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December 2002

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Readers' Comments

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

Transportation Systems Branch
Air Pollution Prevention Directorate
Environment Canada
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K1A 0H3

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This report has been prepared by The Railway Association of Canada in partnership with Environment Canada, for the Transportation Systems Branch, Air Pollution Prevention Directorate, Environment Canada.

Executive Summary

This report contains the Railway Association of Canada's (RAC) filing for 2001 under the terms of the Memorandum of Understanding (MOU) between Environment Canada (EC) and the RAC, signed in 1995 and covering the period 1990–2005.

The data reported by the RAC under the monitoring program include annual traffic volumes and annual diesel fuel consumption for mainline, branchline, yard switching, and passenger service. Included are the annual emissions of oxides of nitrogen (NO_x), carbon dioxide (CO_2), hydrocarbons (HC), oxides of sulphur (SO_x), particulate matter (PM), and carbon monoxide (CO). The report also details measures being undertaken to reduce fuel consumption and emissions.

The railways also calculate and report on their fuel consumption and emissions in three designated Tropospheric Ozone Management Areas (TOMAs): the Lower Fraser Valley in British Columbia, the Windsor–Quebec City corridor, and the Saint John area in New Brunswick. The data for winter and summer operations are also segregated.

Canada's freight railways handled 220.4 million net ton-miles (NTM) of traffic in 2001, compared with 220.8 million NTM in 2000, and consumed slightly less fuel in 2001 than in 2000. Overall rail (which includes passenger) fuel consumption increased to 2017 million litres in 2001 from 1988 million litres in 2000. The important indicator of litres per 1000 NTM decreased to 8.70 in 2001 from 8.73 in 2000 and is down from 11.43 in 1990. Traffic growth, measured in gross ton-miles (GTM), has increased an average of 2.4% per year since 1990. This is significantly higher than the 1.2% predicted when the MOU was signed in 1995.

Intermodal traffic was virtually unchanged from 2000, the number of carloads decreasing 0.25%.

Intercity passenger traffic increased from 4.068 million passengers in 2000 to 4.112 million passengers in 2001. Passenger fuel consumption shows a significant increase in 2001 compared with 2000. However, in 2001, passenger fuel consumption has been separated out of general freight fuel consumption for some railways. Previously, freight and passenger operations were not reported separately in some instances.

A new emissions factor (EF) for NO_x for freight locomotives is used for the first time in 2001. The new NO_x factor was agreed upon following a review of EFs in a recent study.[1]

NO_x emissions in 2001, calculated using the new factor, were 118 kt, slightly above the voluntary cap of 115 kt. Forecasts show that NOx emissions will be progressively reduced as locomotives meeting U.S. Environmental Protection Agency (EPA) Tier 1 and Tier 2 requirements are introduced into the Canadian locomotive fleet and existing high-horsepower mainline locomotives are upgraded to U.S. EPA Tier 0 requirements.

Total rail CO_2 emissions were 5461 kt in 2001, up from 5386 kt in 2000. CO_2 emissions have declined by 8.8% since the peak year 1997, and by 2.2% since 1990.

In recent years, Canada's railways have invested in new fuel-efficient locomotives and high-capacity freight cars and have introduced other operational efficiencies to reduce fuel consumption and associated emissions.

In conclusion, Canada's railways, in the last 10 years, have reduced fuel consumption by 2.1% while increasing traffic by 28%, demonstrating a steady improvement in the area of fuel efficiency and reducing atmospheric emissions.

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1 Review of Memorandum of Understanding between Environment Canada and the Railway Association of Canada Regarding Railway Locomotive Emissions – June 2001.

Résumé

Le présent rapport contient le document déposé par l'Association des chemins de fer du Canada pour l'année 2001 en vertu des dispositions du protocole d'entente (PE) conclu entre Environnement Canada (EC) et l'ACFC, signé en 1995 et portant sur la période 1990 à 2005.

Les données signalées par l'ACFC dans le cadre du programme de surveillance comprennent les volumes annuels de trafic de marchandises et la consommation annuelle de carburant Diesel pour les services de lignes principales et de lignes secondaires, les services de manœuvre et les services voyageur. On y trouvera les émissions annuelles d'oxydes d'azote (NO_X), de dioxyde de carbone (CO_2), d'hydrocarbures (HC), d'oxydes de soufre (SO_X), de particules (P) et de monoxyde de carbone (CO). Le rapport porte également sur les mesures que l'on doit prendre pour réduire la consommation de carburant et les émissions.

De plus, les chemins de fer calculent et déclarent leur consommation de carburant ainsi que les émissions dans trois zones désignées de gestion de l'ozone troposphérique (ZGOT) : la vallée inférieure du Fraser en Colombie-Britannique, le corridor Windsor-Québec et la région de Saint John au Nouveau-Brunswick. Par ailleurs, les données d'hiver et d'été sont indiquées séparément.

Les transporteurs ferroviaires du Canada ont acheminé 220,4 millions de tonnes-milles nettes (TMN) de marchandises en 2001, comparativement à 220,8 millions de TMN en 2000 et ont consommé un peu moins de carburant en 2001 qu'en 2000. La consommation globale de carburant par les compagnies ferroviaires (qui comprend le transport des passagers) a augmenté à 2 017 millions de litres en 2001, de 1 988 millions de litres qu'elle était en 2000. L'indice important énoncé en litres par 1 000 TMN a diminué à 8,70 en 2001, de 8,73 qu'il était en 2000 et même de 11,43 en 1990. La croissance du transport des marchandises en tonnes-milles brutes (TMB) est passée en moyenne à 2,4 % par année depuis 1990. C'est sensiblement plus que l'augmentation de 1,2 % prévue lorsque le PE a été signé en 1995.

Le transport intermodal est resté pratiquement le même qu'en 2000, le nombre de wagonnées ayant diminué de 0,25 %.

Le transport interurbain des passagers a augmenté de 4,068 millions de passagers en 2000 à 4,112 millions en 2001. La consommation de carburant pour ce transport a augmenté de façon marquante en 2001 par rapport à 2000. Cependant, en 2001, certaines compagnies ferroviaires ont indiqué la consommation de carburant pour le transport des passagers séparément de la consommation de carburant pour le transport général des marchandises. Auparavant, le transport des marchandises et des passagers ne faisait pas l'objet d'un rapport distinct dans certains cas.

Un nouveau facteur d'émission (FE) portant sur les NO_X émis par les locomotives de transport de marchandises est utilisé pour la première fois en 2001. Le nouveau facteur des NO_X a été convenu à la suite d'un examen des FE ayant fait l'objet d'une étude récente[1].

Les émissions de NO_X en 2001, calculées à l'aide du nouveau facteur, étaient de 118 kt, légèrement plus élevées que le plafond volontaire de 115 kt. Les prévisions indiquent que les émissions de NO_X seront progressivement réduites à mesure que des locomotives conformes aux exigences de niveaux 1 et 2 de l'Environmental Protection Agency (EPA) des États-Unis prennent leur place dans le parc de locomotives canadien et que les actuelles locomotives de ligne principale à haute puissance sont modernisées en fonction des exigences de niveau 0 de l'EPA.

Le total des émissions de CO_2 des transporteurs ferroviaires se chiffrait à 5 461 kt en 2001, une augmentation par rapport aux 5 386 kt de 2000. Les émissions de CO_2 ont diminué de 8,8 % depuis l'année où elles étaient les plus élevées, soit 1997 et de 2,2 % depuis 1990.

Depuis quelques années, les chemins de fer du Canada ont investi dans de nouvelles locomotives efficaces sur le plan de la consommation de carburant et de nouveaux wagons à marchandises à grande capacité. De plus, ils ont apporté d'autres modifications opérationnelles économiques en vue de réduire la consommation de carburant et les émissions connexes.

En conclusion, les chemins de fer du Canada, depuis les 10 dernières années, ont réduit leur consommation de carburant de 2,1 % et augmenté leur trafic de 28 %, montrant ainsi une amélioration constante de leur efficacité de carburant et une diminution des émissions atmosphériques.

[1] Examen du protocole d'entente conclu entre Environnement Canada et l'Association des chemins de fer du Canada au sujet des émissions des locomotives de chemins de fer — juin 2001.

