened by the Railway Research Advisory Board and Transport Canada to identify priorities for railway research in Canada, an element of which dealt with identification of actions and technological developments envisaged to reduce emissions from railway operations in Canada[31].

26 *Hybrid Technology for the Rail Industry,* paper No. RTD2004-66041 presented by F.W. Donnelly, R.L. Cousineau, et al, Railpower Hybrid Technologies Corp., at the Rail Technology Division conference of the American Society of Mechanical Engineers, Chicago, Illinois – 2004

27 *Maintenance Experience with GenSet Switcher Locomotives to Date,* report by Tad Volkmann, Union Paciific Railroad, published in Proceedings of the 70th Annual Meeting of the Locomotive Maintenance Officers Association (LMOA), Chicago, Illinois – September 21-24, 2008

28 *Maintenance of the BNSF Fuel Cell-Hybrid Switch Locomotive,* report by Arnold Miller et al, Vehicle Projects LLC, published in Proceedings of the 70th Annual Meeting of the Locomotive Maintenance Officers Association (LMOA), Chicago, Illinois – September 21-24, 2008

29 *21st Century Locomotive Technology (locomotive system tasks),* presentation by GE Global Research to the DOE Heavy Vehicle Systems Optimization peer review – April 2006

30 *Railroad and Locomotive Technology Roadmap,* report ANL/ESD/02-6 compiled by F. Stodolsky, Argonne National Laboratories / U.S. Department of Energy – December 2002

31 *Proceedings of the Canadian Railway Research Symposium,* TP14818E, Prepared for Transport Canada under auspices of the Railway Research Advisory Board, Toronto, Ontario – November 28-29, 2007

8 Summary and Conclusions

The Canadian railways are maintaining steady improvement in operational efficiency as measured by fuel consumption and emissions per 1,000 RTK, the unit of work productivity for freight operations. In meeting the objectives of the MOU, the listings below show the status as of 2007:

a. Relative to the targets specified in the MOU for 2010, by category of operation the GHG emissions intensity levels for 2007 compared to 2006 were:

Railway Operation	Units	MOU 2010 target	2006 level	2007 level
Class I Freight	kg / 1,000 RTK	16.98	17.79	17.32
Regional and Short Lines	kg / 1,000 RTK	15.38	15.10	15.21
Intercity Passenger	kg / passenger-km	0.12	0.13	0.13
Commuter Rail	kg / passenger	1.46	1.74	1.71

b. GHG emissions from all railway operations in Canada totalled 6,727.65 kt, down slightly from 6,795.04 kt in 2006. For all freight operations, the GHG emissions intensity (in kg of $CO_{2\ equivalent}$ per 1,000 RTK) decreased from 18.22 in 2006 to 17.75 in 2007, and from 23.88 in 1990, a 25.7 percent improvement.

c. NO_x emissions from all rail operations in 2007 totalled 104.46 kt. Compared to 2006, this is a reduction of 6.9 percent and is 9.2 percent below the 1990 reference level of 115 kt. The emissions of NO_x have averaged 113.79 kt per year since 1990.

d. In terms of emissions intensity, the NO_x level in 2007 for freight trains was 0.27 kg per 1,000 RTK, a 62.8 percent reduction below the 1990 level of 0.43 kg. This stems from the beneficial effect of acquiring new locomotives meeting U.S. EPA emissions standards.

e. Fleet changes, which were the prime contributors to the reduction of GHG and CAC emissions, are listed below:

Actions Taken in 2007	Class I Mainline Freight	Intercity Passenger	Commuter Service
New EPA Tier 2 Locomotives Acquired	85	0	2
High-horsepower Units Upgraded to EPA Tier 0	92	0	0
Medium-horsepower Units Upgraded to EPA Tier 0	10	0	0
Retired 1973-99 era Medium-horsepower Units	50	0	0

f. The in-service Canadian railway diesel locomotive and DMU fleet in 2007 totalled 3,027. There were 1,065 locomotives compliant with the U.S. EPA emissions limits.

g. In 2007, freight fuel consumption per 1,000 RTK decreased 0.5 percent to 5.90 L from 5.93 L in 2006, and 27.1 percent from 7.83 L in 1990. In volume, the rail sector's total diesel fuel consumption in 2007 increased to 2,237.22 million L from 2,210.38 million L in 2006; and from 2,060.66 million L in 1990.

h. The Emissions Factor (in grams per litre of diesel fuel consumed) used to calculate NO_x emitted from freight locomotives was again revised downward for 2007. This reflects the increased number of locomotives in service during 2007 meeting the stringent U.S. EPA Tier 0, Tier 1 or Tier 2 emissions limits.

i. Revenue traffic handled in 2007 by Canada's freight railways, as measured in RTK, rose 0.8 percent over 2006. Since 1990, railway freight traffic RTK has risen by an average annual rate of 2.6 percent for an overall increase of 44.6 percent.

j. The Class I railways were responsible for 93.6 percent of the freight traffic in 1970. Of the 338.32 billion RTK they transported, intermodal accounted for 25.0 percent. Of note is that intermodal tonnage has increased 155.7 percent since 1990. The growth in intermodal traffic is the result of the success of Canadian railways in developing strategic partnerships with shippers and trucking companies for the transportation of goods.

k. VIA Rail Canada's intercity service transported 4.1 million passengers, an increase of 2.2 percent over 2006, while Commuter rail passengers increased by 4.5 percent to 63.39 million.

l. Sulphur content of the diesel fuel consumed averaged 500 ppm across Canada, as compared to 1,275 ppm in 2006, a drop of 60.8 percent.

Photo: Courtesy of Rick Robinson/CP

Appendix A

MEMORANDUM OF UNDERSTANDING
Between
HER MAJESTY THE QUEEN IN RIGHT OF CANADA AS REPRESENTED BY THE MINISTER OF THE ENVIRONMENT WHO IS RESPONSIBLE FOR ENVIRONMENT CANADA AND THE MINISTER OF TRANSPORT, INFRASTRUCTURE AND COMMUNITIES WHO IS RESPONSIBLE FOR TRANSPORT CANADA AND THERAILWAY ASSOCIATION OF CANADA

1.0 OBJECTIVES

This Memorandum of Understanding (”Memorandum”) establishes a framework through which the Railway Association of Canada (RAC), its member companies (Annex 1), Environment Canada (EC), and Transport Canada (TC) will address emissions of criteria air contaminants (CAC) and greenhouse gases (GHG) from railway locomotives operated by Canadian railway companies in Canada.

