Locomotive Emissions Monitoring Program 2008

RAC

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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 Locomotive Emissions Monitoring (LEM) data filing for 2008 has been completed 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. This MOU, in force from 2006 to 2010, identifies targets that the major railway companies committed to pursue during this period:

- **GHG Commitments:**
  – achieve by 2010 aggregate GHG emissions intensity levels.

  Analysis of railway data for 2008 shows that GHG emissions intensities (as $CO_{2\ equivalent}$ per productivity unit) compared to the target levels set out in the MOU for 2010 by category of railway line-haul operation were:

Railway Operation	Units	2006	2007	2008	MOU 2010 target
Class I Freight	kg / 1,000 RTK	17.79	17.32	17.61	16.98
Regional and Short Lines	kg / 1,000 RTK	15.10	15.21	15.80	15.38
Intercity Passenger	kg / passenger-km	0.13	0.13	0.12	0.12
Commuter Rail	kg / passenger	1.74	1.71	1.74	1.46

- **CAC-related Commitments:**
  Tabled below are the fleet change actions taken by the railways in 2008 compared to 2007 and 2006 to comply with the commitments listed in the MOU, that is, to increase the number of locomotives meeting U.S. Environmental Protection Agency (EPA) emissions standards and to retire older locomotives.

		2006			2007[a]			2008			Total
CAC Commitments Listed Under the MOU	Actions Taken	Class I Mainline Freight	Intercity Passenger	Commuter Service	Class I Mainline Freight	Intercity Passenger	Commuter Service	Class I Mainline Freight	Intercity Passenger	Commuter Service	
Acquire only new and freshly manufactured locomotives that meet applicable EPA emissions standards.	New EPA Tier 2 Locomotives Acquired	60	0	0	105[b]	0	2	34	0	26	227
Upgrade, upon remanufacturing all high-hp locomotives to EPA emissions standards	High-horsepower Units Upgrades to EPA Tier 0 or Tier 1	19	0	0	6[c]	0	0	0	0	0	25
Upgrade to Tier 0, upon remanufacturing, all medium hp locomotives built after 1972 beginning in 2010	Medium-horsepower United Upgraded to EPA Tier 0	0	0	0	7[d]	0	0	12	0	0	19
Retire from service 130 medium-hp locomotives built between 1973 and 1999	Retire 1973-99 era Medium horsepower Units	21	0	0	50	0	0	34	0	20	125

a *2007 data were revised as per Audit conducted in 2009. Corresponding emissions values were calculated for 2007 and included in the LEM report for 2008.*

b *Audited from 85 to 105.*

c *Audited from 92 to 6 due to findings that revealed units reported in 2007 as being upgraded to EPA Tier 0 were, in fact, already at EPA Tier 0 and recertified to EPA Tier 0 upon remanufacture.*

d *Audited from 10 to 7.*

In meeting the CAC commitments under the MOU, the railways have focused primarily on purchasing new freshly-manufactured locomotives meeting the EPA Tier 2 emissions standard and retiring 1973-99 era medium-horsepower locomotives. The railways, primarily the Class I freight railways, had already upgraded the majority of their high-horsepower fleet to the EPA Tier 0 standard prior to the signing of the 2006-2010 MOU. Although the reporting on remanufactured already-compliant locomotives is outside the requirements of the 2006 – 2010 MOU, it can be noted that the railways are making significant investments to re-certify their high-horsepower locomotives to the EPA Tier 0 standard upon remanufacture.

Audit of the 2007 LEM Report: As required under Section 5.3 the 2006-2010 LEM MOU, an audit of the 2007 LEM reporting process was conducted in 2009. The findings of the audit determined that some of the values in the 2007 Actions Taken table were misstated or reported incorrectly. As a result, the 2007 inventory required revisions to the number of locomotives reported in the total Class I freight fleet. The 2007 values listed in the Actions Taken table and the 2007 Locomotive Fleet have been revised and will be shown throughout this 2008 LEM Report. The impact of these inventory revisions on the reported 2007 emissions was minimal.

The recommendations of the audit related to data collection methodologies influence the results of follow-on annual LEM reports. The recommendations have been incorporated into data collection and calculations for this 2008 LEM report.

Summary of LEM Data for 2008: Summarized below are the data collection process, input data and calculated emissions from all diesel locomotives operating in Canada during 2008 on the 54 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 RAC member railway. 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, NOx, carbon monoxide (CO), hydrocarbons (HC), particulate matter (PM) and oxides of sulphur (SOx, but expressed as SO_2) are calculated based on the amount of diesel fuel consumed, the emissions factors specific to an individual diesel engine type and duty cycles reflecting a locomotive's operational service. The amount of SOx emitted varies mostly according to the sulphur content of the diesel fuel. Emissions metrics are expressed in terms of absolute mass as well as intensity, that is, a ratio relating emissions to productivity or operational efficiency.

Freight Traffic: In 2008, the railways handled 346.34 billion revenue tonne-kilometres (RTK) of traffic as compared to 361.62 billion RTK in 2007, a decrease of 4.2 per cent. Of the total, Canadian National (CN) and Canadian Pacific (CP), the two Canadian Class I freight railways, were responsible for 93.8 per cent of the traffic. Since 1990, railway freight RTK has risen by an average annual rate of 2.0 per cent.

Intermodal Traffic: Of the total freight carried in 2008, intermodal carloadings dominated at 22 per cent. Class I railways' intermodal traffic decreased from 84.73 billion RTK in 2007 to 83.32 billion RTK in 2008, a drop of 1.7 per cent. Since 1990, container-on-flat car traffic has increased 242.8 per cent while trailer-on-flat car has decreased 67.7 per cent.

Passenger Traffic: Intercity traffic in 2008 by all operators totalled 4.88 million passengers compared to 4.48 million in 2007. The carriers were VIA Rail Canada, CN / Algoma Central, Ontario Northland Railway and Tshiuetin Rail Transportation. VIA Rail Canada transported 4.22 million passengers, that is, 94.3 per cent of the intercity traffic.

Commuter rail traffic increased from 63.39 million passengers in 2007 to 67.05 million in 2008, an increase of 5.8 per cent. This is up from 41.00 million passengers in 1997, when the RAC first started collecting commuter statistics, an increase of 63.5 per cent.

Tourist and Excursion traffic totalled 354 thousand, a decrease of 6.3 per cent below the 378 thousand transported in 2007.

Photo: Courtesy of CN

Fuel Consumption: Overall, the fuel consumed by railway operations in Canada decreased from 2,237.22 million litres (L) in 2007 to 2,183.95 million L in 2008, a reduction of 2.4 per cent. Of this amount, Class I freight train operations consumed 87.1 per cent and Regional and Short Lines consumed 5.1 per cent. Yard switching and work train operations consumed 2.9 per cent and passenger operations accounted for 4.9 per cent (of which 2.7 per cent was for VIA Rail Canada, 1.8 per cent for Commuter Rail, 0.3 per cent for Tourist and Excursion operations and 0.04 per cent 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 2008 was 6.16 L per 1,000 RTK as compared to 5.90 L in 2007. Although this is an increase of 8.8 per cent, this is down from 7.83 L per 1,000 RTK in 1990, a reduction of 21.3 per cent.

For total passenger operations, the overall fuel consumption in 2008 was 3.6 per cent above corresponding figures for 2007. In terms of consumption per unit of productivity, the values for VIA Rail Canada intercity operations in 2008 were 0.039 L versus 0.042 per passenger-km in 2007 and 0.58 L per passenger versus 0.57 in 2007 for the combined Commuter Rail operations.

Locomotive Fleet Inventory: The number of diesel-powered locomotives and diesel mobile units (DMUs) in active service in Canada belonging to RAC member railways totalled 2,823 in 2008 versus 3,044 in 2007. The drop is due to a combination of retirements of older line-haul and switcher locomotives as well as in-service cut-backs due to the reduction in traffic in 2008. For line-haul freight operations, 2,193 are in service of which 1,942 are on Class I railways and 251 are on Regional and Short Lines. A further 424 are in Switching and Work Train operations, of which 347 are in Class I service and 77 in Regional and Short lines. A total of 206 locomotives and DMUs are in passenger operations, of which 78 are in VIA Rail Canada intercity services, 93 in Commuter and 35 are in Tourist and Excursion services.

In 2008, 46.4 per cent of the line-haul locomotives, that is, 1,110 met the stringent U.S. EPA Tier 0, Tier 1 and Tier 2 emissions standards, compared to 1,082 in service in 2007. Although a total of 84 additional Tier-level locomotives were introduced into the Canadian fleet in 2008 the net fleet increase was only 28, as 56 units were taken out of service due to reduced operational requirements and equipment reasons. Of the 60 new high-horsepower locomotives added meeting Tier 2 standards, 34 were by the Class I freight railways and 26 by the commuter railways. There were 12 medium-horsepower locomotives upgraded upon remanufacture to Tier 0 in 2008. Although no high-horsepower locomotives were upgraded to Tier 0 in 2008, there were 56 already at Tier 0 which, upon remanufacture in 2008, were recertified to their Tier 0 standard. As well, 10 were remanufactured retaining their Tier 1 status. In 2008, 54 medium-horsepower locomotives manufactured between 1973 and 1999 were retired.

A new statistic gathered for this LEM reporting was the number of locomotives equipped with a device to minimize unnecessary idling such as an Automatic Engine Stop-Start (AESS) system or Auxiliary Power Unit (APU). The total for 2008 was 1,104, which is 39.1 per cent of the overall in-service fleet.

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 carbon dioxide (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 has been applied to all reported GHG data since 1990 and stems from studies updating the carbon content, density and oxidation rates of Canadian liquid fuels.

The EF used to calculate NOx emitted from freight train locomotives was re-calculated to 43.99 grams / litre (g/L) of diesel fuel consumed for 2008 versus 44.28 g/L in 2007. This lowering reflects the continuing acquisition of new locomotives manufactured to U.S. EPA Tier 2 emissions standards that have been in effect since 2005. Also, upon remanufacture, in-service high-horsepower locomotives have been upgraded to Tier 0.

Emissions: Total GHG emissions were 6,564.44 kt as compared to 6,727.65 kt in 2007 and 6,288.00 kt in 1990. NOx emissions from all rail operations totalled 99.68 kt, as compared to 103.18 kt reported in 2007; a 3.4 per cent reduction. Total HC emissions were 3.85 kt, CO totalled 10.23 kt and PM totalled 3.14 kt. Emissions of SOx in 2008 were 0.55 kt compared to 1.91 in 2007 and 4.80 kt in 2006 prior to the coming into force in June 2007 of regulations limiting railway diesel fuel sulphur content in Canada to 500 ppm. In 2008, the sulphur content of railway diesel fuel averaged 147 ppm.

GHG Emissions Intensity: In contrast to a steady decline in previous years, the 2008 GHG emissions levels per 1,000 RTK for line-haul freight operations were, respectively, 17.61 kg for Class I and 15.8 kg for Regional and Short Lines. When data from all line-haul and switching operations for Class I and Regional and Short Lines are consolidated, the GHG intensity rose to 18.05 kg per 1,000 RTK from 17.75 in 2007. Despite the rise, this was still 23.3 per cent below the 1990 baseline reference. For 2008, Intercity Passenger GHG intensity was 0.12 kg per passenger-km (the same as for 2007) while for Commuter Rail it was 1.74 kg per passenger; up from 1.71 kg per passenger in 2007.

The increase in GHG emissions intensities by the freight railways can be attributed to the 4.2 per cent decrease in 2008 RTK traffic over the 2007 level. In the fourth quarter of 2008, the Canadian economy contracted at an annualized rate of 3.7 per cent, which had a direct negative impact on freight railway traffic. During that quarter, RTK traffic declined 20 per cent on a year-over-year basis.

At the time the GHG emissions intensity targets in the MOU were negotiated, the assumption was that RTK traffic would grow by 3.0 per cent during the course of the MOU. When freight railways experience growth in traffic and use scheduled railway operations, they have the ability to run longer and heavier trains, thus improving GHG emissions intensity levels. However when RTK traffic declines, the railways operate shorter and lighter trains, thus resulting in higher GHG intensity levels. This situation became particularly acute in the fourth quarter in 2008. Unfortunately the impact of the decrease in RTKs on emissions intensity levels could not be offset by the number of efficiency improvements being undertaken by the freight railways, as outlined in Section 7 of the report.

The increase in Commuter Rail GHG intensity levels can be accredited to the introduction of additional scheduling and the

Photo: Courtesy of Rick Robinson/CP

operation of longer trains in 2008. New higher horsepower locomotives were employed to move the longer trainsets. In 2008, GO Transit suspended use of the proprietary FTC fuel extender additive pending resolution of warranty concerns on its new locomotives. Also, the additional scheduling that came online in 2008 resulted in greater capacity within the commuter rail system. This combination of events negatively impacted the GHG intensity level. Generally, when additional service routes are introduced it takes a period of time to increase ridership to fill new capacity. As new capacity is utilized, it is expected that GHG intensity levels will decrease.

CAC Emissions Intensity: NOx emission intensity in 2008 for all freight operations was 0.27 kg per 1,000 RTK, the same as for 2007.

Tropospheric Ozone Management Areas (TOMA): Of the total Canadian rail sector fuel consumed and corresponding GHG emitted in 2008, 2.8 per cent was used in the Lower Fraser Valley of British Columbia, 17.1 per cent in the Windsor-Quebec City Corridor and 0.2 per cent in the Saint John area of New Brunswick. Similarly, NOx emissions for the three TOMA were, respectively, 2.8 per cent, 16.8 per cent and 0.2 per cent.

Emissions Reduction Initiatives by Railways: During 2008, the railways continued to acquire new locomotives compliant with U.S. EPA Tier 2 emissions standards (which came into force January 1st, 2005). These new locomotives are factory-fitted with AESS systems to minimize idling. Upon remanufacture, older locomotives are fitted with APU units. As of 2008, 39.1 per cent of the locomotive fleet has been fitted with AESS or APU devices.

In 2008, CP announced that, assisted by Transport Canada's ecoFREIGHT Program, it will test two GenSet locomotives in southern Ontario road switching service. The motive power of GenSet locomotives consists of three independent 700 horsepower diesel engine generating sets (instead of one 2,000 horsepower diesel engine) which are activated incrementally to supply the traction horsepower required. Overall, the technology aims to achieve significant fuel savings, ultra-low emissions and longer engine life.

Staff training and incentives focussing on fuel conserving train-handling procedures were accelerated. Non-locomotive equipment 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, CN and CP, for shared operation on mainline segments. In 2008, ultra-low sulphur diesel (ULSD) fuel was standardized on VIA Rail Canada and commuter operations. 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 require ULSD fuel and 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 www.railcan.ca/site_ghg_calculator .

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, to further spread such information to its member railways, the RAC participated in the 2008 Rail Conference *'On Board for a Cleaner Environment'* May 6-7 in Toronto convened by Transport Canada's ecoFREIGHT program. The presentations can be viewed on www.ecoaction.gc.ca/ecofreight.

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

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

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

- **Medium-speed diesel engine**: With an operating speed of 800 to 1,100 RPM, this engine is installed in versions from 8 to 16 cylinders at up to 4,400 HP;

- **Multiple 'GenSet' diesel engines**: With an operating speed up to 1,800 RPM, 'stand alone' generating sets (GenSet) each powered by a 700 HP industrial diesel engine driving separate alternators are linked electronically to produce up to 2,000 traction horsepower. For switching locomotive applications, the advantage of this arrangement is that individual GenSet engines can be started or stopped according to the power required.

Locomotive Remanufacture: The 'remanufacture' of a locomotive as a process in which all of the power assemblies of a locomotive engine are replaced with freshly manufactured (containing no previously used parts) or refurbished power assemblies or those inspected and qualified. Inspecting and qualifying previously used parts can be done in several ways, including such things as cleaning, measuring physical dimensions for proper size and tolerance, and running performance tests to assure that the parts are functioning properly and according to specifications. Refurbished power assemblies could include some combination of freshly manufactured parts, reconditioned parts from other previously used power assemblies, and reconditioned parts from the power assemblies that were replaced. In cases where all of the power assemblies are not replaced at a single time, a locomotive will be considered to be 'remanufactured' (and therefore 'new') if all power assemblies from the previously new engine had been replaced within a five year period. *(This definition for remanufactured locomotives is taken from the U.S. Federal Register Volume 63, No.73 April 16, 1998 / Rules and Regulations for the Environmental Protection Agency (EPA) 40 CFR Parts 85, 89 and 92 (Emission Standards for Locomotives and Locomotive Engines)*.