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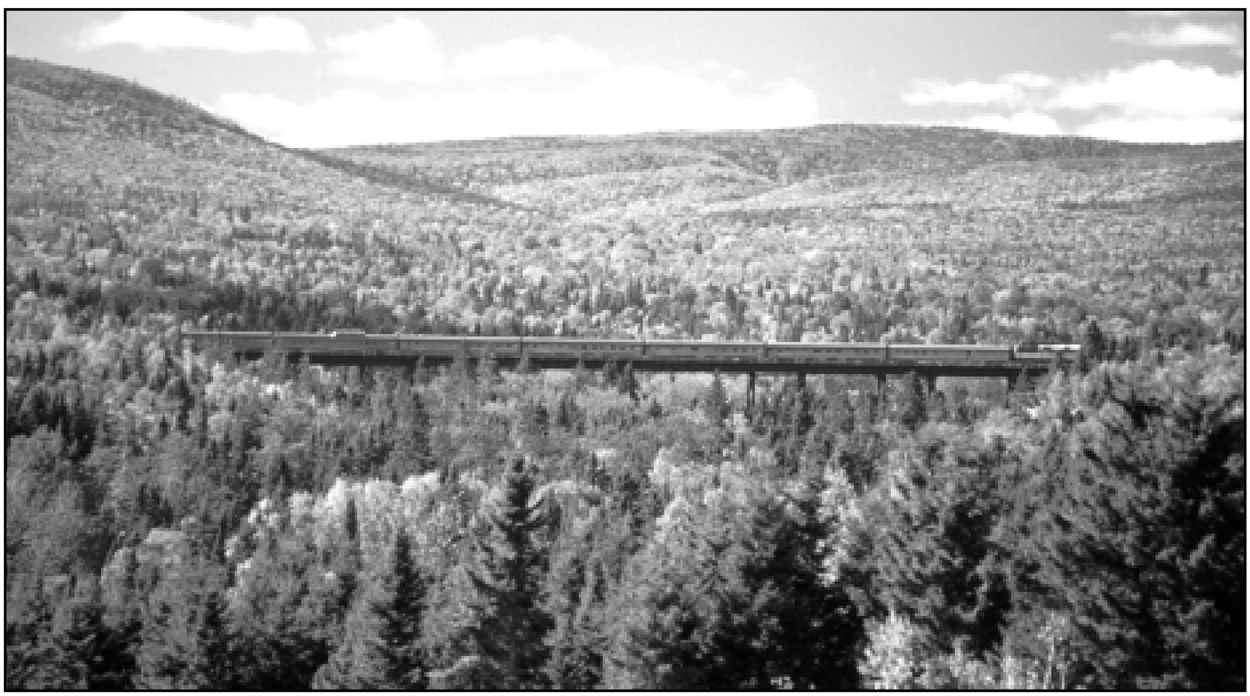
1.0 Introduction

Attached as Appendix A are the terms of the Memorandum of Understanding (MOU) between Environment Canada (EC) and the Railway Association of Canada (RAC) with respect to control of emissions produced by locomotives. They require the RAC to submit an annual report to EC on Locomotive Emissions Monitoring (LEM). The LEM report is to include calendar year data on all rail traffic, diesel fuel consumption, and locomotive exhaust emissions, including carbon dioxide (CO_2), a greenhouse gas. Of particular interest are emissions of oxides of nitrogen (NO_X) vis-à-vis the voluntary cap of 115 kt per year targeted in the MOU. Information is also to be provided on improvements in equipment or operating practices that will lead to fuel and emissions reductions.

The LEM issue for 2001 introduces a new emissions factor (EF) for NO_X. The new EF was agreed upon following a recent review of EFs for the Canadian railway sector. This issue also introduces a new format for the LEM report. Separate sections now highlight traffic growth, locomotive emissions, and greenhouse gas emissions. Also included is a section on research initiatives to reduce fuel consumption and, consequently, greenhouse gas emissions.



2.0 Traffic and Fuel Consumption Data

2.1 Introduction

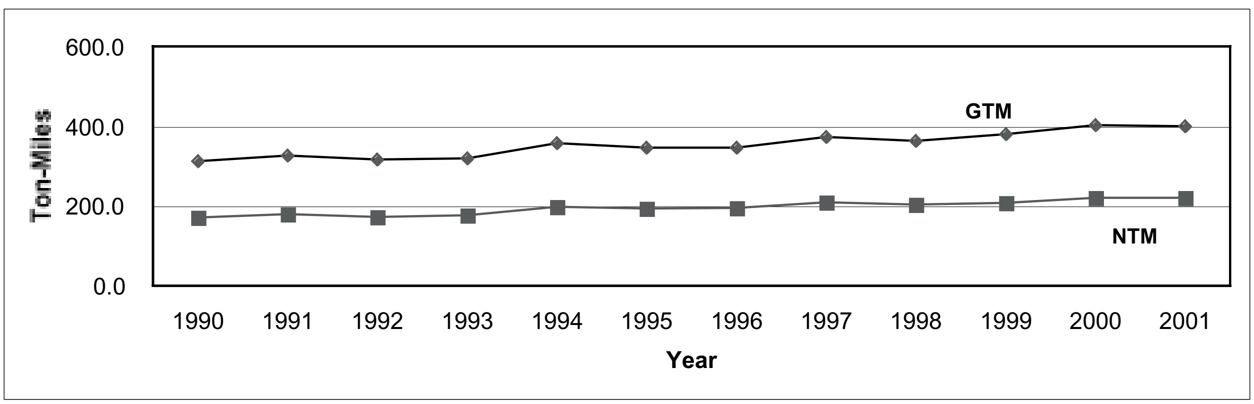
Starting with this issue, 1990 has been selected as the base year for historical data. Statistics dating from 1975 can be found in earlier LEM reports.[2] The significance of this change reflects the relevance of the Kyoto protocol, which also has 1990 as the base year for emissions comparisons.

This issue marks the introduction of metric units for fuel consumption and emissions. Gross ton-miles (GTM) and net ton-miles (NTM) have been retained in American and Imperial units as per current railway convention in North America.

2.2 Traffic

As shown in Table 1, GTM increased from 311.6 million in 1990 to 399.5 million in 2001, a 28% increase in freight traffic. Similarly, NTM increased from 171.3 million in 1990 to 220.4 million in 2001, a 29% increase. These data are shown graphically in Figure 1.

Figure 1: Freight Traffic Data



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2 References:
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

Table 1: Traffic and Fuel Consumption

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
FREIGHT TRAFFIC													
GROSS TON-MILES	GTM x 10^6	311.6	326.6	316.6	319.6	357.4	346.4	346.5	372.7	362.8	380.0	401.8	399.5
NET TON-MILES	NTM x 10^6	171.3	179.8	172.9	176.6	197.9	193.5	194.4	208.3	203.4	206.8	220.8	220.4
	NTM/GTM	0.550	0.550	0.546	0.552	0.554	0.559	0.561	0.559	0.561	0.544	0.550	0.552
FUEL CONSUMPTION													
FREIGHT	L x 10^6	1823	1878	1824	1813	1934	1937	1872	2031	1881	1800	1836	1823
YARD SWITCHING	L x 10^6	120	120	121	124	137	140	136	113	118	87	87	89
WORK TRAIN	L x 10^6	16	13	15	12	12	10	7	6	7	5	4	5
TOTAL FREIGHT OPERATIONS	L x 10^6	1958	2012	1960	1948	2083	2087	2014	2150	2007	1892	1927	1918
PASSENGER FUEL	L x 10^6	103	72	64	69	60	56	59	61	59	58	61	99
TOTAL FUEL	L x 10^6	2061	2084	2024	2017	2143	2143	2073	2211	2066	1950	1988	2017
LITRES PER 1000 GTM	TOTAL FREIGHT	6.2836	6.1600	6.1908	6.0945	5.8281	6.0256	5.8122	5.7688	5.5315	4.9786	4.7964	4.8004
LITRES PER 1000 NTM	TOTAL FREIGHT	11.4288	11.1932	11.3346	11.0313	10.5280	10.7880	10.3577	10.3193	9.8671	9.1477	8.7269	8.7014

The growth in traffic since 1990 has been approximately 2.4% per year (cumulative). This is significantly higher than the annual 1.2% increase in GTM and 1.5% increase in NTM predicted in 1995 when the MOU was signed. Traffic growth is expected to continue in the next several years, but at the slightly slower rate of 1.0 to 1.5%.

2.3 Intermodal

Total intermodal carloads decreased by 0.25% in 2001 compared with 2000. Intermodal traffic represents approximately 7.5% of the total NTM hauled by the railways.

Container on freight car (COFC) traffic decreased slightly from 23.91 million tons in 2000 to 23.85 million tons in 2001, but was up from 10 million tons in 1990. Trailer on freight car (TOFC) traffic decreased slightly from 1.128 million tons in 2000 to 1.125 million tons in 2001. As shown in Figure 2, this is down from 4.1 million tons in 1990.

2.4 Intercity Passenger

The number of intercity rail passengers in 2001 was 4.112 million. This is up from 4.068 million in 2000. The growth in intercity rail passengers is shown in Figure 3.

2.5 Fuel Consumption

As shown in Table 1, freight locomotive fuel consumption decreased from 1958 million litres in 1990 to 1918 million litres in 2001, a 2.0% decrease. As shown in Figure 4, total rail fuel consumption decreased from 2061 million litres in 1990 to 2017 million litres in 2001, a 2.1% decrease.

Canadian railways aim to continue reducing fuel consumption per NTM by implementing a fleet replacement policy of purchasing modern, fuel-efficient locomotives while retiring older, less fuel efficient locomotives. As well, operating practices that reduce fuel consumption will continue to be evaluated and implemented.

In 2001, Canadian railways hauled 28% more NTM tonnage with 2.1% less fuel than in 1990. This fact clearly shows the results of fuel conservation practices put in place by the railways.

The efficiency with which freight traffic is handled has improved overall since 1990, with the improvement between 1997 and 2001 being at a rate considerably better than forecast. This value decreased from 11.43 L per 1000 NTM in 1990 to 8.70 L per 1000 NTM in 2001, a 24% reduction (Figure 5). This shows clearly the success of the Canadian railway in accommodating higher traffic growth while reducing fuel consumption.

