TP 14106E

BIODIESEL AS A LOCOMOTIVE FUEL IN CANADA

Prepared for
Transportation Development Centre
Transport Canada

by

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Since the report deals with the North American railway sector as a whole, units of measure are a mixture of imperial and metric units (as per current Canadian railway convention) and American units (as per current railway convention in the U.S.A.).

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Principal Investigator Robert Dunn

Un sommaire français se trouve avant la table des matières.

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16. Abstract

This report addresses the applicability of biodiesel as a fuel for locomotives in Canada. A literature search was performed and the claims about biodiesel evaluated within the context of the Canadian railway sector. Biodiesel, either neat or blended with petrodiesel, can operate in medium-speed diesel engines in use by Canadian railways, particularly those manufactured before 2000.

For those locomotives manufactured after January 1, 2000, and meeting the U.S. Environmental Protection Agency (EPA) Tier 0, Tier 1 or Tier 2 limits, warranty issues and EPA emissions compliance requirements with biodiesel have yet to be addressed. This could involve extensive durability testing with biodiesel blends as well as EPA compliance testing.

To gain experience to use biodiesel as a fuel for locomotives in Canada, it is envisaged that first introduction be focused on specific locomotive fleets such as passenger operation or freight yard switching operations in specific regions. It is recommended that this step be preceded by laboratory comparative testing of biodiesel blends using both a single cylinder medium-speed diesel engine and a full-size locomotive. This will ensure that the railways have the technical knowledge available when commercial production in Canada can offer biodiesel blends that are price-competitive with petrodiesel.

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16. Résumé

Le présent rapport s'intéresse à l'utilisation éventuelle du biodiesel comme carburant de remplacement pour les locomotives au Canada. Une recherche documentaire a été effectuée; les allégations concernant le biodiesel ont été analysées dans le contexte du transport ferroviaire au Canada. Le biodiesel, à l'état pur ou mélangé avec du pétrodiesel, convient comme carburant pour les moteurs diesel à régime moyen utilisés dans le parc de locomotives des chemins de fer canadiens, particulièrement dans les locomotives construites avant 2000.

Dans le cas des locomotives construites après le 1er janvier 2000, dont les émissions sont conformes aux limites correspondant aux niveaux 0, 1 ou 2 de l'U.S. Environmental Protection Agency (EPA), les questions reliées aux garanties ainsi que la conformité aux normes d'émissions de l'EPA pour les moteurs utilisant le biodiesel n'ont pas encore été réglées. En conséquence, il pourrait être nécessaire de soumettre les moteurs à des essais intensifs de durabilité en fonctionnement avec différents mélanges de biodiesel puis à des essais de conformité aux normes de l'EPA.

Pour acquérir l'expérience nécessaire à l'emploi du biodiesel dans les locomotives canadiennes, on envisage dans un premier temps d'utiliser ce carburant de remplacement dans des parcs spécifiques de locomotives de manœuvre ou de locomotives affectées aux services voyageurs, dans des régions déterminées. Il est néanmoins recommandé que cette étape soit précédée d'essais comparatifs de différentes compositions de biodiesel, avec un moteur diesel monocylindre à régime moyen, à réaliser en laboratoire puis sur une locomotive en vraie grandeur. Lorsque la structure canadienne de production commerciale pourra offrir des mélanges de biodiesel à prix concurrentiel avec le prix du pétrodiesel, les transporteurs ferroviaires intéressés pourront mettre en pratique les connaissances techniques résultant de la recherche.

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EXECUTIVE SUMMARY

This project was initiated by the Transportation Development Centre of Transport Canada to evaluate the potential of biodiesel, or biodiesel blends with regular petroleum diesel fuel, as a suitable alternate fuel for medium-speed diesel engines used by Canadian railways. The interest in biodiesel stems from the reduction, of up to 80 percent, in greenhouse gases (GHG) emitted during the production/processing life cycle for biodiesel, as compared to petroleum diesel fuel (petrodiesel). The GHG reductions from biodiesel accrue primarily from the displacement of the petrodiesel consumed. Biodiesel emissions are also reported to be less harmful to human health. The interest of the railway sector in biodiesel, as voiced by the Railway Association of Canada, stems primarily from the potential to further reduce Canadian railway GHG on an annual basis. Also, in view of growing interest in biodiesel by various jurisdictions in Canada, the railway sector wishes to be prepared should incentives or mandating arise.

To address the applicability of biodiesel as a fuel for locomotives in Canada, a literature search was performed and the claims about biodiesel evaluated within the context of the Canadian railway sector. An important caveat for consideration by the railway sector is that any alternate fuel must be transparent vis-a-vis existing fueling arrangements, not diminish locomotive performance, be price-competitive with petrodiesel, and not have a negative influence on other important pollutant emissions such as the oxides of nitrogen (NOx).

Biodiesel, either neat or blended with petrodiesel, can operate in medium-speed diesel engines in use by Canadian railways, particularly those manufactured before 2000. For those locomotives manufactured after January 1, 2000, and meeting the U.S. Environmental Protection Agency (EPA) Tier 0, Tier 1 or Tier 2 limits, warranty issues and EPA emissions compliance requirements with biodiesel have yet to be addressed. This could involve extensive durability testing with biodiesel blends as well as EPA compliance testing.

GHG emissions reductions are realized, for the most part, on the production side of biodiesel. GHG reductions on the fuel consumption side for transportation are minimal. Neat biodiesel, however, could increase NOx by 2 to 5 percent and increase fuel consumption slightly. To accommodate the high cloud point of neat biodiesel, a blend of 20 percent biodiesel and 80 percent petrodiesel (designated as B20) would be the most appropriate for Canadian transport applications. Thus, with an annual consumption of approximately 2 billion litres per year, the Canadian railway sector represents a potential annual market of about 400 million litres of biodiesel. This would yield a GHG reduction for Canada of about 1.2 billion tonnes annually.

At present, biodiesel production in Canada is limited to small pilot plant quantities. Neat biodiesel is imported from the United States in railway tank car quantities and, currently, a B20 blend in road diesel tends to be a few cents per litre more expensive than petrodiesel. Provincial jurisdictions are promoting the use of biodiesel by eliminating the road tax on biodiesel. Similarly, in the 2003 budget, the federal government has eliminated the excise tax on biodiesel. Feasibility studies are under way for commercial-size biodiesel production plants in Canada that aim to have a pricing formula competitive with petrodiesel. This formula will likely include possibilities for generating revenue from emissions reduction trading that are being examined.

In conclusion, biodiesel can be used as an alternate fuel by Canadian railways. To gain experience, it is envisaged that first introduction be focused on specific locomotive fleets such as passenger operation or freight yard switching operations in specific regions. It is recommended that this step be preceded by laboratory comparative testing of biodiesel blends, using both a single cylinder medium-speed diesel engine and a full-size locomotive. This will ensure that the railways have the technical knowledge available when commercial production in Canada can offer biodiesel blends that are price-competitive with petrodiesel.

SOMMAIRE

Ce projet a été lancé par le Centre de développement des transports, de Transports Canada, dans le but d'évaluer le potentiel du biodiesel ou des mélanges de biodiesel et carburant diesel d'hydrocarbures (pétrodiesel), comme carburant de remplacement acceptable pour les moteurs diesel à régime moyen utilisés par les chemins de fer canadiens. Ce qui rend le biodiesel intéressant, c'est sa réduction éventuelle, jusqu'à 80 p. 100, des gaz à effet de serre (GES) émis durant la phase production/traitement de son cycle de vie, en comparaison des émissions produites par le pétrodiesel. La réduction des GES que permet le biodiesel est due principalement à sa substitution au pétrodiesel qui serait autrement consommé. Également, on signale que les émissions provenant de la combustion du biodiesel sont moins dangereuses pour la santé humaine. L'intérêt que manifeste le secteur ferroviaire pour le biodiesel, selon l'Association des chemins de fer du Canada, vient principalement du potentiel que présente ce carburant de réduire les GES émis chaque année par les chemins de fer canadiens. De plus, avec l'intérêt grandissant manifesté pour ce carburant par les différents niveaux d'administrations au Canada, le secteur ferroviaire veut être prêt à prendre les actions nécessaires en cas de mise en place d'incitatifs ou en cas de besoin.

Pour étudier l'utilisation du biodiesel comme carburant des locomotives au Canada, les chercheurs ont entrepris une recherche documentaire et ils ont évalué les allégations sur ce biocarburant dans le contexte du secteur ferroviaire canadien. Les transporteurs ferroviaires ont fait une mise en garde très importante : l'utilisation d'un carburant de remplacement doit être transparente vis-à-vis des arrangements actuels concernant les approvisionnements en carburant, et elle ne doit pas non plus réduire les performances des locomotives. Le prix du carburant de remplacement doit être concurrentiel par rapport à celui du pétrodiesel et il ne doit pas avoir de conséquences négatives sur les autres émissions importantes comme les oxydes d'azote (NO_x).

