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Biodiesel Mass Transit Demonstration

Final Report

April 2010

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13. ABSTRACT (Maximum 200 words)

The Biodiesel Mass Transit Demonstration report is intended for mass transit decision makers and fleet managers considering biodiesel use. This is the final report for the demonstration project implemented by the National Biodiesel Board under a grant from the Federal Transit Administration. This report evaluates the extended in-use performance of biodiesel (a blend of 20% biodiesel and 80% ultra low sulfur diesel) in an independent engine test and two separate field demonstrations, specifically: a 1,000 hour engine durability test conducted by Southwest Research Institute (SWRI); an over-the-road field test with the St. Louis Metro Bus Transit System implemented by the National Renewable Energy Laboratory (NREL); and an over-the-road field test with the Kansas City Area Transportation Authority led by the National Biodiesel Board (NBB). The results from the demonstration indicate that on-spec biodiesel can serve as a drop-in replacement fuel in existing diesel equipment.

This report provides an introduction, a background, and a summary of the methodology and the research approach; reviews the results; and presents conclusions and lessons learned. This report also summarizes federal and state regulations that may impact fuel choice by transit agency operators. The project also produced a comprehensive report, printed under separate cover and titled, *Biodiesel Fuel Management Best Practices for Transit*.

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Acronyms

AFS	Advanced Fuel Solutions
ASTM	American Society of Testing and Materials International
B100	100% Biodiesel
B20	20% Biodiesel, 80% Petroleum Diesel
B5	5% Biodiesel, 95% Petroleum Diesel
BSFC	Brake Specific Fuel Consumption
CO	Carbon Monoxide
CAA	Clean Air Act
CRADA	Cooperative Research and Development Agreement
DOC	Diesel Oxidation Catalyst
DOF	Diesel Particulate Filter
EGR	Exhaust Gas Recirculation
EISA	Energy Independence and Security Act
EPA	Environmental Protection Agency
FTA	Federal Transit Administration
GHG	Green House Gas Emissions
HC	Hydrocarbon
KCATA	Kansas City Area Transit Authority
MAX	Metro Area Express
NBB	National Biodiesel Board
NO_x	Oxides of Nitrogen
NREL	National Renewable Energy Laboratory
OEM	Original Equipment Manufacturer
PM	Particulate Matter
RFS	Renewable Fuel Standard
S15	15 parts per million Sulfur
S500	500 parts per million Sulfur
SwRI	Southwest Research Institute
TPMAAT	Tenth Percentile Minimum Ambient Air Temperature
ULSD	Ultra Low Sulfur Diesel
UST	Underground Storage Tank
VGT	Variable Geometry Turbocharger

Acknowledgements

Appreciation goes to the project partners: Kansas City Area Transit Authority and the St. Louis Metro Transit for their participation in the transit demonstration; Cummins Engine for providing their equipment for engine testing; and the National Renewable Energy Laboratory for its contributions to the evaluation of St. Louis Metro’s transit operation. Feedback received from workshop participants attending industry conferences through the outreach and education project component is also gratefully acknowledged.

Executive Summary

The goal of the Biodiesel Mass Transit Demonstration was to help urban transit organizations better understand biodiesel use with an emphasis on the St. Louis and Kansas City, Missouri transit systems. A major component of this project was to evaluate the extended in-use performance of B20 (20% biodiesel; 80% ultra-low sulfur diesel (ULSD) fuel with existing diesel buses and stand-alone engines. Three separate studies were undertaken:

- A 1,000 hour durability test with B20 biodiesel blends using a Cummins ISL engine; and
- Two separate over-the-road 12-month field tests with B20 conducted by the St. Louis Metro Bus Transit System (St. Louis Metro), and the Kansas City Area Transportation Authority (KCATA).

Engine durability and over- the- road field tests show biodiesel to be a viable alternative for mass transit.

NBB File Photograph

This report summarizes the methods and primary results for each study. Readers requiring more detail are referred to the full reports available online: *1000 Hours of Durability Evaluation of a Prototype 2007 Diesel Engine Using B20 Biodiesel Fuel*; *St. Louis Metro Biodiesel (B20) Transit Bus Evaluation*; and *B20 Demonstration Project – Kansas City Area Transportation Authority*.[1,2,3]

The 1,000-hour durability and emissions test ran a prototype 2007 model Cummins ISL diesel engine on B20 with no biodiesel-related failures. Results of the durability test indicated B20 is fungible with certain model engines that utilize particulate matter (PM) and nitrogen oxides (NO_x) after treatment equipment. Emission profiles for B20 on these engine types showed a reduction in PM, unburned hydrocarbons, and a slight increase in NO_x. Engine testing and analysis were conducted at the Southwest Research Institute facility in San Antonio, Texas.
The St. Louis Metro transit bus demonstration examined, over a period of 12 months, eight buses operating exclusively on soy-based B20 and seven buses operating exclusively on ULSD in an

[1] 1000 Hours of Durability Evaluation of a Prototype 2007 Diesel Engine Using B20 Biodiesel Fuel. Southwest Research Institute. 2007. http://www.biodiesel.org/resources/reportsdatabase/reports/gen/20080601_gen-395.pdf

[2] St. Louis Metro Biodiesel (B20) Transit Bus Evaluation. 12-Month Final Report. July 2008. http://www.biodiesel.org/resources/reportsdatabase/reports/tra/20080701_tra-57.pdf

[3] B20 Demonstration Project – Kansas City Area Transportation Authority. 2008. http://www.biodiesel.org/resources/reportsdatabase/reports/tra/20081017_Tra-58.pdf

urban setting. The buses were all 2002 GILLIG transit buses equipped with MY 2002 (2004 emissions certification) Cummins ISM engines. The demonstration was conducted under a Cooperative Research and Development Agreement (CRADA) between the National Renewable Energy Laboratory in Golden, Colorado and the National Biodiesel Board (NBB). The results of the demonstration showed: 1) slightly lower fuel economy (1.7%) among buses running on B20; 2) no significant difference in total maintenance costs between the B20 and ULSD bus groups; and 3) lube oil sample analysis indicated no excess wear on metals and some potential benefits with B20 use. Following completion and reporting on the 12-month demonstration funded by FTA, NREL extended the demonstration an additional six months in order to provide more definitive answers to questions about how B20 impacts engine and fuel system maintenance, as well as other factors.

The KCATA demonstration examined 13 buses for a period of 24 months in an urban setting (12 months running on ULSD fuel and 12 months on soy-based B20). The demonstration utilized 2005 GILLIG Low Floor heavy-duty transit buses equipped with 2005 ISM Cummins engines and a Voith transmission. The buses were newly purchased by KCATA for their Metro Area eXpress (MAX) service. Each bus was run on a specific route. Led by the NBB, the KCATA demonstration was designed to augment the larger, more detailed St. Louis Transit system demonstration conducted by NREL. The KCATA demonstration findings showed: 1) the B20 buses exhibited similar fuel economy within bus-to-bus variations, and 2) no significant maintenance issues were noted with the buses running on B20.

These findings indicate that biodiesel performs similar to diesel fuel in the equipment tested.

The project also generated supplemental information: federal and state policy and regulations that can be met utilizing biodiesel and best practices for biodiesel use. This report includes lessons learned during execution of the project.

Quick References for fleets considering biodiesel

Automotive Support	http://www.biodieselautomotive.org/
National Biodiesel Troubleshooting Hotline	http://www.biodiesel.org/Hotline/
Distributor Selection Assistance	http://www.biodiesel.org/buyingbiodiesel/guide/

1. Introduction and Background

Environmental and energy security concerns have led many US transit agencies to investigate or implement alternative fuel programs. This is primarily due to either regulatory requirements or regional consumer pressure. The Federal Transit Administration (FTA) has, in recent years, given considerable attention to providing transit agencies with the information they need to make informed decisions on the incorporation of alternative fuels in their fleet systems. One of the several alternative fuels currently available on the market is biodiesel. The Biodiesel Mass Transit Demonstration project was designed to generate data and information concerning engine-related impacts of B20 (a fuel blend of 20% biodiesel and 80% petroleum diesel) under normal operating conditions that can be used by fleet managers, maintenance personnel, and others associated with urban transit agencies as they evaluate the potential for biodiesel use in their fleets. This is the final report for the demonstration project implemented by the NBB under a grant from the Federal Transit Administration.

This report provides a summary and lessons learned from the three studies completed under the demonstration project: a 1000-hour durability engine test and two separate 12-month over-the-road field tests with B20 conducted by the St. Louis Metro Bus Transit System and the Kansas City Area Transportation Authority. Complete reports for these three studies are available online.

- *1000 Hours of Durability Evaluation of a Prototype 2007 Diesel Engine Using B20 Biodiesel Fuel* *(*http://www.biodiesel.org/resources/reportsdatabase/reports/gen/20080601_gen-395.pdf);
- *St. Louis Metro Biodiesel (B20) Transit Bus Evaluation* (http://www.biodiesel.org/resources/reportsdatabase/reports/tra/20080701_tra-57.pdf);
- *B20 Demonstration Project – Kansas City Area Transportation Authority* (http://www.biodiesel.org/resources/reportsdatabase/reports/tra/20081017_tra-58.pdf).

In addition to engine testing and field runs to evaluate B20 performance, the project also generated a summary of policies and regulations that can be met by utilizing biodiesel (see Appendix B: Policies and Regulations That May Impact Biodiesel Production and Use). A comprehensive report for the petroleum industry, *Biodiesel Fuel Management Best Practices for Transit*, addressing fuel quality, logistics, and transportation costs associated with biodiesel use by transit agencies also was written under this project.[4]

1.1 What is Biodiesel?

Biodiesel is a domestically-produced, renewable alternative fuel comprised of mono-alkyl esters of long chain fatty acids derived from triglycerides such as vegetable oils, animal fats, and/or

[4] Biodiesel Fuel Management Best Practices for Transit. Written by the National Biodiesel Board. FTA Report no: FTA-MO-2607009.2007.1. November 27, 2007.
http://www.biodiesel.org/resources/reportsdatabase/reports/tra/20071127_tra-56t.pdf

waste greases designated B100, and meeting the requirements of the national fuel quality standard, ASTM D 6751[5]. Biodiesel can be used in concentrations up to 20% with petrodiesel (B20) in existing diesel engines with essentially no modification. Biodiesel has a higher cetane value than conventional US based petrodiesel, higher lubricity, and less emissions of unburned hydrocarbons, carbon monoxide, and particulate matter. The BTU content of pure biodiesel, B100, is approximately 8% lower[6, 7] than average No. 2 petrodiesel, but is similar to No. 1 petrodiesel. When used in B20 blends, the BTU content is approximately 1.6% lower than that of average No. 2 petrodiesel, but many operators report they are unable to discern a fuel economy difference between B20 and petrodiesel alone. The biodiesel used in this study was soybean based.

1.2 Biodiesel Use in Mass Transit Systems

Sample data from the 2009 annual *APTA Public Transportation Vehicle Database* show a large majority (75.3%) of transit buses are powered by either diesel (68.9%) or biodiesel (6.4%).[8] Post demonstration interviews were held with KCATA and St. Louis Metro fleet managers. Positive attributes of biodiesel use most frequently noted by these managers were similarities between the operating performance of biodiesel and conventional petroleum-based diesel fuel (petrodiesel) and the lack of changes required in facilities and maintenance procedures when introducing biodiesel in the system. During the interviews, it also was revealed that bus patrons noted an absence of black smoke and a reduction and/or change in exhaust odor associated with biodiesel fuel as compared to petrodiesel fuel. Biodiesel blends function in the engine the same way as petrodiesel does, and it is a fuel that meets environmental and energy security needs without significantly affecting operating performance.