This Memorandum:

- recognizes the successes of the predecessor 1995-2005 Memorandum of Understanding (MOU) between the RAC and EC respecting the control of emissions of nitrogen oxides (NO_x) produced by locomotives during rail operations in Canada (Annex 2); and,
- includes measures, targets and actions which will further reduce emissions from rail operations and help protect health and environment for all Canadians as well as address climate change; and,
- reflects targets and action plans from the rail industry’s emission reduction and fleet renewal strategies for the period 2006-2015.

2.0 DURATION OF THE MEMORANDUM

This Memorandum will come into force upon signing by the duly authorised representatives of the RAC, EC and TC, and will endure until December 31st 2010, unless it is terminated at an earlier date. The party that is terminating the Memorandum will give six months prior formal written notice to the other two parties.

3.0 CRITERIA AIR CONTAMINANT EMISSIONS

Air pollution represents a serious threat to human health and the environment. Air quality issues, such as smog and acid rain, result from the presence of, and interactions between, a group of pollutants known as criteria air contaminants (CACs) and related pollutants (Annex 3). The federal government has taken action to reduce air pollution from on-road and off-road vehicles and engines. This Memorandum builds upon the previous MOU that was signed in 1995. Despite major growth in rail traffic, NO_x emissions averaged below the 115 kilotonnes ”cap” that was set in the MOU. Further reductions in CAC emissions are expected to be achieved under this Memorandum.

3.1 CAC Commitments by the RAC

It is recognised that, during the life of this Memorandum, the U.S. Environmental Protection Agency (EPA) may introduce new emissions standards for locomotives. The RAC will encourage all of its members to conform to all applicable emission standards, including any updated EPA emissions standards respecting new and in-service locomotives manufactured after 1972.

For the same period, the RAC will also encourage its members to adopt operating practices aimed at reducing CAC emissions.

3.2 CAC Commitments by the Major Railway Companies

Canadian National, Canadian Pacific, VIA Rail and GO Transit will, during this Memorandum:

- Acquire only new and freshly manufactured locomotives[1] that meet applicable EPA emissions standards;
- Retire[2] from service 130 medium-horsepower locomotives[3] built between 1973 and 1999;
- Upgrade, upon remanufacturing, all high-horsepower locomotives[4] to EPA emissions standards; and
- Upgrade to Tier 0, upon remanufacturing, all medium horsepower locomotives built after 1972 beginning in 2010.

4.0 GREENHOUSE GAS EMISSIONS

Climate change is a major challenge for transportation, as it is for all other sectors of the Canadian economy. In 2002 railways accounted for 6 megatonnes, or 3 percent of total Canadian transportation GHG emissions (Annex 4).

4.1 GHG Commitments by RAC

For the duration of the Memorandum, the RAC will encourage all of its members to make every effort to reduce aggregate GHG emissions from railway operations.

1 New and freshly manufactured locomotives, Tier 0 and remanufacturing are defined in Title 40, chapter I, subchapter C, part 92 of the US Code of Federal Regulations.

2 These retired locomotives are generally offered for sale, traded for other power or stripped of parts.

3 Medium-horsepower locomotives: locomotives with power between 2000 hp and 3000 hp

4 High-horsepower locomotives: locomotives with power greater than 3000 hp

The 2010 GHG emission targets for the rail industry are:

Class I Freight	16.98 kg $CO_{2\ eq}$ per 1,000 RTK
Short Lines	15.38 kg $CO_{2\ eq}$ per 1,000 RTK
Intercity Passenger	0.12 kg $CO_{2\ eq}$ per passenger-km
Commuter	1.46 kg $CO_{2\ eq}$ per passenger

4.2

For the same time period, the RAC will prepare, in cooperation with all of its members, an Action Plan for reducing GHG emissions within six months of signing of the Memorandum. The Action Plan will set out actions that the RAC and its members will undertake to attain the GHG emission targets. Examples of possible actions are listed in Annex 5.

5.0 REPORTING

5.1 Annual Reporting

The RAC will prepare an annual report by December 31st of each year which will describe the performance under this Memorandum and will contain:

- the information described in section 5.2;
- a summary of the actions undertaken by the RAC's members to conform with all applicable EPA emission standards and to adopt operating practices that reduce CAC emissions;
- a summary of the actions undertaken by the RAC to inform its members about practices or technologies that reduce emissions of CACs and GHGs; and,
- a summary of the annual progress that the RAC and its members have made towards meeting targets in GHG emissions as set out in Section 4.1.

Each annual report will be approved by the Management Committee (Section 6.1). Each annual report shall be published jointly by the parties to the Memorandum and released to the public as soon as possible once approved, including publication on EC, TC and the RAC websites. RAC will be the copyright holder of all rights in and to the annual report. EC and TC will be the licensees of any copyright held by RAC in the annual report. The first report will be for calendar year 2006 and the last report will be for the year 2010.

5.2 Data

5.2.1

The emissions inventory in each annual report will be prepared in accordance with the methodologies described in *"Recommended Reporting Requirements for Locomotive Emissions Monitoring (LEM) Program, September, 1994"* and/or as recommended by the Management Committee.

5.2.2 The annual report will contain the following information:

- the names of the Canadian railway companies that reported under the Memorandum , and their provinces of operation;
- a table describing locomotives that meet the EPA emissions standards;
- the composition of the locomotive fleet by model, year of manufacture, horsepower, engine model, and duty type;
- the gross tonne-kilometres, revenue tonne-kilometres and total fuel consumption data for railway operations during the reported calendar year;
- estimates of the annual emissions of nitrogen oxides (NO_x), hydrocarbons (HC), sulphur oxides (SO_x), particulate matter (PM), carbon monoxide (CO), nitrous oxide (N_2O), methane (CH_4), carbon dioxide (CO_2), and $CO_{2\ equivalent}$, emitted during all rail operations in Canada; and,
- fuel consumption and emissions data will be listed separately and aggregated as follows – passenger, freight, and yard switching services.