Le biodiesel, à l'état pur ou mélangé avec du pétrodiesel, peut être utilisé pour faire fonctionner les moteurs diesel à régime moyen qui équipent les locomotives des transporteurs ferroviaires canadiens, et plus particulièrement celles construites avant 2000. Dans le cas des locomotives construites après le 1er janvier 2000, dont les émissions satisfont aux limites des niveaux 0, 1 ou 2 de l'U.S. Environmental Protection Agency (EPA), les questions reliées aux garanties ainsi que la conformité aux normes EPA n'ont pas encore été réglées. Il faut donc envisager des essais intensifs de durabilité des moteurs en fonctionnement aux différents mélanges de biodiesel, et des essais de conformité aux normes EPA.

Les réductions d'émissions de GES sont pour la majeur partie réalisées durant la phase production du cycle de vie du biodiesel. Quant aux diminutions reliées à la consommation de carburant dans les transports ferroviaires, elles sont minimes. Or, le biodiesel à l'état pur pourrait faire augmenter les émissions de NO_x de 2 à 5 p. 100, et serait accompagnée d'une légère augmentation de la consommation. Pour tenir compte du point de trouble élevé du biodiesel pur, un mélange de 20 p. 100 de biodiesel et de 80 p. 100 de pétrodiesel (mélange désigné B20) conviendrait le mieux aux applications de transport au Canada. Ainsi, avec une consommation d'environ 2 milliards de litres par année, le secteur ferroviaire canadien représente un marché annuel potentiel de 400 millions de litres de biodiesel. Ces données

se traduiraient, pour le Canada, par une diminution annuelle d'environ 1,2 milliard de tonnes de GES.

À l'heure actuelle, la production canadienne de biodiesel est limitée aux faibles quantités qu'autorise une usine pilote de petite taille. Le biodiesel pur est importé des États-Unis par wagons-citernes. Le litre de mélange B20 coûte quelques cents de plus que le pétrodiesel. Les autorités provinciales encouragent l'utilisation du biodiesel en abolissant la taxe sur le biodiesel. Dans son budget de 2003, le gouvernement fédéral a éliminé la taxe d'accise sur le biodiesel. Des études de faisabilité sont en cours pour des installations commerciales de production de biodiesel au Canada, à des prix compétitifs par rapport au pétrodiesel. La formule prévoit vraisemblablement des revenus, qui pourraient être tirés d'un programme d'échange de réductions des émissions de gaz à effet de serre. Cette perspective est actuellement à l'étude.

Pour conclure, le biodiesel peut être utilisé comme carburant de remplacement par les compagnies de chemin de fer canadiennes. Pour acquérir l'expérience nécessaire à l'utilisation du biodiesel comme carburant des locomotives au Canada, on songe d'abord à une application de ce carburant de remplacement à des parcs spécifiques de locomotives de manœuvre ou de locomotives affectées aux trains de voyageurs, dans des régions définies. Il est recommandé de faire précéder cette étape d'une série d'essais comparatifs en laboratoire de différents mélanges de biodiesel, avec un moteur diesel monocylindre à régime moyen, puis dans une locomotive en vraie grandeur. Cette recherche permettra d'assurer que les compagnies de chemin de fer disposeront des connaissances techniques disponibles lorsque la production commerciale, au Canada, pourra offrir des mélanges de biodiesel à prix concurrentiel par rapport au prix du pétrodiesel.

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GLOSSARY

Terminology Related to Biodiesel as a Railway Fuel

Medium-Speed Diesel Engine: This is the type of diesel engine used in railway locomotives in Canada. It is characterized by rotational speeds of 900 to 1,100 rpm and power sizes ranging from 1,000 to 6,000 hp. 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, as compared to using a spark plug).

Biofuel: This is a renewable fuel that can be produced from vegetable oils, animal fats, used cooking oil, various biomass sources, and waste from industry sectors such as forestry.

Biodiesel: This is a biofuel, composed of fatty acid methyl esters, destined for compression ignition combustion in diesel engines. It can be used in either its neat form or as a blend with diesel-grade conventional fossil fuel.

CO (Carbon Monoxide): This gas is a by-product of the combustion of fossil fuels. Relative to other prime movers, it is low in diesel engines. CO is considered a "greenhouse gas" and its accumulation in the atmosphere contributes to global warming.

CO_2 (Carbon Dioxide): This gas is by far the largest by-product of combustion emitted from internal combustion engines and is the "greenhouse gas" that, due to its accumulation in the atmosphere, is considered to be the principal contributor to global warming. CO_2 and water vapour are normal by-products of the combustion of fossil fuels.

NOx (Oxides of Nitrogen): These are the products of nitrogen and oxygen that result from high combustion temperature. NOx has implications for the health of humans, animals and the ecology. NOx is a smog precursor when it reacts with hydrocarbons to form ozone in the presence of sunlight.

O_3 (Ozone): This is a gas formed from the combination of NOx, hydrocarbons and sunlight.

PM (Particulate Matter): This is residue of combustion consisting of solidified carbon particles (or soot) suspended in air that are formed by incomplete combustion of fuel and engine lubricating oil. Compression ignition (diesel) engines generate significantly higher PM emissions than spark-ignited engines.

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

ABBREVIATIONS, ACRONYMS AND SYMBOLS

Organizations, Societies and Agreements

AAR	Association of American Railroads
ASTM	American Society for Testing and Materials
CGSB	Canadian General Standards Board
CN	Canadian National Railway
CP	Canadian Pacific Railway
EC	Environment Canada
EMD	Electro-Motive Division of General Motors
GE	General Electric Transportation Systems Division
MOU	Memorandum of Understanding
RAC	Railway Association of Canada
US EPA	United States Environmental Protection Agency

1. INTRODUCTION

Biodiesel blended with regular petroleum diesel fuel, as an alternate fuel for diesel engines, is currently attracting the attention of the Canadian transportation sector. This attention stems from the approximately 80 percent reductions in life-cycle greenhouse gases (GHG) emitted during production/processing for biodiesel, as compared to petroleum diesel fuel (petrodiesel). The GHG reductions from biodiesel accrue primarily from the displacement of the petrodiesel consumed (1). Also, biodiesel has positive implications for human health (WS 1): it contains effectively no sulphur; the particulates emitted are reported to be less carcinogenic (2, 3) than those found in petrodiesel emissions; it is non-toxic; and it biodegrades more rapidly than petrodiesel (4).

Approximately two billion litres of diesel fuel are consumed annually by the 2,000 freight and passenger locomotives in the Canadian railway fleet (5). The prime mover in all but a few of these locomotives is the medium-speed diesel engine, having power levels ranging up to 6,000 horsepower. Diesel fuel is approximately 7 to 10 percent of railways' operating expenses (6). In Canada, the railways contribute 6 percent or approximately 5,400 kilotonnes (5) of the GHG emitted from all transportation sources. In view of the significance that diesel fuel has for the railways, alternate fuel sources and fuel management strategies are investigated regularly with the aim to reduce operating costs, enhance service performance, increase economic competitiveness and reduce the environmental impact.

The interest of the railway sector in biodiesel, as voiced by the Railway Association of Canada, stems primarily from the opportunity to further reduce GHG on an annual basis. Also, in view of growing interest in biodiesel by various jurisdictions in Canada, the railway sector wishes to be prepared should incentives or mandating arise.

This report addresses the applicability of biodiesel as a fuel for locomotives in Canada. A literature search was performed and the claims about biodiesel evaluated within the context of the Canadian railway sector. An important caveat for consideration by the railway sector is that any alternate fuel must be transparent vis-à-vis existing fueling arrangements, must not diminish locomotive performance and must be price-competitive with petrodiesel. In addition, the alternate fuel must not have a negative influence on other important pollutant emissions such as the oxides of nitrogen (NOx).

When the consideration arises to try an alternate fuel, a railway operator has a checklist of factors to ask about. These factors are the elements equivalent to the "well-to-wheel" life cycle for petrodiesel. This report attempts to address these factors, using the information and data obtained via literature searches and interviews with biodiesel researchers, fuel producers, equipment operators and government policy analysts.