In summary, biodiesel has the following attributes relevant to mass transit systems:

- Integrates into existing petroleum infrastructure – some modifications may be required;
- Similar operating performance to conventional petroleum-based diesel fuel;
- High cetane (>50 vs. ~42);
- High lubricity - 2% blend biodiesel increases lubricity by up to 65%;
- Potential cold flow concerns;
- Flash point (minimum 260^{o}F); and
- Virtually zero sulfur - meets 2006 ULSD rule.

1.3 Impact of Federal and State Regulations on Biodiesel Use

US transit agencies must comply with a number of federal and state regulations targeted at alternative fuel use or emissions reduction. Running buses on biodiesel may enable transit managers to fully or partially comply with these regulations. This section highlights regulations

[5] http://www.biodiesel.org/pdf_files/fuelfactsheets/BDSpec.PDF
[6] http://www.biodiesel.org/pdf_files/fuelfactsheets/emissions.pdf
[7] http://www.biodiesel.org/pdf_files/fuelfactsheets/BTU_Content_Final_Oct2005.pdf
[8] The other 24.7% is composed of: CNG, LNG and blends (18.3%); electric and hybrid (4.9%); gasoline (.7%), and other (.8%). American Public Transportation Association: *2010 Public Transportation Fact Book, Appendix A: Historical Tables*, Washington, DC, April, 2010. p.33.
http://apta.com/resources/statistics/Documents/FactBook/2010_Fact_Book_Appendix_A.pdf

that could impact the use of biodiesel by transit agencies based on input from transit managers contacted in Nebraska, California, Missouri, Arizona, Colorado, Washington State, and Indiana and representing more than 6,000 operating buses. These transit managers identified federal environmental regulations requiring new engine technology, the use of cleaner fuels (e.g. ultra-low sulfur diesel), and air quality controls as having the greatest impact on their choice of fuel. Among the transit agencies contacted, only the California operations emphasized state regulations as significantly impacting their fuel choice. However, with additional states considering fuel standards each year, this may change. States that have passed biodiesel fuel standards include: California, Massachusetts, Minnesota, New Mexico, Oregon, Pennsylvania, and Washington.

Below is a summary of pertinent new engine, clean fuel, and air quality regulations, and additional policies that may impact biodiesel fuel use by transit operators. A more detailed discussion of these regulations is provided at the end of this report. (See see Appendix B: Policies and Regulations That May Impact Biodiesel Production and Use).

- **New Engine Technology**

Clean Diesel Truck and Bus Program – In 2001, the EPA established a comprehensive national control program to regulate heavy-duty vehicles and diesel fuel as a single system (66 FR 5002). As part of this program, new emission standards for heavy-duty engines and vehicles took effect in model years 2007 through 2010 and apply to heavy-duty highway engines and vehicles. These standards are based on the use of high-efficiency catalytic exhaust emission control devices or comparably effective advanced technologies. Because these devices are damaged by sulfur, the program also reduces the level of sulfur in highway diesel fuel by 97 percent. [9]

Updated CAFÉ (Corporate Average Fuel Economy) Standards for Original Engine Manufacturers OEMs - The new CAFÉ standards allow B20-approved vehicles to qualify for CAFÉ credits and are a positive influence on OEMS to produce B20-approved vehicles. Since the CAFÉ rules were first amended to allow for B20-approved vehicle credits in 2009, both Ford and General Motors have fully approved the use of B20 beginning with their 2011 Model Year diesel vehicles.

2010 New Diesel Engine Emissions Standards – In 2007, the EPA required engine manufacturers to significantly lower their diesel emissions of particulate matter, and engines were modified accordingly with equipment such as Diesel Particulate Filters or DPFs. In 2010, the EPA further tightened these standards, requiring that all diesel engines also reduce emissions of NOx (oxides of Nitrogen) down to near zero emissions levels. As a result, all major diesel engine manufacturers have had to completely retool / redesign their diesel engines to meet these requirements, using a variety of technologies to mitigate the NOx emissions. One of the most commonly employed technologies to eliminate NOx is the Selective Catalytic Reduction (SCR) system, which injects small amounts of Diesel Exhaust Fluid (DEF) (otherwise known as Urea)

[9] Environmental Protection Agency: *Regulations Requiring Onboard Diagnostic Systems on 2010 and Later Heavy-Duty Engines Used in Highway Applications Over 14,000 Pounds; Revisions to Onboard Diagnostic Requirements for Diesel Highway Heavy-Duty Applications Under 14,000 Pounds. Regulatory Announcement*, EPA420-F-06-058, December 2006. http://www.epa.gov/obd/regtech/420f06058.pdf

into the exhaust stream where the heat turns it into ammonia. The ammonia then reacts with a catalyst, converting the NOx into Nitrogen and water vapor. Other OEMs have chosen an Exhaust Gas Recirculation (EGR) system to eliminate the NOx emissions.

The result of these stringent new emissions standards on NOx, and the OEMs' equipment solutions to meet them, is that it has effectively taken the potential NOx increase associated with biodiesel use out of the equation as a barrier to using biodiesel blends. Studies-to-date have shown that biodiesel blends work very effectively with the new aftertreatment systems, posing no major difficulties with materials compatibility, engine performance, or emissions controls. (One such study the reader could reference is an NREL paper on "Impacts of Biodiesel Fuel Blends Oil Dilution on Light Duty Diesel Engine Operation", available at http://www.nrel.gov/vehiclesandfuels/npbf/pdfs/44833.pdf .)

Thus, in the process of redesigning their 2010 – 2011 diesel engines to meet the new emissions specifications, several OEMs, including Ford and General Motors, have designed those new engines expressly to support the use of B20 biodiesel blends. Heavy truck and bus manufacturers are also in the process of completing testing of their equipment with B20 blends, and more biodiesel support announcements are expected in the coming months. Now more than 54% of the diesel manufacturers in the U.S. market accept B20 or higher blends in at least some of their equipment, and all manufacturers accept the use of at least B5 biodiesel blends. For a complete listing of OEM Positions of Support for biodiesel, visit http://www.biodiesel.org/resources/oems.

- **Clean Fuel**

Ultra Low Sulfur Diesel Fuel – In December 2000, the EPA finalized Clean Air Act regulations to reduce the sulfur content of on-road diesel fuel by 97% from its current level of 500 ppm to 15 ppm beginning in 2006. As little as 2% biodiesel can be blended into ULSD as a means to improving lubricity while providing environmental, economic, and energy security benefits. In addition to the lubricity benefits, virtually all biodiesel itself contains less than 15 ppm sulfur, which meets 2007 emissions standards and is considered an ULSD fuel by EPA. (See *Appendix B: 3.1 Ultra Low Sulfur Diesel Fuel*).

- **Air Quality Regulations**

Clean Air Act - No motor fuel or motor fuel additive may be sold in the United States unless it is registered with the EPA under the Clean Air Act (CAA). (See 42 U.S.C. 7545(b); 40 CFR Part 79). EPA action related to both the particulate matter and ozone air quality standards can have impacts on state and local policies that may change transit operations in non-attainment areas. (*See Appendix B: 5.0 National Ambient Air Quality Standards (NAAQS)*).

- **Cost and Availability**

Biodiesel Tax Provisions (P.L. 109-190) is designed to make the price of biodiesel competitive with conventional diesel fuel. The credit allows taxpayers to claim the biodiesel tax incentive as either a $1.00 per gallon general business income tax credit or as a $1.00 per gallon blenders excise tax credit. The blender credits went into effect on January 1, 2005 and, unless extended by new legislation, expire on December 31, 2009. There are other production tax credits (i.e. Small Agri-Biodiesel Producer Credit) that could be indirectly passed on to transit operators. Up-to-date information on these tax policies is maintained on the NBB website. (See *Appendix B: 2.1 Biodiesel Tax Provisions*).

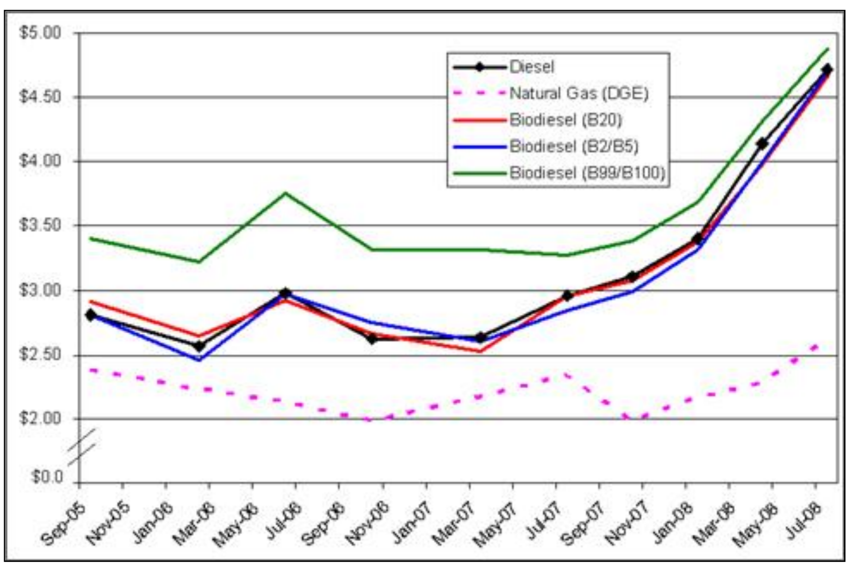
Renewable Fuel Standard - The Energy Independence and Security Act of 2007 (P.L. 110-140) expanded the Renewable Fuel Standard, now referred to as RFS-2. RFS-2 established a use requirement for advanced biofuels that, for the first time, specifically achieves the displacement of petroleum diesel fuel with biomass-based diesel, which includes biodiesel. To qualify as biomass-based diesel, the fuel must reduce greenhouse gas (GHG) emissions by 50% compared to conventional petroleum diesel. (See *Appendix B: 2.5 Renewable Fuel Standard*).

The aforementioned polices should not be considered an exhaustive list. The reader must be aware that policies and regulations are constantly changing.

1.4 Cost of Biodiesel versus Petrodiesel Fuel

Historically, fuel costs for biodiesel have been consistently higher than petrodiesel presenting a barrier to its widespread integration. [Figure 1] However, government policies such as the Energy Independence and Security Act (EISA) of 2007, coupled with the federal tax incentive discussed in the previous section, have driven increased use of biodiesel blends. The biodiesel tax incentive has allowed B20 and lower blends to be priced more competitively with petrodiesel. [Figure 2] Although the 2009 tax incentive recently expired, it is on the congressional agenda to be extended in 2010. In addition to the tax incentives, a number of states also have begun implementing renewable fuel mandates requiring that a certain percentage of all diesel fuel sold contain biodiesel.