Figure 2: Intermodal Traffic

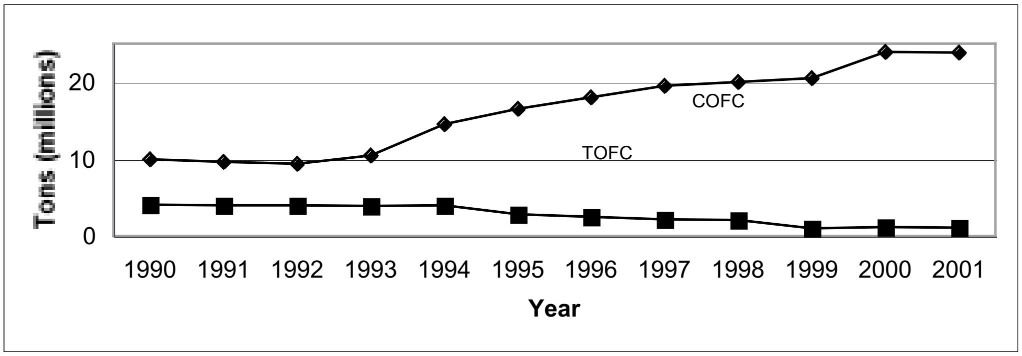


Figure 3: Intercity Rail Passengers

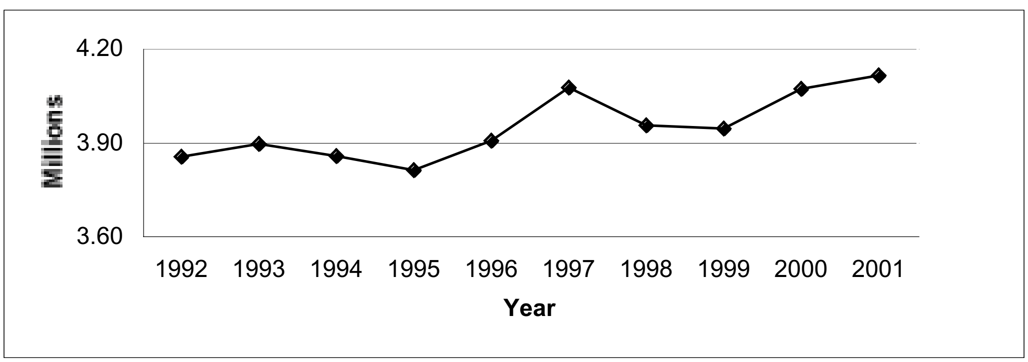


Figure 4: Total Freight Fuel Consumption

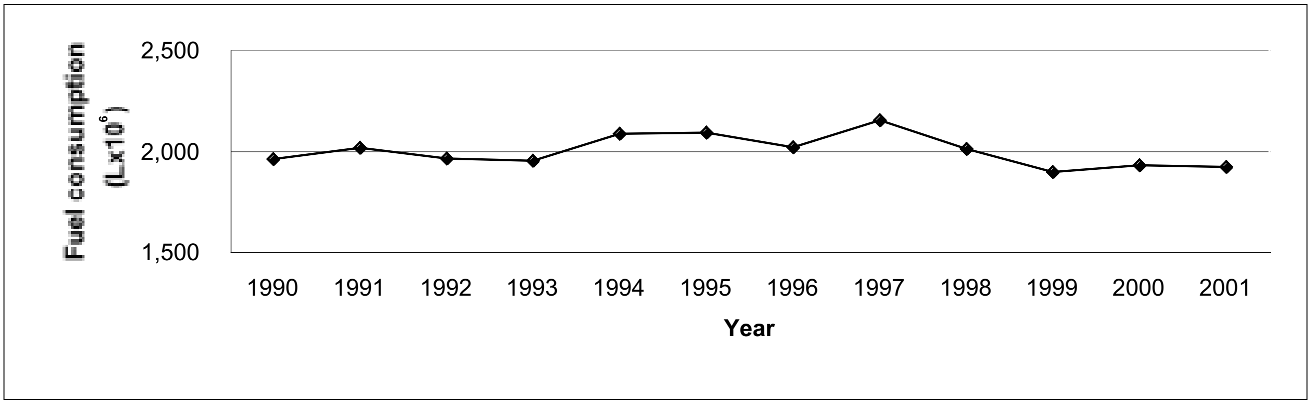
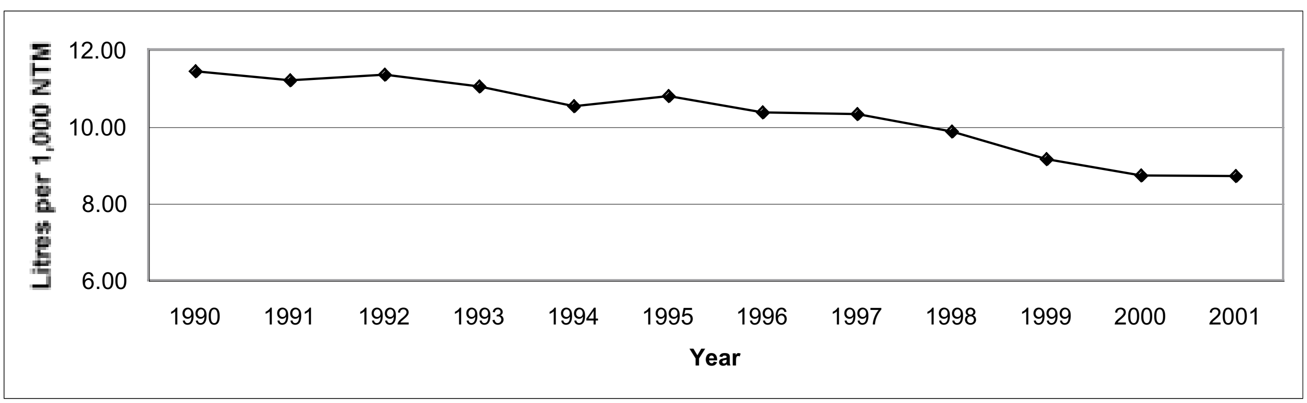


Figure 5: Freight Fuel Consumption per 1000 NTM



3.0 Locomotive Emissions

3.1 Introduction

The emissions from locomotive operations have been calculated using EFs giving quantities of selected exhaust gases and particulate matter (PM) per litre of fuel consumed. EFs are based on emissions data for the different engines in the various throttle notch settings applied to the duty cycle for locomotive operation applicable to Canadian service.[3] These factors were derived from test measurements, in the early 1990s, by the Association of American Railroads (AAR) and the locomotive manufacturers. Also, since then, there has been further testing by the U.S. Environmental Protection Agency (EPA) at Southwest Research Institute on the newest high-horsepower locomotives, plus there have been changes in the operational duty cycle of locomotives. Hence, the EF for NO_X for freight locomotives has been recently updated in a review of the factors.[4]

Emissions are calculated for NO_X, carbon monoxide (CO), hydrocarbons (HC), oxides of sulphur (SO_X), PM, and CO_2 for the several types of service and for the total for all railway operations.

3.2 Canadian Locomotive Fleet

The fleet of locomotives operating in 2001 in Canada is shown in Appendices B (mainline and branchline) and C (switching and yard).

Of interest is the fact that Canadian railways have been renewing their fleets since the early 1990s with new fuel-efficient, higher-horsepower locomotives, and many of these now meet the U.S. EPA Tier 0 emissions limits, which came into effect in 2000. Table 2 shows the introduction rate of these new locomotives and those meeting Tier 0.

When purchasing new locomotives, Canadian railways have made a commitment that they meet the latest EPA Tier level. They are also committed to upgrading their in-service higher-horsepower locomotives to EPA Tier 0 level when next overhauled.

Table 2: New Locomotives Introduced into the Canadian Fleet

Model	1995	1996	1997	1998	1999	2000	2001
New higher-horsepower locomotives	225	350	565	568	657	600	528
Tier 0 locomotives, either new or rebuilt	0	0	0	0	0	80	179
Total	**225**	**350**	**565**	**568**	**657**	**680**	**707**

3 See Tables 10 and 12 in EPS 2/TS/8, Recommended Reporting Requirements for the Locomotive Emissions Monitoring (LEM) Program – September 1994.

4 Review of Memorandum of Understanding between Environment Canada and the Railway Association of Canada Regarding Railway Locomotive Emissions – June 2001.

3.3 Emissions

Annual locomotive emissions are shown in Table 3a (1990–1995) and Table 3b (1996–2001).

3.3.1 Oxides of Nitrogen (NO_x)

As indicated in Table 3b, NO_x emissions were 118.4 kt in 2001. Figure 6 shows the historical record since 1990 vis-à-vis the voluntary cap of 115 kt targeted in the MOU. Freight operations account for 95% of railway-generated NO_x emissions in Canada.

NO_x emissions are related to the emissions profile of individual locomotive types. Canadian railways are committed to purchasing new locomotives that meet U.S. EPA emissions limits. NO_x emissions, therefore, will decrease as the railways introduce new locomotives meeting Tier 0 (Tier 1 starting in 2002) and overhaul older mainline locomotives to Tier 0. Recent forecasts, prepared for the forthcoming EC Criteria Air Contaminants (CAC) Forecast, project that emissions will decrease to approximately 105 kt by 2020 (see Section 3.3.3).

NO_x emissions in terms of kilograms per 1000 NTM have decreased significantly since 1990. The value of total NO_x emissions per work unit is shown in Figure 7.