5.3 Third Party Verification:

A qualified auditor will be given access, each year, or periodically but not more frequently than once a year, to audit the processes and supporting documentation pertaining to the Memorandum. Parties to the Memorandum will select the appropriate auditor capable of independently verifying the reports and will share audit costs. The mandate of the auditor will be decided by the Management Committee.

6.0 MANAGEMENT OF THE MEMORANDUM

6.1

The Memorandum will be governed by a Management Committee comprising of senior officials from the parties to the Memorandum and a representative of an environmental non-governmental organization.

The Director General, Energy and Transportation Directorate of Environment Canada, the Director General of the Office of Environmental Affairs of Transport Canada and the Director General of Rail Safety of Transport Canada, or their delegates will represent the federal government. The RAC and its member companies will be represented by the RAC's Chair of the Environment Committee, and its Vice-President, Operations and Regulatory Affairs, or their delegates.

The RAC, TC and EC will select the environmental non-governmental organization representative prior to the first meeting of the Management Committee. The Management Committee will meet at least once a year.

6.2 The Management Committee will:

- review the annual report before its publication;
- conduct, as necessary, a review of the Memorandum to assess any significant changes to the Canadian rail industry or the Canadian economy in general that can have an impact on the ability of the RAC and its member companies to respect the terms of the Memorandum;
- make recommendations that it deems necessary to improve the Memorandum; and
- at its discretion create, schedule, and oversee the work of a Technical Review Committee (Section 6.3).

6.3 The functions of the Technical Review Committee may include the following:

- oversee reporting and verification activities;
- review and verify annual data submitted to EC and TC by the RAC;
- review as necessary the methodology used for estimating emissions and recommend changes, when appropriate;
- review actions undertaken to achieve the goals of the Memorandum; and undertake any other activities as requested by the Management Committee.

7.0 SUPPORTING THE MEMORANDUM

7.1

EC and TC will work with the RAC in support of the RAC's implementation of measures to reduce emissions of CACs, by providing technical advice on emission reduction technologies and best practices.

7.2

TC will work with the RAC in support of the RAC's implementation of the Action Plan for reducing GHG emissions, including such programs and initiatives as may be established in support of the government's environmental agenda.

7.3

EC and TC will make reasonable efforts to consult with the RAC on the inclusion of rail related research in departmental research and development plans.

7.4

EC and TC will organize and convene jointly with the RAC, a conference or seminar on emissions reduction and environmental best practices in the railway industry.

7.5

EC and TC will recognize, as appropriate, progress achieved by the RAC and its members towards meeting or exceeding emissions reduction objectives. EC and TC will choose the time and manner of any public acknowledgement of the RAC's and its members' achievements.

7.6

EC and TC will share information with the RAC respecting how emissions reduction actions may be credited in accordance with any such mechanisms as may be established for this purpose.

7.7

EC and TC will use best efforts to work with the RAC to address barriers that may impede emission performance in the railway industry.

8.0 GENERAL PROVISIONS AND SIGNATURES

This Memorandum is a voluntary initiative that expresses in good faith the intentions of the Parties. It is not intended to create nor does it give rise to legal obligations of any kind whatsoever. As such, it is not enforceable at law. The government reserves the right to develop and implement regulatory or other measures it deems appropriate to achieve clean air and climate change goals. Nothing in this Memorandum will constrain the Parties from taking further actions relating to CAC and GHG emissions or fuel use that are authorized or required by law.

The parties recognize that the information provided pursuant to the Memorandum will be governed by the applicable legislation concerning protection and access to information.

DATED at Ottawa this 15th day of May 2007

Minister of the Environment

Minister of Transport Infrastructure and Communities

President, Railway Association of Canada

Annex 1

RAC MEMBER COMPANIES
November 2006

Agence métropolitaine de transport	New Brunswick Southern Railway Company Limited
Alberta Prairie Railway Excursions	Norfolk Southern Railway
Amtrak	Okanagan Valley Railway
Arnaud Railway Company	Ontario Northland Transportation Commission
Athabasca Northern Railway Ltd.	Ontario Southland Railway Inc.
Barrie-Collingwood Railway	Ottawa Central Railway Inc.
BNSF Railway Company	Ottawa Valley Railway
Burlington Northern (Manitoba) Ltd.	Québec Cartier Mining Company
Canadian Heartland Training Railway	Québec Gatineau Railway Inc.
Cape Breton & Central Nova Scotia Railway	Québec North Shore and Labrador Railway Company Inc.
Capital Railway	Roberval and Saguenay Railway Company, The
Carlton Trail Railway	Romaine River Railway Company
Central Manitoba Railway Inc.	Savage Alberta Railway, Inc.
Charlevoix Railway Company Inc.	SOPOR
Chemin de fer de la Matapédia et du Golfe inc.	South Simcoe Railway
CN	Southern Manitoba Railway
CP	Southern Ontario Railway
CSX Transportation Inc.	Southern Railway of British Columbia Ltd.
Essex Terminal Railway Company	St. Lawrence & Atlantic Railroad (Québec) Inc.
GO Transit	Sydney Coal Railway
Goderich-Exeter Railway Company Limited	Toronto Terminals Railway Company Limited, The
Great Canadian Railtour Company Ltd.	Trillium Railway Co. Ltd.
Great Western Railway Ltd.	Tshiuetin Rail Transportation Inc.
Hudson Bay Railway	VIA Rail Canada Inc.
Huron Central Railway Inc.	Wabush Lake Railway Company, Limited
Kelowna Pacific Railway Ltd.	West Coast Express Ltd.
Kettle Falls International Railway, LLC	White Pass & Yukon Route
Montréal, Maine & Atlantic Railway, Ltd.	Windsor & Hantsport Railway
New Brunswick East Coast Railway Inc.	

1995 – 2005 MOU REGARDING LOCOMOTIVE EMISSIONS

MEMORANDUM OF UNDERSTANDING
between
ENVIRONMENT CANADA and THE RAILWAY ASSOCIATION OF CANADA

PART 1 - INTRODUCTION

The purpose of this document is to set out the principles of the basic agreements reached among The Railway Association of Canada (RAC), The Canadian Council of Ministers of the Environment (CCME) and Environment Canada (EC) with respect to the control of emissions of oxides of nitrogen (NO_x) produced by locomotives during all rail operations in Canada.