The principal factors include the following:

- What is biodiesel and its feedstock?
- Where is biodiesel produced and what is its availability in Canada?
- What are its specifications vis-a-vis those of conventional railway diesel fuel?
- Which biodiesel fuel or blends should be chosen for a railway operation?
- How secure would the quality and supply of biodiesel and biodiesel blends be?
- How transparent is biodiesel for introduction into a railway operation?
- Are there safety procedures required that are different from handling petrodiesel?
- How does biodiesel affect locomotive performance?
- Are modifications necessary to the engine or locomotive systems?
- Has biodiesel been tried in medium-speed diesel engines?
- Does it have any negative effect on engine and locomotive seals/components?
- What are the engine manufacturers' warranty situations?
- Is the use of biodiesel compatible with the U.S. EPA emissions compliance?
- How would biodiesel or biodiesel blends be delivered to a railway fueling site?
- How does it perform in Canadian winters and during long-term storage?
- What are the emissions characteristics of biodiesel and biodiesel blends?
- Are there human health implications for railway operating crews and fuelers?
- What happens to biodiesel during accidents and spillage situations?
- What are expected prices of biodiesel and biodiesel blends to the railways?
- What are the federal and provincial taxation situations on the use of biodiesel?
- How would biodiesel help the railways meet their Kyoto Protocol goals?
- Can the railways accrue GHG emissions reduction credits that could be sold?
- What testing and evaluation are needed to verify biodiesel performance claims?
- What railway operations are possibilities to demonstrate and evaluate biodiesel?
- Are there envisaged public policy and public relations issues to be addressed?

The findings regarding the above-listed factors are contained in the following sections of this report.

2. BIODIESEL PROPERTIES

2.1 DESCRIPTION

Biodiesel is a fuel manufactured from animal or vegetable fats that has physical properties very similar to petroleum diesel fuel (7). Biodiesel is manufactured by chemically reacting seed oils – such as canola, palm or soy oils, "yellow grease" (waste cooking oils), and animal waste, including deadstock, from the rendering industry – with an alcohol such as methanol to produce chemical compounds known as methyl esters. Methyl esters, when used as fuel, are called biodiesel.

Most biodiesel processing requires treating the fats with alcohol under high temperature and pressure. Some processes require considerable time and energy while other processes, just now approaching commercialization, take much less time and react at lower temperatures. The products from the manufacturing process are methyl esters (biodiesel) and glycerin. The glycerin must be separated from the biodiesel component because it is a thick butter-like component that will block fuel filters.

Biodiesel can be used as a fuel for diesel engines in either its neat (100 percent) form or blended with petrodiesel with minimal or no modification of the diesel engine. Biodiesel dissolves completely in petrodiesel. The most common blended fuel, called B20, is 20 percent biodiesel and 80 percent petrodiesel.

The interest, in Canada, in biodiesel as a transportation fuel stems from the fact that biodiesel is reported to produce lower pollutant emissions from combustion, such as carbon monoxide and particulate matter. As well, the life-cycle GHG emissions are reported to be up to 80 percent lower than petrodiesel (1). Most of the GHG emissions reduction takes place at the feedstock production stage, compared to the refining stage of petrodiesel. A rule of thumb is that petrodiesel refined from Athabaska tar sands requires an input of 1.2 barrels of oil to produce a barrel of synthetic crude; petrodiesel refined from oil wells requires 0.8 barrels of oil to produce a barrel of finished product; and 0.3 barrels of oil (equivalent) is required to produce a barrel of biodiesel.

2.2 AVAILABILITY IN CANADA

At present, no biodiesel is produced in Canada except for small quantities from pilot plant production. However, neat biodiesel is imported in railway tank car quantities from the U.S. by companies such as Canada Clean Fuels, Etobicoke (WS 2), for blending and sale to truck and bus fleets operating in urban areas. The imported biodiesel meets ASTM specification D 6751 and is from soy feedstock produced in Iowa and Nebraska, the producers of which benefit from a US$1.00 to $1.50 subsidy per U.S. gallon. This subsidy is provided by the Commodity Credit Corporation, an arm of the U.S. Department of Agriculture. The motivation for the subsidy is to reduce the dependence on imported energy supplies and act as an indirect way of supporting the U.S. farm economy.

In Canada, production pilot plants produce biodiesel, using a variety of proprietary processes, from grain-based feedstock as well as from waste cooking oils and animal fats. Pilot plants producing biodiesel in either batch or continuous quantities are described in sections 2.2.1 through 2.2.3.

2.2.1 Innovation Place Bioprocessing Centre, Saskatoon, Saskatchewan

This facility is owned by the Government of Saskatchewan (WS 3) and is made available to the agriculture and food sector to develop new products from oil-seed feedstocks. Biodiesel can be produced in batches of approximately 30 tonnes per day. The product is produced to meet the ASTM D 6751 biodiesel fuel specification. The preferable feedstocks at this site are canola and soy. Corn, wheat and grain-based waste have also been examined. Developmental biodiesel processing at this facility has been undertaken by scientists from Agriculture and Agro-Food Canada, the University of Saskatchewan and other organizations sited in the region. The Centre charges between $0.90 and $1.10 per litre for neat biodiesel. The price is influenced by the current prices of oil and natural gas, which fuel the Centre's bioprocess.

2.2.2 BIOX Corporation, Oakville, Ontario

This facility has been purposely built to demonstrate the production of biodiesel based on the proprietary process developed by Dr. David Boocock of the University of Toronto's Chemical Engineering and Applied Chemistry Department. BIOX is a technology development company that is a joint venture of the University of Toronto Innovations Foundation and Madison Ventures Ltd. (WS 4). Its process uses base-catalyzed trans-esterification (specifically transmethylation) of fatty acids to produce methyl esters. It is a continuous process and is not feedstock specific. The unique feature of the BIOX process is that is uses inert reclaimable co-solvents in a single pass reaction taking only seconds at ambient temperature and pressure. The developers are aiming to produce biodiesel that is cost competitive with petrodiesel. The BIOX process handles not only grain-based feedstocks but also waste cooking greases and animal fats. A not insignificant supply of the latter is deadstock. The deadstock supply is from the 7 percent of the farm animals that die annually and have to be disposed of. Prior to the outbreak of Creutzfeldt-Jacob Disease ("mad cow disease") in Europe, deadstock was processed into animal feed. Processing deadstock into biodiesel offers a 'win-win' opportunity to generate revenue from what could otherwise be a serious carcass disposal and environmental problem. BIOX is in negotiation with fuel supplier companies to supply its technology for the construction of a 60 million litre-per-year production facility.

2.2.3 Rothsay, Ville Ste. Catherine, Quebec

Rothsay (WS 5), a division of Maple Leaf Foods, produces biodiesel in a batch process on an as-required basis. Its process can use any of the above mentioned feedstocks. Rothsay produced the biodiesel for the City of Montreal's BIOBUS demonstration (WS 6) that recently ended after one year of operation. The BIOBUS project was a one year trial of biodiesel in the bus fleet assigned to one of the seven garages of the Société de Transport de Montréal. Both seed oils and animal fats have been processed by Rothsay.

Officers associated with some of the pilot plants have indicated plans are in-hand to build commercial-sized plants having an annual output capacity of up to 60 million litres. The plant developers and financial backers are very aware that the overall economics of commercial-sized plants must yield a pricing formula competitive with petrodiesel. Otherwise, there will be no purchasers and hence no market in Canada for biodiesel.

Various studies indicate that the Canadian biodiesel production potential is 5 billion litres per year, using feedstock from the three basic sources: grains, waste cooking grease and deadstock. An influencing factor that could affect this potential is the impact of drought on availability of grain-based feedstock. For example, because of drought in the Prairie Provinces during 2002, the production of canola dropped to 3 million tonnes from the usual season's crop of 6 to 8 million tonnes. However, another projection is that, as the market demand increases, farmers could dedicate for biodiesel production high-yield genetically-modified canola that might not be acceptable for human consumption. It is presumed that the supply of deadstock will remain relatively stable.

2.3 PHYSICAL PROPERTIES

Technically, the term "biodiesel" refers to the fuel in its neat or pure state. This is designated as B100. For transportation applications, economics lead to blending the biodiesel with petrodiesel. For example, the most common blend is 20 percent biodiesel and 80 percent petrodiesel, which is referred to as B20.

2.3.1 Typical Properties

The physical properties of biodiesel (7) are compared to petrodiesel (8) in Table 1.

Table 1: Typical Physical Properties of Railway Petrodiesel and Biodiesel

Physical Characteristic	Petrodiesel	Biodiesel
Fuel composition	Hydrocarbons	FAME*
Carbon chain length	C10-C21	C12-C22
Specific gravity (kg/L @ 15°C)	0.845	0.880
Kinematic viscosity @ 40°C	2.2 to 4.8	3.7 to 5.8
Cetane number	40 to 45	46 to 70
Higher heating value (BTU/lb.)	18,540	16,928 to 17,996
Higher heating value (MJ/kg)	42	38.5 to 41.7
Lower heating value (BTU/lb.)	17,540	15,700 to 16,735
Lower heating value (MJ/kg)	40.6	36.4 to 38.8
Sulfur, % mass	0.04 to 0.25	0.0 to 0.0024
Cloud point (°C)	**	-1.1 to -3.9
Pour point (°C)	**	-40 to 13
Flash point (°C)	40 to 60	100 to 170
Iodine number	NA	60 to 135
Carbon wt (%)	86.5	77

* Biodiesel fuel typically contains up to 14 different types of fatty acids that are chemically transformed into fatty acid methyl esters (FAME).