Figure 6: NO_x Emissions

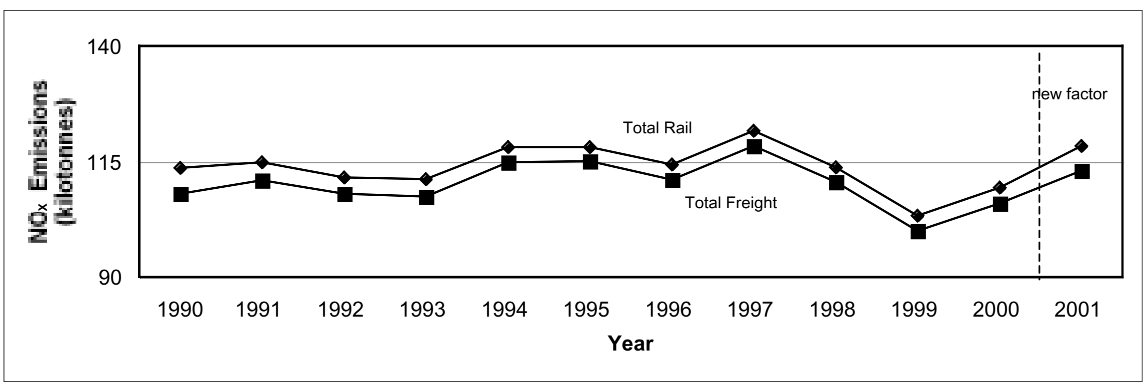


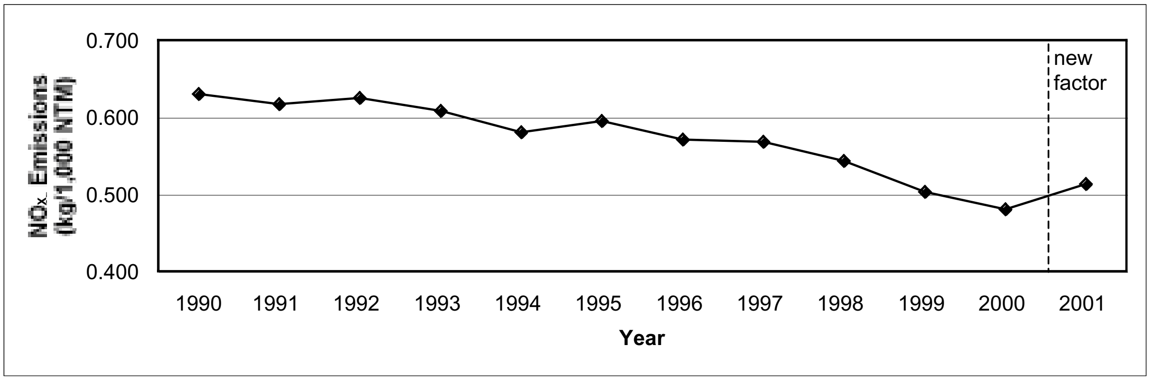
Table 3a: Locomotive Emissions, 1990–1995

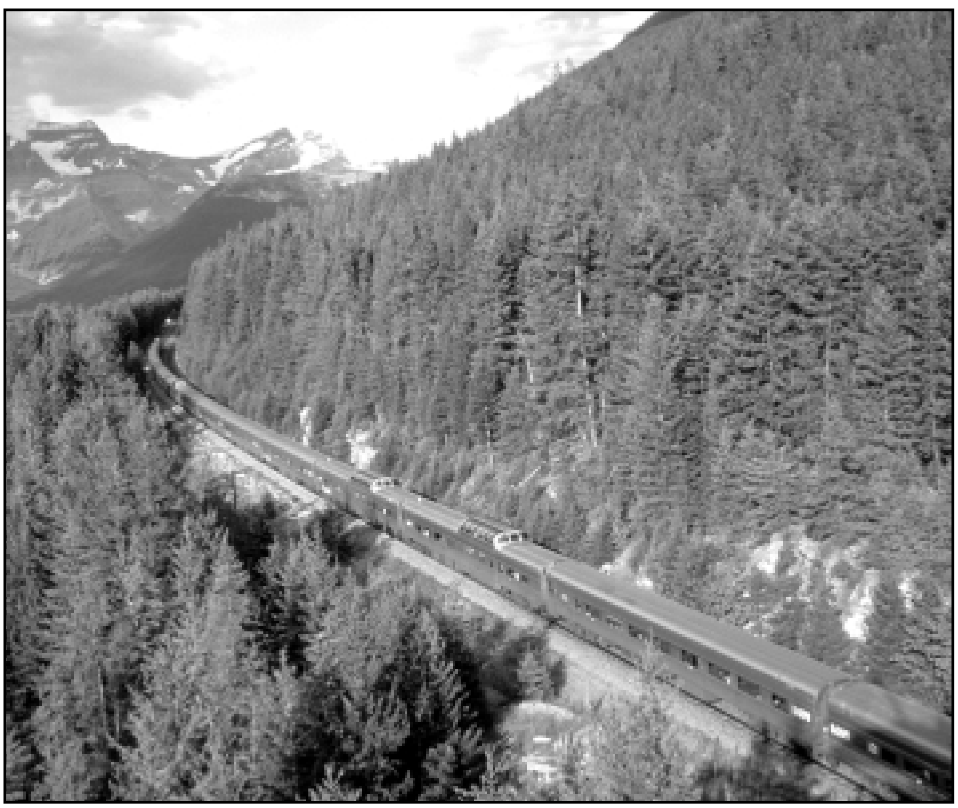
		EMISSIONS FACTORS STANDARD Freight & passenger		Yard & work	1990	1991	1992	1993	1994	1995
		g/L		g/L	kilotonnes					
		1990-2000	2001							
FREIGHT - MAINLINE & BRANCHLINE	NO_x	54.69	58.81		99.68	102.73	99.77	99.16	105.77	105.93
	CO	10.51			19.15	19.73	19.17	19.05	20.32	20.35
	HC	2.73			4.98	5.13	4.98	4.95	5.28	5.29
Adjusted to 0.15% Sulpher Fuel	SO_x	2.54			4.62	4.76	4.63	4.60	4.91	4.91
	PM	1.30			2.37	2.44	2.37	2.36	2.51	2.52
Based on 86.5% Carbon Fuel	CO_2	2709			4937	5088	4942	4912	5239	5247
YARD SWITCHING AND WORK TRAIN SERVICE										
	NO_x			61.01	8.27	8.14	8.28	8.26	9.07	9.14
	CO			10.42	1.41	1.39	1.41	1.41	1.55	1.56
	HC			3.61	0.49	0.48	0.49	0.49	0.54	0.54
Adjusted to 0.15% Sulpher Fuel	SO_x			2.53	0.34	0.34	0.34	0.34	0.38	0.38
	PM			1.48	0.20	0.20	0.20	0.20	0.22	0.22
Based on 86.5% Carbon Fuel	CO_2			2709	367	361	367	366	402	405
PASSENGER										
	NO_x	54.69			5.63	3.94	3.50	3.77	3.28	3.06
	CO	10.51			1.08	0.76	0.67	0.72	0.63	0.59
	HC	2.73			0.28	0.20	0.17	0.19	0.16	0.15
Adjusted to 0.15% Sulpher Fuel	SO_x	2.54			0.26	0.18	0.16	0.18	0.15	0.14
	PM	1.30			0.13	0.09	0.08	0.09	0.08	0.07
Based on 86.5% Carbon Fuel	CO_2	2709			279	195	173	186	162	151
TOTAL RAIL OPERATIONS										
	NO_x	54.69		61.01	113.59	114.81	111.55	111.20	118.12	118.14
	CO	10.51		10.42	21.64	21.88	21.25	21.19	22.50	22.50
	HC	2.73		3.61	5.75	5.81	5.65	5.63	5.98	5.98
Adjusted to 0.15% Sulpher Fuel	SO_x	2.54		2.53	5.23	5.29	5.13	5.12	5.43	5.43
	PM	1.30		1.48	2.70	2.73	2.65	2.65	2.81	2.81
Based on 86.5% Carbon Fuel	CO_2	2709		2709	5584	5645	5483	5465	5804	5805
EMISSIONS FROM FREIGHT OPERATIONS										
	NO_x	54.69	58.81	61.01	107.96	110.87	108.05	107.42	114.84	115.07
	CO	10.51		10.42	20.56	21.13	20.58	20.46	21.87	21.91
	HC	2.73		3.61	5.47	5.61	5.47	5.44	5.82	5.83
Adjusted to 0.15% Sulpher Fuel	SO_x	2.5		2.53	4.97	5.10	4.97	4.94	5.28	5.29
	PM	1.30		1.48	2.57	2.64	2.57	2.56	2.73	2.74
Based on 86.5% Carbon Fuel	CO_2	2709		2709	5305	5450	5310	5278	5642	5653
EMISSIONS PER FREIGHT TRAFFIC UNIT					kg / 1000 NTM					
	NO_x				0.630	0.617	0.625	0.608	0.580	0.595
	CO				0.120	0.118	0.119	0.116	0.111	0.113
	HC				0.032	0.031	0.032	0.031	0.029	0.030
Adjusted to 0.15% Sulpher Fuel	SO_x				0.029	0.028	0.029	0.028	0.027	0.027
	PM				0.015	0.015	0.015	0.014	0.014	0.014
Based on 86.5% Carbon Fuel	CO_2				30.967	30.321	30.707	29.894	28.517	29.223