Figure 1. Price of Diesel Fuel versus B100, B20, B5 from September 2005 to July 2008



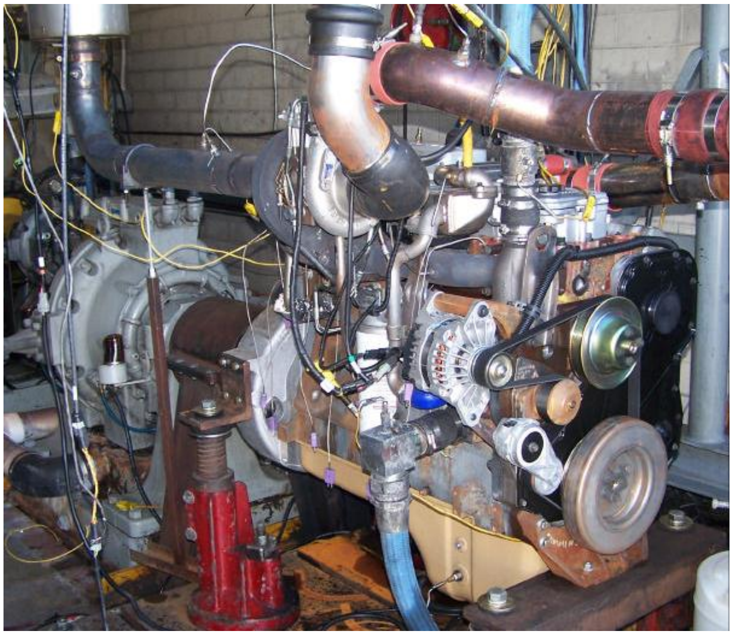
In the past, fuel costs for B100 were higher than petrodiesel, hindering the widespread use of biodiesel. However, the biodiesel tax incentive is designed to encourage production and use of biodiesel blends and has allowed B20 and lower blends to be priced more competitively with petrodiesel.

Source: U.S. Department of Energy, Energy Efficiency and Renewable Energy, Clean Cities Alternative Fuel Price

2. Performance of B20 in Mass Transit Systems

2.1 1,000-hours Durability Engine Test

The focus of this project component was to operate a prototype 2007 model year Cummins ISL diesel engine over a durability cycle for 1,000 hours using soybean-based B20 biodiesel and to determine key engine operating parameters. The test engine was equipped with a diesel oxidation catalyst (DOC) followed by a catalyzed diesel particulate filter (DPF) that use diesel fuel post injection (in-cylinder) for active regeneration. The engine had a variable geometry turbocharger (VGT) and a high-pressure exhaust gas recirculation (EGR) with an EGR cooler. A full report of the engine durability test was prepared by South West Research Institute (http://www.biodiesel.org/resources/reportsdatabase/reports/gen/20080601_gen-395.pdf).



Southwest Research Institute conducted a 1,000-hour durability and emissions test using a prototype 2007 model year Cummins ISL diesel engine.

SwRI Photograph

Engine Testing

The engine testing protocol was a high-load, accelerated durability cycle typically run by Cummins for 1,000 hours and with the high load durability cycle, DPF regeneration was not a problem. After 125 hours and again after 1,000 hours of accumulated durability operation, the Cummins ISL engine was removed from the durability test cell and installed in a transient emissions test cell. The engine was tested according to procedures outlined in the Code of Federal Regulations Title 40 Part 86 Subpart N for heavy-duty on-highway engines. The test sequence conducted on the engine included one cold-start transient Federal Test Procedure test, three hot-start transient Federal Test Procedure tests, and one SET Ramped Modal Cycle. These tests were performed using both the emissions-grade B20 biodiesel fuel as well as the 2007 certification ULSD fuel. Lube oil samples were extracted every 50 hours of accumulated durability operation and analyzed.

Regulated emissions of total hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NO_x), and particulate matter (PM) were measured for each test. Throughout the 1,000 hours of durability operation using B20, the engine ran successfully without problems, except for two instances at 150 hours and 950 hours of engine operation, both of which were not related to biodiesel use.

Emissions

Regulated emission measurements were performed at 125 and 1,000 hours of operation using ultra-low sulfur diesel (ULSD) fuel as well as B20 biodiesel fuel. Emissions of HC, CO, and PM were well below the 2007 standard with no statistical difference between B20 and ULSD. However, B20 resulted in about 6 to 6.5 percent higher NO_x, and about 2.5 to 3.5 percent higher fuel consumption, without the use of a NO_x emissions catalyst. The test results indicate that B20 biodiesel blends will cause no adverse impact to Cummins engine performance. It is imperative, however, the biodiesel used meets ASTM specification, D6751, as this test was performed with in-spec fuel.

Table 1. Summary of Normalized Emission Results for a Cummins ISL Engine After 1,000 Hours of Durability Operation on B20 Fuel

Test Description	Test Name	Normalized Brake-Specific Emissions Results[2]					
		HC[1]	CO[1]	NOx	PM[1]	CO2	BSFC
1000-Hour B20	Cold Start 1	0.00	3.10	0.97	0.60	1.04	1.06
	Hot Start 1	42.2	0.42	1.06	0.71	1.02	1.03
	Hot Start 2	35.4	0.43	1.06	0.71	1.02	1.03
	Hot Start 3	28.1	0.47	1.07	0.92	1.02	1.03
	RMC	33.1	0.36	0.81	0.76	0.89	0.90
	C/H Composite	**36.2**	**0.80**	**1.05**	**0.69**	**1.02**	**1.04**
	Hot Start Ave.	***35.3***	***0.44***	***1.06***	***0.78***	***1.02***	***1.03***
	Hot Start COV	20%	7%	0.8%	15.3%	0.1%	0.1%
1000-Hour Cert. ULSD	Cold Start 1	0.00	5.05	0.90	0.99	1.03	1.03
	Hot Start 1	0.00	1.33	0.99	0.89	1.00	1.00
	Hot Start 2	0.00	0.80	1.01	0.90	1.00	1.00
	Hot Start 3	3.00	0.87	1.00	1.21	1.00	1.00
	RMC	55.0	0.34	0.76	3.86	0.89	0.89
	C/H Composite	**0.00**	**1.86**	**0.98**	**0.91**	**1.01**	**1.01**
	Hot Start Ave. [2]	***1.00***	***1.00***	***1.00***	***1.00***	***1.00***	***1.00***
	Hot Start COV	170%	29%	1.1%	18%	0.2%	0.2%
% Difference (B20-ULSD)/ULSD	RMC	-40%	4.1%	6.7%	-80%	0.5%	2.2%
	C/H Composite	**N/A**	**-57%**	**7.6%**	**-24%**	**1.4%**	**3.1%**
	Hot Start Ave.	***3400%***	***-56%***	***6.5%***	***-22%***	***1.7%***	***3.4%***
	Hot Start t-Test[3]	0.001	0.028	0.001	0.151	0.0002	0.00001

[1]BSHC, BSCO, and BSPM are well below the regulatory standards.

[2]Test results were normalized using the ULSD hot start average emission values.

[3] Values less than 0.05 indicate hot start mean values are significantly different at the 5 % significance level.

In the 1,000-hour durability test, the engine showed no significant changes in operation or performance while operating on B20 compared to ULSD.

This table was prepared bySwRI for NBB under this grant

2.2 St. Louis Metro Bus Transit System Demonstration

The objective of the demonstration was to compare the extended in-use performance of transit buses running on B20 fuel with buses running on ultra-low sulfur diesel (ULSD) for a 12-month period. Performance was evaluated in terms of fuel economy, vehicle maintenance, engine performance, component wear, and lube oil performance. This study examined B20 use in a fleet that used exhaust gas recirculation (EGR) equipped buses. This is the first study to compare the performance of B20 to that of ultra-low sulfur diesel (ULSD). ULSD was introduced in the fall of 2006, which coincided with the demonstration. Having completed and reported on the St. Louis Metro 12-month demonstration funded by FTA, NREL extended the demonstration an additional 6 months. The evaluation was continued to better substantiate how B20 impacts engine and fuel system maintenance as well as other factors. NREL presented a report on the18-month demonstration at the SAE Commercial Vehicle Congress in October 2009.

Real world tests confirm B20 stands up to ULSD.

Photograph Courtesy of St. Louis Metro

Specifically, the demonstration utilized fifteen 40-foot model year (MY) 2002 transit buses manufactured by Gillig and equipped with MY 2002 (2004 emissions certification) Cummins ISM engines. For a period of 12 months, eight of these buses operated exclusively on B20 and the other seven operated exclusively on petroleum ULSD.

Table 2. St. Louis Metro B20 Transit Bus Basic Description

Vehicle Information	Evaluation Buses (Diesel and B20)
Number of Buses	7 Diesel (Bus #s 3401-3407) 8 B20 (Bus #s 3408-3415)
Chassis Manufacturer/Model	Gillig
Chassis Model Year	2002
Engine Manufacturer/Model	Cummins ISM
Engine Model Year	2002 (2004 emissions certification)
Engine Ratings Max. Horsepower Max. Torque	 280hp @ 2100 rpm 900 lb-ft @ 1200 rpm
Fuel Capacity	125 gallons
Transmission Manufacturer/Model	Voith DIWA 863
Curb Weight	29,000 lbs.
Gross Vehicle Weight	40,600 lbs.

The St. Louis project evaluated 15 buses for 12 months to assess biodiesel's performance and considerations.

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Fueling

The B20 and ULSD study groups operated out of different depots at St. Louis Metro, but bus routes were matched for duty cycle parity. Buses at each garage were fueled, either daily or every other day, at two indoor fueling dispensers. Rack-blended (in-line proportional blending) fuel was generally delivered every four to five days. All fuel volume, odometer readings, and maintenance records were logged electronically.

Fuel Economy

St. Louis Metro's implementation of ULSD (less than 15 ppm sulfur) fuel coincided with the start of this demonstration in October 2006, and the start of B20 use at St. Louis Metro. ULSD was required in most areas of the United States beginning in October 2006.

The calculated 12-month average fuel economy for the B20 buses is 1.7% lower than that of the ULSD buses. This difference is expected due to the approximately 2% lower energy content in a gallon of B20 and was found through further analysis not to be statistically significant.

Table 3. St. Louis Metro Bus Fuel Use

Bus	Fuel	Mileage Total	Fuel Used (gallons)	Fuel Economy (mpg)
3401	Diesel	50,154	14,043	3.57
3402	Diesel	45,786	12,797	3.58
3403	Diesel	44,019	12,092	3.64
3404	Diesel	45,252	12,729	3.55
3405	Diesel	42,695	12,397	3.44
3406	Diesel	48,650	13,785	3.53
3407	Diesel	48,851	13,140	3.72
Total	**Diesel**	**325,407**	**90,983**	**3.58**
3408	B20	55,456	15,638	3.55
3409	B20	57,531	15,742	3.65
3410	B20	50,588	14,785	3.42
3411	B20	47,881	14,176	3.38
3412	B20	46,514	12,918	3.60
3413	B20	48,695	14,264	3.41
3414	B20	45,312	12,457	3.64
3415	B20	42,139	12,136	3.47
Total	**B20**	**394,116**	**112,115**	**3.52**

The 12-month average fuel economy for B20 buses is 1.7% lower than that of the ULSD buses. By conventional criteria, the difference is not statistically significant.

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Vehicle Maintenance

Overall, there was no significant difference occurred in total maintenance cost per mile between the two study groups; engine and fuel system related maintenance was not a significant driver in total maintenance costs. For the B20 fueled buses in this demonstration, routine maintenance is performed identically to the diesel buses. The buses evaluated in this study had a 2-year/100,000 mile general warranty, with emissions control systems warranted to 200,000 miles. Thus, all buses operated in this study were outside their warranty or went out of warranty shortly after the start of the demonstration.

The B20 study group had a higher incidence of fuel filter replacements. Initially, fuel filters were intentionally replaced at a 3:1 ratio on B20 buses, as a proactive effort to avoid filter plugging due to loosening of fuel system deposits. The reason for the replacement of ten fuel filters on B20 buses in February 2007 is unknown, but extremely cold temperatures (below cloud point) could be to blame. Also, the B20 study group experienced an elevated number of fuel injector replacements, but all fuel injector failures occurred within the expected mileage range of failure for this group.