Locomotive Utilization Profile: This is the breakdown of locomotive activity within a 24-hour day (based on yearly averages).

|←————————— 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 per cent of a 24-hour day that a locomotive could be used for operational service. Conversely, **Unavailable** is the percentage of the day that a locomotive is being serviced, repaired, remanufactured or in storage. Locomotive available time plus unavailable time equals 100 per cent;

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 per cent of the operating time that the engine is operating at idle or low-idle setting. It can be further segregated into **Manned Idle** (when an operating crew is on-board the locomotive) and **Isolate** (when the locomotive is unmanned);

Duty Cycle: This is the profile of the different locomotive power settings (Low-Idle, Idle, Dynamic Braking, or Notch levels 1 through 8) as percentages of Engine Operating Time.

Railway Productivity Units:

Gross Tonne-Kilometres (GTK): This term refers to the product of the total weight (in tonnes) of the trailing tonnage (both loaded and empty railcars) and the distance (in kilometres) the freight train travelled. It excludes the weight of locomotives pulling the trains. Units can also be expressed in gross ton-miles (GTM).

Revenue Tonne-Kilometres (RTK): This term refers to the product of the weight (in tonnes) of revenue commodities handled and the distance (in kilometres) transported. It excludes the tonne-kilometres involved in the movement of railway materials or any other non-revenue movement. The units can also be expressed in revenue ton-miles (RTM).

Passenger-Kilometres per Train-Kilometre: This term is a measure of intercity train efficiency, 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).

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:

NOx (Oxides of Nitrogen): these are the products of nitrogen and oxygen that result from high combustion temperatures. The amount of NOx emitted is a function of peak combustion temperature. NOx 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 NOx and PM emissions are interdependent; that is, technologies that control NOx (such as retarding injection timing) result in higher PM emissions. Conversely, technologies that control PM often result in increased NOx emissions

SOx (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 xi for conversion values pertaining to diesel fuel combustion.

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

Referencing the above-listed limits for locomotives operating in the U.S.A., the EPA in 2008 put into force revisions which tighten the existing Tier 0 to Tier 2 standards. The revisions are now referred to as Tier 0+, Tier 1+ and Tier 2+ standards. As indicated in the Tables below, they take into account the year of original manufacture of the locomotive. Also, two new, more stringent standards levels were introduced, designated Tier 3 and Tier 4. The revised and new standards are to be phased-in between 2010 and 2015 for locomotives as they become new; new in this case includes both when locomotives are originally manufactured and when remanufactured. It is envisaged that to meet the Tier 4 standards, locomotives manufactured starting in 2015 will require additional exhaust gas treatment technologies to be installed and be dependent upon diesel fuel having a sulphur content capped at 15 ppm. Elaboration on the U.S. EPA locomotive emissions regulations can be viewed on the website: www.epa.gov/otaq/locomotv.htm

Line-Haul Locomotive Emission Standards *g/bhp-hr*

Tier	*MY	Date	HC	CO	NOx	PM
Tier 0+[a]	1973-1992	2010[c]	1.00	5.0	8.0	0.22
Tier 1+[a]	1993-2004[b]	2010[c]	0.55	2.2	7.4	0.22
Tier 2+[a]	2005-2011	2013[c]	0.30	1.5	5.5	0.10[d]
Tier 3[e]	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+ to Tier 2+ line-haul locomotives must also meet switch standards of the same Tier.

b 1993-2001 locomotives that were not equipped with an intake air coolant system are subject to Tier 0+ rather than Tier 1+ standards.

c As early as 2008 if approved engine upgrade kits become available.

d 0.20 g/bhp-hr until January 1, 2013 (with some exceptions).

e Tier 3 line-haul locomotives must also meet Tier 2+ switching standards.

f Manufacturers may elect to meet a combined NOx + HC standard of 1.4 g/bhp-hr.

** MY – Year of original manufacture*

Switching Locomotive Emission Standards *g/bhp-hr*

Tier	*MY	Date	HC	CO	NOx	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	2013[b]	0.60	2.4	8.1	0.13[c]
Tier 3	2011-2014	2011	0.60	2.4	5.0	0.10
Tier 4	2015 or later	2015	0.14[d]	2.4	1.3[d]	0.03

a Tier 1+ and Tier 2+ switching locomotives must also meet line-haul standards of the same Tier.

b As early as 2008 if approved engine upgrade kits become available.

c 0.24 g/bhp-hr until January 1, 2013 (with some exceptions).

d Manufacturers may elect to meet a combined NOx + 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 (NOx, CO, HC, PM) in g/L are specific to individual engine and locomotive types, and are obtained from test measurements.

Emission Factor for Sulphur Dioxide (based on 147 ppm sulphur in diesel fuel)	(SO_2)	0.00025 kg / L

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	
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

* *not present in diesel fuel*

† *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 *NOx per 1,000 RTK*; that is, the mass in kilograms of NOx 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
$CO_{2\ \mathit{equivalent}}$	Carbon Dioxide equivalent of all six Greenhouse Gases
CO	Carbon Monoxide
EF	Emissions Factor
GHG	Greenhouse Gas
HC	Hydrocarbons
NOx	Oxides of Nitrogen
PM	Particulate Matter
SOx	Oxides of Sulphur
SO_2	Sulphur Dioxide
TOMA	Tropospheric Ozone Management Areas

Abbreviations used in Railway Operations

AESS	Automated Engine Start-Stop
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
ULSD	Ultra-low Sulphur Diesel Fuel

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
EMCI	Electro-Motive Canada Inc.
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 2008 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 targets for the major railway companies to achieve during this period:

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

Railway Operation	Units	MOU 2010 target
Class I Freight	kg / 1,000 RTK	16.98
Regional and Short Lines	kg / 1,000 RTK	15.38
Intercity Passenger	kg / passenger-km	0.12
Commuter Rail	kg / passenger	1.46

- **CAC-related Commitments:**
  - acquire only new and freshly manufactured locomotives that meet applicable U.S. Environmental Protection Agency (EPA) emissions standards;
  - upgrade, upon remanufacturing, all high-horsepower locomotives to EPA emissions standards; and
  - upgrade to Tier 0, upon remanufacturing, all medium horsepower locomotives built after 1972 beginning in 2010; and
  - retire from service 130 medium-horsepower locomotives built between 1973 and 1999;

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 (NOx), carbon monoxide (CO), hydrocarbons (HC), particulate matter (PM) and oxides of sulphur (SOx). The SOx 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 2008 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 1999. 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. Appendix G presents the RAC Management Plan for responding to recommendations of the Audit undertaken on the 2007 LEM report.

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; 2007 LEM – Published by RAC – December 2008*

1.1
Audit of the LEM Reporting Process:

As required under Section 5.3 of the 2006-2010 MOU, an audit was conducted in 2009 of the 2007 LEM reporting process. The purpose of the audit was to support transparency with respect to the MOU and to demonstrate credibility of the data contained in the 2007 LEM Report as well as the reported progress towards meeting the reduced greenhouse gas (GHG) emissions targets outlined in the MOU. This objective was achieved through validation of data collection processes and reviewing documentation pertaining to selected data included in the report.

The scope of the audit included the processes and methodology for data collection, normalization and analysis used to develop the report. In particular, the objectives of the audit were to:

- Provide assessment and verification of locomotive inventory data pertaining to Section 3.0 of the MOU to verify that commitments under Section 3.2 of the MOU have been met;
- Provide assessment and verification of GHG data pertaining to Section 4.0 of the MOU to verify that commitments under Section 4.1 of the MOU have been met;
- Provide assessment and verification of NOx, SOx and fuel consumption data pertaining to Section 5.0 of the MOU to verify that commitments under Section 5.2.2 of the MOU have been met; and
- Verify data for fuel used by the different categories of railways, as outlined in Section 5.2.2 of the MOU.

The auditor collected audit evidence and limited assurance for GHG data from document reviews, interviews and physical observation of activities, including:

- Enquiry/interviews;
- Data systems evaluation; and
- Application of a small set of analytical procedures such as re-calculation of emissions data, observation of information management system controls, confirmation of delivery of product, data inspection and data analysis.

1.2
Findings of the Audit

Audit findings were presented in terms of nonconformities (NCs) with the audit criteria, that is, where a stated requirement of the MOU was not met as well as opportunities for improvement (OFIs), that is, suggestions on strengthening the data reporting methodology and processes).

1.2.1.
Nonconformities

During the Audit, one nonconformity was identified vis-à-vis Section 3.2 of the MOU.

Description of finding: The number of new EPA Tier 2 locomotives acquired in 2007 was listed in the 2007 LEM Report as 85. Evidence identified during the audit indicated that the number of EPA Tier 2 locomotives that should have been reported was 105, a misstatement of approximately 24%. The overall reporting of locomotive CAC emissions was not materially impacted by this misstatement.

The reported number of high-horsepower units upgraded to EPA Tier 0 in 2007 was 92. Evidence identified during the audit indicated that the number of high-horsepower locomotives upgraded to EPA Tier 0 reported was 78, a misstatement of approximately 15%. Through secondary information requests made to verify CAC commitments, there were two findings:

- All 72 of the high-horsepower locomotives reported by one of the Class I railways already met the EPA Tier 0 standard and as a result were recertified, not upgraded, when remanufactured in 2007, i.e., these were not reported in a consistent manner; and
- AMEC was unable to obtain sufficient appropriate evidence through the secondary information request to confirm that the 6 units reported by another Class I railway had been upgraded to Tier 0.

Subsequently, the definitions, for LEM reporting, of 'locomotives upgraded to EPA Tier 0' and 'remanufactured Tier 0 locomotives' were clarified by the LEM Technical Review Committee. Further, the reported number of high-horsepower locomotives upgraded to Tier 0 for the year 2007 has been revised to 6 (the original number reported by one of Class I railways). The overall reporting of locomotive CAC emissions was not materially impacted by this misstatement.

The medium-horsepower units upgraded to EPA Tier 0 in 2007 included in the Report is 10. Evidence identified during the audit indicated that the number of upgraded medium-horsepower units reported was 7, a misstatement of 30%. The overall reporting of locomotive CAC emissions was not materially impacted by this misstatement.

Audit Recommendation: Supporting documentation for these data must be retained by the RAC members submitting data for inclusion in the LEM Reports and internal controls for the documentation must be strengthened to allow for the records to be readily identifiable, traceable and retrievable. Records of the original data used for the LEM Reports must be legible, adequately protected, retained for a suitable period of time and disposed of in an appropriate manner. RAC consultants should cross-reference the accuracy and completeness of the locomotive retirement data submitted for the LEM Reports against other relevant sources.

1.3 Opportunities for Improvement

The Audit report identified six Opportunities for Improvement (OFI) to be incorporated in the development of future annual LEM reports:

i) **OFI-01:** A small number of RAC members do not appear to be submitting the information required for the LEM Report in a timely manner. This impacts the preparation time for, and the quality of, the data and information to be included in the annual LEM Reports.

   Audit Recommendation: The RAC should establish a firm cut-off date for receipt of data from RAC members and include a note in the corresponding LEM Report that missing data were not received by the cut-off date. The RAC should strengthen communication of expected timelines for the project and expectations to RAC members, prior to sending out the surveys. The RAC MOU Management Committee as well as the RAC MOU Technical Review Committee meetings may be an opportunity to address this.

ii) **OFI-02:** A small number of RAC members submit inaccurate information in their survey responses used to generate the LEM Report. This impacts the preparation time for, and the quality of, the data and information to be included in the annual LEM Reports.

   Audit Recommendation: The RAC should consider offering training to the survey respondents on: (i) the importance of data; (ii) the timeliness of their responses; and (iii) filling out the LEM portion of the RAC Railway Trends survey, stressing the importance of data accuracy and completeness.

iii) **OFI-03**: No mechanism appears to be in place for interested parties to provide comments on the annual LEM Reports, for example, the type and amount of data and information presented.

   Audit Recommendation: The RAC is to provide contact information within the LEM Report to allow interested parties to make enquiries and to provide feedback. For example, some sections of the LEM Report may not be perceived as useful and could be eliminated. Conversely, RAC members may require additional information that is not presently included in the annual LEM Report.

iv) **OFI-04:** The evaluation of the emissions factors is based on the status of the locomotive inventory at the end of the year. Consequently, the calculations of the emissions for a complete year include improvements that, in some cases, were effective for only a small portion of the year.

   Audit Recommendation: The RAC to interpolate the emissions inventory based on locomotive fleet. Applying the emissions factors on a locomotive inventory taken in July or using interpolation to evaluate mean emissions factors for the complete year would provide more accurate evaluations of the CACs.

v) **OFI-05:** The information provided in the Report is insufficient to allow a reader to fully identify all the changes in the Canadian locomotive fleet.

Audit Recommendation: The RAC should consider including additional information in the Report, for example: (i) list of new locomotives acquired in the year by model; (ii) list of high-horsepower units re-manufactured in the year by model; and (iii) list of medium-horsepower units permanently retired in the year by model and year of original manufacture.

vi) **OFI-06:** The LEM Report (2007) is published on the RAC and Transport Canada websites but is not presently published on the Environment Canada website.

Audit Recommendation: Environment Canada should consider publishing the LEM Report (2007) to their website. Subsequent to the interview, AMEC was advised that the federal Government policy is to post electronic copies of the LEM Report to a single location (Transport Canada's website).

1.4 Audit Conclusion

The audit concluded that the following data and information included in the 2007 Report met an acceptable materiality level:

- Retire 1973-1999 era Medium–horsepower Units for Class I Mainline Freight (Table on page i and page 35 of the Report);
- 2007 GHG emissions intensity data (Table 10 on page 19 of the Report); and
- 2007 Canadian Rail Operations Fuel Consumption (Table 2 on page 8 of Report) and 2007 CAC Emissions (Table 11 on page 22 of the Report).

The audit found the following values in the 2007 Report did not meet an acceptable materiality level and were materially misstated:

- New EPA Tier 2 Locomotives Acquired for Class I Mainline Freight in 2007;
- High-horsepower Units Upgraded to EPA Tier 0 in 2007; and
- Medium-horsepower Units Upgraded to EPA Tier 0 in 2007.

Although the values identified above were found to be materially misstated, the calculated locomotive CAC and GHG emissions in the Report were not materially impacted by the differences in the locomotive inventory identified by the audit.

1.5 Corrective Actions Undertaken

The audit recommendations that pertain to data collection have been incorporated into the development the 2008 LEM report. In addition, based on the revised Tier-level locomotive numbers identified by the Audit, the emissions for 2007 have been re-calculated and appear in this 2008 LEM report. The revisions reflect:

- the reported number of EPA Tier 2 locomotives for the year 2007 has been revised from 85 to 105.
- the reported number of high-horsepower locomotives upgraded to Tier 0 for the year 2007 has been revised from 92 to 6.
- the reported number of medium-horsepower locomotives upgraded to Tier 0 for the year 2007 was revised from 10 to 7.

Recommendations of a post-production nature will be implemented on an on-going basis.

Appendix G contains the RAC's Management Plan which identifies the actions that have been undertaken and those that will be undertaken in implementing the recommendations from the Audit of the 2007 LEM report.

2 Traffic and Fuel Consumption Data

2.1 Freight Traffic Handled

As shown in Table 1 and Figure 1, traffic in 2008 handled by Canadian railways totalled 656.62 billion gross tonne-kilometres (GTK) compared with 676.43 billion GTK in 2007. This decrease reflects the downturn in the economy experienced in 2008. For the 1990 reference year, the value was 454.94 billion GTK. Similarly, revenue traffic in 2008 declined to 346.34 billion revenue tonne-kilometres (RTK) from 361.62 billion RTK in 2007, but is up from 250.13 billion RTK in 1990. As a percentage, the traffic in GTK in 2008 was 2.9 per cent below the 2007 level, but 44.3 per cent over the 1990 level. RTK in 2008 decreased by 4.2 per cent compared to 2007 but is 38.5 per cent over that for 1990. Since 1990, the average annual growth was, respectively, 2.5 per cent for GTK and 2.1 per cent for RTK.