Table 3b: Locomotive Emissions, 1996–2001

		EMISSIONS FACTORS STANDARD Freight & passenger		Yard & work	1996	1997	1998	1999	2000	2001
		g/L		g/L	kilotonnes					
		1990-2000	2001							
FREIGHT - MAINLINE & BRANCHLINE	NO_x	54.69	58.81		102.37	111.05	102.90	98.43	100.43	107.21
	CO	10.51			19.67	21.33	19.77	18.91	19.29	19.15
	HC	2.73			5.11	5.55	5.14	4.92	5.02	4.98
Adjusted to 0.15% Sulpher Fuel	SO_x	2.54			4.75	5.15	4.77	4.57	4.66	4.62
	PM	1.30			2.43	2.64	2.45	2.34	2.39	2.37
Based on 86.5% Carbon Fuel	CO_2	2709			5071	5501	5097	4875	4975	4938
YARD SWITCHING AND WORK TRAIN SERVICE										
	NO_x			61.01	8.71	7.28	7.65	5.60	5.53	5.74
	CO			10.42	1.49	1.24	1.31	0.96	0.94	0.98
	HC			3.61	0.52	0.43	0.45	0.33	0.33	0.34
Adjusted to 0.15% Sulpher Fuel	SO_x			2.53	0.36	0.30	0.32	0.23	0.23	0.24
	PM			1.48	0.21	0.18	0.18	0.14	0.13	0.14
Based on 86.5% Carbon Fuel	CO_2			2709	386	323	339	248	245	254
PASSENGER										
	NO_x	54.69			3.23	3.34	3.23	3.17	3.34	5.41
	CO	10.51			0.62	0.64	0.62	0.61	0.64	1.04
	HC	2.73			0.16	0.17	0.16	0.16	0.17	0.27
Adjusted to 0.15% Sulpher Fuel	SO_x	2.54			0.15	0.15	0.15	0.15	0.15	0.25
	PM	1.30			0.08	0.08	0.08	0.08	0.08	0.13
Based on 86.5% Carbon Fuel	CO_2	2709			159	165	159	157	165	268
TOTAL RAIL OPERATIONS										
	NO_x	54.69		61.01	114.31	121.67	113.78	107.21	109.30	118.36
	CO	10.51		10.42	21.77	23.22	21.69	20.48	20.88	21.17
	HC	2.73		3.61	5.79	6.14	5.75	5.41	5.51	5.59
Adjusted to 0.15% Sulpher Fuel	SO_x	2.54		2.53	5.26	5.61	5.24	4.94	5.04	5.11
	PM	1.30		1.48	2.72	2.89	2.71	2.55	2.60	2.64
Based on 86.5% Carbon Fuel	CO_2	2709		2709	5617	5989	5596	5281	5386	5461
EMISSIONS FROM FREIGHT OPERATIONS										
	NO_x	54.69	58.81	61.01	111.08	118.33	110.55	104.03	105.96	112.95
	CO	10.51		10.42	21.15	22.58	21.07	19.87	20.24	20.13
	HC	2.73		3.61	5.63	5.98	5.59	5.25	5.34	5.32
Adjusted to 0.15% Sulpher Fuel	SO_x	2.5		2.53	5.11	5.45	5.09	4.80	4.89	4.86
	PM	1.30		1.48	2.64	2.81	2.63	2.47	2.52	2.51
Based on 86.5% Carbon Fuel	CO_2	2709		2709	5457	5824	5436	5124	5220	5193
EMISSIONS PER FREIGHT TRAFFIC UNIT					kg / 1000 NTM					
	NO_x				0.571	0.568	0.543	0.503	0.480	0.513
	CO				0.109	0.108	0.104	0.096	0.092	0.091
	HC				0.029	0.029	0.027	0.025	0.024	0.024
Adjusted to 0.15% Sulpher Fuel	SO_x				0.026	0.026	0.025	0.023	0.022	0.022
	PM				0.014	0.014	0.013	0.012	0.011	0.011
Based on 86.5% Carbon Fuel	CO_2				28.069	27.956	26.730	24.778	23.643	23.567

Figure 7: NO_X Emissions per 1000 NTM





3.3.2 Carbon Dioxide (CO_2)

CO_2 is a greenhouse gas and is under considerable scrutiny as a result of the Canadian government's stated intent to ratify the Kyoto protocol. The transportation sector is a significant contributor to greenhouse gas emissions. As shown in Figure 8, the Canadian railway industry has demonstrated that it has made significant progress in lowering its greenhouse gas emissions. CO_2 emissions by the railway sector in 2001 are 2.1% lower than in 1990 despite a 28% increase in tonnage hauled. This fact is the result of improvements in fuel efficiency in railway operations (see Section 2.5 and Figure 4).

Figure 9 shows the reduction in CO_2 emissions that has occurred since 1997 when the railways were able to take real advantage of the new fuel-efficient locomotives. It is expected that this trend of lower emissions of CO_2 per NTM will continue. New initiatives by Canada's railways, discussed in Section 4, show that the railways are continuing to investigate ways to reduce fuel consumption that would lead to further reduction in greenhouse gas emissions.

Figure 8: CO_2 Emissions

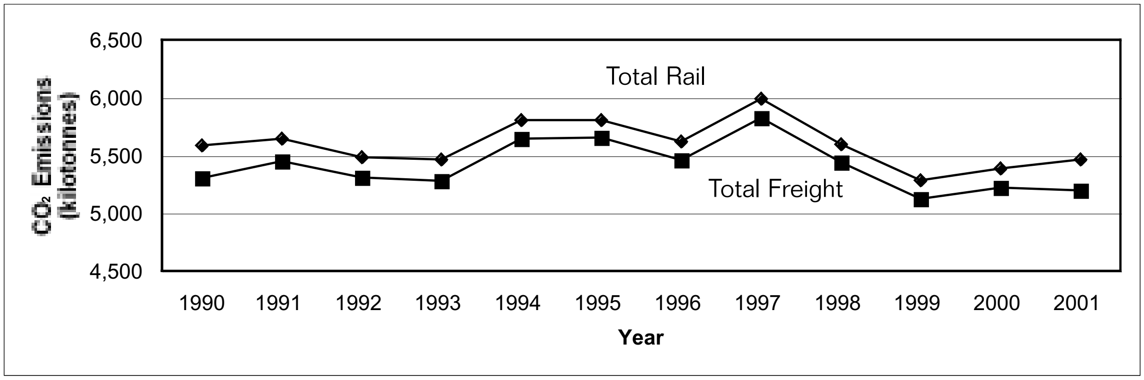
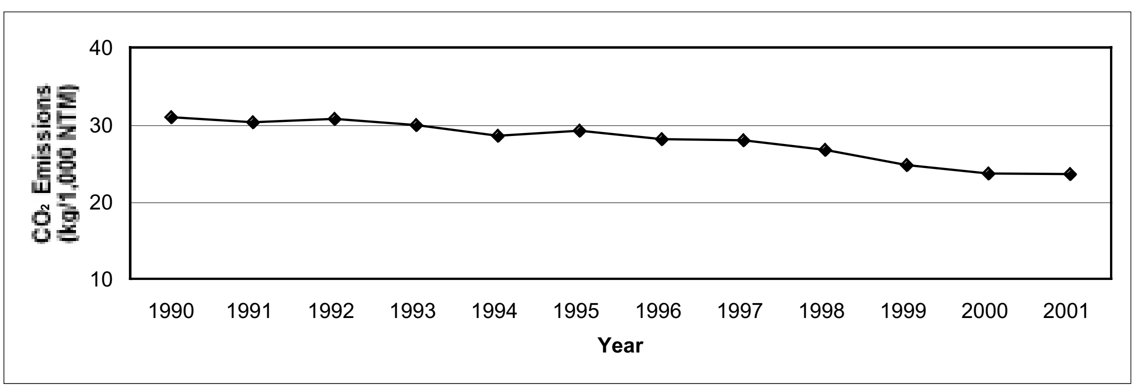


Figure 9: CO_2 Emissions per 1000 NTM

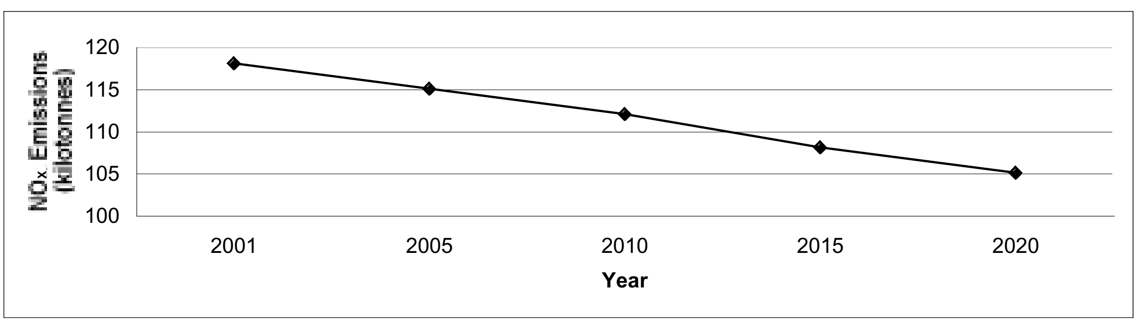


3.3.3 Emissions Forecast

Emissions are related to fuel consumption, fleet technology makeup, and traffic volumes. The predicted emissions trends were recently reviewed for EC's CAC Forecast. In this review, a conservative growth and fleet replacement scenario was used. It was also predicted that the locomotive fleet would continue to be renewed with the latest version of the U.S. EPA Tier level and that the older, high-horsepower fleet would be upgraded, upon overhaul, to Tier 0. Under this scenario, NO_X emissions are predicted to decrease progressively to approximately 105 kt per year by 2020 (Figure 10).

A more rapid fleet replacement or overhaul of older, high-horsepower locomotives to Tier 0 by the railways would further accelerate the reduction in NO_X emissions, which would be well below 100 kt by 2020. This could be counteracted, or course, by a change in traffic growth.