The *engine and fuel system* maintenance cost per mile was 35% higher for the B20 buses than the ULSD buses. These higher costs for the B20 study group were driven primarily by an elevated number of fuel injector replacements. Nevertheless, the bus to bus variability is so high that this difference is not statistically significant. These engine and fuel system maintenance costs are higher through the first several months for the B20 group, driven by the elevated number of fuel filter and fuel injector replacements. However, throughout the 12-month testing period, the total maintenance cost per mile was only 0.32% higher for the B20 buses than the ULSD buses.

Table 4. Total Maintenance Cost – St. Louis Metro

Total Maintenance Cost Comparison					
Bus	**Fuel**	**Mileage Total**	**Labor Hours**	**Parts Cost**	**Cost ($/mile)***
3401	Diesel	50,154	459	$ 12,923	$ 0.716
3402	Diesel	45,786	324	$ 5,842	$ 0.482
3403	Diesel	44,019	364	$ 8,361	$ 0.604
3404	Diesel	45,252	293	$ 7,876	$ 0.498
3405	Diesel	42,695	305	$ 4,283	$ 0.457
3406	Diesel	48,650	442	$ 9,498	$ 0.649
3407	Diesel	48,851	332	$ 9,430	$ 0.533
Total	**Diesel**	**325,407**	**2,520**	**$ 58,214**	**$ 0.566**
3408	B20	55,456	501	$ 12,762	$ 0.682
3409	B20	57,531	440	$ 8,092	$ 0.523
3410	B20	50,588	423	$ 11,574	$ 0.647
3411	B20	47,881	398	$ 7,540	$ 0.574
3412	B20	46,514	404	$ 9,673	$ 0.642
3413	B20	48,695	317	$ 4,369	$ 0.415
3414	B20	45,312	316	$ 8,221	$ 0.530
3415	B20	42,139	318	$ 5,778	$ 0.514
Total	**B20**	**394,116**	**3,116**	**$ 68,010**	**$ 0.568**

* Assumed labor cost of $50/hour

The total maintenance cost per mile was 0.32% higher for the B20 buses than the ULSD buses, which by conventional criteria is not statistically significant. Both soot in oil and wear metals were lower with B20 use.

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Lube Oil Analysis and Results

In general, there appeared to be no harm to lube oil with B20 use, and some potential benefits. Both soot in oil and wear metals were lower with B20 use as compared to ULSD. TBN, kinematic viscosity, and corrosion were slightly compromised with B20 use, but oil was still "in-grade" throughout the 6,000 mile oil interval.

Wear appeared slightly lower with B20, but corrosion appeared slightly higher with B20, both at high mileage. However, the oil remained "in-grade" throughout the oil drain period.

2.3 Kansas City Area Transportation Authority Demonstration

The KCATA demonstration was designed to augment the larger, more detailed St. Louis Metro study conducted by NREL and the 1,000-hour durability new engine testing. The demonstration engines were equipped with particulate. The KCATA project goal was to track and document the effects of using B20 fueled transit buses in an urban setting comparing select major operating and performance parameters with buses operating exclusively on 100% petroleum diesel. The parameters included maintenance costs related to the engine, fuel tank, or fuel delivery system with particular emphasis on repairs associated with filter change-outs or leaking oil or fuel.

The objectives of this project component were to:

1) Document and track the effects of B20 use under normal operating conditions for as long a period as funding permitted (originally estimated at six months); and
2) Track maintenance costs, analyzing their impact on "day-to-day" operations of buses running on biodiesel as compared to buses running on petrodiesel alone.

The KCATA purchased 13 new buses with Cummins engines and Voith transmissions. The routes were similar (negating any topography affects), and the drivers of the 13 buses drove for identical periods of time (three month shifts on a single bus each). Each bus generally operated both a short and long run on this route each day. During this period of time the fleet did, however, switch from S500 petrodiesel to S15 ULSD[10].

Kansas City Area Transportations Authority buses operated on B20 on both short and long routes.

NBB File Photograph

[10] B20 Demonstration Project: Kansas City Area Transportation Authority. http://www.biodiesel.org/resources/reportsdatabase/reports/tra/20081017_tra-58.pdf

Fueling

Soy-based biodiesel (B100) was procured by Carter Energy in Kansas City from a number of national biodiesel producers and delivered as a splash-blended B20 blend to the KCATA facility and stored in a separate, dedicated 25,000 gallon underground storage tank. Carter Energy received valid Certificates of Analysis (COAs) with each B100 load to insure it met current ASTM specifications at the time of delivery. The dedicated storage tank at KCATA is underground. The tank was cleaned before the project began, and was used only for this project. The buses were fueled each night at an indoor facility on the KCATA grounds. KCATA fuel procurement and administrative personnel reported no problems with fuel handling or storage.

Fuel economy (miles per gallon) for each bus (#'s 3500 to 3512) was calculated from fuel consumption and mileage records kept by KCATA in their maintenance department. This data is presented in the following table.

Table 5. Fuel Economy Values for KCATA Fleet

	September 2005 - August 2006 Standard #2 Diesel			September 2006 to August 2007 B20 w/ ULSD			
Bus #	total miles	gallons	composite D2 mpg	total miles	gallons	composite B20 mpg	Difference with B20, mpg
3500	37,642.2	11,250.7	3.35	38,754.6	12,628.0	3.07	-0.28
3501	40,959.7	11,842.5	3.46	37,706.1	11,382.8	3.31	-0.15
3502	40,948.3	12,259.2	3.34	40,787.7	12,600.6	3.24	-0.10
3503	39,836.3	11,810.3	3.37	38,431.9	12,122.9	3.17	-0.20
3504	38,086.3	11,197.7	3.40	38,859.3	11,644.2	3.34	-0.06
3505	40,247.1	12,017.5	3.35	38,071.4	11,853.7	3.21	-0.14
3506	39,845.9	11,323.8	3.52	38,404.9	11,912.4	3.22	-0.30
3507	39,939.3	11,825.8	3.38	39,984.5	12,275.1	3.26	-0.12
3508	40,643.1	11,508.9	3.53	37,702.5	11,117.3	3.39	-0.14
3509	41,289.7	12,557.8	3.29	37,910.0	11,950.9	3.17	-0.12
3510	39,859.6	11,789.7	3.38	38,504.9	11,357.3	3.39	0.01
3511	39,392.7	12,458.5	3.16	39,746.8	12,066.9	3.29	0.13
3512	24,586.8	7,804.6	3.15	41,036.5	12,478.7	3.29	0.14
	503,277.0	**149,647.0**	**3.36**	**505,901.1**	**155,390.8**	**3.26**	-0.10

Fuel economy differences are well within the variability experienced from bus to bus for both the petrodiesel and the B20 groups.

Fuel Economy

Fuel economy differences for the 12 month average with the petrodiesel only buses ranged from a low of 3.15 mpg to a high of 3.53 mpg (total range 0.38 mpg) while the B20 buses ranged from a low of 3.07 mpg to a high of 3.39 mpg (total range of 0.32 shown in Table 6). The summary averages from the two groups yielded overall fuel economy of the petrodiesel buses of 3.36 mpg while the B20 buses averaged 3.26 mpg, a difference of 0.10 mpg. This difference is well within the variability experienced from bus to bus for both the petrodiesel and B20 groups.

Given the wide variety of fuel economy values from bus to bus over the 12 month average (range of 0.32 to 0.38 mpg from bus to bus within the B20 and petrodiesel only groups respectively), the even wider range of fuel economy on a month by month basis (range of 0.72 mpg from bus to bus in September 2006 for instance), and the unknown effects of the impact of the switch to ULSD which was used by all the B20 buses, this data set demonstrates similar fuel economy for petrodiesel and B20 in actual field use.

Vehicle Maintenance

Typical scheduled maintenance occurred every 6,000 miles for each bus. Operational maintenance records were obtained from KCATA maintenance staff for each bus and analyzed for any additional maintenance and associated costs that may have occurred due to use of B20 versus the previous period of time when the bus ran on standard #2 diesel.

3. Transit Operator Concerns Addressed by the Study

Although the *Mass Transit Demonstration Project* was developed to demonstrate the use of biodiesel in transit systems in Missouri, the results obtained address issues of importance to transit operators on a national level.

3.1 Logistics and Transportation Costs Associated with Use of Biodiesel

To better disseminate what was learned through the project studies, the NBB partnered with Advanced Fuel Solution (AFS), a petroleum distribution expert in Northeast USA, to develop several resource documents. Updates to a map of operating biodiesel plants and plants under construction were funded in part by this project. A current version of this resource is maintained on the NBB website[11] and shown in *Appendix C: Location of Domestic Commercial Biodiesel Production Plants*. A separate map of biodiesel distributors in the US as of April 2008 is also shown in Appendix C

3.2 Biodiesel Fuel Handling and Management Practices

A finalized report detailed biodiesel fuel handling and management practices to ensure a smooth transition and experience with biodiesel blends. The report covers fuel differences, biodiesel basics, and blending and handling procedures[12].

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[11] http://www.biodiesel.org/buyingbiodiesel/guide/

[12] *Best Fuel Management Practices for Transit.* http://www.biodiesel.org/resources/reportsdatabase/reports/tra/20071127_tra-56t.pdf

3.3 Dissemination of Data and Information from the Study

A comprehensive education and outreach plan for this project was carried out over a 7-month period from May through November 2008 and included presentations at six major industry conferences plus the 2009 Bus Con. The focus of the presentations was to educate the transit industry about the emission, energy and operational characteristics of biodiesel and to address industry concerns regarding biodiesel use with ULSD in new 2007 diesel engine technology. Results of the demonstration and engine testing also were made available at the Green Car Congress newsletter website, an online newsletter with accompanying blog for reader comments. o the public via press releases such as this one posted on the

4. Lessons Learned

4.1 Project Execution – Challenges and Resolutions

Demonstration Partners

The KCATA and St. Louis Metro demonstrations offer a basic methodology by which other urban bus fleet demonstrations could be evaluated and could gain meaningful results regarding biodiesel use versus conventional petroleum diesel. The transit fleet supervisors at KCATA and St. Louis Metro were asked to provide an overall picture, both pro and con, of their individual experiences with biodiesel as they related to the fleet studies. Both said they were satisfied with the fuel in their operations, they had been adequately educated about the fuel before implementation (each had used the fuel previously), and they were pleased with the minimal overall maintenance problems. **St. Louis Metro is still using biodiesel in their Illinois fleet.** St. Louis Metro decided to use an 11 percent blend of biodiesel (B11) to capture the state tax incentive. KCATA is not currently using biodiesel because of the increased cost associated with fuel purchasing. **KCATA officials said they would definitely use biodiesel again** if the fuel cost was equal to or less than diesel fuel and they would be open to participating in another large-scale demonstration project. Both St. Louis Metro and KCATA cited budget concerns as the primary reason for not continuing widespread biodiesel use.

Specifically, KCATA officials stated fuel quality was their number one issue and specifically they were concerned with water in the biodiesel which was thought to have an adverse effect on their injectors, although this was not proven by their engine manufacturer at the time of the test. In addition, there was a logistical issue with tank storage in terms of having to dedicate one of their three existing tanks to B20 for only the 13 buses, while the other two storage tanks had to work for fueling the remainder of their fleet. This problem was solely a result of running a 'test case' and probably would not be typical in other fleets running a greater percentage of their vehicles on biodiesel.

St. Louis Metro's concerns with biodiesel had mainly to do with ensuring consistent fuel quality, biodiesel's compatibility with ULSD, and making sure the biodiesel was properly blended when it arrived at their facility for storage.

Project Managers

During the course of the project, project managers and partners were able to resolve issues and challenges that arose. Equally valuable, was that none of these issues compromised the successful completion of the project.