** Cloud point and pour point are manufactured to suit the locale where the fuel is to be consumed. The 2.5% winter design temperature is used as a guide.

2.3.2 Specifications

The American Society for Testing and Materials (ASTM) published a specification for neat (100 percent) biodiesel – ASTM D 6751. The European specification for pure biodiesel is DIN 952. The specifications aim to ensure that biodiesel has the fuel properties for safe operation in a compression ignition (diesel) engine and to ensure that poor processing has not contaminated the fuel with products that will create engine damage. The standards are independent of any manufacturing process or feedstock. Table 2 details ASTM D 6751.

Table 2: ASTM D 6751 Biodiesel Fuel (B100) Blend Stock for Distillate Fuels

Property	Test Method	Limits
Flash Point, °C	D 93	130.0 min
Water and Sediment, % vol	D 2709	0.050 max
Kinematic Viscosity, 40°C, mm^2/sec	D 445	1.9 - 6.0
Sulfated Ash, % mass	D 874	0.020 max
Sulfur, % mass	D 5453	0.05 max
Copper Strip Corrosion	D 130	No. 3 max
Cetane Number	D 613	47 min
Cloud Point, °C	D 2500	Report
Carbon Residue, 100% sample, % mass	D 4530	0.050 max
Acid Number, mg KOH/gm	D 664	0.80 max
Free Glycerin, % mass	D 6584	0.020 max
Total Glycerin, % mass	D 6584	0.240 max
Phosphors content, % mass	D 4951	0.001 max
Distillation, 90% recovered, °C	D 1160	360 max

Specifications for biodiesel blends are under development. For example, the Canadian General Standards Board (CGSB) has work in progress toward producing a standard for a 20 percent blend. Similarly ASTM has a provisional standard for a 20 percent biodiesel (PS 121), which is shown in Table 3.

Table 3: ASTM PS 121 Biodiesel B20 Biodiesel Blend

Property	Test Method	Limits
Flash Point, °C	D93	100.0 min
Water and Sediment, % vol	D2709	0.050 max
Kinematic Viscosity, 40°C, mm^2/sec	D445	1.9 - 6.0
Sulfated Ash, % mass	D874	0.020 max
Sulfur, % mass	D5453	0.0015 max
Copper Strip Corrosion	D130	No. 3 max
Cetane Number	D613	46 min
Cloud Point, °C	D2500	Report
Carbon Residue, 100% sample, % mass	D4530	0.050 max
Carbon Residue, Ramsbottom, % mass	D524	0.090 max
Acid Number, mg KOH/gm	D664	0.80 max
Free Glycerin, % mass	D6584	0.020 max
Total Glycerin, % mass	D6584	0.240 max

2.4 CRITICAL PROPERTIES

Several of the physical properties in Tables 2 and 3 are important for Canadian railway operation, particularly in the winter.

2.4.1 Cloud Point

The cloud point is the temperature at which waxes first start to crystallize in diesel fuel. Cloud point is an indication of the lowest temperature at which diesel fuel can be used before wax crystals will block fuel filters. It predicts, therefore, the lowest temperature of the fuel for operability. Diesel fuel is refined to be above the cloud point for a specific locale of railway operation. Generally in Canada, fuel is designed to the 2.5 percent winter design temperature (WDT). The 2.5 percent WDT is defined as the percentage of time the monthly temperature falls below the indicated temperature. For example, a 2.5 percent WDT of -25°C means that, statistically, 2.5 percent of the time the temperature in that monthly period drops below -25°C. Statistics are available in 15 day periods for every month and have been recorded at every airport in Canada.

Biodiesel has a higher cloud point than petrodiesel. The cloud point of neat biodiesel can be from -10°C to +20°C depending on the raw material source (3). When blended with petrodiesel at 20 percent (B20), the cloud point can be 3 to 5°C higher than petrodiesel. This introduces a higher degree of risk of fuel filter blockages with waxy components than with petrodiesel in winter. Canadian diesel fuel is treated with additives that keep the wax crystals from agglomerating into large crystals. It is likely these additives will be similarly effective with biodiesel.

Canadian railways have designed their locomotive fuel tanks so that, in winter, hot fuel from the engine is returned to a “hot well” or a specific compartment of the fuel tank. Fuel drawn into the engine for combustion is drawn from the hot well or hot compartment. This design has permitted Canadian railways to operate with a minimum of risk of fuel filter blockages caused by wax build-up on the filters. The highest risk with any fuel is when a full load of fuel is introduced into a locomotive fuel tank and the locomotive immediately powers up to full power for heavy haul service. Any wax crystallization in the fuel would quickly block fuel filters as the “hot well” would not have enough time to melt the wax.

It is yet to be determined whether B20 blends can perform in a satisfactory manner in locomotives under Canadian winter operations. Investigations in this regard will be required. However, indications from Canada Clean Fuels are that no cloud point problems arose in the B20 blend delivered to truck and bus fleets in the Toronto region during the winters of 2001-02 and 2002-03, the latter being particular severe.

2.4.2 Energy Content

The energy content of neat biodiesel, measured as MJ/kg, is 1 to 10 percent less than petrodiesel (3), depending on raw material sources (7). A B20 blend would have a proportionate reduction in energy content. This suggests a 0.2 to 2.0 percent increase in fuel consumption based on energy content alone. Locomotive operating range, therefore, could be slightly less than with petrodiesel. Tests done at the Southwest Research Institute on a GM EMD GP-38 locomotive (9) showed that the test locomotive was capable of obtaining full power output with biodiesel. Although this single test is the only data available at this time, it suggests that biodiesel would not compromise horsepower requirements to any significant degree. In Canadian railway applications, sustained power for heavy haul over mountainous terrain is an important criterion for biodiesel acceptability.

In some tests with high-speed diesel engines in fleets such as buses, some operators have reported a loss of power with biodiesel blends. Upon investigation, however, it was found that fuel filters were becoming blocked with contaminants such as soot or glycerin. It is important, therefore, to separate biodiesel quality (contaminants) issues from biodiesel energy content as a reason for reports of power loss with biodiesel.

2.4.3 Glycerin Content

Glycerin is a thick butter-like by-product of the production of biodiesel and must be removed at the manufacturing plant, before delivery. A small amount of glycerin contaminant would cause fuel filter blockage, particularly at the point of delivery. Fuel transfer filters would block quickly if glycerin were present in the biodiesel.

2.4.4 Stability

Stability is a broad term that describes the ability of fuel to withstand hot and cold temperatures, and to resist oxidation and water absorption. Biodiesel is possibly less stable than petrodiesel because of the nature of the methyl ester chemicals in biodiesel. The laboratory tests that predict stability are acid number and iodine number. The higher the numbers, the more susceptible the fuel is to stability problems. Different feedstocks have been found to have different laboratory test results (7). It is not known how these tests correlate to actual in-service locomotive biodiesel performance.

Long-term storage stability and thermal stability of biodiesel should be evaluated under Canadian railway operations. Test programs to date indicate that both storage and thermal stability has not been a problem in truck and bus fleet demonstration projects; however, no experience has been gathered under Canadian railway operations where large wayside fuel storage tanks and locomotive hot wells are common. This is a property that requires careful study.

2.4.5 Lubricity

Diesel fuel additive quantities of less than 1 percent have been used in regular diesel fuel to add lubricity to the fuel. Lubricity of some low-sulfur (500 ppm) diesel fuel has been found to be a problem for some engine fuel pumps and injection equipment. Lubricity additives are now quite common in diesel fuel. Lubricity in Canadian railway engines has not been identified as a problem. Canadian railway experience with low-sulfur diesel fuel, hence low lubricity, is extensive. For example, low-sulfur diesel fuel derived from the Athabaska tar sands has been used in locomotives operating in western Canada since the early 1970s.

2.5 BIODIESEL BLENDS

Biodiesel can be used without engine modification in diesel engines at very low percentages (less than 1 percent) and up to neat (100 percent). Neat biodiesel has been tested in the Tri-Country Commuter Rail Authority (Tri-Rail) in Florida without operating problems (10). Neat biodiesel has a cloud point of around 0°C, which is all right for Florida but not for Canadian winter operations, where it is generally set at -15 to -25°C.

The most common biodiesel blend is a 20 percent mixture of biodiesel in petrodiesel, commonly designated as B20. This has been chosen primarily for operational reasons. The cloud point of B20 raises the cloud point of petrodiesel from 3 to 5°C. The B20 blend also lowers the cost to close to that of petrodiesel and brings the energy content close to that of petrodiesel.

In Europe, most regular diesel fuel contains 2 to 5 percent biodiesel. The European position with regard to mandatory content of biofuels in diesel has recently changed (WS 7). In its new proposal, the European Parliament has amended the Council's common position in regard to the mandatory content of biofuels in diesel and gasoline. In the modified version of the proposal, the Parliament has replaced the mandatory targets for biofuels with the concept of "reference figures" for the total of biofuels placed on the market. The reference figures were set at 2 percent for 2005 and 5.75 percent for 2010.