Table 1

Total Freight Traffic

Tonne-kilometres (billion)

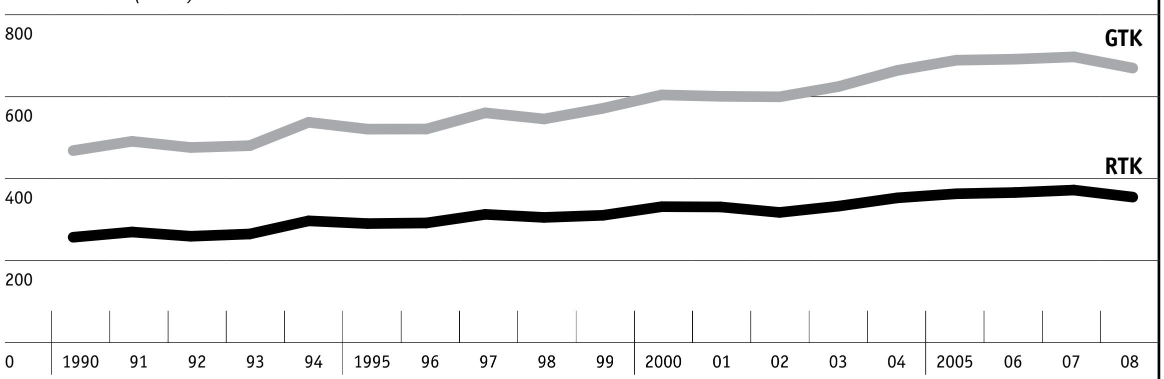
	1990	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
GTK											
Class I						569.75	608.51	628.09	629.93	638.66	621.90
Regional + Short Line						36.57	35.97	40.45	41.07	37.77	34.72
Total	454.94	554.82	586.56	583.2	582.06	606.26	644.48	668.54	671.00	676.43	656.62
RTK											
Class I						300.51	320.27	328.24	330.96	338.32	324.99
Regional + Short Line						23.07	22.96	24.67	24.87	23.30	21.35
Total	250.13	301.96	322.38	321.74	308.76	323.58	343.23	352.91	355.83	361.62	346.35
Ratio of RTK/GTK	0.550	0.544	0.550	0.552	0.531	0.534	0.533	0.528	0.530	0.535	0.527

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

Figure 1

Total Freight Traffic (1990-2008)

Tonne-kilometres (billion)



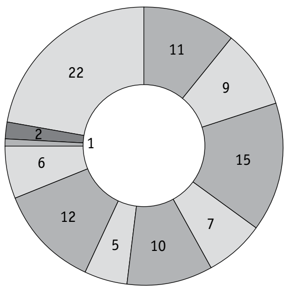
In 2008, Class I GTK traffic decreased by 2.6 per cent to 621.90 billion from 638.66 billion in 2007. This was 94.7 per cent of the total GTK hauled. Class I RTK traffic decreased 3.9 per cent in 2008 to 324.99 billion from 338.32 billion in 2007. Class I railways accounted for 93.8 per cent of the total RTK. Of the total freight traffic, Regional and Short Lines were responsible for 34.72 billion GTK (or 5.3 per cent) and 21.35 billion RTK (or 6.2 per cent). In 2008, the Regional and Short Lines experienced an 8.4 per cent decrease in RTK compared to 2007.

2.1.1

Freight Carloads by Commodity Grouping

Figure 2

Canadian Rail Originated Freight Carloads by Commodity Grouping



11%	Agriculture	12%	Fuels & Chemicals
9%	Coal	6%	Paper Products
15%	Minerals	1%	Food Products
7%	Forest Products	2%	Manufactured & Miscellaneous
10%	Metals	22%	Intermodal
5%	Machinery & Auto		

2.1.2

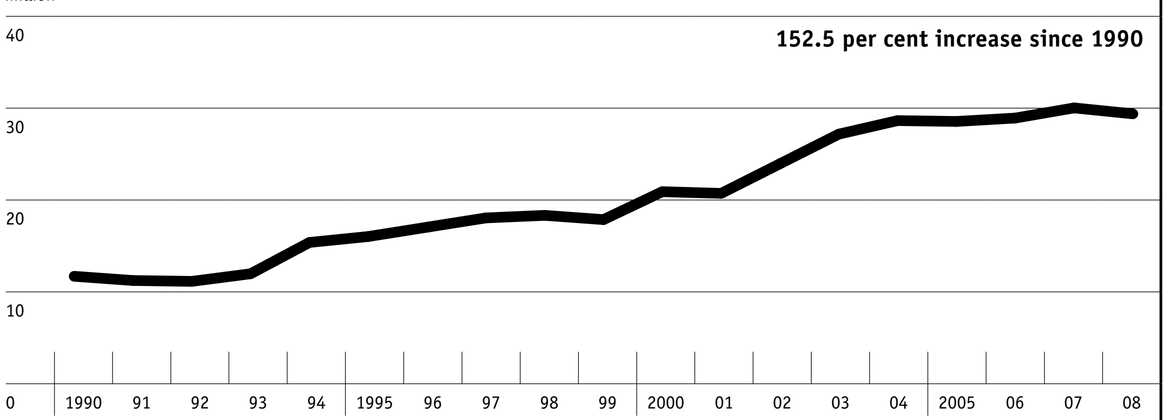
Class I Intermodal Traffic

The number of intermodal carloads handled by the Class I railways in Canada in 2008 rose to 845,684 from 828,020 in 2007, an increase of 2.1 per cent. Intermodal tonnage dropped 1.3 per cent to 32.29 million tonnes from 32.70 million tonnes in 2007. Overall, since 1990 intermodal tonnage comprising both container-on-flat-car and trailer-on-flat-car traffic has risen 152.5 per cent equating to an average annual growth of 8.5 per cent.

Figure 3

Class I Intermodal Tonnage

million



Class I intermodal RTK totalled 83.32 billion in 2008 versus 84.73 billion for 2007, a drop of 1.7 per cent. Of the 324.99 billion RTK transported by the Class I railways in 2008, intermodal accounted for 25.6 per cent 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].

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 2008 in Canada totalled 4.88 million, as compared to 4.48 million in 2007. The carriers were VIA Rail Canada, CN / Algoma Central, Ontario Northland Railway and Tshiuetin Rail Transportation. Of the total, 94.3 per cent was transported by VIA Rail Canada, that is, 4.61 million. This was a 10.1 per cent increase from the 4.18 million transported in 2007, and an increase of 22.0 per cent from 3.46 million in 1990. In terms of revenue passenger-kilometres (RPK), the figure for VIA Rail Canada for 2008 was 1,530 million, versus 1,407 million for 2007. It is up from 1,235 million in 1990, a rise of 23.9 per cent. The annual statistics since 1990 for VIA's traffic and RPK are displayed in Figures 4 and 5.

Figure 4
VIA Rail Canada Passenger Traffic
million

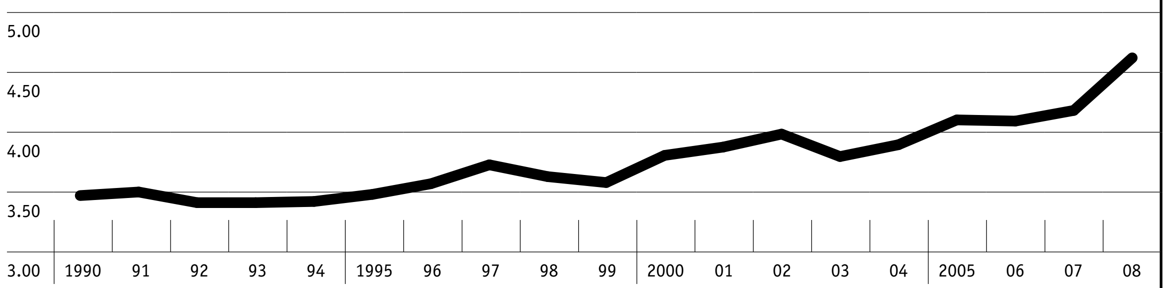
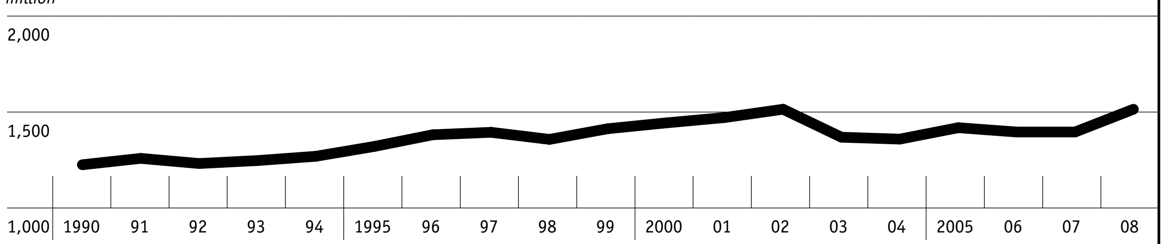
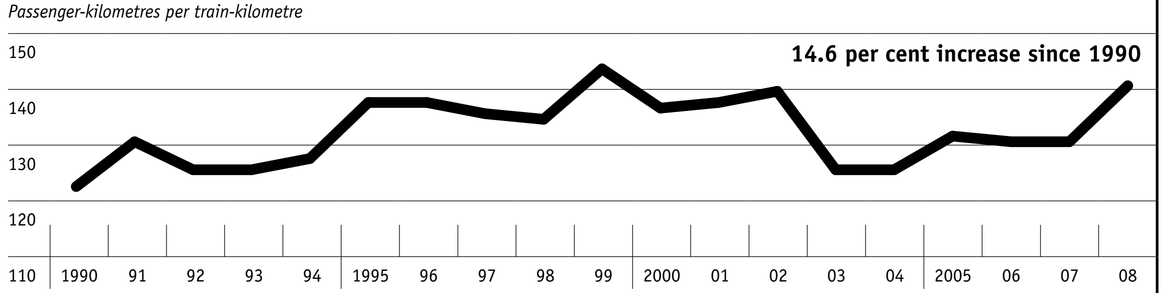


Figure 5
VIA Rail Canada Revenue Passenger-Kilometres
million



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 2008 was 141 passenger-km per train-km, versus 131 in 2007, but above the 1990 baseline of 123. As a percentage, train efficiency in 2008 was 14.6 per cent over that in 1990.

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



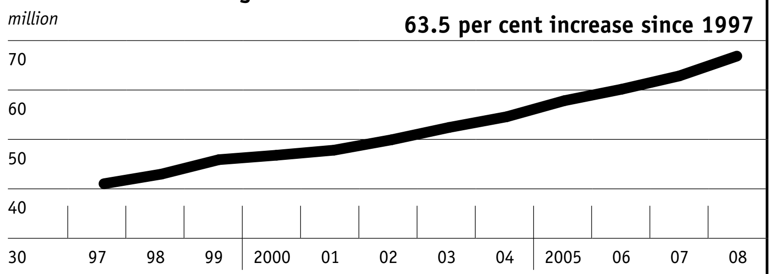
2.2.2

Commuter Rail

Commuter rail passengers in 2008 totalled 67.05 million. This is up from 63.39 million in 2007, an increase of 5.8 per cent. As shown in Figure 7, by 2008, commuter traffic has increased 63.5 per cent 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 5.8 per cent 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



2.2.3

Tourist and Excursion Services

In 2008, the nine railways offering tourist and excursion services transported 354 thousand passengers as contrasted to 378 thousand in 2007, a decrease of 6.3 per cent. The railways reporting these services were: Alberta Prairie Railway Excursions, Barrie-Collingwood Railway, CN / Algoma Central (also operates a scheduled passenger service), CP / Royal Canadian Pacific, Great Canadian Railtour Company, 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 decreased to 2,183.95 million L in 2008 from 2,237.22 million L in 2007 in comparison with 2,060.66 million L in 1990. As a percentage, fuel consumption in 2008 was 2.4 per cent lower than in 2007 but was 6.0 per cent over the 1990 level.

Table 2

Canadian Rail Operations Fuel Consumption

Litres (million)

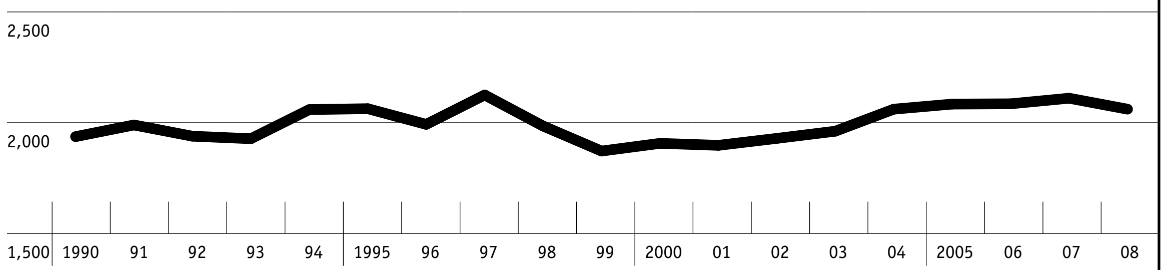
	1990	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Freight Train	1,822.60	1,799.72	1,836.37	1,823.21	1,870.44	1,909.40	2,009.50	2,033.33	2,037.05	2,066.64	2,015.09
Yard Switching	119.36	86.85	86.63	89.86	73.79	69.20	70.79	67.85	64.67	62.20	55.30
Work Train	16.00	5.00	4.00	4.86	5.70	4.90	4.17	6.73	7.49	6.09	7.57
Total Freight Operations	1,957.96	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	2,077.96
Total Passenger Operations	102.70	58.29	60.87	99.20	100.75	99.18	99.93	101.10	101.17	102.30	105.99
Total Rail Operations	2,060.66	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	2,183.95

2.3.1
Freight Operations

Fuel consumption in 2008 for all freight train, yard switching and work train operations was 2,077.96 million litres, a drop of 2.7 per cent from the 2,134.92 million L consumed in 2007 but 6.1 per cent over the 1990 level of 1,957.96 million L. The trend since 1990 in overall freight operations fuel consumption is shown in Figure 8.

Figure 8
Freight Operations Fuel Consumption
Litres (million)

6.1 per cent increase over 1990

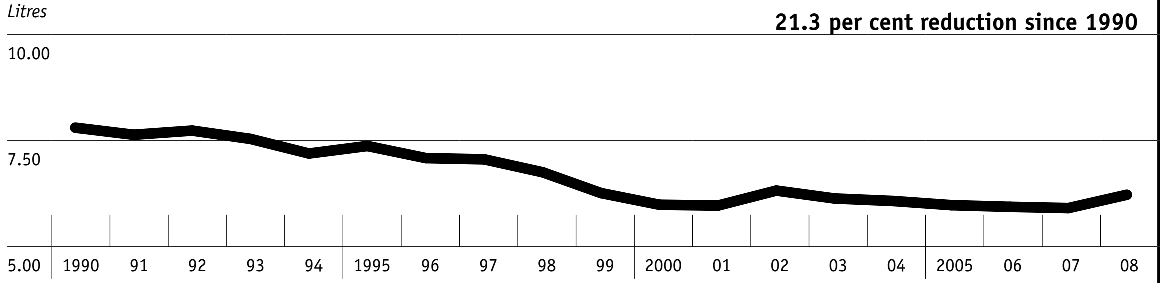


A measure of freight traffic fuel efficiency is the amount of fuel consumed per 1,000 RTK. As shown in Figure 9, this value for freight traffic in 2008 was 6.16 L per 1,000 RTK compared to 5.90 L per 1,000 RTK in 2007. It has decreased from 7.83 L per 1,000 RTK in 1990.

As a percentage, freight traffic fuel consumption per 1,000 RTK in 2008 was 4.3 per cent above the 2007 level. This reversal in trend from previous years was due to the economic downturn that came into effect in 2008. However, the 2008 level was still 21.3 per cent lower than in that of 1990 which shows the ability of the Canadian freight railways to accommodate traffic growth while reducing fuel consumption per unit of work.

Figure 9
Freight Fuel Consumption per 1,000 RTK
Litres

21.3 per cent 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 focused upon and evaluated. Section 7 of this report discusses the fuel consumption reduction initiatives implemented or under examination in 2008.

Table 3 shows the freight operations fuel consumption by service type for 2008 compared to years 2003 through 2007. Of the total diesel fuel consumed in freight operations in 2008, Class I freight trains accounted for 91.6 per cent, Regional and Short Lines 5.4 per cent and Yard Switching and Work Train 3.0 per cent. Of note from Table 2 and Table 3 data, due to operational changes resulting in reduced switching activities, the percentage consumed by Yard Switching and Work Train operations of total freight train operations has been reducing steadily

Table 3

Freight Operations Fuel Consumption

Litres (million)

Freight Train Operations	2003	2004	2005	2006	2007	2008
Class I	1,775.80	1,870.60	1,893.19	1,914.92	1,948.75	1902.88
Regional and Short Line	133.60	138.90	140.14	122.13	117.89	112.20
Sub-total	**1,909.40**	**2,009.50**	**2,033.33**	**2,037.05**	**2,066.64**	**2,015.09**
Yard Switching	69.20	70.79	67.85	64.67	62.20	55.30
Work Train	4.90	4.17	6.73	7.49	6.09	7.57
Sub-total	**74.10**	**74.96**	**74.58**	**72.16**	**68.29**	**62.87**
Total	**1,983.50**	**2,084.46**	**2,107.91**	**2,109.21**	**2,134.92**	**2,077.96**

2.3.2
Passenger Services

Overall rail passenger fuel consumption, that is, the sum of intercity, commuter and tourist and excursion train operations, was 105.99 million L in 2008, up from 102.30 million L in 2007, a rise of 3.6 per cent. The breakdown and comparison with previous years are shown on Table 4.

VIA's fuel consumption in 2008 increased 1.2 per cent over that of 2007. Commuter rail fuel consumption in 2008 increased 8.1 per cent over the 2007 level.