- **Fuel Quality Control**

In the early stages of the St. Louis Metro demonstration, fuel blending issues arose. NREL determined, based upon fuel sample blend content analysis, that some B20 samples were not actually B20. NREL initiated discussions with the fuel supplier, HWRT, to resolve the issue and requested that St. Louis Metro collect the B20 delivery samples to ensure accuracy. St. Louis Metro began collecting the B20 delivery samples, but struggled with fuel shipping protocols in sending the samples to NREL for analysis. NREL was successful in resolving the situation by contracting with SwRI to send a local contractor to obtain weekly B20 dispenser samples from St. Louis Metro and immediately mail them back to SwRI for fuel quality analysis including blend level. This was a different system than the random dip samples delivered by HWRT and St. Louis Metro during the first year. Based on the findings from the NREL study, one solution is to use a distributor that meter blends its fuel. NREL further recommends that a transit operator collect several random samples of the fuel deliveries to be tested by an outside lab to ensure they are receiving the blend level they are paying for.

- **Data Gathering Protocol**

Although KCATA did not have fuel blending issues, it did experience difficulty with paperwork associated with collecting data for the demonstration. The burden of paperwork was resolved by KCATA and the project managers. A simplified reporting plan was developed that alleviated the amount of paperwork previously generated. It was decided that KCATA would collect data on only the most critical components associated with B20 use in the 13 demonstration buses (e.g., maintenance records and fuel economy data in condensed spreadsheet form). This would save KCATA considerable employee time as well as costs associated with the actual retrieval and processing of paperwork. In return, KCATA continued to utilize B20 for as long as project funds remained available to the fuel cost differential, extending beyond the original six months. The project managers were able to collect more data than was originally intended in this short project and the partners were pleased with the outcome and the accomplishments of the effort.

- **Biocontamination**

In early 2008, Metro discovered and started trying to correct a fuel bio-contamination problem throughout its facilities (B2,ULSD, B20 fuels). In April 2008, Metro made a decision to cease all biodiesel use at its facilities to assist in cleaning up the fuel storage bio-contamination issue that had afflicted all four of its garages regardless of biodiesel use. Prior to this action, Metro had increased filtration at the pump and dispenser head to isolate the problem from the in service bus fleet. This effort seems to have been successful. In September 2008, Metro restarted B20 fueling at its Brentwood Garage after gaining confidence that they had eliminated the bio-contamination completely throughout their systems. B20 use was not implicated in the problem and the Debaliviere Garage experienced the same issue fueling only with ULSD. NREL would recommend regular inspection (water bottom testing), maintenance and cleaning of all fuel storage tanks & lines as a regular part of operations.

4.2 Feedback from the Transit Industry

In addition to the field demonstrations and the engine study, the NBB solicited feedback from transit fleet operators nationwide familiar with the implementation and use of biodiesel blends at their facilities and in their fleets. Each fleet manager/operator was asked a series of questions that had a direct bearing on their willingness to use biodiesel blends (primarily B2 – B20), either currently or in the future, and what lessons they have learned from their use of biodiesel. A tally of the responses indicated that, with the exception of feedstock type, all topic areas were deemed of importance to transit fleets – **with an emphasis on fuel quality, economics/price, and engine warranties**. A copy of the form used to interview operators is in *Appendix D: Transit Operator feedback form*. Based on these responses, it could be concluded that as long as fuel quality standards are met, the feedstock itself is less of a priority to managers and operators.

Fleet operators and managers also were asked in what general areas they would like to gain more knowledge regarding all aspects of biodiesel from production through end use. Overall, the respondents would like to see more technical assistance available from the NBB as well as material on the applicability of the current ASTM specification and the BQ-9000 program. BQ-9000 couples the foundation of universally accepted quality management systems with the product specification ASTM D 6751, and has become the premier quality designation in the industry (see Appendix A: Biodiesel Background). They also would be open to receiving regular e-mail correspondence and participating in national webinars in order to maximize the amount of information received for their time invested.

New plant and distribution maps, as well as reports analyzing petroleum infrastructure and biodiesel management, worked to inform transit operators about biodiesel logistics and operation costs.

NBB File Photograph

In addition to speaking directly with transit managers and operators, exit surveys for workshops held at the NAFA (May 08) and BusCon (Sep 08) conferences were conducted. The participants responding expressed interest in additional information on the following topics: sustainability (77%), implementation toolkit (77%), terminal distribution (78%), and storage and handling (83%).

The results of a *National Transit Fleet Survey of Biodiesel Use and Those Considering Biodiesel* provide additional information on the needs of mass transit operators. In 2007, the Transportation Research Board of the National Academies[13] published a report concerning a detailed survey of transit fleets that used biodiesel in various blend levels as well as those not currently using it. Fleet size varied from 10 to over 1,000 vehicles and blend levels were almost exclusively B2 – B20. Geographic location of the fleets ranged from Florida to Vermont to Washington State to Arizona.

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[13] Transit Cooperative Research Program. TCRP Synthesis 72. *Use of Biodiesel in a Transit Fleet – A Synthesis of Transit Practice*. Transportation Research Board of the National Academies. Washington, DC.

For transit agencies currently using biodiesel, the total number of vehicles was almost 6,000 and the majority was not required to utilize biodiesel in their fleet at a B2 – B20 blend level. Some transit agencies reported some initial delivery, storage, and vehicle-related problems primarily related to fuel filters and cold weather problems (e.g., cloud point control), almost all of which occurred in January when the temperature was around or below (depending upon geographic location) the TPMAAT (tenth percentile minimum ambient air temperature – the temperature used for determining expected cloud point). A majority of these problems were corrected when temperatures increased in later months. In addition, it is important to note that only slightly greater than one-half (55%) of the agencies that use biodiesel required the use of ASTM-specification fuel for their operation. It is apparent from these problems that an educational program focused on the ASTM specification and proper handling, storage, and distribution would have helped immensely. In fact, many OEMs will not honor warranties of biodiesel blends unless the biodiesel meets ASTM D6751.

For the fleets that were not using biodiesel but wanted to begin using it, they were primarily interested in biodiesel's environmental advantages and performance benefits. Reasons for excluding biodiesel ranged from higher cost to material incompatibility to having to use much of the higher blends to achieve emissions reductions. Fuel quality, compatibility with ULSD, and cold weather concerns were also mentioned. Eight of the ten fleets elicited concerns could have been addressed briefly but no focused educational programs to the petroleum distributors and the fleets were provided. One of the outcomes of the evaluation is a recommendation that petroleum marketer and distributer reeducation will improve the success of biodiesel introduction in transit operations.

5. Conclusions

The results from the three studies indicate that biodiesel can serve as a drop-in replacement for diesel fuel in existing diesel equipment. It is of the utmost importance that fuel quality be monitored and recorded. The NBB has data that shows that biodiesel not meeting specification ASTM D6751 will cause performance issues and is thus not fit for this purpose.

When considering biodiesel use, storage and handling must also be taken into account. In general, the same rules for the treatment of diesel apply to biodiesel:

- Store biodiesel in a cool, dry area not exposed to sunlight,
- Use biodiesel within 6 months to avoid fuel degradation,
- Be aware of the cloud point and cold flow properties of the resulting blend and apply this to the TPMAAT operating conditions,
- Secure fuel from a reputable distributor who is aware of good fuel blending practices, and
- Clean and maintain storage vessels to avoid microbial contamination.

The best way to follow these guidelines is to purchase fuel from a reputable biodiesel distributor. Not only will these distributors have handled the biodiesel properly, but they will also be able to answer the buyer's questions about future fuel handling. As always, the NBB recommends buying fuel from a BQ-9000 certified marketer. A list of BQ-9000 distributors can be found in

Appendix A: Biodiesel Background. For a list of other distributor locations visit: http://www.biodiesel.org/buyingbiodiesel/guide/.

A B20 biodiesel blend is low enough that no specialized training is needed. As such, the technicians in the field studies were not specifically informed on biodiesel properties. However, it is important to note that if the vehicle has been using petrodiesel for a significant amount of time (greater than a few years), then biodiesel's cleaning properties may cause filter fouling the first few times used. Older vehicles (pre 1995) may have fuel lines and gaskets made from polymers that are incompatible with higher blends of biodiesel. Occasionally, users may experience fuel leaks with B20 if older fuel lines are made from these polymers. It is recommended to switch to an acceptable polymer if the user experiences leaking[14].

The National Biodiesel Board presented study results at a series of conferences, meetings, and workshops at major industry events

NBB File Photograph

The NBB has learned that technician understanding of renewable fuels is vital to accurate operability diagnosis. This shortcoming on behalf of the ethanol industry has shown NBB that a lack of outreach can negatively impact fuel perception. The NBB has created a technician training program with proactive outreach activities and a "train yourself" website, found here: http://www.biodieselautomotive.org/.

If fleets do experience issues and technicians are not able to ascertain the problem, the NBB also provides a National Troubleshooting Hotline. This resource aims to improve user experiences with biodiesel. The toll free number is expected to remain active through 2012. For more information on the Hotline visit http://www.biodiesel.org/hotline/.

Although the studies generated needed empirical data for education and outreach efforts, the survey results indicate a significant lack of knowledge in the marketplace regarding biodiesel properties and handling. Efforts should be further undertaken to educate transit fleets and fuel distributors on the properties of biodiesel. Now that biodiesel is recognized as fully fungible in 5

[14] http://www.biodiesel.org/pdf_files/fuelfactsheets/Materials_Compatibility.pdf

percent blends in diesel fuel and heating oil (refer to Appendix A) many distributors should be made aware of their product compositions.

The testing under this project was performed using biodiesel made from soybean oil. While ASTM specifies that fuel from any feedstock is fit for purpose so long as it meets the limits in D6751, these studies were not run with biodiesel produced from possible future feedstocks. Examples of such feedstocks include:

- Algae
- Camelina
- Jatropha

The NBB recommends that future testing include securing fuel from new and future feedstocks meeting ASTM D6751.

The work completed in this project evaluated model year 2007 and older engines. It should be noted that at the time of publication, no 2010 model year engines had been evaluated by a public agency using biodiesel. Therefore, NBB recommends further testing and evaluation of biodiesel in model year 2010 engines.

Lastly, the engine results from this study indicate a slight NO_x increase with a B20 blend. Other engine studies demonstrate that NO_x emissions at the B20 level can either increase or decrease depending on engine model and year, load, and duty cycle[15]. Thus, NO_x emissions are inconclusive at this point. If future work is undertaken the NBB believes a strategic use of resources would be to further evaluate NO_x emissions for B20 and lower blends using a variety of feedstocks on multiple engines utilizing new emissions reduction technologies.

[15] *Biodiesel Emissions from Heavy-Duty Engines*. McCormick, Robert and Yanowitz, Janet. National Renewable Energy Laboratory, 2009.

Appendix A: Biodiesel Background

The legal and technical definitions for biodiesel are listed below:

Biodiesel, n—a fuel comprised of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats, designated B100, and meeting the requirements of ASTM D 6751.

Biodiesel Blend, n—a blend of biodiesel fuel meeting ASTM D 6751 with petroleum-based diesel fuel, designated BXX, where XX represents the volume percentage of biodiesel fuel in the blend.