The Memorandum of Understanding (MOU) has been developed from the recommendations contained in the joint Environment Canada / Railway Association of Canada (EC/RAC) report entitled "Recommended Reporting Requirements for the Locomotive Emissions Monitoring (LEM) Program".

PART 2 - BACKGROUND

The Railway Association of Canada, being an association of environmentally concerned corporations doing business in Canada, proposed to the Canadian Council of Ministers of the Environment (CCME), a voluntary cap on the total emissions of oxides of nitrogen from locomotive engines in Canada of 115 kilotonnes per year. The RAC proposal for a voluntary cap on NO_x emissions has been included in the CCME NO_x/VOC Management Plan and is officially validated by this MOU.

PART 3 - THE PROGRAM

Between January 1, 1990 and December 31, 2005 the RAC will endeavour to collect all data necessary to calculate the total amount of emissions of oxides of nitrogen (NO_x) produced during all rail operations in Canada and, if necessary, take whatever action is necessary to avoid exceeding the agreed maximum NO_x emissions of 115 kilotonnes per year.

The RAC will make every effort to report once per year to Environment Canada in the manner described below. The data collected should represent the activity of all RAC members and the RAC will endeavour to encourage Associate members of the RAC and non-members to participate in the data reporting.

The RAC also agrees to monitor developments in railway operations technology and encourage member railways to implement new cost-effective technologies that will reduce the NO_x emissions from their new equipment.

PART 4 - REPORTS

As outlined in the joint EC/RAC report entitled "Recommended Reporting Requirements for the Locomotive Emissions Monitoring (LEM) Program", the RAC will make every effort to submit to Environment Canada annual reports containing the following information;

1) A list of the Gross Ton Miles (GTK), Net Ton Miles (RTK) and total fuel consumption data for railway operations plus estimates of the emissions of oxides of nitrogen (NO_x), hydrocarbons (HC), oxides of sulphur (SO_x), particulate matter (PM), carbon monoxide (CO) and carbon dioxide (CO_2) using the RAC emissions factors as corrected in Table 9 of the Report referenced above. All fuel consumption and emissions data will be listed separated with respect to passenger, freight and yard switching services. These data will be submitted for the reporting year and will include revised projections for years 1995, 2000 and 2005;

   In addition to the national aggregate figures, fuel consumption and emissions should be provided for each Tropospheric Ozone Management Area (TOMA) as geographically defined in the NO_x/VOCs Management Plan (CCME, 1990);

2) The emissions data for the TOMAs should be further separated into two additional categories: the Winter Months and the Critical Ground Level Ozone Forming Months of May, June, July, August and September;

3) Updated information should be provided about the composition of the locomotive fleet by year of manufacture, horsepower, engine model, duty type and railway company;

4) A brief written update should be provided on the progress of the railway industry in introducing new, more NO_x-efficient operating procedures and/or technology on rail operations;

5) Companies should submit a report on any emissions control systems, hardware or techniques installed or implemented during an engine rebuild program that would effect NO_x emissions;

6) A report should be provided on new emissions performance data and new emissions factors for locomotives operated by railways obtained from the AAR, the manufacturers or other agencies;

7) Information should be provided about changes in the properties of diesel fuels used when the properties significantly depart from those specified in the Canadian General Standards Board Specifications CAN/CGSB-3-18-92, entitled Diesel Fuel for Locomotive Type Medium Speed Diesel Engines. Data should be reported from any tests on the sensitivity of emissions from various locomotive engines to fuel quality or to alternative fuels; and

8) A brief report should be provided on the progress and success of any other emissions reduction initiatives or changes in operational procedure, as well as any major changes in the type of duty cycles or service that would significantly affect emissions and their relative percentage of the overall railway operation.

The RAC will make every effort to submit an annual report containing all of the information indicated above by June 30th of the year following the report year. The first report covered by the MOU will be for the year 1990 and last report under this MOU will be for the year 2005.

PART 5 - GENERAL

The baseline of 115 kilotonnes per year for locomotive NO_x emissions is based upon the best technical information that was available by the end of 1989 and on projections for traffic increases. It is understood that, if new emissions factors significantly departing from those used to determine the baseline are developed as a result of advanced research on engine emissions or if the rail traffic growth rate is significantly impacted by a shift of traffic from or to another mode of transport, a new environmental review will be initiated.

Although both of the parties hereto have indicated by their signature, acceptance of the principles set out herein, this MOU is not intended to create a legally binding agreement and shall not be construed as creating enforceable contractual obligations among the parties hereto.

DATED at Ottawa this 27th day of December, 1995

Sheila Copps

Minister of the Environment

R.H. Ballantyne

President, Railway Association of Canada

Annex 3

CRITERIA AIR CONTAMINANTS

Air pollution is linked to respiratory diseases (e.g. asthma and chronic obstructive pulmonary disease), cardiovascular disease, allergies, and neurological effects. Air pollution can also prejudice the quality of soil and water resources.

The most important Criteria Air Contaminants (CAC's) produced by locomotives include:

- Sulphur Oxides (SO_x);
- Nitrogen Oxides (NO_x);
- Particulate Matter (PM);
- Hydrocarbons (HC); and
- Carbon Monoxide (CO).

NO_x and HC contribute to the formation of ground-level ozone, which is a respiratory irritant and one of the major components of smog. Smog has been identified as a contributing factor in thousands of premature deaths across the country each year, as well as increased hospital visits, doctor visits and hundreds of thousands of lost days at work and school. Environmental problems attributed to smog include effects on vegetation, structures, and visibility and haze (mainly due to fine PM).

Acid deposition, which is a more general term than acid rain, is primarily the result of emissions of SO_2 and NO_x that can be transformed into secondary pollutants. Damage caused by acid deposition affects lakes, rivers, forest, soils, fish and wildlife populations and buildings.

Photo courtesy of GO Transit

GREENHOUSE GASES

Photo: Courtesy of CN

The greenhouse effect is the term used to describe the role of the atmosphere in insulating the planet from heat loss. Greenhouse gases (GHG) are gases in the atmosphere that give rise to this greenhouse effect. This "natural greenhouse effect" is an important phenomenon to biological life on Earth.