Figure 10: Forecast of NO_X Emissions



3.4 Locomotive Duty Cycle

The duty cycle of the locomotives was recently evaluated by Canada's Class 1 railways and by a commuter railway by evaluating the time spent at each notch level for a statistically significant sample of locomotives. The duty cycles, shown in Table 4, are for road freight, passenger, and switching service. Also shown is the duty cycle used to calculate emissions data in 1990. The influence of duty cycles on NO_x emissions has been found to be minimal,[5] even though duty cycles have changed since 1990, particularly in the amount of time spent in dynamic braking. The variation in NO_x emission factors, for example, is ±0.7% for older locomotives and ±1.2% for newer, higher-horsepower locomotives.

Table 4: Duty Cycle by Locomotive Service

Service	Percentage of time*									
	Idle	N1	N2	N3	N4	N5	N6	N7	N8	DB
2001 Freight	58.1	3.9	5.0	4.4	3.7	3.3	3.0	1.5	12.0	5.1
2001 Passenger	69.6	0.0	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 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

* N1 = Notch 1, N2 = Notch 2, etc.; DB = dynamic brake.

5 Transport Canada Report TP 13945E, Influence of Duty Cycles and Fleet Profile on Emissions from Locomotives in Canada.

4.0 Emissions Reduction Initiatives

Locomotive exhaust emissions can be reduced not only via engine technology but also via a variety of train handling and infrastructure improvements. The principal initiatives being pursued by Canadian railways are listed in this section

4.1 Fleet Renewal

Canadian railways are progressively renewing their fleet by purchasing new locomotives. They are committed to purchasing new locomotives to the latest Tier level emissions limits required by the U.S. EPA, which is currently Tier 0. They are also upgrading, upon next overhaul, their higher-horsepower locomotives to Tier 0. These costly measures will ensure that emissions, particularly NO_x emissions, will continue to be reduced.

4.2 Co-Production

Co-production initiatives are being implemented. An example is an agreement between Canada's two class 1 railways to share track. This agreement allows the railways to haul heavily loaded trains over lighter-grade (less steep) track on one railway and light loads (empty cars) on heavier-grade track on the other. The result of this agreement has lowered fuel consumption, and hence emissions, on both railways.

4.3 Participation in Government Incentive Programs

The railways are taking advantage of Transport Canada's Freight Sustainability Demonstration Program, which provides funding for fuel reduction schemes. Some examples are top of rail lubrication, electronic fuel injection, and automatic stop/start systems.

4.4 Train Handling Practices

The proportion of mainline locomotives fitted with dynamic brake equipment continues to increase. This allows the increased use of the dynamic brake for control of train speed 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 the fuel consumption to be increased significantly. 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.

4.5 Rail Gauge Face Lubrication

Efficient rail gauge face lubrication has been shown in many tests to reduce fuel consumption. The railways have ongoing programs to ensure that the system of track-mounted rail lubricators is maintained in good operating condition. Railways that have applied on-board locomotive wheel flange lubricators also have programs to keep these in working order.

4.6 Freight Car Productivity Improvement

The maximum allowable axle load has been increased on many lines in Canada. This enables the railways to use certain cars with a gross weight on rail of up to 286 000 lb. instead of 263 000 lb. The gross to tare ratio of such freight cars is increased so that the quantity of GTM accumulated to move a given amount of freight is reduced, contributing to the improvement in the ratio of NTM to GTM. Productivity improvements and the associated reduction in emissions are expected to continue.

4.7 Low-idle Applications

The railways are extending the application of the "low-idle" feature to more mainline locomotives. This feature allows the diesel engine to idle at a reduced speed with a consequently reduced load from fans. The reduction in fuel consumption can be as much as 10 L/h; on the accepted duty cycles, it can be as much as 3% of the annual fuel consumption. The use of the low-idle feature is limited in some cases by the ability of the auxiliary power system to generate sufficient power for battery charging. However, a continued reduction in overall fuel consumption is expected from this feature.

4.8 Automatic Start/Stop Systems

Railways are installing devices on switching locomotives that will automatically shut down and restart the diesel engine when the locomotive is not in use. The device is regulated by several locomotive system parameters, such as water temperature and battery condition. It will restart the engine to idle for a time to prevent freezing and to charge the batteries. The railways now have a policy of shutting down unused engines when ambient temperatures permit; the "Smart Start" systems will allow this practice to be extended all year.

5.0 Diesel Fuel Properties

The railways use diesel fuel that complies with the existing engine builder requirements of an average sulphur content of no greater than 5000 parts per million (ppm). In general, Canadian railways use fuel with a much lower average sulphur content of approximately 1500 ppm. The industry is committed to making its best effort to use even lower sulphur content diesel fuel in the near future. Discussions by the RAC with the fuel procurement officers in the major railways have been initiated with a view to purchasing low-sulphur diesel fuel from refiners that can guarantee to supply the low-sulphur fuel without a price premium. Reducing SO_x emissions is consistent with the rail industry's ongoing commitment to reduce emissions harmful to the environment, humans, and the ecology — be they greenhouse gas emissions or other health-harming emissions — through reduced fuel consumption and the introduction of EPA Tier 0 compliant locomotives, operational efficiencies, and the latest available technologies designed to increase tractive effort to yield performance gains.

6.0 Fuel Consumption and Emissions in Tropospheric Ozone Management Areas

6.1 Data Derivation

Three Tropospheric Ozone Management Areas (TOMAs) have been designated as being of particular interest for emissions. These areas, and the sections of the several railways that operate within them, are shown in Appendix D.

The fuel consumption in these TOMAs is derived from knowledge of the total traffic in the areas, expressed in GTM, as a proportion of the total rail traffic in Canada. The emissions are then calculated using the established factors for the various gases.

The fuel consumed in the TOMAs is also shown as a percentage of the total fuel consumption in all rail operations. The results for the three TOMAs are shown in Table 5.

The balance of the total fuel consumption — i.e., 80.44% — in 2001 was used outside of the three TOMAs across the rest of the country. The resulting emissions were therefore spread widely over areas with a relatively low population density.

6.2 Seasonal Data

The emissions in the TOMAs during 2001 have been divided according to two seasonal periods:

- Winter (7 months): January to April and October to December, inclusively.
- Summer (5 months): May to September, inclusively, as specified in the initiating MOU.

Data on the division of traffic by winter/summer periods were received from the major railways for their entire systems. The division of traffic in the TOMAs in the seasonal periods was then taken as equal to that on the whole system for each railway. As the split was very close to the proportion of days in the periods, the latter ratio was used for the smaller railways for which no seasonal traffic data were received.

The fuel consumption in each TOMA was therefore divided in the proportion derived for the traffic on each railway, except in the case of GO Transit in TOMA No. 2, where the actual seasonal fuel consumption data were available. The emissions in the seasonal periods were then calculated as before, the results being shown in Table 6.

Table 5: TOMAs Fuel Consumption as Percentage of Total Fuel Consumption

TOMA	1995	1996	1997	1998	1999	2000	2001
Lower Fraser Valley, B.C.	4.27	4.42	4.17	4.26	4.24	4.02	3.83
Windsor–Quebec City Corridor	14.7	15.3	14.83	16.29	17.13	17.35	15.62
Saint John area, N.B.	0.11	0.13	0.09	0.10	0.11	0.12	0.11

Table 6: TOMAs – Traffic, Fuel, and Emissions Data, 2001

					No.1 LOWER FRASER VALLEY, B.C.			No.2 WINDSOR–QUEBEC CITY			No.3 SAINT JOHN, N.B., AREA		
						SEASONAL SPLIT			SEASONAL SPLIT			SEASONAL SPLIT	
					GTM	Winter	Summer	GTM	Winter	Summer	GTM	Winter	Summer
CN				million gtm	5 301	58.0%	42.0%	37 588	58.0%	42.0%	355	58.53%	41.47%
CP				million gtm	9937	58.0%	42.0%	17 703	58.0%	42.0%			
B.C. RAIL *				million gtm	277	58.0%	42.0%						
BURLINGTON NORTHERN SANTA FE RAILROAD				million gtm	298	58.0%	42.0%						
SOUTHERN RAILWAY OF B. C.				million gtm	125	58.0%	42.0%						
GO TRANSIT				million gtm					58.6%	41.4%			
ESSEX TERMINAL RAILWAY				million gtm				20	58.0%	42.0%			
GODERICH - EXETER RAILWAY				million gtm				59	58.1%	42.0%			
CSX				million gtm				185	58.1%	42.0%			
CONRAIL				million gtm				0	58.1%	42.0%			
SO. ONT.-RAILINK				million gtm				135	58.1%	42.0%			
NORFOLK SOUTHERN				million gtm				591	58.1%	42.0%			
OTTAWA VALLEY - RAILINK				million gtm				399	58.1%	42.0%			
QUEBEC GATINEAU				million gtm				663	58.1%	42.0%			
QUEBEC SOUTHERN				million gtm				48	58.1%	42.0%			
ST. LAWRENCE & ATLANTIC				million gtm				66	58.1%	42.0%			
N.B. SOUTHERN RAILWAY				million gtm							80	58.08%	41.92%
TOTAL FREIGHT				million gtm	15 938			57 457			435		
VIA				million gtm	51	58.08%	41.92%	1533	58.1%	42.0%			
FUEL CONSUMPTION													
FUEL RATE - FREIGHT SERVICE				L/1000 gtm	4.8			5			5.0		
FUEL RATE - PASSENGER SERVICE				L/1000 gtm	16.1			16			16.1		
FREIGHT FUEL CONSUMPTION IN TOMA				million litres	76.5	44.4	32.1	286	165.9	120.1	2.2	1.3	0.212
VIA FUEL CONSUMPTION IN TOMA				million litres	0.8	0.5	0.3	25	14.4	10.4			
GO TRANSIT				million litres				4	2.6	1.8			
TOTAL FUEL CONSUMPTION IN TOMA				million litres	77.3	44.9	32.5	315	182.8	132.3	2.2	1.3	0.212
CANADIAN TOTAL FUEL CONSUMPTION				million litres	2017			2017.0			2017.0		
TOMA FUEL CONSUMPTION AS % CANADIAN TOTAL					3.83%			15.62%			0.11%		
EMISSIONS	EMISSIONS FACTORS (g/L)												
	MAINLINE	YARD	COMBINED**										
OXIDES OF NITROGEN (NO_x)	58.81	61.01	59.2	kilotonnes	4.58	2.66	1.92	18.65	10.82	7.83	0.13	0.07	0.05
CARBON MONOXIDE (CO)	10.51	10.42	10.5	kilotonnes	0.81	0.47	0.34	3.31	1.92	1.39	0.02	0.01	0.01
HYDROCARBONS (HC)	2.73	3.61	2.9	kilotonnes	0.22	0.13	0.09	0.91	0.53	0.38	0.01	0.00	0.00
SULPHUR OXIDES (SO_x)	2.54	2.53	2.5	kilotonnes	0.20	0.11	0.08	0.80	0.46	0.34	0.01	0.00	0.00
PARTICULATE MATTER (PM)	1.3	1.48	1.3	kilotonnes	0.10	0.06	0.04	0.41	0.24	0.17	0.00	0.00	0.00
CARBON DIOXIDE (CO_2)	2709	2709	2709	kilotonnes	209.49	121.51	87.98	853.64	495.26	358.46	5.87	3.43	2.60