Biodiesel, as defined in D 6751, is registered with the US EPA as a fuel and a fuel additive under Section 211(b) of the Clean Air Act. The EPA surveyed and averaged several emissions studies to show that biodiesel produces the following regulated emissions reductions when burned in diesel engines intended for on road use[16]:

AVERAGE BIODIESEL EMISSIONS COMPARED TO CONVENTIONAL DIESEL, ACCORDING TO EPA

Emission Type	B100	B20
Regulated		
Total Unburned Hydrocarbons	-67%	-20%
Carbon Monoxide	-48%	-12%
Particulate Matter	-47%	-12%
Nox	+10%	+2% to -2%
Non-Regulated		
Sulfates	-100%	-20%*
PAH (Polycyclic Aromatic Hydrocarbons)**	-80%	-13%
nPAH (nitrated PAH's)**	-90%	-50%***
Ozone potential of speciated HC	-50%	-10%

* Estimated from B100 result
** Average reduction across all compounds measured
*** 2-nitroflourine results were within test method variability

While ASTM D6751 refers to the blendstock specification for B100, or neat biodiesel, biodiesel has now been approved in diesel fuel and home heating oil in blends up to 5% by volume without disclosure. This decision came in 2008 as the diesel fuel industry accepted biodiesel's performance history and added biodiesel to both D975 (diesel fuel) and D396 (heating oil). A separate fuel specification was also published for biodiesel blends between 6 and 20 percent. This fuel standard, known as D7467, is used by many OEMs who warranty biodiesel blends.

16 The National Biodiesel Board. "Biodiesel Emissions." http://www.biodiesel.org/pdf_files/fuelfactsheets/emissions.pdf

An increasing requirement for OEM warranties is the use of biodiesel coming from a BQ-9000 Producer or Laboratory. BQ-9000 is a voluntary fuel quality assurance program, overseen by the National Biodiesel Accreditation Commission (NBAC) and adopted by the National Biodiesel Board and the Canadian Renewable Fuels Association.

BQ-9000 couples the foundation of universally accepted quality management systems with the product specification ASTM D 6751, and has become the premier quality designation in the industry. The program covers storage, sampling, testing, blending, shipping, distribution, and fuel management practices. Producers, marketers and laboratories are eligible to become an Accredited Producer, Certified Marketer or Certified Laboratory under BQ-9000. More information about the program is available at http://www.bq9000.org/. A list of BQ-9000 Producers and Distributors is available at http://www.bq-9000.org/companies/producers.aspx and http://www.bq-9000.org/companies/marketers.aspx.

Appendix B: Policies and Regulations That May Impact Biodiesel Production and Use

Contents

1. Overview

US transit agencies must comply with a number of federal and state regulations targeted at alternative fuels use or the reduction of emissions. The use of biodiesel may enable transit managers to fully or partially comply with these regulations. The overall purpose of this summary is to provide an overview of rules and regulations that could impact the use of biodiesel by transit agencies. After an initial assessment of federal rules and regulations, urban transit agencies were contacted in Nebraska, California, Missouri, Arizona, Colorado, Washington state, and Indiana to gather 'on the ground' input. These transit managers were contacted via phone surveys and represented more than 6,000 operating buses. Although it did not impact the type of data being gathered, some of the transit managers contacted had experience utilizing biodiesel blends. Transit managers primarily highlighted federal environmental regulations requiring the use of cleaner fuels (e.g. ultra-low sulfur diesel) and new engine technology and air quality regulations that may impact fuel choice in a given region or air shed. Of the transit agencies contacted, only California operations highlighted state regulations to a significant degree.

The following sections will overview federal rules and regulations that may impact the use of biodiesel blends. Additional policy and regulations were identified and summarized that impact biodiesel cost, quality, and availability. Although beyond the scope of the original project, a limited number of state programs are also profiled.

It should be noted the following are examples of federal policies and regulations that may impact transit agencies and should not be considered an exhaustive list. The reader must also be aware that policy and regulations are constantly changing.

2. Cost & Availability

The following policies impact primarily cost and availability of biodiesel blends to consumers, such as urban transit systems.

2.1 Biodiesel Tax Provisions

President Bush signed into law the American JOBS Creation Act of 2004 on October 22, 2004 that included the first federal biodiesel tax incentive. The biodiesel tax incentive is a federal income tax credit or federal excise tax credit that brings lower-cost biodiesel to biodiesel consumers. The credit originally equated to one penny per percent of biodiesel in a fuel blend made from agricultural products like vegetable oils, and one-half penny per percent for recycled oils. The incentive was subsequently extended through December 31, 2008, as part of the Energy Policy Act of 2005 (P.L. 109-190). H.R. 1424, the Emergency Economic Stabilization Act of 2008 (P.L. 110-343), again extended the incentive for one year through December 31, 2009, and provided that all biodiesel, regardless of feedstock origin, was eligible for the full value of the excise tax credit.

The biodiesel tax incentive is designed to encourage the production and use of biodiesel by making the fuel price competitive with conventional diesel fuel. In general, current law allows taxpayers to claim the biodiesel tax incentive as either a $1.00 per gallon general business income tax credit or as a $1.00 per gallon blenders excise tax credit. To qualify for the biodiesel tax incentive, the fuel must by statute meet both the ASTM D6751 fuel specification and the Environmental Protection Agency's (EPA) registration requirements under Section 211 of the Clean Air Act. The income tax credit can be claimed either as a biodiesel mixture credit, which provides the incentive for each gallon of biodiesel that is blended with conventional diesel fuel, or as a B100 biodiesel credit for each gallon of pure biodiesel that is used as a fuel.

Current law also provides for a biodiesel blenders excise tax credit. Fuel blenders who have federal excise tax liability can offset that liability with an excise tax credit based on the number of gallons (and type) of biodiesel they blend into petroleum diesel. Those who do not have sufficient federal excise tax liability can apply for a rebate from the federal government for the full amount of the incentive in excess of the amount used to offset the excise tax liability. The B100 biodiesel credit and biodiesel mixture income tax credit are coordinated to take into account amounts claimed via the blenders credit. The vast majority of biodiesel tax incentives are claimed as a blenders excise tax credit. The blender credits were effective on January 1, 2005, and, unless extended by new legislation, expire on December 31, 2009. These policies represent the most significant piece of legislation impacting biodiesel demand.

Although viewed as highly successful at increasing production and consumption of biodiesel blends, Congress has proposed modifications to the biodiesel tax incentive. Specifically, the current blenders excise tax credit would be changed to a production excise tax credit of equivalent value. Industry stakeholders believe the proposed changes would help remedy shortcomings of the current tax credit and preserve the basic elements that have helped to serve as a catalyst for increased biodiesel production. If enacted, the producers excise tax credit would help ease administrative burdens for producers and blenders and help to eliminate potential transshipment schemes. Stakeholders believe the transition to a production excise tax credit could be accomplished with minimal disruptions in the market and would preserve the liquidity of the incentive.

2.2 IRS Reporting and Dyeing Requirements

The Internal Revenue Service requires that all companies selling fuel commercially in the U.S. report the amount of fuel sold and pay the appropriate federal excise tax (commonly referred to as road tax) to the U.S. Treasury. The amount of this tax, and associated state tax varies depending on whether the fuel is to be used for on-road or off-road purposes. IRS regulations require that all exempt (typically off-road) fuel be dyed red, and substantial penalties have been levied for those who use red dyed fuel for on-road use. The current dyeing protocols for those blending biodiesel are still somewhat in question.

For several years, the Internal Revenue Code has required that diesel fuel destined for tax-exempt uses be indelibly dyed. Prior to enactment of the JOBS Act, the IRS had become aware of several instances where jobbers were defrauding the government and consumers by purchasing tax-exempt diesel and then tampering with dye systems, or not manually dying the fuel, and selling it as tax-paid on-road diesel fuel. The JOBS Act included language amending the Internal Revenue Code to require diesel fuel and kerosene destined for non-taxable use to be indelibly dyed by “tamperproof, mechanical dye injection.” On April 26, 2000, final temporary regulations were published in the Federal Register with an effective date of October 24, 2005. If passed in current form, downstream blending of biodiesel for the exempt markets will be significantly impacted due to the costs associated with mechanical dye systems and the probable reduced interest by downstream blenders to invest in such equipment.

Due to concerns that covered entities may not be able to comply with the specific requirements of the temporary regulations, the IRS has issued transition rules which provide relief until such time as the final regulations are completed and published in the Federal Register. The temporary regulations state that a mixture of diesel fuel or kerosene and biodiesel will be treated as being dyed by mechanical injection if all the following requirements are met—

- Blend contains at least 80% diesel fuel (i.e. blends up to and including B20);
- Diesel fuel or kerosene in the blend was dyed by a mechanical injection system;
- Blend is created at a facility that is not a terminal; and
- Dye concentration of the finished blend meets the federal requirement when it is removed from the facility where it was made.

2.3 Small Agri-Biodiesel Producer Credit

Transit operators could indirectly benefit from the Small Agri-Biodiesel Producer Credit which is a production incentive created by the Energy Policy Act of 2005. Agri-biodiesel production facilities, with annual production of less than 60 million gallons, are eligible for an income tax credit equal to $0.10 per gallon on up to 15 million gallons. To qualify for the small producer credit, fuel must be produced from either virgin vegetable oils or animal fats. The income tax credit is treated as a general business credit and expires on December 31, 2009. This policy helps keep biodiesel cost competitive with diesel fuel.

2.4 Infrastructure Incentives

The 2005 Energy Policy Act of 2005 (P.L. 109-58) included provisions to provide a 30% federal income tax credit, limited to $30,000 per site, to organizations that install alternative fuel fueling infrastructure. The term "qualified alternative fuel vehicle refueling property" has the meaning given to by section 179A(d) of the Energy Policy Act of 2005, but only with respect to (among others) any mixture of biodiesel determined without regard to any use of kerosene and contains at least 20% biodiesel. For the first time, this federal income tax credit will also be available to government agencies. Credits are limited to property placed in service after December 31, 2005. Although biodiesel blends can be utilized in existing diesel infrastructure, tank limitations exist at terminals and downstream blending facilities. In addition, investment in retail facilities has been limited. Incentives such as this federal incentive could help spur acceptance and availability of biodiesel blends.

2.5 Renewable Fuel Standard

The Energy Independence and Security Act of 2007 (PL. 110-140) expanded the Renewable Fuel Standard (RFS). The RFS-2, effective on March 26, 2010, established a use requirement for advanced biofuels that, for the first time, specifically achieves the displacement of petroleum diesel fuel with biomass-based diesel, which includes biodiesel. To qualify as biomass-based diesel, the fuel must reduce greenhouse gas (GHG) emissions by 50% compared to conventional petroleum diesel. Under RFS-2, the following volumes of biomass-based diesel must be used domestically:

Year	Volume in Millions of Gallons
2009	500
2010	650
2011	800
2012	1,000
2013	1,000 min

From 2013 through 2022, RFS-2 requires the use of a minimum of 1 billion gallons of biomass-based diesel, and the Administrator of EPA has the authority to increase this requirement. To qualify as biomass-based diesel, the renewable fuel must be biodiesel and must reduce greenhouse gas (GHG) emissions by 50% compared to the petroleum diesel it replaces.

3. Operability

3.1 Ultra Low Sulfur Diesel Fuel

Biodiesel could be included as a low level (2%) blending component in diesel fuel as a means to improve fuel lubricity while providing environmental, economic, and energy security benefits. In

December 2000, the EPA finalized Clean Air Act regulations to reduce the sulfur content of on-road diesel fuel by 97% from its current level of 500 ppm to 15 ppm beginning in 2006. The proposed sulfur reduction rule is designed to make diesel fuel compatible with exhaust after treatment devices that engine manufacturers are designing to meet 2007 emissions standards. However, the general consensus is that the primary process of removing sulfur, called hyrdotreating, negatively impacts the lubricity characteristics of the fuel. This will necessitate that refiners include lubricity additives to maintain fuel quality and engine performance. **Previous research mentioned above has documented the lubricity benefits of biodiesel at very low percentages. In addition to the lubricity benefits of biodiesel, biodiesel itself contains less than 15 ppm sulfur. This provides an even stronger case for inclusion of biodiesel at the 2% level in all the on-highway diesel fuel sold in the US in 2006 and beyond.**

The EPA also announced that after 2007, diesel fuel used in off-road, locomotive and marine applications must contain less than 500 ppm sulfur. The sulfur level in off-road fuel will be further reduced to 15 ppm in 2010. This equates to a 99% reduction in sulfur content compared to levels currently included in off-road diesel fuel. The refining process that removes sulfur from on-road diesel fuel also destroys the lubricity characteristics of off-road diesel fuel. As a result, some type of lubricity enhancement for off-road diesel fuel will be needed as well.