Table 4

Passenger Services Fuel Consumption

Litres (million)

	2003	2004	2005	2006	2007	2008
VIA Rail Canada	60.99	60.37	60.09	58.63*	58.97	59.70
Amtrak		0.65	0.64	0.64	0.64	0.79
Commuter	31.54	33.79	35.31	34.23	35.94	38.85
Tourist Train and Excursion	6.65	5.12	5.06	7.67	6.75	6.65
Total	**99.18**	**99.93**	**101.10**	**101.17**	**102.30**	**105.99**

* *Corrected to 58.75 following an internal VIA audit in 2007 of its 2006 operations.*

3 2008 Locomotive Inventory

The active fleet (as defined in the Glossary of Terms) of diesel locomotives and DMUs in Canada in 2008 totalled 2,823. Locomotives assigned to line-haul freight train operations in 2008 totalled 2,193. Passenger train motive power totalled 206 (197 locomotives and 9 DMUs) and Yard Switching and Work Train locomotives totalled 424. The detailed inventory is shown in Appendix B. Only locomotives powered by diesel engines have been included in the 2008 inventory. Excluded were steam locomotives, non-powered slug units and EMUs as they do not contribute diesel combustion emissions.

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.

As reference, Table 5 shows the U.S. EPA compliance schedule in effect up to 2008 for the reduction of NOx emissions according to the year a locomotive was freshly manufactured. Those now complying with Tier 2 limits will have NOx emissions 59.3 per cent lower than locomotives manufactured prior to 2000. The NOx emissions intensity for the Canadian fleet, therefore, is projected to decrease as the railways continue to introduce new locomotives, plus voluntarily retrofit high-horsepower and medium-horsepower in-service locomotives to U.S. EPA Tier 0 when remanufactured.

Table 5
NOx Emissions Reduction Schedule for Line-haul Locomotives

U.S. EPA Compliance Level	Years in effect	NOx *g/bhp-hr*	Per cent 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 - 2008	5.5	59.3

Photo: Courtesy of CN

The actions taken by the railways in 2008 compared to 2007 and 2006 are displayed in the matrix below:

CAC Commitments Listed Under the MOU	Actions Taken	2006			2007[a]			2008			Total
		Class I Mainline Freight	Intercity Passenger	Commuter Service	Class I Mainline Freight	Intercity Passenger	Commuter Service	Class I Mainline Freight	Intercity Passenger	Commuter Service	
Acquire only new and freshly manufactured locomotives that meet applicable EPA emissions standards.	New EPA Tier 2 Locomotives Acquired	60	0	0	105[b]	0	2	34	0	26	227
Upgrade, upon remanufacturing all high-hp locomotives to EPA emissions standards	High-horsepower Units Upgrades to EPA Tier 0 or Tier 1	19	0	0	6[c]	0	0	0	0	0	25
Upgrade to Tier 0, upon remanufacturing, all medium hp locomotives built after 1972 beginning in 2010	Medium-horsepower United Upgraded to EPA Tier 0	0	0	0	7[d]	0	0	12	0	0	19
Retire from service 130 medium-hp locomotives built between 1973 and 1999	Retire 1973-99 era Medium horsepower Units	21	0	0	50	0	0	34	0	20	125

a *2007 data were revised as per Audit conducted in 2009. Corresponding emissions values were calculated for 2007 and included in the LEM report for 2008.*

b *Audited from 85 to 105.*

c *Audited from 92 to 6 due to findings that revealed units reported in 2007 as being upgraded to EPA Tier 0 were, in fact, already at EPA Tier 0 and recertified to EPA Tier 0 upon remanufacture.*

d *Audited from 10 to 7.*

Of note is that in 2008, 56 high-horsepower locomotives already at Tier 0 were remanufactured with their Tier 0 status being re-certified. As well, 10 were remanufactured retaining their Tier 1 status.

Table 6 shows the progressive number of locomotives meeting Tier 0, Tier 1 or Tier 2 compared to the total number of freight and passenger train locomotives. In 2008, 46.4 per cent of the line-haul freight and passenger locomotives met EPA Tier-level emissions standards.

Table 6

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

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Total number of freight train and passenger train line-haul locomotives[a]	1,991	2,048	2,069	2,129	2,300	2,363	2,425	2,565	2,390
Number of freight train and passenger train locomotives meeting U.S. EPA Tier 0, Tier 1 and Tier 2 emissions limits	80	179	189	634	842	870	956	1,082[b]	1,110

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

b *Audited from 1,065 to 1,082*

As listed in Appendix B, a total of 84 additional Tier-level locomotives were introduced into the Canadian fleet in 2008 by the Class I and Regional freight railways and GO Transit commuter railway. However, as shown in Table 6, the net fleet increase over 2007 was 28. This is because 56 Tier-level locomotives listed in the 2007 LEM fleet roster were removed from service in 2008 for operational and equipment reasons.

A new statistic gathered for this LEM reporting was the number of locomotives equipped with automated anti-idling systems to minimize unnecessary idling. The total for 2008 was 1,104, which is 39.1 per cent of the in-service fleet.

4 Diesel Fuel Properties

The RAC survey showed that in 2008 the weighted average sulphur content of the diesel fuel used by Canadian railways was 147 ppm. This is down from the average of 500 ppm in 2008 and 1,275 ppm in 2006. As noted in Section 5, this resulted in a lower emission factor used to calculate the emitted amount of oxides of sulphur (SOx, but expressed as SO_2).

Influencing railway diesel fuel properties has been the requirement, effective June 1, 2007, to comply with the Environment Canada regulation limiting sulphur content to 500 ppm (or 0.05 per cent). This precedes a further reduction that will come into effect June 1, 2012, limiting sulphur content to 15 ppm (or 0.0015 per cent) – referred to as ultra-low sulphur diesel (ULSD) fuel. The fact that the 2008 average sulphur content was lower than 500 ppm shows that ULSD is already being used extensively. VIA Rail Canada and the commuter railways have, since 2007, standardized on the use of ULSD fuel.

Photo courtesy of VIA Rail

5 Locomotive Emissions

5.1 Emissions Factors

Photo: Courtesy of Rick Robinson/CP

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 has been applied to all reported GHG data since 1990 and stems from recent studies of the carbon content, density and oxidation rates of Canadian liquid fuels.

Similarly, EFs for the Criteria Air Contaminants (CAC), that is, NOx, CO, HC, PM and SOx, emitted from locomotive diesel engines have been calculated in grams per litre (g/L) of fuel consumed. Except for SOx (which is primarily 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 OEMs. 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 the commissioning by Transport Canada of 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 and 2008, 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[10,11]. 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 NOx emitted from all freight train locomotives. For 2008, it was re-calculated to 43.96 g/L versus 44.28 g/L for 2007. The progressive lowering of the NOx 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, when overhauled or remanufactured, of in-service locomotives.

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, Division of CAD Railway Industries, Lachine, Quebec – April 2008*

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*

11 AAR Locomotive Emissions Testing 2008*, Report LA-09 prepared by Brian Smith, Transportation Technology Center, Inc., a subsidiary of the Association of American Railroads, Pueblo, Colorado – January 2009*

Table 7 also shows that the EF used to calculate CO emitted in 2008 from freight train locomotives was re-calculated downwards to 4.73 g/L versus 5.35 g/L for 2007. This stems from the receipt of additional emissions test results during 2008 that permitted an updated curve-fitting of the data spread. Similarly, when updated 2008 emissions test data were added to the database spread for locomotive types used in switching and passenger operations, the EFs for CO were adjusted accordingly. As these data were deemed to be more representative and accurate, they were used for the 2008 calculations, which also contributed to the significant variance in NOx 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 2008. Table 7 shows a somewhat erratic annual variability in HC and PM EFs which is deemed due to changes in the fleet mix of locomotives, the availability of evermore emissions data each year, the updating of duty cycles including adding in 2008 duty cycles for intercity passenger and regional freight and tightening of measurement procedures. Since 2007, the passenger train EFs have been based on a consolidation of data from both intercity and commuter services. Prior to 2007, data to calculate EFs were only available for commuter train locomotives.

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

Table 7

Railway Operations CAC Emissions Factors Evolution

grams / litre

	NOx	CO	HC[a]	PM[a]	SOx[b]
Freight Train (Consolidation of Class I and Regional and Short Lines Data)					
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[c]	44.28	5.35	1.68	1.60	0.85
2008	43.96	4.73	1.72	1.45	0.25
Passenger Train (Prior to 2007, Data for Commuter Train Services only)					
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
Consolidated 2008	58.46	3.82	0.94	0.76	0.25
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
2008	77.89	4.67	4.56	2.34	0.25

a Annual erratic variability deemed due to changing fleet mix, updating of EFs and tightening of measurement procedures

b SOx EF for 2008 calculated based on a diesel fuel sulphur content of 147 ppm and for 2007 a content of 500 ppm

c Emissions Factors revised to reflect Audited Tier-level locomotive numbers in 2007 fleet

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 as of when updated for the various freight services, that is, Class I mainline, road switching, yard switching, regional lines and short lines, plus intercity and commuter rail passenger services. Duty cycle updates of regional mainline freight and commuter services were done in 2008 while the most recent updates of other services were undertaken in 2007. 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 anti-idling 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 and Year of Update

Per cent of Engine Operating Time

	Idle	N1	N2	N3	N4	N5	N6	N7	N8	DB
2007 - 2008 Updates										
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 Switch	77.6	4.3	4.4	2.8	2.2	1.4	1.1	0.6	3.2	2.4
2008 Regional Mainline Freight	67.4	8.3	4.9	4.1	3.5	2.0	2.0	1.6	6.2	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
2008 Commuter (Note 1)	61.4		2.3	2.2	2.1	1.3	1.2	1.8	24.0	3.7
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

Note 1: 2008 Commuter – Idle and N1 are the same power notch position

5.3
Emissions Generated

5.3.1
Greenhouse Gases (GHG)

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 2008, GHG emissions produced by the railway sector as a whole (expressed as $CO_{2\ equivalent}$) were 6,564.44 kt, as compared to 6,727.68 kt in 2007 and 6,196.70 kt in 1990. This is a rise of 5.9 per cent since 1990, with a corresponding rise of 38.5 per cent in RTK traffic.

It was reported in the *National Inventory Report 1990 – 2006* submitted by Environment Canada in 2008 to the UNFCCC that an adjustment was made to the emission factor for $CO_{2\ equivalent}$, lowering it from 3.07415 kg/L to 3.00715 kg/L[12]. For consistency in comparison purposes, the GHG values displayed for all years from 1990 in Table 9 and Figure 10 have been adjusted to the lower value. Also reported was that the transportation sector produces almost 27.0 per cent of all Canadian GHG emissions and railway operations account for 3.0 per cent of the transportation contribution.

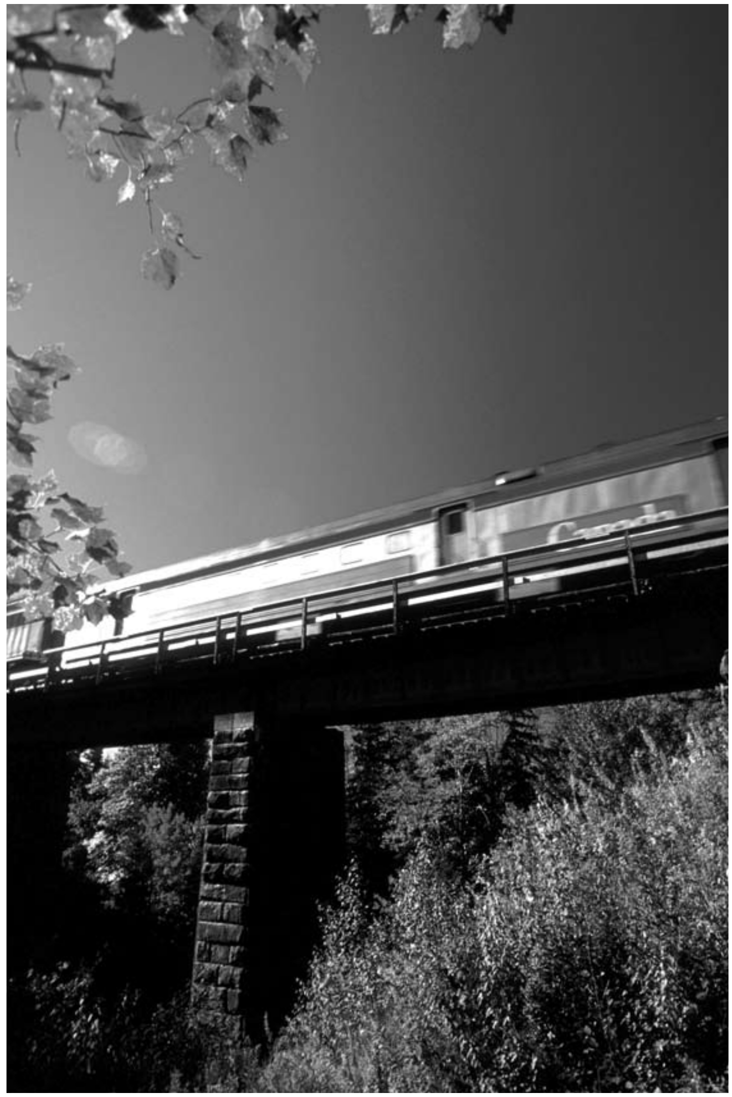


Photo courtesy of VIA Rail

12 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 www.ec.gc.ca/pdb/ghg/inventory_e.cfm*

Table 9

Locomotive GHG Emissions

in kilotonnes

Operations	1990	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Total Railway												
$CO_{2\ equivalent}$	6,196.70	6,210.72	5,863.52	5,977.82	6,065.81	6,162.58	6,260.86	6,568.79	6,642.83	6,646.95	6,727.68	6,564.44
CO_2	5,487.53	5,499.95	5,192.48	5,293.70	5,371.62	5,456.83	5,544.35	5,817.03	5,882.60	5,886.24	5,957.73	5,815.83
CH_4	6.48	6.50	6.14	6.26	6.35	6.46	6.55	6.88	6.95	6.97	7.05	6.88
N_2O	702.69	704.27	664.90	677.86	687.84	699.29	709.96	744.88	753.28	753.74	762.90	744.72
Passenger – Intercity, Commuter, Tourist / Excursion												
$CO_{2\ equivalent}$	308.83	175.94	175.29	183.05	298.31	298.85	297.62	300.50	304.03	304.24	307.62	318.73
CO_2	273.49	155.81	155.23	162.10	264.17	264.17	263.56	266.11	269.23	269.42	272.42	282.25
CH_4	0.32	0.18	0.18	0.19	0.31	0.32	0.31	0.31	0.32	0.32	0.32	0.33
N_2O	35.02	19.95	19.88	20.76	33.83	34.36	33.75	34.08	34.48	34.50	34.88	36.14
Freight Train – Line Haul												
$CO_{2\ equivalent}$	5,480.83	5,657.84	5,412.02	5,522.23	5,482.66	5,624.69	5,740.47	6,042.87	6,114.53	6,125.71	6,214.70	6,056.65
CO_2	4,853.58	5,010.33	4,792.65	4,890.25	4,855.21	4,980.98	5,083.51	5,351.30	5,414.76	5,424.66	5,503.46	5,366.16
CH_4	5.74	5.93	5.67	5.78	5.74	5.89	6.01	6.33	6.40	6.42	6.51	6.35
N_2O	621.51	641.58	613.70	626.20	621.71	637.82	650.95	685.24	693.37	694.63	704.73	687.14
Yard Switching and Work Train												
$CO_{2\ equivalent}$	407.04	376.94	276.21	272.54	284.84	239.04	222.77	225.42	224.27	217.00	205.36	189.06
CO_2	360.46	333.81	244.60	241.35	252.24	211.68	197.28	199.62	198.61	192.16	181.85	167.42
CH_4	0.42	0.39	0.29	0.29	0.30	0.25	0.23	0.24	0.23	0.23	0.22	0.20
N_2O	46.16	42.74	31.32	30.90	32.30	27.11	25.26	25.56	25.43	24.61	23.29	21.44
Total – Freight Operations												
$CO_{2\ equivalent}$	5,887.87	6,034.78	5,688.23	5,794.77	5,767.50	5,863.73	5,963.24	6,268.29	6,338.80	6,342.71	6,420.06	6,245.71
CO_2	5,214.04	5,344.14	5,037.25	5,131.60	5,107.45	5,192.66	5,280.79	5,550.92	5,613.37	5,616.82	5,685.31	5,533.58
CH_4	6.16	6.32	5.96	6.07	6.04	6.14	6.24	6.57	6.63	6.65	6.73	6.55
N_2O	667.67	684.32	645.02	657.10	654.01	664.93	676.21	710.80	718.80	719.24	728.02	708.58
Emissions Intensity – Total Freight (kg / 1,000 RTK)												
$CO_{2\ equivalent}$	23.54	20.32	18.84	17.98	17.92	18.99	18.43	18.26	18.37	17.83	17.75	18.05
CO_2	20.85	18.00	16.68	15.92	15.87	16.82	16.32	16.17	15.91	15.79	15.72	15.98
CH_4	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
N_2O	2.67	2.30	2.14	2.04	2.03	2.15	2.09	2.07	2.04	2.02	2.01	2.05
Emissions Intensity – Class I Freight Line Haul (kg / 1,000 RTK)												
$CO_{2\ equivalent}$							18.16	17.62	17.73	17.79	17.32	17.61
Emissions Intensity – Regional and Short Line Freight Train (kg / 1,000 RTK)												
$CO_{2\ equivalent}$							17.81	18.58	17.46	14.77	15.22	15.80