Notes:
* B.C. RAIL gtm for TOMA No. 1 derived as % length of line in TOMA No. 1 of total line length.
** Combined emission factors derived from standard & yard factors with fuel consumption data from Table 1.

7.0 Observations

In 2001, the emissions of NO_x were above the voluntary cap of 115 kt. The higher NO_x emissions were the result of a new EF for NO_x and the increase in traffic since 1990, which was significantly greater than forecast when the MOU was signed in 1995. The beneficial effect of the introduction of new, more fuel-efficient locomotives, meeting U.S. EPA Tier 0 and Tier 1, into the fleet is expected to progressively reduce NO_x emissions in the future.

The rates of emission of NO_x and CO_2 in kilograms per 1000 NTM have decreased overall since the 1990s. The rate of decrease was greatest in 1998, 1999, and 2000, showing the effects of the continual improvement in the fuel efficiency of rail transportation.

One area of traffic growth has been in the movement of containers, which is extremely sensitive to highway competition. Although the tonnage of intermodal traffic on Canadian railways decreased by 0.27% in 2001, the increase in container movement since 1990 is significant, both in absolute terms and as a percentage of total tonnage moved.

8.0 Concluding Remarks

Traffic levels will continue to be monitored closely to determine if the recent accelerated increase in rail traffic is short term or representative of a higher rate of growth. If the latter case prevails, then consideration should be given to the revision of the measure by which improvements are reported. This concept was recognized in the EC Report "Recommended Reporting Requirements for the Locomotive Emissions Monitoring (LEM) Program."[6] This revision could, for example, be based on the division of traffic between modes of transport. It would give credit for the net reduction in emissions resulting from a diversion of traffic from the highway to the railways or for the avoidance of adding traffic to the highway mode.

The railway industry in Canada continues its long-term trend of improving the efficiency of its operations, including fuel consumption and emissions per unit of traffic hauled.

6 Environment Canada, Environmental Protection Series, Report EPS 2/TS/8, September 1994.

Appendix A:

Memorandum of Understanding between Environment Canada and the Railway Association of Canada

Part 1 — Introduction

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

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

Part 2 — Background

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

Part 3 — The Program

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

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

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

Part 4 — Reports

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

1. A list of the Gross Ton Miles (GTM), Net Ton Miles (NTM) and total fuel consumption data for railway operations plus estimates of the emissions of oxides of nitrogen (NO_x), hydrocarbons (HC), oxides of sulphur (SO_x), particulate matter (PM), carbon monoxide (CO) and carbon dioxide (CO_2) using the RAC emissions factors as corrected in Table 9 of the Report referenced above;

2. 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;

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

4. 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;

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

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

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

8. 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;

9. 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

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

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

Part 5 — General

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

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

DATED at this day of 1995

MINISTER OF THE ENVIRONMENT	THE RAILWAY ASSOCIATION OF CANADA
______________________________	______________________________
Sheila Copps	R.H. Ballantyne

Appendix B:

Canadian Locomotive Fleet – Mainline & Branchline, 2001

Builder*	Model	Engine Model	HP	Year	Total	CN	CP	Via Rail	B.C. Rail	GO Transit	Total Other
GM/EMD	SD-90 "H"	16V-265H	6000		4		4				0
	SD-90	16V-710G3C	4300		61		61				0
	SD-75	16V-710G3C	4300	96-01	179	173					6
	SD-70	16V-710G3B	4000	95	28	26					2
	SD-60	16V-710G3	3800	85-89	63	63					0
	F59PH	12V-710G3	3000	88-95	62					45	17
	SD-50	16V-645F3B	3600	85-94	60	60					0
	GP-45	20V-645	3200		2						2
	SD-45-2	16V-645	3200		6						6
	SD-40	20V-645E3	3200		2						2
	SD-40	16V-645E3	3000	66-80	683	234	438				11
	SD-40	16V-645E3B	3000	85-87	22				22		0
	SD-40	16V-645E3C	3000		51			51			0
	SD-40	16V-645D3A	2250	64-66	6						6
	GP-40	16V-645	3000		51	40					11
	SD-38	16V-645	2000		4						4
	GP-38	16V-645	2000		124	79					45
	GP-35R	16V-645	2500		3						3
	GP-35	16V-645	2000		2						2
	FP-9A	16V-645C	1800		7			7			0
	MP-15	12V-645	1500		3						3
	GP-9	16V-645	1800		26						26
	SW-1200	16V-645	1200		1						1
	SW-1000	8V-645E	900		2						2
	GP-35	16V-567C	2500	63	2						2
	GP-9	16V-567C	1750		7						7
	GP-9	16V-567C	1700		1						1
	F92B	16V-567C	1750		1						1
	GP-7	16V-567C	1500		1						1
	SW-9	8V-567C	900		10						10
Subtotal					**1474**	**675**	**503**	**58**	**22**	**45**	**171**
MLW		16V-251E	2400		7						7
		16V-251E	2000		1						1
	CE-424		2000		1						1
		12V-251	2000		6						6
		16V-251E	1800		21						21
	RS-23		1000		9						9
	Talent DM	BR643	1000		3						3
Subtotal					**48**	**0**	**0**	**0**	**0**	**0**	**48**
GE	Dash 9-44CM	16V-7FDL	4400	94-98	160	143			14		3
	Dash 9-44CW	16V-7FDL	4400	94-98	240		240				0
	P42DC	16V-7FDL	4250		18			18			0
	Dash 8-40CM	16V-7FDL	4000	90-94	83	55			26		2
	B39-8	16V-FDL16	3900	88	7				7		0
	B39-7	16V-FDL16	3600	80	10				10		0
	B39-7ME	16V-FDL16	3600	80	5				5		0
		12V-7FDL12	2250	89-90	3						3
Subtotal					**526**	**198**	**240**	**18**	**62**	**0**	**8**
Other	**Slug**	**1000**									**1**
Total Mainline & Branchline					**2049**	**873**	**743**	**76**	**84**	**45**	**228**

*GE/EMD = General Motors – Electromotive Division; MLW = Montreal Locomotive Works; GE = General Electric Transportation.

Appendix C:

Canadian Locomotive Fleet – Yard & Switching & Grand Total, 2001

Builder*	Model	Engine Model	HP	Year	Total	CN	CP	Via Rail	B.C. Rail	GO Transit	Total Other
GM/EMD		16V-645	3000		32		24				8
		16V-645E	2000	71-75,86	153	24	129				
		16V-645	1800		171	168					3
		16V-645	1750		197		196				1
		16V-645	1500		1						1
		12V-645E	1500	71-80	0						
		12V-645C	1350	87-89	0						
		12V-645	1200		32	30					2
		16V-567	1750		1						1
	GP-9	16V-567	1700		1						1
	SW-1500	16V-567	1500		28		19				9
	SW-1200	12V-567	1200		49		43				6
		12V-567	1200		2						2
		8V-567	900		2		2				
		8-695E			2			2			
Subtotal					**671**	**222**	**413**	**2**	**0**	**0**	**34**
MLW		Alco MRS18	1800		3				1		2
		12V-251B	1800	56-65	12						12
		12V-251B	1400	59-60	2						2
Subtotal					**17**	**0**	**0**	**0**	**1**	**0**	**16**
Other	CAT	12V-3512	2000		27				27		
	Budd RDC		520		2		2				
	Steam				6		1				5
	Slug				10				10		
	F9A or B		1750		8						8
	F97A		1750		1						2
			600		1						1
Subtotal					**55**	**0**	**3**	**0**	**37**	**0**	**16**
Total Yard & Switching					**743**	**222**	**416**	**2**	**38**	**0**	**66**
Total Mainline & Branchline					**2049**	**873**	**743**	**76**	**84**	**45**	**228**
Grand Total – Mainline, Branchline, Yard & Switching					**2792**	**1095**	**1159**	**78**	**122**	**45**	**294**

*GE/EMD = General Motors – Electromotive Division; MLW = Montreal Locomotive Works; GE = General Electric Transportation.