2.6 FUEL CONSUMPTION

Fuel consumption is expected to increase slightly with biodiesel because of the lower energy content, that is, a 36.4 to 38.8 MJ/kg lower heating value for biodiesel versus 40.6 MJ/kg for petrodiesel. The amount of increase would vary with service and blending ratio, but is expected to be approximately 1 percent with a B20 fuel.

2.7 COSTS

Costs of biodiesel are related to the source of the raw (feedstock) material (7). Waste products such as "yellow grease" or animal fats from the rendering industry, including deadstock, are quite inexpensive at the present time. "Yellow grease" would have virtually no cost as a feedstock until the demand for it becomes competitive between biodiesel manufacturers. Animal fats have an additional cost that would be associated with preparing the tallow for processing. The production cost for biodiesel for these feedstocks would be in the order of 25 to 35 cents per litre (7). Adding a profit margin and taxes to the production cost makes the market price approximately 55 cents per litre. Currently, Canadian railways purchase petrodiesel at 40 to 45 cents per litre. A B20 biodiesel, even with some tax relief, would still be about 2 to 3 cents per litre more expensive than petrodiesel.

The amount of "yellow grease" or animal fats available for processing into biodiesel would be sufficient to supply one Canadian biodiesel processing plant with an output of 60 million litres per year. Higher production of biodiesel would require the processing of seed oils (6).

Soy and canola oils are commodities traded on the international markets; therefore, the cost of seed oils for biodiesel production would be market driven. These oils would be the most expensive of the raw material biodiesel production costs. It is predicted that soy oil, for example, would have production costs of about 50 cents per litre. Added to this would be taxes and mark-up, which would make biodiesel from seed oils such as soy about 60 cents per litre. A B20 blend would therefore be 3 to 4 cents per litre higher than petrodiesel. The cost differential between biodiesel and petrodiesel would become less if market prices of petrodiesel increased while those of biodiesel either decreased or remain unchanged.

Production costs are expected to decrease when commercial-size plants come into production. At the present time in Canada, only small demonstration plants exist. Production costs have therefore not yet been optimized. The BIOX Corporation envisages biodiesel production costs to be competitive with petrodiesel for a commercial-size production plant that uses its proprietary process.

3. BIODIESEL EXPERIENCE

Despite its cost, biodiesel is a fast growing alternate fuel. In road transportation, 200 biodiesel-fuelled public and private fleets in Canada and the U.S. have accumulated 100 million kilometres. It is being promoted for several reasons:

a) as new market opportunities for farmers. Canadian provincial governments, such as Alberta, Saskatchewan and Ontario (11), foresee biodiesel as a value added product that would increase farm revenues;

b) as a solution to a significant waste disposal problem. Waste animal fats from the rendering industry are no longer reprocessed into a protein supplement for animal feed because of the risk of Creutzfeldt-Jacob Disease ("mad cow disease"). Consequently, there have been few markets for deadstock and other animal fats. Biodiesel production would help solve this major problem;

c) as being acceptable under the Clean Air Act in the United States that promotes the use of alternate fuels, including biodiesel.

Because of its current higher price, market acceptance of biodiesel has been the major obstacle to be overcome. Tax reduction or tax elimination has been a method used by governments to promote the use of biodiesel. Also, consistent biodiesel quality has been a concern in the past. This has been overcome by the development of biodiesel specifications that producers must meet. The next step will be to develop a specification for biodiesel blends, such as a B20, that would ensure the quality of the blended fuel.

In Canada, several truck and bus fleet operators have underway or have undertaken biodiesel trials. These include the Toronto Hydro truck fleet and the Société de Transport de Montréal (STM) bus fleet.

3.1 USE IN HIGH-SPEED DIESEL ENGINES

The STM is a source of Canadian operating experience. The STM BIOBUS project experience shows that the engines in its buses, Detroit Diesel 6V-71 and 6V-92 and Cummins 8.3 turbo, have been operating during the one-year trial at one of its seven garages with a minimum of problems. The project was funded ($1.3 million) by NRCan and several Quebec provincial departments. Rothsay produced the biodiesel in its pilot plant on an as-required batch basis and splash blended the biodiesel with petrodiesel to produce a B20. The biodiesel is added hot (35^{o}C) to the truck containing petrodiesel, which could be at temperatures as low as -15^{o}C in Montreal winters. Truck delivery is to indoor storage at STM.

Sources at STM report that at the start of the trial, bus filters were rapidly blocked with what appeared to be soot. The investigation into the problem indicated that the biodiesel blend was lifting soot off the walls of the bus fuel tank and depositing it on the bus fuel filters. Biodiesel has some detergent properties that account for this soot lifting. After this initial start-up difficulty the buses operated without operating problems during the one-year trial. Several incidences of glycerin contamination, causing truck delivery unloading filters to block, were reported.

There were also reports of loss of power by drivers; however, it has been difficult to establish the reason for the reports. These are common even with buses operating with standard diesel fuel.

3.2 USE IN MEDIUM-SPEED DIESEL ENGINES

There is limited biodiesel experience with medium-speed diesel engines. The Tri-County Commuter Rail Authority (Tri-Rail), a passenger railway operating along the intercoastal waterway in Florida, used neat biodiesel for a three month period without any operating problems (10). The test was run on an F40PHL-2, 3,200 horsepower locomotive. Of interest to Tri-Rail was the enhanced biodegradation of biodiesel compared to petrodiesel. The intercoastal waterway would be sensitive to diesel fuel spills. The trial ended after three months and proved that this locomotive could run satisfactorily on biodiesel, if necessary. The higher cost of biodiesel makes its continued use prohibitive at this time.

In California, the Sierra Railroad is running on neat biodiesel (WS 8). It is using locomotive engines to generate electrical power. The interest here is the lower GHG emissions of the overall biodiesel life cycle compared to petrodiesel.

As well, there are older models of medium-speed diesel engines in barge service undergoing biodiesel trials. The experience to date shows that there are no short-term operating problems when using biodiesel in medium-speed diesel engines.

3.3 USE IN GAS TURBINE ENGINES

The recent unveiling in Canada by Bombardier Transportation (WS 9) of its prototype high-speed JetTrain passenger train powered by a Pratt & Whitney Canada PW150 gas turbine raised the question as to its operability on biodiesel or biodiesel blends. The 5,000 horsepower gas turbine is an aero-derivative and originally designed to operate on JT8 aviation jet fuel. It has been modified to operate on ASTM 975 diesel No.2 fuel. Information from Pratt & Whitney Canada revealed that, to date, no performance or emissions testing has been done using biodiesel. Should testing using biodiesel occur, the aspects of critical interest to the development engineers would be the effect of low ambient temperatures on startability and operations, and whether the biodiesel would produce smoke and undue carbon erosion of the combustor nozzle and turbine blades.

4. EMISSIONS

4.1 POLLUTANTS

Most biodiesel emissions testing has been performed on high-speed diesel engines and has provided some indicators on what might be expected in medium-speed diesel engines (WS 1). Table 4 summarizes the test results of the National Renewable Energy Laboratory, a division of the U.S. Department of Energy, regarding emitted pollutants from biodiesel and biodiesel blends versus petrodiesel.

Table 4: Emissions Reduction of Biodiesel Relative to Petrodiesel

Pollutant	B20	B10
Unburned Hydrocarbons, %	-11.09	-56.3
Particulate Matter, %	-18.0	-55.4
NOx, %	+1	+6
CO, %	-13	-43
CO_2, %	-16	-78

The Southwest Research Institute (SwRI) tested B20 biodiesel in a GM EMD GP-38 locomotive and found similar results to that found in high-speed diesel engines (9). NOx increased 5 to 6 percent; HC increased 1 percent, and CO decreased by approximately 20 percent. PM did not decrease, but it was noted that, with this older two-stroke engine, PM is mostly lubricating oil derived.

The NOx increase is of concern to Canadian railways (12). The Railway Association of Canada (RAC) has signed a Memorandum of Understanding (MOU) with Environment Canada (EC) in which it has agreed to cap NOx emissions at 115 kilotonnes per year through to 2005 (13). Because of the significant increase in traffic since the MOU was signed in 1995, the RAC annual report shows that the railways are always very close to the cap (5), even with all the fuel saving initiatives implemented by RAC members. Biodiesel could make it more difficult for the RAC to meet its NOx cap with EC.

Extrapolating the emissions profile from truck-size high-speed engines to medium-speed locomotive engines is problematic. It is thus desirable that a systematic comparative testing program be commissioned to establish a sound database on emissions from Canadian locomotives. In particular, there is a need to perform testing on Canadian freight locomotives, such as the older model GM EMD SD-40 locomotives, to more closely align test data to the Canadian fleet.