Climate change occurs when the total amount of the sun's energy absorbed, does not equal the amount of energy released, causing an imbalance in the radiative exchange. Consequently, humans can also cause temperatures and the climate system to change. Human activities such as the burning of fossil fuels, deforestation or land surface change, industrial processes, etc., are increasing the concentration of GHGs in the atmosphere. This additional increase of GHG is known as the "enhanced greenhouse effect", where more incoming energy is trapped within the atmosphere. This can have serious impacts on the physical and chemical processes, and biological life on Earth.

There are some GHGs that are present in the atmosphere due to both natural processes and human activities. The most significant GHGs produced by locomotives include:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)

For estimating the emissions from the transportation sector, the CO_2 and other GHG emissions depend upon the amount of fuel consumed, the carbon content of the fuel, and the fraction of the fuel oxidized. The emissions factors have been obtained and developed from a number of studies conducted by Environment Canada, the U.S. Environmental Protection Agency (EPA), and other organizations, both domestic and international.

The $CO_{2\,equivalent}$ is the sum of the constituent greenhouse gases expressed in terms of their equivalents to the Global Warming Potential of CO_2. The $CO_{2\,equivalent}$ is estimated with the following equation:

$$CO_{2\,equivalent} = (CO_2 \text{ emissions} \times 1) + (CH_4 \text{ emissions} \times 21) + (N_2O \text{ emissions} \times 310)$$

REDUCTION OF GREENHOUSE GAS EMISSIONS FROM THE RAIL SECTOR

The Action Plan for Reducing GHG Emissions may include the following kinds of elements:

Operational Improvement

- **Consolidation of cars with similar destination into blocks:**
  This step reduces delays at intermediate locations by simplifying process for employees, eliminating the duplication of work and helping to ensure fluid rail yards and terminals. It also reduces transit time for shipments throughout the network and increases car availability for customers.
- **Scheduling:**
  There are methods to improve the scheduling of trains with other railways and develop systems designed to share advanced information to thereby improve service.
- **Distributive power:**
  It enables the placement of locomotives at different locations throughout a train, as opposed to placing all the locomotives at the front of the train. This allows for improved acceleration, braking and overall control of the train especially where severe grades and curvature exist. Better rail-wheel adhesion and improved application of available motive power increases fuel efficiency, and improved train handling capabilities improves throughput and reduces costs.
- **Code for best practices:**
  The development and promotion of a code will allow the sharing of best practices amongst all railways and increase the use of such best practices thereby generating additional fuel savings for the industry.

Technology / Equipment Upgrades

- **Anti-idling devices and strategies:**
  Studies show that idling locomotives consume approximately four per cent of the total volume of fuel consumed in railway operations. Technologies such as automatic stop/start systems and hybrid switching locomotives as well as operational changes can potentially reduce idling significantly and generate important fuel savings.
- **Equipment:**
  Equipment upgrades include using improved steel wheel tread profiles, lightweight rail cars, and the introduction of “steering trucks” on rail cars. These new materials and designs reduce the weight of freight cars and their rolling resistance, enabling to haul more cargo per unit of energy used.

Greater participation in federal programs

Examples of federal programs include:

- **Freight Technology Demonstration Fund:**
  Under this program, Transport Canada is funding projects that can demonstrate and encourage the take-up of technologies and best practices that can reduce both CAC and GHG emissions from any freight mode.
- **Freight Technology Incentives Program:**
  The program provides financial incentives for the purchase and installation of efficiency enhancing and emissions reduction technologies and equipment in any freight mode.

Appendix B-1

Locomotive Fleet 2007 – Freight Train Mainline and Road Switching Operations

Manufacturer	Model	EPA Tier Level	Engine	HP	Year Built	Year Rebuilt	Total	CN	CP	Total Class I	Regional	Short Lines	Total Regional and Short Lines
EMCC	SD70M-2	Tier 2	16V-710	4300	2005-2007		75	75		75			
GM/EMD	SD90MAC-H		16V-265H	6000	2000		4		4	4			
	SD90MAC		16V-710	4300	1998-1999		61		61	61			
	SD75	Tier 0	16V-710	4300	1996-1999	2002-2005	167	167		167			
	SD75		16V-710	4300	1996-1999		12	6		6	6		6
	SD70	Tier 0	16V-710	4000	1995	2001-2005	22	22		22			
	SD70		16V-710	4000	1995		4	4		4			
	SD60	Tier 0	16V-710	3800	1985-1989	2002-2005	53	53		53			
	SD60		16V-710	3800	1985-1989		9	9		9			
	SD50	Tier 0	16V-645	3600	1985-1987		9	9		9			
	SD50		16V-645	3600	1985-1987		42	42		42			
	SD45-2		16V-645	3600	1972-1974		4					4	4
	SD40-2	Tier 0	16V-645E3B	3000	1975-1985		10	10		10			
	SD40-2		16V-645E3B	3000	1973-1980		464	115	328	443	18	3	21
	SD40-2		16V-645	3000	1966-1971	1995	12		12	12			
	SD40-1		16V-645	3000	1966-1971		11					11	11
	SD40-Q		16V-645	3000	1966-1971	1992-1995	26	26		26			
	SD38-2		16V-645	2000	1975		3	3		3			
	SD38		16V-645	2000	1971-1974		4					4	4
	SD18		16V-645	1800			1					1	1
	GP40-3		16V-567	3000	1966-1968		5					5	5
	GP40-2		16V-645	3000	1974-1991		81	59	4	63	3	15	18
	GP40		16V-645	3000	1975-1987		8					8	8
	GP38-3		16V-645E	2000	1981-1983		4					4	4
	GP38-2		16V-645	2000	1970-1986		131		112	112		19	19
	GP38-2		16V-645	2000	1972-1974		125	76	15	91	11	23	34
	GP35-3		16V-645	2500			3					3	3
	GP35-2		16V-645	2000	1963-1966		6					6	6
	GP30		16V567D3A	2500	1961-1963		1					1	1
	GP20		16V-567	1800	1959-1962		1					1	1
	GP-18		16V-567C	1800			1					1	1
	GP15		12V-645	1500	1970		3					3	3
	GP10		16V567D3A	1800	1967-1977		2					2	2
	GP9		16V-645	1800	1982-1991		28	28		28			
	GP9		16V-645	1800	1954-1981	1980-1991	46		46	46			
	GP9		16V-567	1800	1955-1968		10					10	10
	GP9		16V-567C	1750	1950-1960		15					15	15
	SW9		8V-567C	900	1956-1964		10					10	10
	MP-15		16V-645E	1500	1976		3					3	3
	GMD-1		12V-645	1200	1981-1985		31	27		27		4	4
	SW1200		12V-645	1200	1960		1					1	1
	SW1000		8V-645E	900	1967-1969		2					2	2
	EMD-1		12V-567	1200	1958		1					1	1
Sub-Total							**1511**	**731**	**582**	**1313**	**38**	**160**	**198**