While a B2 blend may cost slightly more than conventional lubricity additives, biodiesel would provide some potential benefits to the blender such as no overdosing concerns, petroleum displacement, and carbon reduction.

4. Biodiesel Fuel Quality Regulatory and Enforcement Standards

When on-spec biodiesel is properly blended into on-spec diesel fuel, the result is a high quality, premium fuel that has been shown to perform well in virtually any unmodified diesel engine. In contrast, the use of any off-spec fuel, including off-spec biodiesel, could cause performance problems and/or lead to equipment damage.

Rigorous adherence to the ASTM D6751 specification is needed in order to: protect consumers from unknowingly purchasing substandard fuel; maintain the integrity of the nation's fuel supply; and protect the reputation of biodiesel as a high quality, high performance alternative fuel. Sale of off-spec fuel is usually a violation of federal and state law. Several federal and state government agencies are responsible for the regulation and enforcement of fuel quality in the United States. The following measures will enhance overall fuel quality. These measures are important for urban transit operators to understand.

Government Adoption of ASTM D6751**.** Adoption of ASTM D6751 at all government levels – federal, state and local – as a legal requirement for the manufacture and sale of biodiesel.

ASTM Standards for Biodiesel Blends**.** ASTM has adopted ASTM D7467 for biodiesel blends containing between 6% and 20% biodiesel. ASTM also recognizes that blends as high as 5% biodiesel are allowable in ASTM D975 for diesel fuel and ASTM D396 for heating oil providing the biodiesel meets ASTM D6751.

BQ-9000 Certification**.** The NBB created the National Biodiesel Accreditation Commission in 2000 and charged it with developing a certification program for quality biodiesel producers and marketers. The resulting certification program is BQ-9000. There are three certifications: *Certified Marketer, Accredited Producer and Certified Laboratory.* In all cases, the certified party must possess a quality manual, a quality control system, and employ best practices as required assuring the delivery of a quality product.

Environmental Protection Agency. The Clean Air Act (CAA) provides EPA with the authority to regulate fuels and fuel additives in order to reduce the risk to public health from exposure to their emissions. The regulations at 40 CFR Part 79 (from the U.S. Government Printing Office) require that each manufacturer or importer of gasoline, diesel fuel, or a fuel additive, have its product registered by EPA prior to its introduction into commerce. Registration involves providing a chemical description of the product and certain technical, marketing and health-effects information. This allows EPA to identify the likely combustion and evaporative emissions. In certain cases, health-effects testing is required for a product to maintain its registration or before a new product can be registered. EPA uses this information to identify products whose emissions may pose an unreasonable risk to public health, warranting further investigation and/or regulation. EPA enforcement criteria for ASTM D6751 are as follows:
No motor fuel or motor fuel additive may be sold in the United States unless it is registered with the EPA under the CAA. (See 42 U.S.C. 7545(b); 40 CFR Part 79).

A biodiesel producer may satisfy the Tier 1 and Tier 2 Health Effects testing requirements by a) conducting the testing according to 40 CFR 79, or b) by arranging for access to “Group Data” on the testing of a product which is representative of all products in that group. (See 40 CFR 79.56). The NBB completed the required testing and submitted the required Health Effects Group Data on biodiesel that met the nationally accepted biodiesel standard at the time of testing. This standard has since been adopted as ASTM D6751, which has incorporated various improvements over time.

Any biodiesel that obtains registration via access to the NBB’s Health Effects Data must meet the current version of ASTM D6751.

An EPA inspector has, upon presentation of appropriate credentials, the right to enter any refinery, distributor, carrier, importer, wholesale purchaser, or retail outlet to make inspections, take samples, obtain information and records, and conduct tests to determine compliance with the fuel quality regulations of this Part. (See 40 CFR 80.4).

EPA’s motor fuel regulations are enforced by the EPA Office of Enforcement and Compliance Assurance and by the Certification and Compliance Division of the Office of Transportation and Air Quality (OTAQ). OTAQ inspectors collect and test samples both on a regular basis and on a complaint basis. OTAQ inspectors have full access to the National Vehicle and Fuel Emissions Laboratory and its 400 employees at Ann Arbor, Michigan.

Penalties: Any person who violates EPA regulations shall be liable to the United States for a civil penalty of not more than $25,000 for every day of such violation plus the amount of economic benefit or savings resulting from the violation. (See 40 CFR 80.5).

Parties deemed in violation: When violation of an EPA fuel standard is detected at a carrier's facility, the carrier and the refiner shall be deemed in violation. When detected at a distributor's facility, the distributor, the carrier, and the refiner shall be deemed in violation. When detected at a branded retail outlet, the retailer, the distributor, the carrier, and the refiner shall be deemed in violation. (See 40 CFR 80.30).

Internal Revenue Service. The IRS has an active enforcement division for fuel compliance, which includes approximately 130 fuel compliance officers nationwide, who routinely enforce fuel issues related to gasoline and diesel fuel. The IRS currently coordinates with the American Petroleum Institute on issues related to fuel compliance.
ASTM D6751 compliance is required of biodiesel gallons on which biodiesel tax credit is claimed (See 26 U.S.C. 40A(d)(1)). The blender claiming the credit is required to obtain from the biodiesel producer a certificate stating, under penalty of perjury, that the biodiesel or agri-biodiesel is properly registered with the EPA and meets the requirements of ASTM D6751. (See IRS Notice 2005-62, sec. 2(h)(ii)). IRS penalties can be imposed on anyone who willfully signs any return, statement, or other document filed under penalties of perjury, which is known not to be true and correct as to every material matter. The entity shall be guilty of a felony, and upon conviction, shall be fined not more than $100,000 ($500,000 in the case of a corporation) or imprisoned not more than three years, or both, together with the costs of prosecution. (26 U.S.C. 7206).

State Agencies**:** Most routine enforcement measures for fuels in the United States are conducted by state governments through their bureau of weights and measures. The majority of states regulate fuel quality for all types of fuels, and have sufficient state statutory authority to enforce fuel quality compliance. However, not all states currently regulate all fuels, and a few states do not regulate any fuels. NBB has an active project to catalogue the information by state and to educate states about biodiesel so that they can effectively monitor biodiesel quality. NBB has gathered information for various states and currently makes it available on the NBB website, www.biodiesel.org under the Resources tab.

5. National Ambient Air Quality Standards (NAAQS)

The Clean Air Act Amendments of 1990 require EPA to set National Ambient Air Quality Standards (NAAQS) for pollutants considered harmful to public health and the environment. The Clean Air Act established two types of national air quality standards. ***Primary standards*** set limits to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly. ***Secondary standards*** set limits to protect public welfare, including protection against decreased visibility, damage to animals, crops, vegetation, and buildings.
The EPA Office of Air Quality Planning and Standards (OAQPS) has set National Ambient Air Quality Standards for six principal pollutants, which are called "criteria" pollutants. They are:

- Carbon Monoxide
- Lead
- Nitrogen Dioxide
- Particulate Matter (PM_{10} and $PM_{2.5}$)
- Ozone
- Sulfur Oxides

EPA action related to both the particulate matter and ozone air quality standards can have impacts on transit agencies operating in non-attainment areas. A description of the two programs, based upon EPA information, is detailed in the following pages.

5.1 Ground Level Ozone Standards

EPA first issued standards for ground-level ozone in 1971 and revised the standard in 1979 and 1997. Each state must develop a State Implementation Plan (SIP) describing how it will attain and maintain the NAAQS. In other words, how it plans to clean up polluted areas and keep them clean. In some cases where the EPA fails to approve a SIP, the Agency can issue and enforce a Federal Implementation Plan (FIP) to ensure attainment and maintenance of the NAAQS. In June 2007, the Agency proposed to revise the 1997 standards. The proposed revisions would strengthen the standards to increase public health protection and prevent environmental damage from ground-level ozone.

<u>Background on Ozone</u>

Ozone (O3) is a gas composed of three oxygen atoms. It is not usually emitted directly into the air, but at ground-level is created by a chemical reaction between oxides of nitrogen (NOx) and volatile organic compounds (VOC) in the presence of sunlight. Ozone has the same chemical structure whether it occurs miles above the earth or at ground-level and can be "good" or "bad," depending on its location in the atmosphere.

Ground-level or "bad" ozone is not emitted directly into the air, but is created by chemical reactions between oxides of nitrogen (NOx) and volatile organic compounds (VOC) in the presence of sunlight. Emissions from industrial facilities and electric utilities, motor vehicle exhaust, gasoline vapors, and chemical solvents are some of the major sources of NOx and VOC. Breathing ozone can trigger a variety of health problems including chest pain, coughing, throat irritation, and congestion. It can worsen bronchitis, emphysema, and asthma. Ground-level ozone also can reduce lung function and inflame the linings of the lungs. Repeated exposure may permanently scar lung tissue.

<u>Revising the National Ambient Air Quality Standards for Ozone</u>

In 1997, EPA revised the national ambient air quality standard for ground-level ozone, setting it at 0.08 parts per million averaged over an 8-hour time frame. Then in April 2004, EPA designated or identified the attainment status of areas across the country with respect to that standard. Both of these actions took effect on June 15, 2004. On June 20, 2007, EPA proposed to strengthen the national ambient air quality standards for ground-level ozone, the primary component of smog. The proposed revisions reflect new scientific evidence about ozone and its effects on people and public welfare. EPA's proposal would revise both ozone standards: the *primary* standard, designed to protect human health; and the *secondary* standard, designed to protect welfare (such as vegetation and crops). The existing primary and secondary standards, set in 1997, are identical: an 8 hour standard of 0.08 parts per million (ppm).

The proposed revisions would set the primary standard to .070-.075 ppm and the secondary standard to either a new form of the standard designed specifically to protect sensitive plants from damage caused by repeated ozone exposure throughout the growing season or identical to the primary 8-hour standard. EPA plans to issue a final rule in Spring 2008.

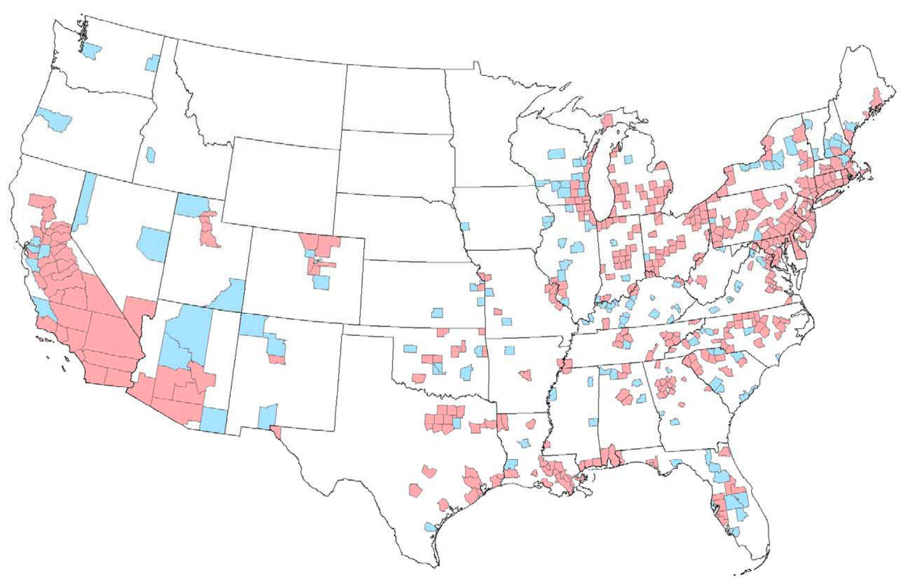
State Designations

Current designations of ozone non-attainment areas can be viewed at the EPA website at http://www.epa.gov/ozonedesignations/. The proposed ozone standard would have the impact of increasing areas that have not reached attainment.