Figure 10

Total Railway GHG Emissions

kilotonnes of $CO_{2\ equivalent}$

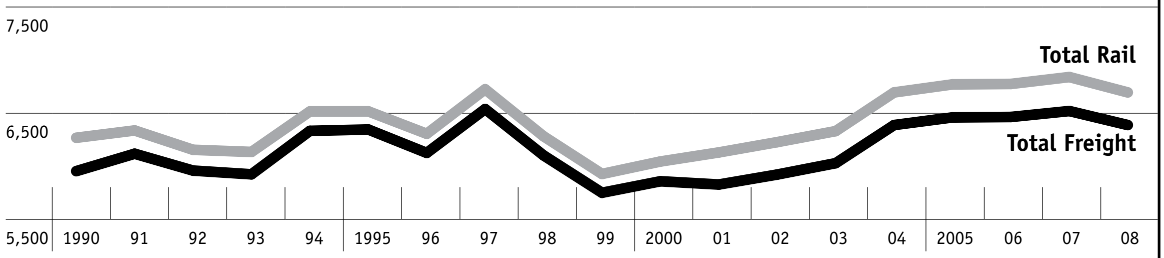
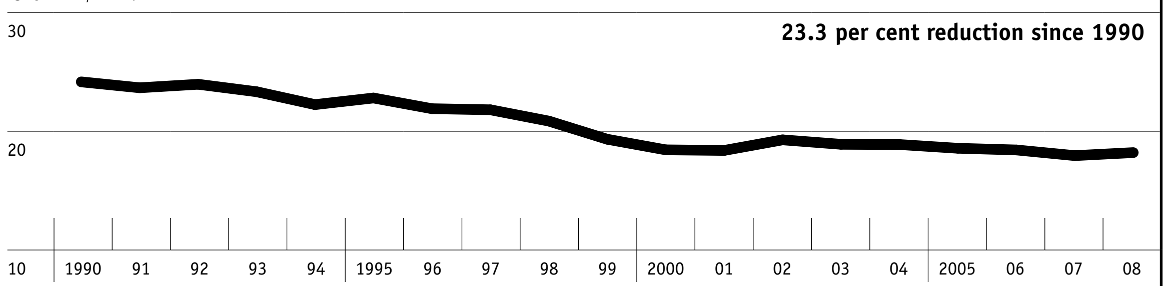


Figure 11 shows the GHG emissions intensities trend line for freight traffic which increased in 2008 to 18.05 kg per 1,000 RTK from 17.75 in 2007 but decreased from 23.88 in 1990. The yearly values are listed in Table 9. As a percentage, the 2008 GHG emissions intensity for total freight was 1.7 per cent above 2007 and 23.3 per cent below 1990 levels.

Figure 11

Total Freight GHG Emissions Intensity

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



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 line-haul operation. Vis-à-vis the 2010 target, Table 10 shows the emissions intensity levels for the years 2003 to 2008 for, respectively, Class I freight, Regional and Short Lines, Intercity Passenger and Commuter Rail. Except for intercity passenger operations, the emissions reduction trend rose in 2008 vis-à-vis the 2010 target.

Table 10

GHG Emissions Intensities by Category of Operation

Railway Operation	Units	2003	2004	2005	2006	2007	2008	2010 Target
Class I Freight	kg / 1,000 RTK	18.16	17.62	17.73	17.79	17.32	17.61	16.98
Regional and Short Lines	kg / 1,000 RTK	17.81	18.59	17.46	15.10	15.21	15.80	15.38
Intercity Passenger	kg / passenger-km	0.14	0.14	0.13	0.13	0.13	0.12	0.12
Commuter Passenger	kg / passenger	1.82	1.89	1.87	1.74	1.71	1.74	1.46

The increase in GHG emissions intensities by the freight railways can be attributed to the 4.2 per cent decrease in 2008 RTK traffic over the 2007 level. In the fourth quarter of 2008, the Canadian economy contracted at an annualized rate of 3.7 per cent, which had a direct negative impact on freight railway traffic. During that quarter, RTK traffic declined 20 per cent on a year-over-year basis.

At the time that GHG emissions intensity targets in the MOU were negotiated, the assumption was that RTK traffic would grow by 3.0 per cent during the course of the MOU. When freight railways experience growth in traffic and use scheduled railway operations, they have the ability to run longer and heavier trains, thus improving GHG emissions intensity levels. However, when RTK traffic declines, railways operate shorter and lighter trains, thus resulting in higher GHG intensity levels. This situation became particularly acute in the fourth quarter in 2008. Unfortunately the impact on emissions intensity levels of the decrease in RTK traffic could not be offset by the number of efficiency improvements being undertaken by the freight railways, as outlined in Section 7 of the report.

The increase in Commuter Rail GHG intensity levels can be accredited to the introduction of additional scheduling and the operation of longer trains in 2008. New higher horsepower locomotives were employed to move longer train sets. This combination of events negatively impacted the GHG intensity level. Generally, when additional service routes are introduced it takes a period of time to increase ridership to fill new capacity. As new capacity is utilized, it is expected that GHG intensity levels will decrease. Another influence was a suspension by GO Transit during 2008, due to new locomotive warranty reasons, of the use of the proprietary FPC fuel extender additive.

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 horizontal gray line.

Figure 12

Class I Freight GHG Emissions Intensity

kg per 1,000 RTK

Figure 13

Regional and Short Lines GHG Emissions Intensity

kg per 1,000 RTK

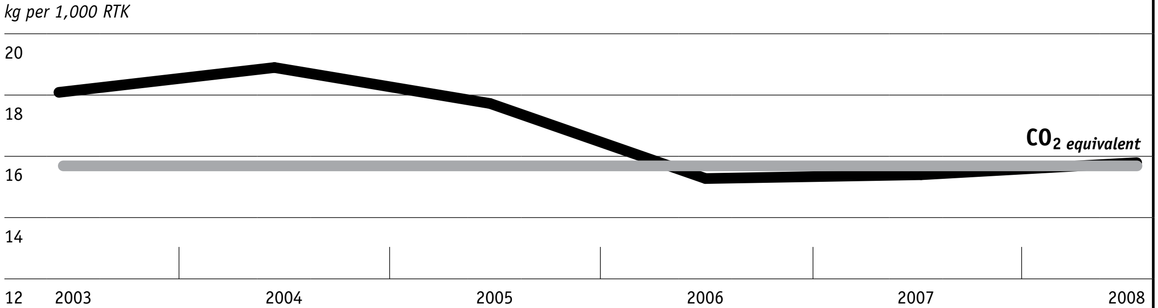


Figure 14

Intercity Passenger GHG Emissions Intensity

kg per passenger-km

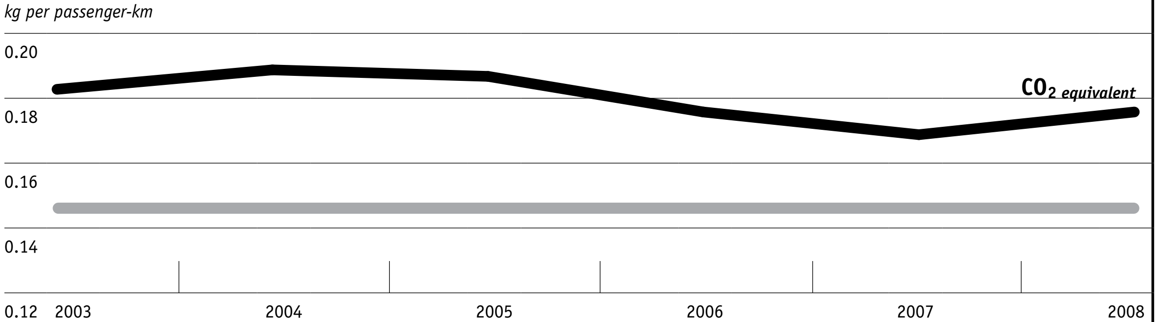
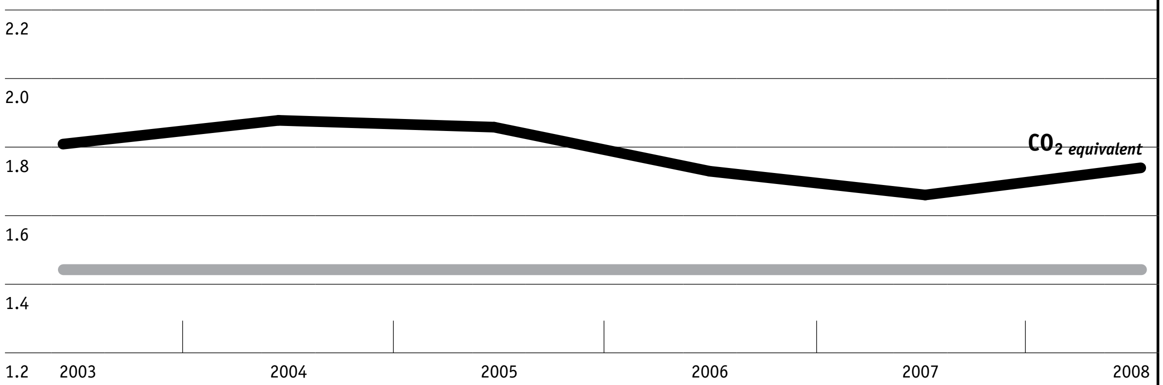


Figure 15

Commuter Rail GHG Emissions Intensity

kg per passenger



5.3.2

Criteria Air Contaminants (CAC)

Table 11 displays the CAC emissions produced annually by locomotives in operation in Canada, namely NOx, CO, HC, PM and SOx. 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 (NOx). As shown in Table 11, railway-generated NOx emissions in 2008 totalled 99.68 kt, as compared to 103.18 kt in 2007 and 113.59 kt for 1990, the baseline year. Total rail NOx emissions in 2008 were 3.4 per cent lower than in 2007 and 12.2 per cent lower than in 1990. Since 1990, NOx emissions have averaged 112.98 kt per year. Freight operations accounted for 93.8 per cent of railway-generated NOx emissions in Canada.

The NOx emissions intensity, i.e., the quantity of NOx emitted per unit of productivity, was 0.27 kg per 1,000 RTK in 2008 – which was the same as in 2007. This is down from 0.43 kg per 1,000 RTK in 1990. Figure 16 is indicative of the historical trend in NOx emissions per 1,000 RTK for freight operations since 1990. The significant 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

37.2 per cent reduction since 1990

Total Freight NOx Emissions Intensity

kg of NOx per 1,000 RTK

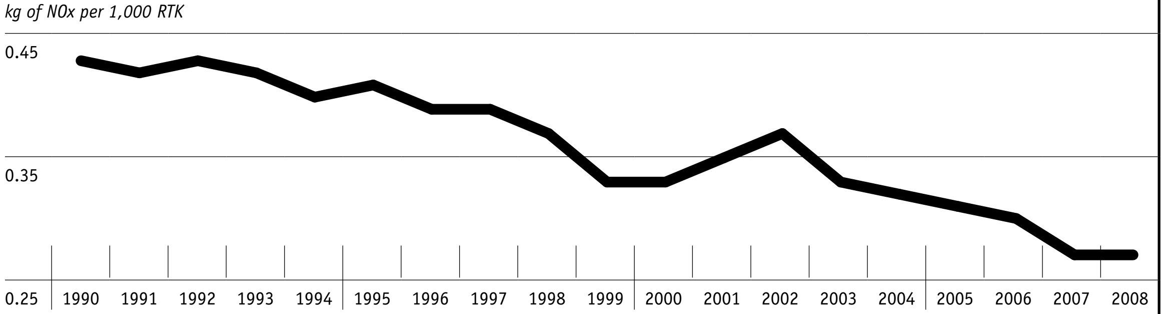


Table 11

Locomotive CAC Emissions

in kilotonnes

Operations	1990	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Total Railway											
NOx	113.59	103.21	109.30	118.36	120.21	111.32	117.05	114.86	112.22	103.18	99.68
CO	21.64	20.48	20.87	21.17	20.46	22.66	16.28	16.47	15.78	11.76	10.23
HC	5.75	5.41	5.52	5.59	5.66	5.14	6.59	6.67	4.42	3.88	3.85
PM	2.70	2.56	2.60	2.64	2.68	2.55	4.80	3.99	2.77	3.54	3.14
SOx	5.22	4.95	5.04	5.11	5.19	4.93	4.23	5.09	4.80	1.91	0.55
Total Passenger											
NOx	5.63	3.17	3.34	5.41	5.47	5.31	6.10	6.88	6.63	6.33	6.20
CO	1.08	0.61	0.64	1.04	1.05	1.04	0.92	0.93	0.52	0.40	0.40
HC	0.28	0.16	0.17	0.27	0.27	0.27	0.23	0.24	0.20	0.09	0.10
PM	0.13	0.08	0.08	0.13	0.13	0.13	0.14	0.14	0.13	0.08	0.08
SOx	0.26	0.15	0.15	0.25	0.25	0.23	0.23	0.23	0.22	0.09	0.03
Freight Train Line-haul											
NOx	99.68	94.43	100.43	107.21	109.86	101.50	105.57	102.64	100.89	91.52	88.58
CO	19.15	18.91	19.29	19.15	19.63	20.85	14.40	14.59	14.87	11.05	9.54
HC	4.98	4.92	5.02	4.98	5.10	4.60	6.05	6.12	3.99	3.48	3.46
PM	2.37	2.34	2.39	2.37	2.43	2.31	4.53	3.73	2.53	3.30	2.91
SOx	4.62	4.57	4.66	4.62	4.74	4.52	3.83	4.71	4.42	1.76	0.50
Yard Switching and Work Train											
NOx	8.27	5.60	5.53	5.74	4.88	4.51	5.38	5.34	4.70	5.33	4.90
CO	1.41	0.96	0.94	0.98	0.83	0.77	0.96	0.95	0.39	0.31	0.29
HC	0.49	0.33	0.33	0.34	0.29	0.27	0.31	0.31	0.23	0.31	0.29
PM	0.20	0.14	0.13	0.14	0.12	0.11	0.13	0.13	0.11	0.16	0.15
SOx	0.34	0.23	0.23	0.24	0.20	0.18	0.17	0.17	0.16	0.06	0.02
Total – Freight Operations											
NOx	107.95	100.03	105.96	112.95	114.74	106.01	110.95	107.98	105.59	96.85	93.48
CO	20.56	19.87	20.23	20.13	20.46	21.62	15.36	15.54	15.26	11.36	9.83
HC	5.47	5.25	5.35	5.32	5.39	4.89	6.36	6.43	4.22	3.79	3.75
PM	2.57	2.48	2.52	2.51	2.55	2.42	4.66	3.86	2.64	3.46	3.06
SOx	4.96	4.80	4.89	4.86	4.94	4.70	4.00	4.88	4.58	1.82	0.52
Total Freight Emissions Intensity *kg / 1,000 RTK*											
NOx	0.43	0.33	0.33	0.35	0.37	0.33	0.32	0.31	0.30	0.27	0.27
CO	0.08	0.07	0.06	0.06	0.07	0.07	0.05	0.04	0.04	0.03	0.03
HC	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	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
SOx	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00

Note: 2007 CAC masses revised to reflect Audited Tier-level locomotive numbers in fleet

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 NOx emissions in the TOMAs as a percentage of the total NOx emissions for all rail operations. This illustrates the relative concentration of railway operations in the TOMA.

Table 12
TOMA Percentages of Total Fuel Consumption and GHG Emissions

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Lower Fraser Valley, B.C.	4.2	4.0	3.8	3.4	3.4	3.4	3.2	2.8	3.0	2.8
Windsor-Quebec City Corridor	17.1	17.4	15.6	17.1	19.4	19.1	17.4	16.8	17.4	17.1
Saint John, N.B.	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Table 13
TOMA Percentages of Total NOx Emissions

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Lower Fraser Valley, B.C.	4.4	3.9	3.9	3.4	3.4	3.4	3.2	2.8	2.9	2.8
Windsor-Quebec City Corridor	17.8	16.8	15.8	17.2	19.7	18.7	17.9	17.4	16.6	16.8
Saint John, N.B.	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2

6.2
Seasonal Data

The emissions during 2008 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 were available. The emissions in the seasonal periods were then calculated as per Section 6.1. The results are shown in Tables 14 to 16.