Appendix B-1 cont'd

Locomotive Fleet 2007 – Freight Train Mainline and Road Switching Operations

Manufacturer	Model	EPA Tier Level	Engine	HP	Year Built	Year Rebuilt	Total	CN	CP	Total Class I	Regional	Short Lines	Total Regional and Short Lines
GE	ES44DC	Tier 2	GEVO 12	4400	2005-2007		70	70		70			
	ES44AC	Tier 2	GEVO 12	4400	2006-2007		60		60	60			
	AC4400	Tier 1	7FDL16	4400	2002-2004		136		117	117	17	2	19
	AC4400	Tier 0	7FDL16	4400	2000-2001		68		56	56	12		12
	AC4400	Tier 0	7FDL16	4400	1996-1999		184		184	184			
	Dash 9-44CW	Tier 1	7FDL16	4400	2002-2004		59	59		59			
	Dash 9-44CW	Tier 0	7FDL16	4400	2000-2001		40	40		40			
	Dash 9-44CW	Tier 0	7FDL16	4400	1996-1999	2001-2003	110	101		101	9		9
	Dash 9-44CW		7FDL16	4400	1996-1999		14	12		12	2		2
	Dash 8-40CM		7FDL16	4400	1990-1992		25	26		25			
	Dash 8-40CM		7FDL16	4000	1990-1992		59	55		56	3		3
	B39-8E		7FDL16	3900	1987-1988		16	12		12		4	4
	Dash 7		7FDL16	3600	1978		1	1		1			
Sub-Total							**842**	**376**	**417**	**793**	**43**	**6**	**49**
MLW	M636		16V-251E	3600	1970-1972		4				4		4
	C-424		16V-251	2400	1963-1966		2					2	2
	HR-412		12V-251	2000	1971		1					1	1
	M420		12V-251-B	2000	1971-1975		13					13	13
	RS-18		12V-251	1800	1954-1958		16				1	15	16
Sub-Total							**36**	**0**	**0**	**0**	**5**	**31**	**36**
Total Freight Train Locomotives *(Class I, Regional and Short Lines)*							**2389**	**1107**	**999**	**2106**	**86**	**197**	**283**

Appendix B-2

Locomotive Fleet 2007 – Yard Switching and Work Train Operations

Manufacturer	Model	Engine	HP	Year Built	Year Rebuilt	Total	CN	CP	Total Class I	Regional	Short Lines	Total Region
GM/EMD	SD40-2	16V-645	3000	1973-1985		28		28	28			
	GP38-2	16V-645	2000	1970-1986		35	27		27		8	8
	GP9	16V-645	1800	1954-1981		3					3	3
	GP9	16V-645	1800	1954-1994		130	130		130			
	GP9	16V-645	1750	1954-1981	1980-1991	143		141	141	1	1	2
	GP9	16V-645	1700	1960		3					3	3
	GP9	16V-567	1750	1951-1963		4				3	1	4
	GP15	16V-645	1500	1981-1984		3					3	3
	GP7	16V-567	1500	1950-1973	1980-1988	17		16	16		1	1
	GMD-1	645C	1200	1988-1989		0						
	SW1500	12V-567	1500	1951-1978		10					10	10
	SW1200RM	645C	1200	1987		0						
	SW1200	12V-567	1200	1955-1962		27	8	16	24		3	3
	SW900	8V-567	900	1955		1		1	1			
	SW9	12V-567	1200	1953		2		1	1		1	1
	SW14			1950		1					1	1
Sub-Total						**407**	**165**	**203**	**368**	**4**	**35**	**39**
GE	B23 Super7	7FDL12	2250	1990-1991		3					3	3
	C30-7		3000			6					6	6
	45T	Cummins	2x150	1947		1					1	1
MLW	RS18	12V-251	1800	1954-1958		16					16	16
	RS-18-CAT	Cat 3516	2000			6	6		6			
	RS23		1000	1959-1960		4					4	4
	M420	16V-251	2000	1972-1973		2					2	2
	S-13	6-251	1000	1959-1960		4					4	4
ALCO	S2	6-539	1000	1944		1					1	1
Sub-Total						**43**	**6**	**0**	**6**	**0**	**37**	**37**
Total – Switching and Work Train						**450**	**171**	**203**	**374**	**4**	**72**	**76**
Total – Freight Operations						**2839**	**1278**	**1202**	**2480**	**90**	**269**	**359**

Appendix B-3

Locomotive Fleet 2007 – Passenger Train Operations

Manufacturer	Model	EPA Tier Level	Engine	HP	Year Built	Year Rebuilt	Total	VIA Rail Canada	Commuter	Tourist and Excursion
GM/EMD	F59PH		12-710G3B	3000	1988-1989		45		45	
	F59PH		12-710G3B	3000	1988-1989	1998-2002	15		15	
	FP40PH2		16V-645E3C	3000	1987-1989		54	48	6	
	FP7A		16V-567C	1500	1953-1958		1			1
	FP9A		16V-567C	1750	1953-1958		4	1		3
	FP9B		16V-567C	1750	1953-1958		1			1
	GP-9		16V-645	1800	1959	1989	4		4	
	GP40-2		16V-645E3C	3000	1974-1976	2001	9			9
	SW-1000		8-695E	1200	1966		2	2		
MotivePower	MP36PH-3C	Tier 2	16V-645F3B	3600	2006		1		1	
	MP40PH-3C	Tier 2	16V-645E3C	4000	2007		1		1	
GE	P42DC		7FDL16	4250	2001		21	21		
	DL535		ALCO 251D	1200	1969		7			7
	LL162/162		ALCO 251B	990	1954-1956		11			11
Bombardier	Talent DMU		BR643	2x423	2001		3		3	
Budd	DD6-110		Detroit Diesel	2x260	1955		1			1
	RDC-1		Cummins	2x300	1956-1958		2	2		
	RDC-2		Cummins	2x300	1956-1958		2	2		
	RDC-4		Cummins	2x300	1955		1	1		
Other										
R&H	28 ton			165	1950		1			1
CLC	44 ton		H44A3	400	1960		1			1
GE	70 ton			600	1948		1			1
Total – Passenger Train Locomotives							**188**	**77**	**75**	**36**
Total – Freight and Passenger Locomotives							**3027**			