4.2 GREENHOUSE GASES

The purported reductions in GHG emissions of up to 80 percent are “life cycle” reductions (1). It has been determined that these GHG emissions reductions are almost entirely on the production side of the life cycle. Formulae have been established that determine the CO_2 absorption in growing seed grains, such as soy and canola beans, and the production energy consumption compared with petrodiesel refinery production (9). Figures as high as 80 percent in reductions have been determined in favour of biodiesel.

On the transportation side, the CO_2 reduction appears to be minimal. This is because of the lower energy content and slightly higher fuel consumption of biodiesel. Reports show the CO_2 to be +/- 1 percent of petrodiesel, depending on the engine.

Although the net benefit to Canada as a whole would be positive with biodiesel, there would most likely have to be some financial incentive or advantage before Canadian railways would agree to use biodiesel.

4.3 EMISSIONS CERTIFICATION

New Canadian locomotives have been and are being purchased to the U.S. EPA tier level in effect at the time of purchase. These locomotives were certified as EPA-compliant using typical in-service diesel fuel. In 1998 the U.S. EPA promulgated its "Rules and Regulations on Emission Standard for Locomotives and Locomotive Engines" in 1998 (13). Clause 92.113c, dealing with other fuels, states: "For locomotives or locomotive engines which are designed to be capable of using a type of fuel (or mixed fuel) other than diesel fuel or natural gas fuel (eg. methanol), and which are expected to use that type of fuel (or mixed fuel) in service, a commercially available fuel of that type shall be used for exhaust emissions testing. …" This means that in order to maintain U.S. EPA certification when using biodiesel, U.S. EPA-compliance testing would have to be performed on existing U.S. EPA-compliant locomotives originally certified with petrodiesel. Table 5 lists the U.S. EPA emissions limits and introduction schedule.

Table 5: Emissions Standards for Locomotives (g/bhp-hr)

Duty Cycle	HC*	CO	NOx	PM
Tier 0 (1973 - 2001)				
Line-haul	1.0	5.0	9.5	0.60
Switcher	2.1	8.0	14.0	0.72
Tier 1 (2002 - 2004)				
Line-haul	0.55	2.2	7.4	0.45
Switcher	1.2	2.5	11.0	0.54
Tier 2 (2005 and later)				
Line-haul	0.3	1.5	5.5	0.20
Switcher	0.6	2.4	8.1	0.24
Current Estimated Locomotive Emissions Rates (1997)				
Line-haul	0.5	1.5	13.5	0.34
Switcher	1.1	2.4	19.8	0.41
* *HC standard is in the form of total hydrocarbons (THC) for diesel engines. For locomotives and locomotive engines fuelled by alcohol or natural gas, equivalent THC standards apply.*				

4.4 EMISSIONS TRADING

The prospect of emissions reduction trading arose in the context of the National Round Table on the Environment and Economy that was convened in 2000. The National Round Table concluded that "there were merits to an emissions trading regime whereby companies that emit GHG would meet their commitments either by reducing their emissions directly or by purchasing domestic offsets or international permits. The requirement for emitters to hold permits for their emissions creates an incentive for the use of lower-emissions technologies and energy sources"(15). Now that the Kyoto Protocol has been ratified by the Government of Canada, the status as described in the Climate Change Plan for Canada is that "the Government of Canada will continue to work with industry, provinces, territories and stakeholders to clarify the architecture on a workable, efficient and effective domestic emissions trading system." (WS 10).

How the final emissions trading scheme unfolds will be of obvious interest to the railway sector. It is conceivable that the GHG reductions stemming from use of biodiesel fuel could yield credits that could be traded and revenue generated therefrom. However, indications are that the producers of alternate fuels emitting lower GHG feel that they should own the credits. Other viewpoints are that these credits should be shared with the user of the fuel. This stance is based on the logic that without the user's role, there would be fewer markets for the fuel producer and, hence, fewer opportunity to earn credits. It is expected that future development to define the domestic emissions trading system will be monitored by the Canadian railway sector.

5. WARRANTY ISSUES

Warranty of new locomotives is an important issue for Canadian railways. It is also important when locomotive replacement components are purchased. At this point, the two North American locomotive engine builders are still developing their position on biodiesel usage in their locomotives.

Two areas where biodiesel is of concern to the engine builders are described in sections 5.1 and 5.2.

5.1 ENGINE RELIABILITY

Locomotive manufacturers issue performance warranties based on specific diesel fuel properties outlined in their diesel fuel specifications. Using diesel fuel outside of these specified properties could reduce engine performance and reliability, and could void the warranties requiring the use of standard diesel fuel. To satisfy the locomotive manufacturers that biodiesel blends would perform in their engines without a negative impact on performance, the engine builders or interested railways would have to undertake extensive testing and evaluation. Appendix A outlines a proposed test program that would generate data to quantify the performance and emissions from the use of biodiesel blends.

5.2 EMISSIONS COMPLIANCE

Canadian railways purchase locomotives from manufacturers that certify their engines meet U.S. EPA emissions regulations. The certification has been issued based on specific petrodiesel fuel properties outlined in the U.S. EPA rules. Biodiesel chemical properties are different from petrodiesel. As a consequence, biodiesel would require new U.S. EPA-compliance testing. Without this testing, the locomotive manufacturers could not certify their locomotives as U.S. EPA compliant.

6. GOVERNMENT POLICY

6.1 TAXATION ISSUES

6.1.1 Federal

Canadian railways pay a federal excise tax of approximately 4 cents per litre on diesel fuel. In order to promote the use of biodiesel, the federal government has eliminated this excise tax on the biodiesel component. With blend rates of 20 percent, the maximum effect on costs would be less than 1 cent per litre. As the current price of biodiesel blends is several cents per litre higher than petrodiesel, this amount of excise tax reduction in itself is unlikely to attract Canadian railways to use biodiesel.

6.1.2 Provincial

Canadian railways pay a provincial consumption tax that is calculated on the amount of diesel fuel consumed in the respective provinces. This tax varies from province to province but, like the federal excise tax, even a complete elimination of the consumption tax on the biodiesel component would unlikely be enough to eliminate the current cost differential of biodiesel.

6.2 PUBLIC RELATIONS AND POLICY ISSUES

Biodiesel appears to have all the attributes for successful public relations. It is envisaged that use of biodiesel by a railway would result in accolades from the public. A public relations campaign would appear to be straightforward in its message that biodiesel reduces the life-cycle GHG and related PM and HC emissions, that PM is less carcinogenic than that from petrodiesel, that biodegradability is enhanced, that the energy supply is diversified and that it has beneficial spin-offs for the agricultural economy.

The experience of bus and truck fleets with biodiesel is useful to examine and extrapolate to the railway context. One example is the City of Montreal's STM BIOBUS demonstration project. Public transportation authorities are generally the leaders in demonstrating more environmentally friendly technology due to the fact that they can be used as instruments of public policy to demonstrate how the public's tax funds can be used to increase quality of life. This project stems from ongoing public pressure to reduce the release of contaminants into the atmosphere. The public is advocating Canadian federal and provincial agencies to propose ever more stringent limits on emissions. Public policy implementation has to maintain a balance between the regulations or voluntary limits being proposed, the ability of industry to deploy appropriate technology, the provision of incentives or tax relief (where and if required) and the realities of market forces. Also, a reality is that Canadian actions must generally be in harmony with those imposed by U.S. authorities such as the U.S. EPA and the California Air Resources Board. Some of the public policy actions that could give impetus to the widespread availability of biodiesel in Canada are the recent ratification of the Kyoto Protocol on Climate Change and the Ontario Government considering the recommendations of the Ontario Select Committee on Alternate Fuels Sources, Recommendation 122 of which states: "The Ontario government shall require all railroads operating in Ontario to utilize "clean" diesel according to the following schedule: 'road grade' diesel by January 1, 2004 and diesel-ethanol (or diesel with similar technical specifications) by January 1, 2005". This infers the possibility of mandating and, hence, is an issue that the railway sector should monitor closely.

Although of indirect concern to the railway sector, one issue that could arise if biodiesel becomes widespread is the use of canola and soy plant stock that has been genetically modified to be more productive. How the growing public concern about genetically modified plants will play out is an uncertainty at present.

7. POTENTIAL RAILWAY BIODIESEL USERS

7.1 PASSENGER OPERATIONS

7.1.1 Urban Commuter Rail Operation

Commuter rail services, such as the Agence métropolitaine de transport (AMT) in Montreal, GO Transit in Toronto or the West Coast Express (WCE) in Vancouver, which use medium-speed diesel engines, would be candidates for biodiesel. They operate in urban communities where public awareness would be added benefit. Commuter railways could use biodiesel if the cost of biodiesel were competitive with petrodiesel, mandated or otherwise compensated for. Their region-specific operations lend themselves to being demonstration sites as their fleets can be closely controlled and monitored. As commuter rail operations are under provincial jurisdiction, the respective provincial governments could show leadership in reducing GHG emissions by arranging for biodiesel to be the fuel of choice. Table 6 lists the main features of these commuter railways.