Table 14

TOMA No. 1 – Lower Fraser Valley, B.C.
Traffic, Fuel and Emissions Data, 2008

	TOMA Region No. 1 LOWER FRASER VALLEY, B.C. SEASONAL SPLIT		
	Year	**Winter**	**Summer**
	Total	**58%**	**42%**
TRAFFIC		*(million GTK)*	
CN	7,101	4,119	2,982
CP	9,455	5,484	3,971
Burlington Northern Santa Fe	653	379	274
Southern Railway of BC	317	184	133
Total Freight Traffic	**17,526**	**10,166**	**7,360**
FUEL CONSUMPTION		*(million litres)*	
Freight Operations			
Freight Fuel Rate: 3.25 litres/1,000 GTK			
Total Freight Fuel Consumption	**56.96**	**33.04**	**23.92**
Passenger Operations			
VIA Rail Canada	0.43	0.25	0.18
Great Canadian Railtour Company	2.57	1.49	1.08
West Coast Express	1.17	0.68	0.49
Total Passenger Fuel Consumption	**4.17**	**2.42**	**1.75**
Total Rail Fuel Consumption	**61.13**	**35.46**	**25.67**
EMISSIONS		*(kilotonnes)*	
Emissions Factors: NOx 44.98 g/L	2.75	1.60	1.15
CO 4.67 g/L	0.29	0.17	0.12
HC 1.67 g/L	0.10	0.06	0.04
PM 1.40 g/L	0.09	0.05	0.04
SOx 0.25 g/L	0.02	0.01	0.01
CO_2 2663 g/L	162.78	94.41	68.37
CH_4 3.15 g/L	0.19	0.11	0.08
N_2O 341 g/L	20.84	12.09	8.75
$CO_{2\ equivalent}$ 3007.15 g/L	183.82	106.62	77.20

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

Table 15

TOMA No. 2 – Windsor – Quebec City Corridor
Traffic, Fuel and Emissions Data, 2008

	TOMA Region No. 2 WINDSOR–QUEBEC CITY CORRIDOR SEASONAL SPLIT		
	Year	**Winter**	**Summer**
	Total	**58%**	**42%**
TRAFFIC		*(million GTK)*	
Freight Operations			
CN	54,286	31,486	22,800
CP	34,568	20,049	14,519
CSX	272	158	114
Essex Terminal Railway	40	23	17
Goderich – Exeter Railway	297	172	125
Montreal, Maine & Atlantic	690	400	290
Norfolk Southern	1	1	0
Ottawa Central	167	97	70
Ottawa Valley – RaiLink (Note 1)	-	-	-
Quebec Gatineau	1,443	837	606
St. Lawrence & Atlantic	431	250	181
Total Freight Traffic	**92,195**	**53,473**	**38,722**
FUEL CONSUMPTION		*(million litres)*	
Freight Operations			
Freight Fuel Rate: 3.25 litres/1,000 GTK			
Total Freight Fuel Consumption (million litres)	299.64	173.79	125.85
Passenger Operations			
VIA Rail Canada	35.88	20.81	15.07
Commuter Rail	37.21	21.58	15.63
Total Passenger Fuel Consumption	**73.09**	**42.39**	**30.70**
Total Rail Fuel Consumption (million litres)	**372.73**	**216.18**	**156.55**
EMISSIONS		*(kilotonnes)*	
Emissions Factors (Note 2): NOx 44.98 g/L	16.77	9.73	7.04
CO 4.67 g/L	1.74	1.01	0.73
HC 1.67 g/L	0.62	0.36	0.26
PM 1.40 g/L	0.52	0.30	0.22
SOx 0.25 g/L	0.32	0.19	0.13
CO_2 2663 g/L	992.59	575.70	416.89
CH_4 3.15 g/L	1.17	0.68	0.49
N_2O 341 g/L	127.10	73.72	53.38
$CO_{2\ equivalent}$ 3007.15 g/L	1,120.86	650.10	470.76

Note 1: Ottawa Valley – RaiLink data is included in CP data
Note: 2: EFs adjusted for mix of Freight and Passenger traffic.

Table 16

TOMA No. 3 – Saint John Area, New Brunswick
Traffic, Fuel and Emissions Data, 2008

	TOMA Region No. 3 SAINT JOHN, NB SEASONAL SPLIT		
	Year	**Winter**	**Summer**
	Total	**58%**	**42%**
TRAFFIC		*GTK million*	
Freight Operations			
CN	753	437	316
New Brunswick Southern Railway	542	314	228
Total Freight Traffic	**1,295**	**751**	**544**
FUEL CONSUMPTION		*(million litres)*	
Freight Operations			
Freight Fuel Rate: 3.25 litres/1,000 GTK			
Total Freight Fuel Consumption	**4.25**	**2.47**	**1.78**
Passenger Operations	0	0	0
Total Rail Fuel Consumption	**4.25**	**2.47**	**1.78**
EMISSIONS		*(kilotonnes)*	
Emissions Factors: NOx 44.98 g/L	0.19	0.11	0.08
CO 4.67 g/L	0.02	0.01	0.01
HC 1.67 g/L	0.01	0.01	0.00
PM 1.40 g/L	0.01	0.01	0.00
SOx 0.25 g/L	0.00	0.00	0.00
CO_2 2663 g/L	11.32	6.57	4.75
CH_4 3.15 g/L	0.01	0.01	0.00
N_2O 341 g/L	1.45	0.84	0.61
$CO_{2\ equivalent}$ 3007.15 g/L	12.78	7.41	5.37

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

7 Emissions Reductions Initiatives

The railways undertook various initiatives and deployed new technology in 2008 aimed at reducing locomotive diesel engine exhaust emissions, both overall and in terms of intensity per unit of work performed. Reductions 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 improvements that increase operational fluidity resulting in reduced fuel consumption and, hence, emissions. Section 7.1 describes the awareness generation actions of the RAC, while subsequent sections list the initiatives being pursued, or explored, by the railways or equipment supply companies regarding new technology, operating procedures, infrastructure enhancements and governmental funding support for actions to reduce fuel consumption and emissions.

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 Rail and Tourist and Excursion 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 2008, recipients of the RAC Environmental Awards were CPR and VIA Rail Canada.

In 2008, the RAC-developed on-line Rail Freight Greenhouse Gas (GHG) Calculator, a web-based user-friendly tool for calculating the GHG emissions associated with specific shipments was in active use[13]. 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. As new data become available, the RAC updates the "input" factors employed to ensure it always reflects the particulars of the current transportation situation. The Calculator can be accessed at www.railcan.ca/site_ghg_calculator.

7.2
Equipment-related Initiatives

7.2.1
Locomotive Fleet Renewal

Canadian freight and commuter railways are progressively renewing their fleets by acquiring new locomotives that are compliant with U.S. EPA emissions standards, the current on being the Tier 2 standard that came into force in 2005. As of the end of 2008, 263 locomotives in the Canadian fleet meet this standard. Of the total, 236 are assigned to freight line-haul operations while 27 are in Commuter Rail services. Their diesel engines emit 62% less NOx 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.

Being examined for new yard and road switching locomotives are GenSet locomotives in which instead of a large medium-speed diesel engine the motive power is two or three smaller industrial Tier 3 diesel engines packaged as individual generator sets (hence the name 'GenSets'). As each set turns itself on and off electronically as needed, the result is in lower fuel consumption and emissions. Compared to a conventional Tier 0 switcher locomotive, the

13 RAC Launches New Environmental Tool for Shippers, *Press Release issued by the Railway Association of Canada, Ottawa, May 6, 2008*

GenSets have demonstrated a three-fold reduction in HC, CO and PM and less than half the NOx emissions. In 2008, CP commenced in-service evaluation of two GenSet switchers produced by National Railway Equipment with support from the Transport Canada ecoFREIGHT program[14].

7.2.2
Tier 2 Engine Retrofits

The railways are also exploring options of retrofitting existing locomotive bodies with new Tier-compliant diesel engines. In this regard, CP is examining replacing a road switcher's existing EMD 16-cylinder 16V-567 or 16V-645 series engine with a new Tier 2 compliant 2,000 hp turbocharged 8-cylinder 8V-710 series engine having electronic fuel injection[15]. Fuel consumption reductions up to 25 per cent are claimed. The locomotive control system has been upgraded with a microprocessor-based unit that not only controls wheel slippage to maximize tractive effort but also operates all engine diagnostics and its flexible software program allows the engine to be fine-tuned for future emissions compliance.

7.2.3
Fleet Upgrading and Maintenance

Upon remanufacture, the Class I freight railways are upgrading to EPA Tier 0 limits in-service high-horsepower locomotives manufactured prior to 2000, a commitment under the MOU. Also, selected medium-horsepower locomotives have been upgraded to Tier 0. 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 NOx, and PM, will continue to be reduced.

7.2.4
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 per cent 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. All new Tier 2 locomotives are equipped with the low idle function as a standard feature.

7.2.5
Engine Anti-Idling 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 to idle for a time to prevent radiator coolant freezing and to charge the batteries. These include auxiliary power units as well as the automatic engine stop/start (AESS) systems that new locomotives come equipped with. The latter extends the time during the warmer seasons when the locomotive engine can be shut down. Monitoring of line-haul locomotives equipped with a properly operating AESS system has shown annual average savings per locomotive of 30,000 L[16]. Analyses of fleet operations indicate that the capital and installation costs of an auxiliary power unit to maintain critical systems for a shut-down locomotive can be recouped within 2.2 years[17].

14 ecoFreight Delivers ecoFriendly Locomotives*, Press Release issued by Canadian Pacific Railway, Calgary, Alberta, May 6, 2008*

15 New Electro-Motive 710 ECO TM Repower Locomotive Enters Service*, Press Release issued by Electro-Motive Diesel Inc., LaGrange, Illinois, June 4, 2008*

16 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*

17 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*

7.2.6
Low and Ultra-Low Sulphur Diesel Fuel

Sulphur in diesel fuel influences emissions both directly in the amount of SOx produced and indirectly by enabling exhaust emissions reduction technologies such as diesel particulate filters and oxidation catalysts to function and not become contaminated[18].

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 per cent), 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 per cent) will be the only diesel fuel marketed in Canada available to the railways. In view of the environmental benefits of ULSF, VIA Rail Canada and the commuter passenger railways standardized on its use.

7.2.7
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) 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 per cent reduced the aerodynamic resistance coefficient sufficient to save up to 2.4 L/km of fuel[19].

7.2.8
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 E-mailed alerts[20].

7.2.9
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.

18 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*

19 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*

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

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 to make them more fuel efficient, 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 AESS systems. The use of 15 ppm ultra-low sulphur fuel (ULSF) has been standardized for VIA's operations. Not only does ULSF reduce SOx emissions but also sulphur-based PM formed during diesel combustion.

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
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.

7.2.12
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.

All commuter railways have standardized on ultra-low sulphur diesel fuel. West Coast Express is working with Environment Canada to test and evaluate on two of its locomotives diesel exhaust oxidation catalyst after-treatment devices, for which use of ultra-low sulphur diesel fuel is necessary for their functioning.

7.2.13
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. The advantages were confirmed in tests at Engine Systems Development Centre of CAD Railway Industries in Lachine, Quebec, which showed a 2.5 to 7.0 per cent reduction (depending on notch and load) with concomitant reductions in CO and smoke emissions of 2.8 to 5.8 per cent, but a slight increase in NOx emissions[21].

7.2.14
Alternate Fuels

Interest in alternatives to diesel No.2 fuel stems from general concern about GHG emissions and the long-term availability of petroleum-based diesel No.2 fuel. A candidate alternate fuel is biodiesel produced from agricultural feedstock whose life-cycle CO_2 is significantly lower than standard diesel fuel emissions. The Southern Railway of British Columbia initiated in 2008 an operational evaluation of biodiesel to fuel its locomotives.

21 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*

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 impact significantly 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 AESS or APU 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[22]. 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 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.

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

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. Testing of laser glazing by the Transportation Test Center Inc. on its Facility for Accelerated Service Testing at Pueblo, Colorado using an 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 per cent on curved track and 3 per cent on tangent track[23].

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 per cent over its length exhibited fuel consumption savings (and hence emissions reductions), respectively, 2.3, 2.5 and 10.5 per cent[24].

23 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*

24 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 on directional running in the Fraser Canyon region of B.C. Directional running 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[25].

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. The programs' details can be viewed on: www.tc.gc.ca/programs/environment/ecofreight/about/programincentive.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. 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[26]. 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 per cent at power notches N1 to N4 and, over the line-haul and switch cycles respectively, PM reductions of 52 and 50 per cent, CO reductions of 82 and 81 per cent and HC reductions of 38 and 34 per cent, but with some increase in NOx and smoke emissions[27]. 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 per cent and in HC of 30 per cent[28]. 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. 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[29]. The battery pack also permits the recoupment and storage of braking energy.

Being accepted into operational service in 2008 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

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

26 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*

27 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*

28 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*

29 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*

Photo courtesy of GO Transit

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[30].

A proof-of-concept hydrogen-fueled fuel cell-battery hybrid switcher locomotive has been 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 is the most powerful fuel cell land vehicle yet built. It is under test verification at the Transportation Technology Centre Inc., Pueblo, Colorado. The objective is to ultimately realize technology for a locomotive not requiring fossil fuel and, hence, obviating GHG and CAC emissions[31].

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[32]. Target fuel consumption reduction is 20 per cent (with a concomitant 10 per cent CAC reduction) of which 15 per cent is contributed from regenerating captured braking energy, 1 to 3 per cent from the trip optimizer and 2 to 4 per cent 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[33].

Regarding non-locomotive equipment, initial operations of Electronically Controlled Pneumatic (ECP) brake systems are being evaluated in single-product unit train consists such as those operated by the Quebec North Shore 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, the RAC participated in the 2008 Rail Conference *'On Board for a Cleaner Environment'* May 6-7 in Toronto convened by Transport Canada's ecoFREIGHT program. The presentations can be viewed on www.ecoaction.gc.ca/ecofreight .

30 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*

31 Testing of the BNSF Fuelcell Switch Locomotive*, report by Arnold Miller et al, Vehicle Projects LLC, published in Proceedings of the 71st Annual Meeting of the Locomotive Maintenance Officers Association (LMOA), Chicago, Illinois – September 16-18, 2009*

32 21st Century Locomotive Technology (locomotive system tasks)*, presentation by GE Global Research to the DOE Heavy Vehicle Systems Optimization peer review – April 2006*

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

8 Summary and Conclusions

The economic downturn in 2008 impacted on the Canadian railways' ability to maintain a steady improvement in operational efficiency as measured by fuel consumption and to meet the emissions intensity targets of the MOU. At the time that GHG emissions intensity targets in the MOU were negotiated, the assumption was that RTK traffic would grow by 3.0 per cent during the course of the MOU. When freight railways experience growth in traffic and use scheduled railway operations, they have the ability to run longer and heavier trains, thus improving GHG emissions intensity levels. However with the downturn in traffic in 2008, the railways scheduled shorter and lighter trains resulting in higher GHG intensity levels. RTK traffic in 2008 decreased 4.2 per cent from the 2007 level. The downturn in RKT traffic became particularly acute in the fourth quarter of 2008 when the Canadian economy contracted at an annualized rate of 3.7 per cent. The direct negative impact on freight railway traffic was a decline of 20 per cent on a year-over-year basis. Unfortunately the impact on emissions intensity levels of the decrease in RTK traffic could not be offset by the number of efficiency improvements being undertaken by the freight railways.