Appendix C

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
	Westminster

BNSF	All
Southern Railway of British Columbia 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

TOMA Region No. 2
Windsor - Quebec City Corridor, Ontario and Quebec

CN

District **Champlain**

Subdivisions

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

District **Great Lakes**

Subdivision

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

CP

Operations Service Area **Montreal**

Subdivisions All

Operations Service Area **Southern Ontario**

Subdivision

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

Agence métropolitaine de transport	All
Capital Railway	All
GO Transit	All
VIA Rail Canada	Part
CSX	All
Essex Terminal Railway	All
Goderich – Exeter Railway	All
Montreal Maine & Atlantic	All
Norfolk Southern	All
Ottawa Central	All
Ottawa Valley – RaiLink	Part
Quebec Gatineau	All
Southern Ontario – RailAmerica	All
St. Lawrence & Atlantic	All

Appendix D

Traffic and Fuel Consumption
U.S. Units

Freight Traffic *billion*	**1990**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Gross Ton Miles (GTM)	311.6	362.8	380.0	401.8	399.5	398.7	415.3	441.47	457.95	459.63	463.36
Revenue Ton Miles (RTM)	171.3	203.4	206.8	220.8	220.4	211.5	221.7	235.11	241.74	243.74	247.71
Ratio of RTM / GTM	0.550	0.561	0.544	0.550	0.552	0.530	0.534	0.533	0.528	0.530	0.535

Fuel Consumption ***U.S. Gallons*** *million*	1990	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Freight Train Service	481.49	497.04	475.45	485.13	481.66	493.48	504.30	530.87	537.17	538.15	545.96
Yard Switching	31.53	31.27	22.94	22.89	23.74	19.47	18.28	18.70	17.92	17.08	16.43
Work Train	4.23	1.85	1.32	1.06	1.28	1.50	1.29	1.10	1.78	1.98	1.61
Total Freight Operations	517.25	530.16	499.71	509.07	506.68	514.45	523.87	550.67	556.87	557.21	564.00
Total Passenger Operations	27.13	15.46	15.40	16.08	26.21	26.58	26.15	26.40	26.71	26.73	27.03
Total Rail Operations	544.39	545.62	515.11	525.16	532.89	541.04	550.02	577.07	583.58	583.94	591.03

Appendix E-1

Locomotive GHG Emissions
U.S. Units

	1990	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
					1,000 tons						
Freight Train											
$CO_{2\ equivalent}$	6129	6327	6052	6175	6130	6281	6419	6809	6890	6903	6850
CO_2	5443	5618	5374	5484	5443	5578	5700	6047	6119	6130	6066
CH_4	6.28	6.48	6.20	6.33	6.28	6.44	6.58	6.98	7.06	7.08	7.18
N_2O	680	702	671	685	680	697	712	755	764	766	777
Yard Switching and Work Train											
$CO_{2\ equivalent}$	456	421	309	304	316	269	249	254	252	244	226
CO_2	405	374	274	270	281	239	221	225	224	217	200
CH_4	0.47	0.43	0.32	0.31	0.32	0.28	0.26	0.26	0.26	0.25	0.24
N_2O	51	47	34	34	35	30	28	28	28	27	26
Freight Operations											
$CO_{2\ equivalent}$	6585	6748	6360	6480	6446	6550	6667	7063	7142	7147	7076
CO_2	5848	5992	5648	5754	5724	5816	5921	6272	6343	6347	6266
CH_4	6.75	6.91	6.52	6.64	6.60	6.71	6.83	7.24	7.32	7.33	7.42
N_2O	730	748	706	719	715	727	740	783	792	793	802
Passenger Operations											
$CO_{2\ equivalent}$	346	198	195	205	333	336	333	339	343	343	339
CO_2	308	176	173	182	296	299	295	301	304	304	300
CH_4	0.35	0.20	0.20	0.21	0.34	0.34	0.34	0.35	0.35	0.35	0.35
N_2O	38	22	22	23	37	37	37	38	38	38	38
Total - Rail Operations											
$CO_{2\ equivalent}$	6932	6947	6555	6685	6779	6886	7000	7402	7485	7490	7415
CO_2	6156	6169	5822	5936	6020	6115	6217	6573	6647	6651	6567
CH_4	7.10	7.12	6.72	6.85	6.95	7.06	7.17	7.58	7.67	7.68	7.77
N_2O	769	771	727	742	752	764	776	821	830	831	841
Freight Operations Emissions Intensity *(lb / 1000 RTM)*											
$CO_{2\ equivalent}$	76.89	66.35	61.51	58.69	58.49	61.93	60.15	60.08	59.09	58.64	57.13
CO_2	68.28	58.92	54.63	52.12	51.95	55.00	53.42	53.36	52.48	52.08	50.60
CH_4	0.08	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
N_2O	8.53	7.36	6.82	6.51	6.49	6.87	6.67	6.66	6.55	6.50	6.48