Table 6: Commuter Railways

Operation	Number of Locomotives	Annual Fuel Consumption
Montreal - AMT	15	2.56 million litres
Toronto - GO Transit	45	21.6 million litres
Vancouver - WCE	6	1.00 million litres

Appendix B contains a scenario envisaging the use of B20 fuel in GO Transit's operations.

7.1.2 Intercity Passenger Operation

VIA Rail Canada operates intercity passenger service in Canada. Its services are categorized as Corridor, Trans-continental and Regional. As the Quebec-Windsor Corridor service has its own dedicated locomotives and consists, this service lends itself to a demonstration using biodiesel. VIA Rail operates 35 locomotives in the Corridor that consume approximately 30 million litres of petrodiesel annually. VIA Rail Canada's new GE P42-DC locomotives operate in the Quebec-Windsor Corridor and they are certified as meeting U.S.EPA Tier 0. Certification issues with biodiesel would have to be addressed with these locomotives.

The Corridor service is being promoted as more environmentally friendly than the competing air or automobile transportation modes. This potential is influencing Bombardier Transportation to propose for the Corridor service its new JetTrain passenger train, which has a gas turbine engine producing less than one-twentieth the NOx of a conventional diesel locomotive. Fuelling the JetTrain with biodiesel would further contribute to reducing emissions. As with the commuter railways, operating costs are extremely important, and any incremental costs due to biodiesel would have to be compensated for.

7.2 FREIGHT OPERATIONS

7.2.1 Switching Operation

Switching operations in Canada offer the best opportunity for biodiesel use in Canada. As the engines in switching service are usually older engines, warranty issues are not as critical. Similarly, the engines, being older, are usually not U.S. EPA compliant. Although the NOx with biodiesel is 2 to 5 percent higher than petrodiesel, switching engines generate only 3 to 5 percent of Canadian NOx totals. The increase in NOx would therefore be negligible. Also, the duty cycle of switchers is such that fuel consumption differences would be minimal.

Switching locomotives consume approximately 5 percent of Canadian railway diesel fuel. Although the GHG benefits with the use of biodiesel in switching locomotives would be minimal, it would provide a good starting point from which to gain experience and information on biodiesel or biodiesel blends in Canada.

Switching yards for both Class 1 railways are found in all major Canadian cities. There are 643 switching locomotives in Canada; CN and CP account for 638 of these (2). Appendix C outlines a proposed evaluation of biodiesel for freight switching operations.

7.2.2 Mainline Freight Operation

Canadian railways operate a modern fleet of locomotives, a large number of which are still on warranty and are certified to meet the U.S. EPA emissions rules and regulations. It would be difficult at this time to use biodiesel in freight operations. However, certain intermodal services with dedicated equipment and routes could be candidates. Of course, any higher cost associated with biodiesel would have to be compensated for. Higher NOx associated with the use of biodiesel could have a negative effect on RAC members being able to meet their commitment to Environment Canada vis-à-vis the NOx cap established in their MOU on locomotive emissions. Similarly, as the GHG emissions reductions are found mostly on the production side of biodiesel and not on the usage side, for the railways to benefit they would likely make the sharing of emissions credits a condition of purchase from a biodiesel producer.

8. CONCLUSIONS

The examination of the potential applicability of biodiesel as a fuel for locomotives in Canada has resulted in the following conclusions.

1. Technically, biodiesel can be used in medium-speed diesel engines. To date, limited testing and usage in locomotives manufactured prior to 2000 has shown that biodiesel can be used without engine modification and can attain full operating power.

2. The use of biodiesel can reduce the amount of GHG generated from the fuel consumed by the Canadian railways, and hence contribute to help Canada comply with the goals of the Kyoto Protocol. The contribution would be directly proportional to the volume of petrodiesel displaced.

3. A blend of 20 percent biodiesel and 80 percent petrodiesel (B20) appears most compatible with Canadian railway and climate conditions. A B20 blend equates to an overall annual railway market potential of 400 million litres of neat biodiesel.

4. In Canada, biodiesel is currently available in restricted quantities from pilot plants or by importation from the United States. Feasibility studies are underway for commercial-size plants.

5. To gain railway acceptance, biodiesel blends would have to be price competitive with petrodiesel as well as consistent in quality and security of supply.

6. Warranty issues on locomotives manufactured since 2000 that comply with U.S. EPA emissions limits would have to be resolved before biodiesel could gain widespread usage in mainline freight operations.

7. There is a need by railway operators for data on the performance and emissions resulting from biodiesel blends combusted in locomotives typical of those on Canadian railways.

8. Commuter rail services and switching operations would be suitable starting points to introduce biodiesel into the Canadian railway sector.

9. RECOMMENDATIONS

The following recommendations stem from the findings and conclusions of the study.

1. The railway sector and associated agencies should actively monitor the various initiatives underway in Canada to promote, financially facilitate and realize the commercial supply of biodiesel, aimed at being a price-competitive, quality-consistent and less GHG-intensive fuel that is a candidate for use in the medium-speed diesel engines in Canadian railway locomotives.

2. Steps should be taken to obtain data so as to quantify the performance and emissions from the use of biodiesel blends in locomotives of the type in use on Canadian railways via:

   a) Testing on the single-cylinder laboratory medium-speed engine (such as exists at Engine Systems Development Centre (ESDC), Lachine, Quebec) according to protocols of the Association of American Railroads; and subsequently

   b) Testing at ESDC of a locomotive of the type in Canadian railway service according to procedures specified in Part 92 (Control of Air Pollution from Locomotive and Locomotive Engines) of Title 40 of the Code of Federal Regulations (40 CFR) administered by the U. S. Environmental Protection Agency.

3 Opportunities should be examined wherein biodiesel can be introduced into segments of the Canadian railway fuel market. Feasibility studies should be commissioned to characterize the supply and usage aspects, quantify the expected environmental benefits and define the pricing formulae that could make biodiesel blends competitive with petrodiesel. This can be facilitated by a governmental agency:

   a) Issuing to the Canadian railway and fuel supply sectors a “Call for Expressions of Interest” regarding the use of biodiesel in locomotives.

   b) Convening a conference or workshop on locomotive emissions with a session on alternate fuels that includes biodiesel and ethanol.

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WEBSITES

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www.biodiesel.org

WS 2 Canada Clean Fuels:
www.canadacleanfuels.com/biodiesel.html

WS 3 Innovation Place Bioprocessing Centre:
www.innovationplace.com

WS 4 BIOX Corporation:
www.bioxcorp.com

WS 5 Rothsay:
www3.sympatico.ca/rothsay

WS 6 Société de Transport de Montréal, BIOBUS demonstration:
www.stcum.qc.ca/English/info/a-biobus.htm

WS 7 European Commission Policy on Biodiesel:
www.euractiv.com/cgi-bin/cgint.exe/?targ=1&204&OIDN=1504950

WS 8 Sierra Railroad:
srolle.home.attbi.com/refs.htm

WS 9 Bombardier Transportation:
www.transportation.bombardier.com/

WS 10 Government of Canada:
www.climatechange.gc.ca

APPENDIX A

Benchmarking Biodiesel versus Petrodiesel in Medium-Speed Diesel Engines as Used in Locomotives in Canada

PROPOSED TEST PROGRAM

Subject: **Benchmarking Biodiesel versus Petrodiesel in Medium-Speed Diesel Engines as Used in Railway Locomotives in Canada**

Objective: **To generate data to quantify the performance and emissions resulting from the use of biodiesel blends**

Two-Phase Approach: **Using the test facilities of the Engine Systems Development Centre (ESDC) located in Lachine, Quebec, measurements of performance and emissions would be taken using, respectively:**

a) The ESDC single-cylinder laboratory engine (representative of medium-speed locomotive engines) operated according to the 3x3 test matrix procedure of the Association of American Railroads to establish baseline properties, the mapping of the combustion characteristics, optimum mixture proportions, and performance parameters as input for subsequent testing.

b) An actual locomotive (provided via a member of the Railway Association of Canada) that would be instrumented and stationary-tested in ESDC's test cell to measure its performance according to the procedures specified in Part 92 (Control of Air Pollution from Locomotive and Locomotive Engines) of Title 40 of the Code of Federal Regulations (40 CFR) administered by the U.S. Environmental Protection Agency.

Phase I: **The envisaged matrix of tests to be undertaken on the ESDC single-cylinder laboratory engine is shown below, lasting one week with an estimated cost of $20,000.**

The test matrix envisages three biodiesel blends – neat, B-10 and B-20 – according to the 3-step AAR profile; that is, each blend is tested for 3 to 5 hours at each of three power (notch) settings (or until conditions stabilize). The neat biodiesel would meet ASTM Specification D 6751.

Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**
petrodiesel baseline	neat biodiesel	B-20 blend	B-10 blend	petrodiesel baseline
warm-up	warm-up	warm-up	warm-up	warm-up
idle	idle	idle	idle	idle
notch 2	notch 2	notch 2	notch 2	notch 2
notch 5	notch 5	notch 5	notch 5	notch 5
notch 8	notch 8	notch 8	notch 8	notch 8

Fuel requirements:

	Diesel Fuel (litres)	Biodiesel (litres)
Day 1	600	0
Day 2	0	600
Day 3	480	120
Day 4	540	60
Day 5	600	0
Total	2220	780

ESDC has in-house fuel mixing equipment that would be used for fuel blending.

Phase II: **The envisaged test of a complete locomotive would be according to the 13-point emissions test protocol of the U.S. Environmental Protection Agency. The biodiesel blend tested would be the one that exhibited the best performance on the single-cylinder test engine. The locomotive test would take 4 to 5 days for an estimated cost of $60,000.**

Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**
petrodiesel baseline	neat biodiesel	B-20 blend	B-10 blend	petrodiesel baseline
warm-up	warm-up	warm-up	warm-up	warm-up
idle	idle	idle	idle	idle
notch 2	notch 2	notch 2	notch 2	notch 2
notch 5	notch 5	notch 5	notch 5	notch 5
notch 8	notch 8	notch 8	notch 8	notch 8

Fuel requirements for an GM EMD SD-40 type locomotive:

	Diesel Fuel (litres)	Biodiesel (litres)
Day 1	1200	0
Day 2	0	1200
Day 3	960	240
Day 4	1080	120
Day 5	1200	0
Total	4440	1560

ESDC has in-house fuel mixing equipment that would be used for fuel blending.

Image of the single-cylinder test engine and locomotive test cell with emissions-measuring instrumentation in the ESDC facility is shown below.

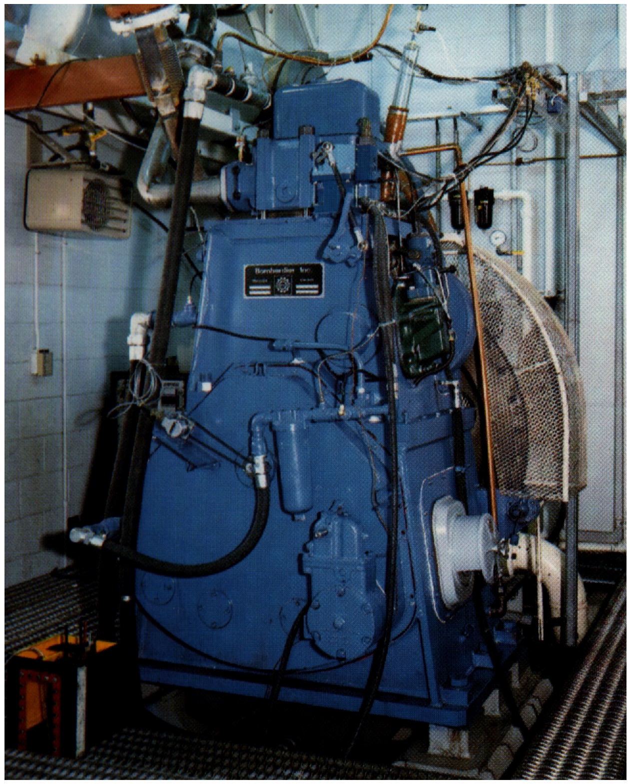
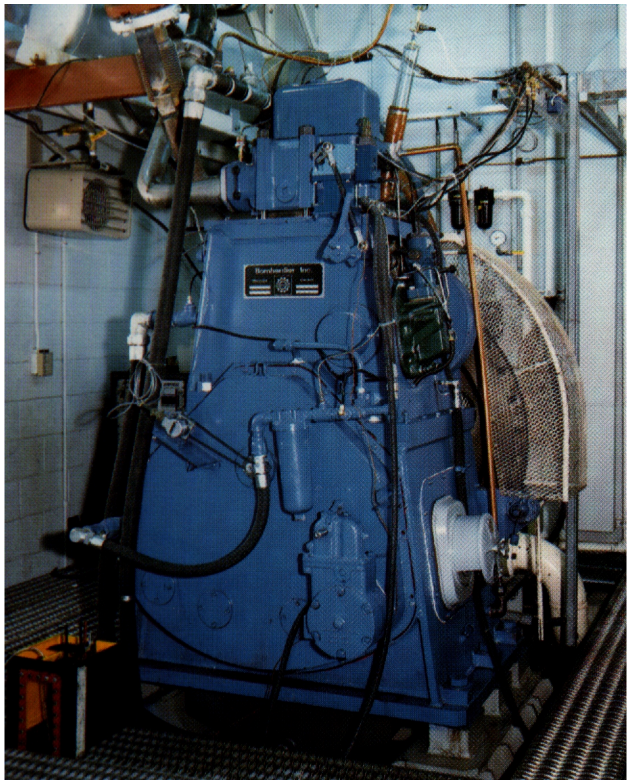


Image of the single-cylinder test engine and locomotive test cell with emissions-measuring instrumentation in the ESDC facility is shown below.



APPENDIX B

Evaluating Biodiesel Blend in a Locomotive Fleet:

A Commuter Rail Site-Specific Application

PROPOSED EVALUATION IN OPERATIONAL SERVICE

Subject:	**Evaluation of Biodiesel in a Commuter Rail Operation**
Objective:	**To gain experience using a biodiesel blend to fuel a passenger railway**
Candidate Site:	**The Commuter Rail Operations of GO Transit, Toronto, Ontario**
Measurable Goals:	On a six month trial (summer months) basis, to measure the number of tonnes of greenhouse gas (namely CO_2) not produced due to the displacement of petrodiesel by a biodiesel blend; and to identify any operational problems experienced.
Features:	a) GO Transit currently consumes approximately 25 million litres of petrodiesel per year; b) Consumption during business week is approximately 90,000 litres per day; c) GO Transit operates 45 locomotives over 361 route kilometres of track.
Potential CO_2 Reduction:	a) if a B10 biodiesel blend were to be used annually, this would require approximately 2.5 million litres per year of neat biodiesel, which represents an estimated 5.5 kilotonnes of CO_2 not emitted. b) if a B20 biodiesel blend were to be used annually, this would require 5 million litres per year of neat biodiesel, which represents an estimated 11 kilotonnes of CO_2 not emitted. Notes: CO_2 emission = 2709 g/L Biodiesel = 80% CO_2 emissions reduction compared to petrodiesel.
Biodiesel Supply:	Potentially to be supplied from a commercial-size processing plant yet to be committed for construction in Canada.
Fueling Scheme:	Pre-mixed biodiesel, blended by splash blending, to be delivered by tank truck feeding into four storage tanks of 0.5 million litres capacity overall.
Caveat:	Railway operators request that use of biodiesel blends should: a) be price-competitive with petrodiesel, b) be transparent vis-à-vis fueling operations, c) not diminish locomotive performance, and d) be within current emissions limits, in particular, NOx.

APPENDIX C

Evaluating Biodiesel Blend in a Locomotive Fleet:

A Freight Switching Site-Specific Application

PROPOSED EVALUATION IN OPERATIONAL SERVICE

Subject: **Evaluation of Biodiesel in a Switching Rail Operation**

Objective: **To gain experience using a biodiesel blend to fuel a Switching Locomotive**

Candidate Site: **The Switching Rail Operations of a Class 1 Railway**

Measurable Goals: On a six month trial (summer months) basis, to measure the number of tonnes of greenhouse gas (namely CO_2) not produced due to the displacement of petrodiesel by a biodiesel blend; and to identify any operational problems experienced.

Features:
a) Canadian Class 1 switching locomotives currently consume approximately 90 million litres of petrodiesel per year;
b) Canadian Class 1 railways operate 638 locomotives in 8 main yards across Canada;
c) Selecting one switching yard for the trial would involve 80 locomotives consuming approximately 10 million litres of petrodiesel per year.

Potential CO_2 Reduction:
a) if a B10 biodiesel blend were to be used annually, this would require approximately 1 million litres per year of neat biodiesel, which represents an estimated 2.2 kilotonnes of CO_2 not emitted.
b) if a B20 biodiesel blend were to be used annually, this would require 2 million litres per year of neat biodiesel, which represents an estimated 4.4 kilotonnes of CO_2 not emitted.

Notes: CO_2 emission = 2709 g/L
Biodiesel = 80% CO_2 emissions reduction compared to petrodiesel.

Biodiesel Supply: Potentially to be supplied from a commercial-size processing plant yet to be committed for construction in Canada.

Fueling Scheme: Pre-mixed biodiesel, blended by splash blending, to be delivered by tank truck feeding into one storage tank of 0.5 million litres capacity overall.

Caveat: Railway operators request that use of biodiesel blends should:
a) be price-competitive with petrodiesel,
b) be transparent vis-à-vis fueling operations,
c) not diminish locomotive performance, and
d) be within current emissions limits, in particular, NOx.