In meeting the objectives of the MOU, the particulars experienced by the 54 RAC member railways as of end of 2008 were:

a. Relative to the targets specified in the MOU for 2010, the emissions intensity levels of GHG (as $CO_{2\ \mathit{equivalent}}$) by category of operation for 2008 compared to previous years were:

Railway Operation	Units	2006	2007	2008	MOU 2010 target
Class I Freight	kg / 1,000 RTK	17.79	17.32	17.61	16.98
Regional and Short Lines	kg / 1,000 RTK	15.10	15.21	15.80	15.38
Intercity Passenger	kg / passenger-km	0.13	0.13	0.12	0.12
Commuter Rail	kg / passenger	1.74	1.71	1.74	1.46

b. GHG emissions from all railway operations in Canada totalled 6564.44 kt, down 2.4 per cent from 6,727.65 kt in 2007 reflecting a reduction in fuel consumption due to a 4.2 per cent drop in freight RTK traffic. For all freight operations, the GHG emissions intensity (in kg of $CO_{2\ \mathit{equivalent}}$ per 1,000 RTK) increased from 17.75 in 2007 to 18.05 in 2008. However, compared to 23.88 in 1990, it is a 24.4 per cent improvement.

c. For Commuter Rail operations, the increase in GHG intensity levels to 1.74 kg per passenger from 1.71 in 2007 can be attributed to the introduction of additional scheduling and the operation of longer trains in 2008. Furthermore, new high-horsepower locomotives were employed to move the longer trainsets. In 2008, GO Transit suspended use of the proprietary FTC fuel extender additive pending resolution of warranty concerns on its new locomotives. This combination of events negatively impacted the GHG intensity level. Generally, when new service routes are introduced it takes a period of time to increase ridership to fill new capacity.

d. NOx emissions from all rail operations in 2008 totalled 99.68 kt. Compared to 2007, this is a reduction of 3.4 per cent and is 12.2 per cent below the 1995-2005 MOU reference level of 115 kt per year. The emissions of NOx have averaged 112.98 kt per year since 1990.

e. In terms of emissions intensity, the NOx level in 2008 for freight trains was 0.27 kg per 1,000 RTK, the same value as 2007. The 37.2 per cent reduction below the 1990 level of 0.43 kg stems primarily from the beneficial effect of acquiring new locomotives meeting U.S. EPA emissions standards as well as upgrading in-service locomotives to EPA Tier 0 emissions limits.

f. The in-service diesel-powered Canadian freight and passenger railway locomotive and DMU fleet totalled 2,823 units in 2008. There were 1,110 locomotives compliant with the U.S. EPA emissions limits, which is 46.4 per cent of the line-haul fleet.

g. The number of locomotives equipped with Automatic Engine Stop-Start systems to minimize unnecessary idling totalled 1,104, which is 39.1 per cent of the in-service fleet.

h. Fleet change actions undertaken in 2008 according to MOU commitments are tabled below:

Actions Taken	Class I	Intercity	Commuter	Total
New EP New EPA Tier 2 Locomotives Acquired	34	0	26	60
High-horsepower Units Upgraded to EPA Tier 0	0	0	0	0
Medium-horsepower Units Upgraded to EPA Tier 0	12	0	0	12
Retire 1973-99 era Medium-horsepower Units	34	0	20	54

i. In volume, the rail sector's total diesel fuel consumption in 2008 decreased to 2,183.95 million L from 2,237.22 million L in 2007; but up from 2,060.66 million L in 1990. The lower fuel consumption reflects the impact of the economic decline on 2008 freight traffic.

j. In terms of productivity, due to the effects of the economic decline the freight fuel consumption per 1,000 RTK in 2008 rose 8.8 per cent to 6.16 L from 5.90 L in 2007, but is 21.3 per cent down from 7.83 L in 1990.

k. The Emissions Factor (in grams per litre of diesel fuel consumed) used to calculate NOx emitted from freight locomotives was again revised downward to 43.96 g/L for 2008. This reflects the increased proportion of locomotives in service during 2008 meeting the stringent U.S. EPA Tier 0, Tier 1 or Tier 2 emissions limits.

l. Revenue traffic handled in 2008 by Canada's freight railways, as measured in RTK, fell 4.2 per cent compared to 2007. Since 1990, railway freight traffic RTK has risen by an average annual rate of 2.1 per cent for an overall increase of 38.5 per cent.

m. The Class I railways were responsible for 93.8 per cent of the freight traffic in 2008. Of the 325 billion RTK they transported, intermodal accounted for 25.6 per cent. Of note is that intermodal tonnage has increased 152.5 per cent 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.

n. VIA Rail Canada's intercity service transported 4.22 million passengers, an increase of 1.0 per cent over 2007, while Commuter Rail passengers increased by 5.8 per cent to 67.05 million.

o. Sulphur content of the diesel fuel consumed averaged 147 ppm across Canada in 2008, which is 70.6 per cent below the regulated limit of 500 ppm that came into effect July 2007.

Notice of Clarification

The metrics for the 2010 GHG emission targets for intercity passenger and commuter rail were incorrectly recorded in the Memorandum of Understanding signed on May 15th, 2007. This Notice of Clarification corrects that error.

Section 4.1 'GHG Commitments by RAC' lists the targets for intercity passenger and commuter rail. The metric for these targets should be changed from "kg $CO_{2\ equivalent}$ per 1000 passenger-km" to "kg $CO_{2\ equivalent}$ per passenger-km" for intercity passenger rail; and from "kg $CO_{2\ equivalent}$ per 1000 passengers" to "kg $CO_{2\ equivalent}$ per passenger" for commuter rail.

As a result, the 2010 GHG emission targets for intercity passenger and commuter rail are the following:

Intercity Passenger:
0.12 kg $CO_{2\ equivalent}$ per passenger-km; *and*

Commuter:
1.46 kg $CO_{2\ equivalent}$ per passenger.

Approved by the Management Committee of the Memorandum of Understanding on emissions of criteria air contaminants and greenhouse gases from railway locomotives operated by Canadian railway companies in Canada.

May 2010.

Photo courtesy of VIA Rail

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 (NOx) 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, NOx 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 Railway Association of Canada

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 Railway Association of Canada 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 Railway Association of Canada 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 per cent 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. The 2010 GHG emission targets for the rail industry are:

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

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.

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*

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 (NOx), hydrocarbons (HC), sulphur oxides (SOx), 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

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Minister of the Environment

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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.
Canadian Pacific Railway	Québec North Shore and Labrador Railway Company Inc.
Cape Breton & Central Nova Scotia Railway	Roberval and Saguenay Railway Company, The
Capital Railway	Romaine River Railway Company
Carlton Trail Railway	Savage Alberta Railway, Inc.
Central Manitoba Railway Inc.	SOPOR
Charlevoix Railway Company Inc.	South Simcoe Railway
Chemin de fer de la Matapédia et du Golfe inc.	Southern Manitoba Railway
CN	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.	

Annex 2

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 (NOx) 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 NOx emissions has been included in the CCME NOx/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 (NOx) produced during all rail operations in Canada and, if necessary, take whatever action is necessary to avoid exceeding the agreed maximum NOx 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 NOx 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 (NOx), hydrocarbons (HC), oxides of sulphur (SOx), 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 NOx/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 NOx-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 NOx 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 NOx 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

Minister of the Environment

Minister of Transport Infrastructure and Communities

Annex 3

Criteria Air Contaminants

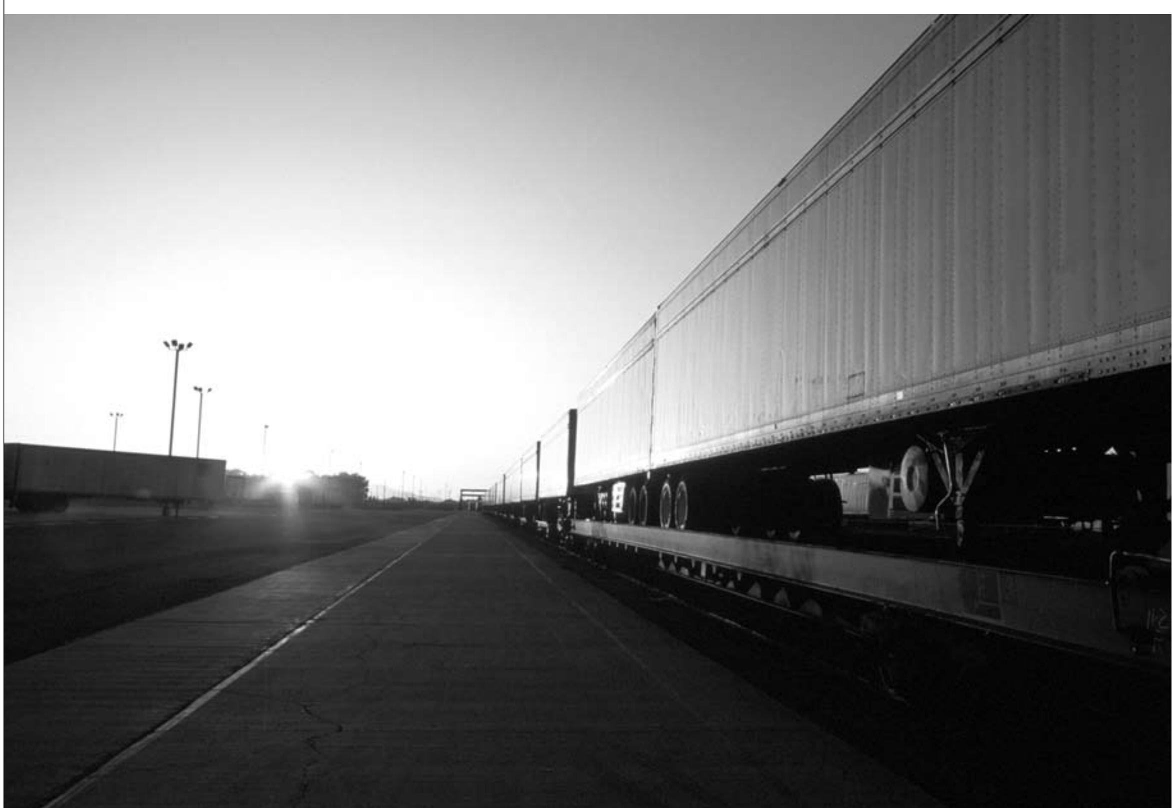
Air pollution is linked to respiratory diseases (e.g. asthma and chronic obstructive pulmonary disease), cardiovascular disease, allergies, and neurological effects. Air pollution can also prejudice the quality of soil and water resources.

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

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

NOx 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 NOx that can be transformed into secondary pollutants. Damage caused by acid deposition affects lakes, rivers, forest, soils, fish and wildlife populations and buildings.



Annex 4

Greenhouse Gases

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

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

Annex 5

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 2008 – Freight Train Line-haul and Road Switching Operations

Manufacturer	Model	EPA Tier Level	Engine	HP	Year of Manufacture	Year of Remanufacture	CN	CP	Total Class 1	Regional	Short Lines	Total Regional and Short Lines	Total
EMCC	SD70M-2	Tier 2	16V-710	4300	2005-2007		72		72				72
GM/EMD	SD90MAC		16V-710	4300	1998-1999			61	61				61
	SD75	Tier 0	16V-710	4300	1996-1999	2002-2005	161		161				161
	SD75		16V-710	4300	1996-1999		5		5	6		6	11
	SD70	Tier 0	16V-710	4000	1995	2001-2005	21		21				21
	SD70		16V-710	4000	1995		4		4				4
	SD60	Tier 0	16V-710	3800	1985-1989	2002-2005	49		49				49
	SD60		16V-710	3800	1985-1989		6		6				6
	SD40-2	Tier 0	16V-645E3B	3000	1975-1985	2007	9		9				9
	SD40-2	Tier 0	16V-645E3B	3000	1975-1985	2008		12	12				12
	SD40-2		16V-645E3B	3000	1972-1979			115	115				115
	SD40-2		16V-645E3B	3000	1980-1989		106	143	249				249
	SD40-2		16V-645E3B	3000	1980-1989	1994-1995				13		13	13
	SD40-2		16V-645	3000	1972-1979	1995				5		5	5
	SD40-2		16V-645	3000	1972-1979						11	11	11
	SD40-Q		16V-645	3000	1966-1971	1992-1995	26		26				26
	SD38-2		16V-645	2000	1975		3		3		3	3	6
	SD38		16V-645	2000	1971-1974						4	4	4
	SD18		16V-645	1800							1	1	1
	GP40-3		16V-567	3000	1966-1968						2	2	2
	GP40-3		16V-567	3000	1966-1968	2002					3	3	3
	GP40-2		16V-645	3000	1972-1991		49	4	53	3	11	14	67
	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			112	112				112
	GP38-2		16V-645	2000	1972-1986		74		74		14	14	88
	GP38-2		16V-645E	2000	1969-1981			15	15				15
	GP38		16V-645	2000	1966-1986					11	22	33	33
	GP35-3		16V-645	2500							3	3	3
	GP35-2		16V-645	2000	1963-1966						1	1	1
	GP35-2		16V-645	2000	1963-1966	1979					3	3	3
	GP30		16V-567D3A	2500	1961-1963						3	3	3
	GP20		16V-567	1800	1959-1962						1	1	1
	GP15		12V-645	1500	1970						3	3	3
	GP10		16V-567D3A	1800	1967-1977						2	2	2
	GP9		16V-645	1800	1982-1991		27		27				27
	GP9		16V-645	1800	1954-1981	1980-1991		46	46				46
	GP9		16V-567	1800	1955-1968						7	7	7
	GP9		16V-567C	1750	1950-1960						15	15	15
	MP15		16V-645E	1500	1976						3	3	3
	GMD-1u		12V-645	1200	1981-1985						4	4	4
	EMD-1		12V-567	1200	1958						1	1	1
	SW1200		12V-645	1200	1960						1	1	1
	SW1000		8V-645E	900	1967-1969						2	2	2
	SW9		8V-567C	900	1956-1964						10	10	10
Sub-Total							**612**	**508**	**1,120**	**38**	**142**	**180**	**1,300**

Appendix B-1 (continued)

Locomotive Fleet 2008 – Freight Train Line-haul and Road Switching Operations

Manufacturer	Model	EPA Tier Level	Engine	HP	Year of Manufacture	Year of Remanufacture	CN	CP	Total Class 1	Regional	Short Lines	Total Regional and Short Lines	Total
GE	ES44DC	Tier 2	GEVO 12	4400	2005-2008		74		74				74
	ES44AC	Tier 2	GEVO 12	4400	2006-2008			90	90				90
	AC4400	Tier 1	7FDL16	4400	2002-2004	2008		10	10				10
	AC4400	Tier 1	7FDL16	4400	2002-2004			107	107	7		7	114
	AC4400	Tier 0	7FDL16	4400	2000-2001	2008		3	3				3
	AC4400	Tier 0	7FDL16	4400	2000-2001			52	52	24		24	76
	AC4400	Tier 0	7FDL16	4400	1995-1999	2008		53	53				53
	AC4400	Tier 0	7FDL16	4400	1996-1999			131	131				131
	Dash 9-44CW	Tier 1	7FDL16	4400	2002-2004		59		59				59
	Dash 9-44CW	Tier 0	7FDL16	4400	2000-2001		38		38				38
	Dash 9-44CW	Tier 0	7FDL16	4400	1996-1999	2001-2003	101		101	9		9	110
	Dash 9-44CW		7FDL16	4400	1996-1999		12		12	2		2	14
	Dash 8-40CM		7FDL16	4400	1990-1992		26		26				26
	Dash 8-40CM		7FDL16	4000	1990-1992		54		54	3		3	57
	B39-8E		7FDL16	3900	1987-1988		12		12		7	7	19
Sub-Total							**376**	**446**	**822**	**45**	**7**	**52**	**874**
MLW	M420		12V-251B	2000	1971-1975						16	16	16
	RS-18		12V-251B	1800	1954-1958						3	3	3
Sub-Total							**0**	**0**	**0**	**0**	**19**	**19**	**19**
Total Freight Train Locomotives (Class 1, Regional and Short Lines)							**988**	**954**	**1,942**	**83**	**168**	**251**	**2,193**

Appendix B-2

Locomotive Fleet 2008 – Yard Switching and Work Train Operations												
Manufacturer	Model	Engine	HP	Year of Manufacture	Year of Remanufacture	CN	CP	Total Class 1	Regional	Short Lines	Total Regional and Short Lines	Total Canadian Switching Fleet
GM/EMD	SD40-2	16V-645	3000	1973-1985			35	35				35
	GP38-2	16V-645	2000	1970-1986		20		20		8	8	28
	GP9	16V-645	1800	1954-1981						3	3	3
	GP9	16V-645	1800	1954-1994		116		116				116
	GP9	16V-645	1750	1954-1981	1980-1991		122	122	1	1	2	124
	GP9	16V-645	1700	1960						2	2	2
	GP9	16V-567	1750	1951-1963					3	1	4	4
	GP7	16V-567	1500	1950-1973	1980-1988		13	13		2	2	15
	SW1500	12V-567	1500	1951-978						8	8	8
	SW14	12V-645E	1400	1950	1982					1	1	1
	SW1200	12V-567	1200	1955-1962		5	13	18		3	3	21
	GMD-1	12V-645C	1200	1988-1989		22		22				22
	SW9	12V-567	1200	1953						1	1	1
	SW900	8V-567	900	1955			1	1				1
Sub-Total						**163**	**184**	**347**	**4**	**30**	**34**	**381**
GE	C30-7	7FDL	3000	1976-86						12	12	12
	B23 Super7	7FDL12	2250	1990-1991						10	10	10
	45T	Cummins	2x150	1947						1	1	1
MLW	RS-18	12V-251B	1800	1954-1958						11	11	11
	RS-23	6-251C	1000	1959-1960						4	4	4
	S-13	6-251C	1000	1959-1960						2	2	2
	S-13	6-251C	1000	1959-1960	1978					2	2	2
ALCO	S-2	6-539T	1000	1944						1	1	1
Sub-Total						**0**	**0**	**0**	**0**	**43**	**43**	**43**
Total – Yard Switching and Work Train						**163**	**184**	**347**	**4**	**73**	**77**	**424**
Total – Freight Train Mainline and Road Switching						**988**	**954**	**1942**	**83**	**168**	**251**	**2,193**
Total – Freight Operations						**1,151**	**1,138**	**2,289**	**87**	**241**	**328**	**2,617**