Appendix E-2

Locomotive CAC Emissions
U.S. Units

		1990	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
		1,000 tons										
Freight Train	NO_x	109.80	113.30	108.42	110.59	118.23	121.28	112.10	116.27	112.90	110.98	102.08
	CO	21.19	21.86	20.92	21.34	21.19	21.74	22.19	15.86	16.04	16.36	12.27
	HC	4.82	4.97	4.76	4.85	4.82	4.94	5.04	6.66	6.73	4.39	3.88
	PM	2.41	2.48	2.38	2.43	2.41	2.47	2.52	4.99	4.10	2.78	3.66
	SO_x	4.82	4.97	4.76	4.85	4.82	4.94	5.04	4.22	5.02	4.86	1.94
Yard Switching and Work Train	NO_x	7.23	7.93	5.85	5.85	5.98	4.98	4.66	5.93	5.87	5.17	5.86
	CO	1.38	1.36	1.00	1.00	1.02	0.85	0.80	1.06	1.05	0.43	0.34
	HC	0.48	0.47	0.34	0.34	0.35	0.29	0.27	0.34	0.34	0.25	0.34
	PM	0.19	0.19	0.14	0.14	0.14	0.12	0.11	0.14	0.14	0.12	0.18
	SO_x	0.32	0.31	0.23	0.23	0.24	0.20	0.18	0.19	0.19	0.18	0.07
Freight Operations	NO_x	117.03	121.23	114.27	116.44	124.21	126.26	116.76	122.19	118.77	116.15	107.94
	CO	22.57	23.22	21.92	22.34	22.21	22.59	22.99	16.92	17.09	16.79	12.61
	HC	5.30	5.44	5.10	5.19	5.17	5.23	5.31	7.00	7.07	4.64	4.22
	PM	2.60	2.67	2.52	2.57	2.55	2.59	2.63	5.13	4.24	2.90	3.84
	SO_x	5.14	5.28	4.99	5.08	5.06	5.14	5.22	4.41	5.21	5.04	2.00
Passenger Operations	NO_x	6.20	3.97	3.90	4.10	6.66	6.79	6.65	6.72	7.57	7.29	6.96
	CO	1.20	0.69	0.67	0.71	1.15	1.17	1.15	1.01	1.03	0.57	0.44
	HC	0.31	0.18	0.18	0.19	0.30	0.31	0.30	0.25	0.26	0.22	0.10
	PM	0.15	0.09	0.08	0.09	0.14	0.15	0.14	0.15	0.15	0.14	0.09
	SO_x	0.27	0.16	0.15	0.16	0.26	0.27	0.26	0.25	0.25	0.24	0.10
Total - Rail Operations	NO_x	123.23	125.20	118.17	120.54	130.87	133.05	123.41	128.91	126.34	123.44	114.91
	CO	23.77	23.91	22.59	23.05	23.36	23.76	24.14	17.93	18.12	17.36	13.05
	HC	5.61	5.62	5.28	5.38	5.47	5.54	5.61	7.26	7.33	4.86	4.32
	PM	2.75	2.76	2.60	2.66	2.69	2.74	2.77	5.29	4.50	3.05	3.93
	SO_x	5.41	5.44	5.14	5.24	5.32	5.41	5.48	4.66	5.46	5.28	2.10
Freight Operations Emission Intensity *(lb / 1,000 RTM)*	NO_x	1.37	1.19	1.11	1.05	1.13	1.19	1.05	1.03	0.99	0.95	0.87
	CO	0.26	0.23	0.21	0.20	0.20	0.21	0.21	0.14	0.13	0.14	0.10
	HC	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.04	0.03
	PM	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.04	0.03	0.02	0.03
	SO_x	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.02

Note: For 2007, SO_x values adjusted for a diesel fuel sulphur content of 500 ppm

Appendix F

RAC Member Railways in 2007, with Provinces of Operation

Railway	Provinces of Operation
Agence métropolitaine de transport	Québec
Alberta Prairie Railway Excursions	Alberta
Amtrak	British Columbia, Ontario, Québec
Arnaud Railway Company	Québec
Barrie-Collingwood Railway	Ontario
BNSF Railway Company	British Columbia
Burlington Northern (Manitoba) Ltd.	Manitoba
Canadian Heartland Training Railway	Alberta
CP	British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Québec
Cape Breton & Central Nova Scotia Railway	Nova Scotia
Capital Railway	Ontario
Carlton Trail Railway	Saskatchewan
Central Manitoba Railway Inc.	Manitoba
Charlevoix Railway Company Inc.	Québec
Chemin de fer de la Matapédia et du Golfe Inc.	Québec
CN	British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Québec, New Brunswick, Nova Scotia
CSX Transportation Inc.	Ontario, Québec
Essex Terminal Railway Company	Ontario
GO Transit	Ontario
Goderich-Exeter Railway Company Ltd.	Ontario
Great Canadian Railtour Company Ltd.	British Columbia
Great Western Railway Ltd.	Saskatchewan
Hudson Bay Railway	Manitoba
Huron Central Railway Inc.	Ontario
Kelowna Pacific Railway Ltd.	British Columbia
Kettle Falls International Railway, LLC	British Columbia

Montréal, Maine & Atlantic Railway, Ltd.	Québec, New Brunswick
New Brunswick East Coast Railway Inc.	New Brunswick
New Brunswick Southern Railway Company Ltd.	New Brunswick
Nipissing Central Railway Company	Ontario, Québec
Norfolk Southern Railway	Ontario
Okanagan Valley Railway	British Columbia
Ontario Northland Transportation Commission	Ontario, Québec
Ontario Southland Railway Inc.	Ontario
Ottawa Central Railway Inc.	Ontario, Québec
Ottawa Valley Railway	Ontario, Québec
Québec Cartier Mining Company	Québec
Québec Gatineau Railway Inc.	Québec
Québec North Shore and Labrador Railway Company Inc.	Québec, Newfoundland and Labrador
Roberval and Saguenay Railway Company,The	Québec
Romaine River Railway Company	Québec
SOPOR	Québec
South Simcoe Railway	Ontario
Southern Ontario Railway	Ontario
Southern Railway of British Columbia Ltd.	British Columbia
St. Lawrence & Atlantic Railroad (Québec) Inc.	Québec
Sydney Coal Railway	Nova Scotia
Toronto Terminals Railway Company Limited, The	Ontario
Trillium Railway Co. Ltd.	Ontario
Tshiuetin Rail Transportation Inc.	Québec
VIA Rail Canada Inc.	British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Québec, New Brunswick, Nova Scotia
Wabush Lake Railway Company, Limited	Newfoundland and Labrador
West Coast Express Ltd.	British Columbia
White Pass & Yukon Route	British Columbia, Yukon Territory

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