Appendix D:

Railway Lines Included in Tropospheric Ozone Management Areas

TOMA No. 1: Lower Fraser Valley, British Columbia

CP Rail System

Operations Service Area	Subdivisions
Vancouver	Cascade
	Mission
	Page

Canadian National Railway

Division	Subdivisions
Pacific	Rawlison
	Yale

B.C. Rail	**3.07% of total**
Burlington Northern Railroad	**All**
Southern Railway of British Columbia Ltd.	**All**

TOMA No. 2: Windsor–Quebec City Corridor, Ontario and Quebec

CP Rail System

Division	Subdivisions	Remarks
SLH Quebec	All	
SLH Ontario	All	
Northern Ontario	Chalk River	Smith Falls-Arnprior

Canadian National Railway

District — **Champlain**

Subdivisions

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

District — **Great Lakes**

Subdivisions

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

Essex Terminal Railway	**All**
Goderich – Exeter Railway	**All**
CSX	**All**
Norfolk Southern	**All**
Ottawa Valley – RaiLink	**Part**
Quebec – Gatineau	**All**
Quebec – Southern	**All**
So. Ont. – RaiLink	**All**
St. Lawrence & Atlantic	**All**

TOMA No. 3: Saint John area, New Brunswick

Canadian National Railway

District	Subdivisions
Champlain	Denison
	Sussex

Glossary: Terminology of Diesel Locomotive Emissions and Related Technology

CO (Carbon Monoxide): This toxic gas is a by-product of the combustion of fossil fuels. Relative to other prime movers, it is low in diesel engines.

CO_2 (Carbon Dioxide): This gas is by far the largest combustion by-product emitted from engines. Because of its accumulation in the atmosphere, it is considered to be the principal greenhouse gas contributing to global warming. 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 consumption. For transportation applications, this could include using more fuel-efficient engines or using more fuel-efficient modes for the transport of passengers, goods, and bulk commodities.

Duty Cycle: The duty cycle for a locomotive refers to the percentage of time the locomotive is operated at different power settings. Locomotives have eight power settings or "notches," plus low idle, idle, and dynamic braking settings.

Dynamic Braking: A term characterizing a train operating mode in which the traction motors of a locomotive are controlled to function as generators and, hence, retard the motion of the train. Dynamic braking requires an application of engine power equivalent to Notch 1 or 2 throttle setting. Dynamic braking reduces fuel consumption and, hence, exhaust emissions by eliminating braking under power (to keep the train stretched out).

EF (Emissions Factors): The EFs of a locomotive are the average mass of a product that is emitted in the combustion of a specified amount of fuel. They are calculations based on data from test measurements of specific emissions, the locomotive's operational duty cycle, and the specific fuel consumption of its engine. In this report, the units are grams of a specific pollutant per litre of diesel fuel consumed (g/L).

GTM (Gross Ton-Miles): Refer to the product of the tons carried and the distance travelled; the tons carried are the total weight of the train excluding the contribution of the weight of the locomotives pulling the train.

HC (Hydrocarbons): These are the result of incomplete combustion of diesel fuel and small amounts of lubricating oil that are not oxidized during the combustion process. HC emissions result from partial combustion caused by short combustion time and low combustion temperatures, which can occur during excessive idling at low power levels.

Locomotive Prime Mover: The medium-speed diesel engine provides the predominant motive power for locomotives in operation on Canadian railways. It has found its niche as a result of its fuel efficiency, ruggedness, reliability, and installation flexibility. Combustion takes place in a diesel engine by compressing air and then injecting diesel fuel near top dead centre where auto-ignition occurs (compression ignition).

Low-idle and Engine Shutdown Options: Outfitting locomotive engines with a low-idle option and, when in standby use, with mechanisms for automatic engine shutdown and restart (to avoid water coolant freezing) leads to reduced overall locomotive fuel consumption and emissions.

NO_x (Oxides of Nitrogen): These are the products of nitrogen and oxygen that result from high combustion temperature. NO_x have implications for the health of humans, animals, and the ecology. NO_x react with hydrocarbons to form low-level ozone in the presence of sunlight. The NO_x emission level can be lowered by reducing combustion temperatures; one way is to retard injection timing and another is exhaust gas recirculation, both of which could result in higher fuel consumption and lower total power from the engine.

NTM (Net Ton-Miles): Refer to the product of the tons of goods carried and the distance travelled; the tons of goods carried refer to the total weight of the goods in the cars of the train handled over the distance moved and include the ton-miles involved in the movement of railway materials.

O_3 (Ozone): This is a gas formed from the combination of NO_x, hydrocarbons, and sunlight. In lower atmospheric zones, ozone combines with other pollutants to form smog.

PM (Particulate Matter): This is residue of combustion, consisting of soot, unburned fuel, and lubricating oil. Increasing the combustion temperatures and duration can lower PM. Technologies that control NO_x, such as retarding injection timing, usually result in higher PM emissions. Conversely, technologies that control PM often result in increased NO_x emissions. However, reducing NO_x emissions will yield reductions in ambient concentrations of secondary PM. For example, it is estimated that about 4 tonnes of nitrate particulate are formed from every 100 tonnes of NO_x emitted.

Products of Combustion: The products of combustion include carbon dioxide, water vapour, partially combusted fuel — hydrocarbons (HC) and particulate matter (PM) — carbon monoxide, and the oxides of nitrogen (NO_x) and sulphur (SO_x). The high temperatures typical of combustion in the cylinder of a diesel engine cause oxygen and nitrogen from the intake air to combine as NO_x. NO_x are invisible, toxic gases and precursors to low-level ozone development and can form fine aerosol particles of salts that contribute to acidic precipitation (commonly known as acid rain, snow, or fog). If the combustion temperature is decreased to reduce NO_x, the amount of non-combusted fuel that may be emitted as PM or gaseous HC tends to increase. HC react with NO_x and other pollutants to form ground-level ozone (smog).

SO_x (Oxides of Sulphur): These are the result of burning diesel fuels that contain sulphur compounds. These emissions can be reduced by using diesel fuel with lower sulphur content.

Abbreviations

AAR	Association of American Railroads
CAC	Criteria Air Contaminants
CCME	Canadian Council of Ministers of the Environment
CN	Canadian National Railways
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COFC	Container on Freight Car
CP	Canadian Pacific Railway
DB	Dynamic Brake
EC	Environment Canada
EF	Emissions Factor
g	Gram
GE	General Electric Transportation
GM/EMD	General Motors - Electromotive Division
GTM	Gross Ton-Miles
h	Hour
HC	Hydrocarbons
HP	Horsepower
kg	Kilogram
kt	Kilotonne
L	Litre
lb.	Pound
LEM	Locomotive Emissions Monitoring
MLW	Montreal Locomotive Works
MOU	Memorandum of Understanding
N1 ...	Notch 1....
NO_x	Oxides of Nitrogen
NTM	Net Ton-Miles
PM	Particulate Matter
ppm	Part per Million
RAC	Railway Association of Canada
SO_x	Oxides of Sulphur
TOFC	Trailer on Freight Car
TOMA	Tropospheric Ozone Management Area
U.S. EPA	United States Environmental Protection Agency
Via Rail	Via Rail Canada

Participating Railways

(as of the end of 2001)

Agence métropolitaine de transport
Alberta Prairie Railway Excursions
Amtrak
Arnaud Railway Company
Athabaska Northern Railway Ltd.
Barrie-Collingwood Railway
BC Rail Ltd.
Burlington Northern (Manitoba) Ltd.
Burlington Northern and Santa Fe Railway Company, The
Canadian American Railroad Company
Canadian Pacific Railway
Cape Breton & Central Nova Scotia Railway
Capital Railway
Cartier Railway Company
Central Manitoba Railway Inc.
Central Western Railway
Chemin de fer Baie des Chaleurs
Charlevoix Railway Company Inc.
Chemin de fer de la Matapédia et du Golfe Inc.
CN
CSX Transportation Inc.
Esquimalt & Nanaimo Railway
Essex Terminal Railway Company
Ferroequus Railway Company Limited
GO Transit
Goderich-Exeter Railway Company Limited
Great Canadian Railtour Company Ltd.
Huron Central Railway Inc.
Kelowna Pacific Railway Ltd.
Lakeland & Waterways Railway
Mackenzie Northern Railway
New Brunswick East Coast Railway Inc.
New Brunswick Southern Railway Company Limited
Norfolk Southern Corporation
Ontario Northland Transportation Commission
Ontario Southland Railway Inc.
Ottawa Central Railway Inc.
Ottawa Valley Railway
Québec Gatineau Railway Inc.
Québec North Shore and Labrador Railway Company Inc.
Québec Southern Railway Company Ltd.
Roberval and Saguenay Railway Company, The
South Simcoe Railway
Southern Manitoba Railway
Southern Ontario Railway
Southern Railway of British Columbia Ltd.
St. Lawrence & Atlantic Railroad (Québec) Inc.
Toronto Terminals Railway Company Limited, The
Trillium Railway Company Limited
VIA Rail Canada Inc.
Wabush Lake Railway Company, Limited
West Coast Express Ltd.
White Pass & Yukon Route
Windsor & Hantsport Railway
Wisconsin Central Ltd.