Appendix B-3

Locomotive and DMU Fleet 2008 – Passenger Train Operations										
Manufacturer	Model	EPA Tier Level	Engine	HP	Year of Manufacture	Year of Remanufacture	VIA Rail Canada	Commuter	Tourist and Excursion	Total
GM/EMD	F59PHI		12-710G3B	3000	1988-1989	1998-2002		29		29
	F59PHI		12-710G3B	3000	1988-1989	2000-2001		11		11
	FP40PH2		16V-645E3C	3000	1987-1989		49	8		57
	FP40PH2		16V-645E3C	3000	1987-1989	1995		5		5
	GP40-2		16V-645E3C	3000	1974-1976	1993		5		5
	GP40-2		16V-645E3C	3000	1974-1976	2001			9	9
	GP9u		16V-645	1800	1959	1989		4		4
	FP9A		16V-567C	1750	1953-1958				3	3
	FP9B		16V-567C	1750	1955				1	1
	SW1200		8-645E	1200	1966		2			2
MotivePower	MP40PH-3C	Tier 2	16V-710G3B	4000	2007			27		27
	MP36PH-3C	Tier 2	16V-645F3B	3600	2006			1		1
GE	P42DC		7FDL16	4250	2001		21			21
	DL535		ALCO 251D	1200	1969				8	8
	LL162/162		ALCO 251B	990	1954-1956				11	11
Bombardier	Talent DMU		BR643	2x423	2001			3		3
Budd	RDC-1 DMU		Cummins	2x300	1956-1958		2			2
	RDC-2 DMU		Cummins	2x300	1956-1958		2			2
	RDC-4 DMU		Cummins	2x300	1955		2			2
Other										
GE	70 ton		FWT-6T	600	1948				1	1
CLC	44 ton		H44A3	400	1960				1	1
Ruston & Hornsby	28 ton			165	1950				1	1
Sub-Totals							**78**	**93**	**35**	**206**
Total Passenger Locomotives										**197**
Total DMUs										**9**

Canadian Fleet Summary		Emissions Levels			
		Tier 0	Tier 1	Tier 2	Total
Freight Train Locomotives	2,193	663	183	236	1,082
Switching and Work Train Locomotives	424				
Total Freight Operations	**2,617**				
Passenger Train Locomotives	197			28	28
Diesel Mobile Units (DMUs)	9				
Total Passenger Operations	**206**	**663**	**183**	**264**	**1,110**

Appendix C

Railway Lines Included in Tropospheric Ozone Management Areas

TOMA Region No. 1:
Lower Fraser Valley, British Columbia

CN

Division	**Subdivision**
Pacific	Squamish
	Yale

CP

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

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

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**

Subdivisions

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**

Subdivisions

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

TOMA Region No. 3:
Saint John Area, New Brunswick

CN

District	**Subdivision**
Champlain	Denison
	Sussex

Appendix D

Traffic and Fuel Consumption (U.S. Units)

Freight Traffic
billion

	1990	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Gross Ton-Miles (GTM)	311.6	380.0	401.8	399.5	398.7	415.3	441.47	457.95	459.63	463.36	449.79
Revenue Ton-Miles (RTM)	171.3	206.8	220.8	220.4	211.5	221.7	235.11	241.74	243.74	247.71	237.25
Ratio of RTM / GTM	0.550	0.544	0.550	0.552	0.530	0.534	0.533	0.528	0.530	0.535	0.527

Fuel Consumption
million gallons

	1990	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Freight Train Service	481.49	475.45	485.13	481.66	493.48	504.3	530.87	537.17	538.15	545.96	532.35
Yard Switching	31.53	22.94	22.89	23.74	19.47	18.28	18.70	17.92	17.08	16.43	14.61
Work Train	4.23	1.32	1.06	1.28	1.50	1.29	1.10	1.78	1.98	1.61	2.00
Total – Freight Operations	517.25	499.71	509.07	506.68	514.45	523.87	550.67	556.87	557.21	564.00	548.96
Total – Passenger Operations	27.13	15.40	16.08	26.21	26.58	26.15	26.40	26.71	26.73	27.03	28.00
Total Rail Operations	544.38	515.11	525.15	532.89	541.03	550.02	577.07	583.58	583.94	591.03	576.96

Appendix E-1

Locomotive GHG Emissions

U.S. Units x 1,000 tons

	1990	1999	2000	2001	2002	2003	2004	2005	2,006	2007	2008
Total Rail Operations											
CO_2 *equivalent*	6,846	6,463	6,589	6,686	6,792	6,901	7,240	7,322	7,326	7,415	7,236
CO_2	6,062	5,723	5,835	5,921	6,015	6,111	6,412	6,484	6,488	6,567	6,410
CH_4	7.16	6.77	6.90	7.00	7.12	7.22	7.58	7.66	7.68	7.77	7.58
N_2O	776	733	747	758	771	783	821	830	831	841	821
Passenger Operations											
CO_2 *equivalent*	194	193	202	329	329	328	331	335	335	339	351
CO_2	172	171	179	291	291	291	293	297	297	300	311
CH_4	0.20	0.20	0.21	0.34	0.35	0.34	0.34	0.35	0.35	0.35	0.36
N_2O	22	22	23	37	38	37	38	38	38	38	40
Freight Train – Line-haul											
CO_2 *equivalent*	6,237	5,966	6,087	6,044	6,200	6,328	6,661	6,740	6,752	6,850	6,676
CO_2	5,523	5,283	5,391	5,352	5,491	5,604	5,899	5,969	5,980	6,066	5,915
CH_4	6.54	6.25	6.37	6.33	6.49	6.62	6.98	7.05	7.08	7.18	7.00
N_2O	707	676	690	685	703	718	755	764	766	777	757
Yard Switching and Work Train											
CO_2 *equivalent*	415	304	300	313	263	245	248	247	239	226	208
CO_2	367	269	265	277	233	217	220	218	211	200	184
CH_4	0.43	0.32	0.32	0.33	0.28	0.25	0.26	0.25	0.25	0.24	0.22
N_2O	47	34	34	36	30	28	28	28	27	26	24
Total – Freight Operations											
CO_2 *equivalent*	6,652	6,270	6,387	6,357	6,463	6,573	6,909	6,987	6,991	7,076	6,884
CO_2	5,890	5,552	5,656	5,629	5,723	5,821	6,118	6,187	6,191	6,266	6,099
CH_4	6.97	6.57	6.69	6.66	6.77	6.88	7.24	7.31	7.33	7.42	7.22
N_2O	754	711	724	721	733	745	783	792	793	802	781
Freight Operations Emissions Intensity *lb per 1,000 RTM*											
CO_2 *equivalent*	65.40	60.63	57.85	57.68	61.12	59.29	58.77	57.80	57.36	57.13	58.03
CO_2	57.92	53.69	51.23	51.08	54.12	52.51	52.05	51.19	50.80	50.60	51.42
CH_4	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
N_2O	7.42	6.88	6.56	6.54	6.93	6.72	6.66	6.55	6.50	6.48	6.58

Appendix E-2

Locomotive CAC Emissions

U.S. Units x 1,000 tons

	1990	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Total – Rail Operations												
NOx	123.23	125.20	118.17	120.54	130.87	133.05	123.41	128.91	126.34	123.44	113.49	109.65
CO	23.77	23.91	22.59	23.05	23.36	23.76	24.14	17.93	18.12	17.36	12.94	11.25
HC	5.61	5.62	5.28	5.38	5.47	5.54	5.61	7.26	7.33	4.86	4.27	4.24
PM	2.75	2.76	2.60	2.66	2.69	2.74	2.77	5.29	4.50	3.05	3.89	3.45
SOx	5.41	5.44	5.14	5.24	5.32	5.41	5.48	4.66	5.46	5.28	2.10	0.61
Passenger Operations												
NOx	6.20	3.97	3.90	4.10	6.66	6.79	6.65	6.72	7.57	7.29	6.96	6.82
CO	1.20	0.69	0.67	0.71	1.15	1.17	1.15	1.01	1.03	0.57	0.44	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	0.11
PM	0.15	0.09	0.08	0.09	0.14	0.15	0.14	0.15	0.15	0.14	0.09	0.09
SOx	0.27	0.16	0.15	0.16	0.26	0.27	0.26	0.25	0.25	0.24	0.10	0.03
Freight Train – Line-haul												
NOx	109.80	113.30	108.42	110.59	118.23	121.28	112.10	116.27	112.90	110.98	100.67	97.44
CO	21.19	21.86	20.92	21.34	21.19	21.74	22.19	15.86	16.04	16.36	12.16	10.49
HC	4.82	4.97	4.76	4.85	4.82	4.94	5.04	6.66	6.73	4.39	3.83	3.81
PM	2.41	2.48	2.38	2.43	2.41	2.47	2.52	4.99	4.10	2.78	3.63	3.20
SOx**	4.82	4.97	4.76	4.85	4.82	4.94	5.04	4.22	5.02	4.86	1.94	0.55
Yard Switching and Work Train												
NOx	7.23	7.93	5.85	5.85	5.98	4.98	4.66	5.93	5.87	5.17	5.86	5.39
CO	1.38	1.36	1.00	1.00	1.02	0.85	0.80	1.06	1.05	0.43	0.34	0.32
HC	0.48	0.47	0.34	0.34	0.35	0.29	0.27	0.34	0.34	0.25	0.34	0.32
PM	0.19	0.19	0.14	0.14	0.14	0.12	0.11	0.14	0.14	0.12	0.18	0.17
SOx	0.32	0.31	0.23	0.23	0.24	0.20	0.18	0.19	0.19	0.18	0.07	0.02
Total Freight Operations												
NOx	117.03	121.23	114.27	116.44	124.21	126.26	116.76	122.19	118.77	116.15	106.53	102.83
CO	22.57	23.22	21.92	22.34	22.21	22.59	22.99	16.92	17.09	16.79	12.50	10.81
HC	5.30	5.44	5.10	5.19	5.17	5.23	5.31	7.00	7.07	4.64	4.17	4.13
PM	2.60	2.67	2.52	2.57	2.55	2.59	2.63	5.13	4.24	2.90	3.81	3.37
SOx	5.14	5.28	4.99	5.08	5.06	5.14	5.22	4.41	5.21	5.04	2.00	0.57
Freight Operations Emissions Intensity *lb per 1,000 RTM*												
NOx	1.37	1.19	1.11	1.05	1.13	1.19	1.05	1.03	0.99	0.95	0.86	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	0.09
HC	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.04	0.03	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	0.03
SOx	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.02	0.00

Note 1: 2007 CAC masses revised to reflect Audited Tier-level locomotive numbers in fleet

Note 2: For 2008, SOx values calculated for a diesel fuel sulphur content of 147 ppm

Appendix F

RAC Member Railways in 2008, with 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
Canadian Pacific	British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Québec
Cape Breton & Central Nova Scotia Railway	Nova Scotia
Capital Railway	Ontario
Carlton Trail Railway	Saskatchewan
Cartier Mining Company	Québec
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 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

Appendix G

Railway Association of Canada Management Plan for Responding to Audit of the 2007 Locomotive Emissions Monitoring Program Report

Listed below are the recommendations extracted from the Audit report of the 2007 Locomotive Emissions Monitoring (LEM) Program report. Corresponding to each recommendation is the action that the Railway Association of Canada (RAC) will take.

Non-Conformities

NC-01

Recommendation:

Supporting documentation for these data must be retained by the RAC members submitting data for inclusion in the LEM Reports and internal controls for the documentation must be strengthened to allow for the records to be readily identifiable, traceable and retrievable. Records of the original data used for the LEM Reports must be legible, adequately protected, retained for a suitable period of time and disposed of in an appropriate manner.

RAC consultants should cross-reference the accuracy and completeness of the locomotive retirement data submitted for the LEM Reports against other relevant sources.

Management Plan:

The RAC will request the following actions of RAC member railways:

- Retain supporting documentation of the data they submit for inclusion in the LEM Reports;
- Strengthen internal controls for the documentation to allow for the records to be readily identifiable, traceable and retrievable.
- Records, of the original data used for the LEM Reports, be legible, adequately protected, retained for a suitable period of time (five years) and disposed of in an appropriate manner.
- Request data, such as the year end locomotive inventory, prior to sending out the full *RAC Trends Survey* in order to give the consultants, who prepare the LEM report, additional time to review, analyze, and organize the data.

The RAC will direct its consultants to take the following action:

- Cross reference the accuracy and completeness of the locomotive retirement data submitted for LEM Reports against other relevant sources.

Opportunities for Improvement:

OFI-01

Recommendation:

RAC should establish a firm cut-off date for receipt of data from RAC members and include a note in the corresponding LEM Report that missing data were not received by the cut-off date.

RAC should strengthen communication of expected timelines for the project and expectations to RAC members, prior to sending out the surveys. RAC MOU Management Committee as well as RAC MOU Technical Review Committee meetings may be an opportunity to address this.

Management Plan:

The RAC has taken the following actions:

- For the collection of the 2008 *Railway Trends data* and data for the 2008 LEM report, the RAC took over the data collection process, previously solely contracted to Bob McCabe. In 2009, the RAC hired a full-time staff member whose primary responsibility is the collection and compilation of *Railway Trends* data and to organize data for LEM reporting.
- For the collection of the 2008 data, the RAC will strengthen communication of expected timelines to RAC members, prior to sending out the *2008 Railway Trends* survey.

The RAC will take the following action:

- Where feasible request data, for LEM reporting, prior to sending out the full *RAC Trends Survey* in order to give the consultants, who prepare the LEM report, additional time to review, analyze, and organize the data.
- The RAC does not agree with the recommendation that data received after the cut-off date should be omitted from the LEM report. Efforts should be made, when feasible, to accommodate the inclusion of late data in order to improve overall LEM reporting. However, efforts have and will be made to encourage RAC members to submit data within the state deadline.

OFI-02

Recommendation:

RAC should consider offering training to the survey respondents on: (i) the importance of data; (ii) the timeliness of their responses; and (iii) filling out the LEM portion of the RAC Railway Trends survey, stressing the importance of data accuracy and completeness.

Management Response:

The RAC has taken the following action:

- For the collection of the 2008 LEM data, the RAC improved communications with RAC member railways in terms of importance of data accuracy and completeness

The RAC will take the following action:

- The RAC will consider offering training to the survey respondents on:) the importance of data; (ii) the timeliness of their responses; and (iii) filling out the LEM portion of the RAC Railway Trends survey

OFI-03

Recommendation:

RAC to provide contact information within the LEM Report to allow interested parties to make enquiries and to provide feedback. For example, some sections of the LEM Report may not be perceived as useful and could be eliminated. Conversely, RAC members may require additional information that is not presently included in the annual LEM Report.

Management Plan:

The RAC will take the following action:

- In an effort to improve feedback from the public on LEM reports, a RAC contact will be listed in the LEM reports in order to receive comments.

OFI-04

Recommendation:

RAC to interpolate the emissions inventory based on locomotive fleet. Applying the emissions factors on a locomotive inventory taken in July or using interpolation to evaluate mean emissions factors for the complete year would provide more accurate evaluations of the CACs.

Management Plan:

The RAC has undertaken the following action:

- The LEM Technical Review Committee (TRC) has discussed the timing of the collection of the locomotive inventory at great length and on numerous occasions. A decision was made by the TRC that the locomotive inventory, for LEM reporting, would be the locomotive inventory as of December 31st of each year. It is the opinion of the RAC and the TRC that moving the date of the inventory, to July for example, would not resolve the issue raised is audit fining OFI-04.

OFI-05

Recommendations:

RAC should consider including additional information in the Report, for example: (i) list of new locomotives acquired in the year by model; (ii) list of high-horsepower units re-manufactured in the year by model; and (iii) list of medium-horsepower units permanently retired in the year by model and year of original manufacture.

Management Plan:

RAC will take the following actions:

- The RAC supports this recommendation and will make a recommendation to the LEM Management Committee and the LEM Technical Review Committee to consider including additional information in the Report, for example: (i) list of new locomotives acquired in the year by model; (ii) list of high-horsepower units re-manufactured in the year by model; and (iii) list of medium-horsepower units permanently retired in the year by model and year of original manufacture.

OFI-06

Recommendation:

Environment Canada should consider publishing LEM Report (2007) to their website. Subsequent to the interview, AMEC was advised that the federal Government prefers posting electronic copies of the LEM Report to a single location (TC's website). A hyperlink has been added to EC's website directing interested parties to TC's website.

Management Plan:

The following action has been taken:

- A URL has been provided on Environment Canada's website to the LEM reports which are posted on Transport Canada's website.