Counties With Monitors Violating the Current Primary 8-hour Ozone Standard 0.08 parts per million

(Based on 2003 – 2005 Air Quality Data)

Counties With Monitors Violating Alternate 8-hour Ozone Standards 0.070 and 0.075 parts per million



5.2 Particulate Matter Standards

The nation's air quality standards for particulate matter were first established in 1971 and were not significantly revised until 1987, when EPA changed the indicator of the standards to regulate inhalable particles smaller than, or equal to, 10 micrometers in diameter (that's about 1/4 the size of a single grain of table salt).

Ten years later, after a lengthy review, EPA revised the PM standards, setting separate standards for fine particles ($PM_{2.5}$) based on their link to serious health problems ranging from increased symptoms, hospital admissions and emergency room visits for people with heart and lung disease, to premature death in people with heart or lung disease.

The 1997 standards also retained but slightly revised standards for PM_{10} which were intended to regulate "inhalable coarse particles" that ranged from 2.5 to 10 micrometers in diameter. PM_{10} measurements, however, contain both fine and coarse particles.

EPA revised the air quality standards for particle pollution in 2006. The 2006 standards tighten the 24-hour fine particle standard from the current level of 65 micrograms per cubic meter ($\mu g/m^3$) to 35 $\mu g/m^3$, and retain the current annual fine particle standard at 15 $\mu g/m^3$. The Agency decided to retain the existing 24-hour PM_{10} standard of 150 $\mu g/m^3$. The Agency revoked the annual PM_{10} standard, because available evidence does not suggest a link between long-term exposure to PM_{10} and health problems.

Background on Particulate Matter

As reported by EPA, particle pollution or particle matter is a complex mixture of extremely small particles and liquid droplets in the air. These particles can appear from nitrates, ammonium, carbon, metals and water that are found in coal, oil, gasoline, organic gases and high temperature industrial processes. While the larger particles come from things such as re-suspended dust, coal and oil fly ash, aluminum and silica which are brought into the environment by construction and demolition, and dust tracked onto roads by farms, mines, and unpaved roads. Both of these particles can be inhaled by humans and can pose health risks.

The previous air quality standards included standards for fine particles (those being 2.5 micrometers in diameter and smaller) and inhalable coarse particles (those being between 2.5 micrometers in diameter and smaller than 10 micrometers).

The standards for fine particles are broken up into two categories: and annual standard, which is designed to protect against health effects cause by exposures ranging from days to years; and a 24 hour standard, which provides additional protection on days with high peak fine particle concentrations.

The standards for coarse particles are also broken up into two categories: annual standard and a 24 hour standard. Although these standards sound the same, there are many different regulations set in place differentiating the two forms of particles. Studies have shown that short term exposure to coarse particles in urban and industrial areas are associated with health risks. Retaining the 24 hour standard will provide protection in all areas of the country against the effects of short term exposure to such coarse particles.

Revising the National Ambient Air Quality Standards for Particulate Matter
On March 29, 2007, EPA issued a final rule defining requirements for state plans to clean the air in 39 areas where particle pollution levels do not meet national air quality standards. State plans under this final rule, known as the Clean Air Fine Particle Implementation Rule, are the next step toward improving air quality for millions of Americans.

Once an area is designated as nonattainment, the Clean Air Act requires the state to submit an implementation plan to EPA within three years. For the 1997 fine particle standards, state plans are due in April 2008. A Tribal area designated as not attaining the standards may submit an implementation plan. If they elect not to do so, the law requires EPA to develop an implementation plan on their behalf.

State Designations
In 2004, several areas in the United States were designated as not meeting the 1997 air quality standards for fine particulate matter ($PM_{2.5}$). In 2006, EPA strengthened the air quality standards for particle pollution. The Agency expects designations based on 2007-2009 air quality data to take effect in 2010. Current designations of particulate matter non-attainment areas can be viewed at the EPA website at http://www.epa.gov/oaqps001/greenbk/ancl.html. The proposed particulate matter standard would have the impact of increasing areas that have not reached attainment.

5.3 Biodiesel and the Proposed Particulate and Ozone Air Quality Standards

Biodiesel Emissions Benefits
Biodiesel exhaust is safer for people to breathe than diesel fuel. The biodiesel industry has performed EPA Tier I testing to quantify emission characteristics as required by Section 211(b) of the Clean Air Act Amendments. Biodiesel and biodiesel blends generate reductions in all of the regulated emissions except NO_x. This NO_x increase can be effectively eliminated with the use of normal mechanical remediation techniques (e.g. catalysts or engine timing changes). Research also documents the fact that the ozone forming potential of the hydrocarbon emissions of pure biodiesel is nearly 50% less than that of petroleum diesel fuel. Pure biodiesel does not contain sulfur and therefore reduces the sulfur dioxide exhaust from diesel engines to virtually zero. An EPA study reviewing relevant biodiesel emission research confirmed that biodiesel provides emissions benefits.[17]

Biodiesel also reduces other carcinogenic air toxics important to society today. Research conducted in the United States showed biodiesel emissions have decreased levels of all target polycyclic aromatic hydrocarbon (PAH) and nitrited polycyclic aromatic hydrocarbon (nPAH) compounds, as compared to petroleum diesel exhaust.[18] PAH and nPAH compounds have been identified as potential cancer causing compounds. Targeted PAH compounds were reduced by 75% to 85%, with the exception of benzo(a)anthracene, which was reduced by roughly 50%. Target nPAH compounds were also reduced dramatically with biodiesel, with 2-nitrofluorene

[17] U.S. Environmental Protection Agency, Assessment and Standards Division Office of Transportation and Air Quality, A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions: Draft Technical Report, EPA420-P-02-001, October 2002.
[18] Chris Sharp, Characterization of Biodiesel Exhaust Emissions for EPA 211(b), (San Antonio: Southwest Research Institute, January 1998).

and 1-nitropyrene reduced by 90%, and the rest of the nPAH compounds reduced to only trace levels. All of these reductions are due to the fact the biodiesel contains no aromatic compounds.

Average Biodiesel Emissions Compared To Conventional Diesel[19]

Emission Type	B100	B20
Regulated		
Total Unburned Hydrocarbons	-67%	-20%
Carbon Monoxide	-48%	-12%
Particulate Matter	-47%	-12%
NO_x	+10%	+2% to -2%
Non-Regulated		
Sulfates	-100%	-20%*
PAH (Polycyclic Aromatic Hydrocarbons)**	-80%	-13%
nPAH (nitrated PAH's)**	-90%	-50%***
Ozone potential of speciated HC	-50%	-10%

* Estimated from B100 result

** Average reduction across all compounds measured

*** 2-nitroflourine results were within test method variability

Biodiesel can help address several of the concerns related to the global effects of climate change as well as help meet the national goals for the net reduction of atmospheric carbon. As a renewable fuel derived from organic materials, biodiesel and biodiesel blends reduce the net amount of carbon dioxide in the biosphere. A U.S. study has found that biodiesel production and use, in comparison to petroleum diesel, produces 78.5% less lifecycle CO_2 emissions.[20] Carbon dioxide is "taken up" by the annual production of crops such as soybeans and then released when vegetable oil based biodiesel is combusted.

6. State Initiatives

There are a number of state initiatives that also could impact the sale and use of biodiesel blends, thus impacting the transit industry. Generally speaking, these initiatives can be divided into the broad categories of demand-side incentives, supply-side incentives, and definitional regulations. New laws have ranged from state policy to adequately define biodiesel to reductions in state excise or sales tax for biodiesel blends to a mandate for the use of B5 blends in all diesel fuel consumed in the state. State policy also has helped to encourage the production of biodiesel through legislation that creates incentive funds for manufacturing facilities or income tax credits

[19] National Biodiesel Board, "Biodiesel Emissions Fact Sheet".

[20] John Sheehan, James Camobreco, James Duffield, Michael Graboski and Housein Shapouri, Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus (Golden: National Renewable Energy Laboratory, May 1998), NTIS, BF886002.

on plants and equipment. Although outside the scope of the original project, a few state programs are highlighted below as examples of key state policy.

6.1 Illinois

The State of Illinois enacted a sales tax exemption for biodiesel blends greater than 10% and a partial sales tax exemption for biodiesel blends between 1% and 10% through the passage of HB46 in July, 2003. Diesel fuel users typically pay federal excise tax, state sales tax (at a rate of 6.25%), and state excise tax. State sales tax is calculated after federal excise tax has been added and prior to state excise tax. This legislation would reduce the levels of sales tax paid on biodiesel blends greater than 1%. Specifically, sales tax on blends between B1 and B10 are reduced by 20% and the sales tax is eliminated on blends greater than B10.

Biodiesel is defined as a renewable diesel fuel derived from biomass that is intended for use in diesel engines. Biodiesel blends are blends of biodiesel with petroleum-based diesel fuel that the resultant product contains no less than 1% and no more than 99% biodiesel. The legislation went into effect in July of 2003 and has demonstrated significant market acceptance. Distributors report increased sales of B11 blends to diesel consumers.

6.2 Missouri

Missouri state agencies currently follow guidelines established by the Fuel Conservation for State Vehicles Program, which was passed into law by the Missouri Legislature in 1991 and amended in 1998. This law, RSMo 414.400 - 414.417, charges the Department of Natural Resources with development and implementation of a program to reduce fuel consumption, improve fleet management, and promote the use of alternative fuels. Similar to EPAct, this legislation requires the acquisition of alternative fueled vehicles. The statute also requires that at least 30 percent of all motor fuel purchased annually for use in AFVs, calculated in gasoline gallon equivalents, be an alternative fuel by July 1, 2001 provided that suppliers or state agencies have or can reasonably be expected to have established alternative fuel refueling stations as needed.

The impact of this state statute was enhanced in 2002, when the Missouri legislature passed RSMo 414.365. This law requires the Missouri Department of Transportation (MoDOT) to develop a program that provides for the opportunity to use fuel with at least the biodiesel content of B20 in its vehicle fleet and heavy equipment that use diesel fuel. The following MoDOT AFV requirements were summarized in Missouri legislation and will be employed:

On or before July 1, 2004, at least 50 percent of the department’s vehicle fleet and heavy equipment that use diesel fuel shall use fuel with at least the content of B20, if such fuel is commercially available;

On or before July 1, 2005, at least 75 percent of the department’s vehicle fleet and heavy equipment that use diesel fuel shall use fuel with at least the content of B20, if such fuel is commercially available.

In addition, SB 244 established a Self-Sustaining Biodiesel Revolving Fund in 2001. The fund is administered by the Department of Natural Resources (DNR) and is available to all state fleets. The fund pays the incremental cost of biodiesel.

Two additional pieces of legislation have been passed in Missouri that impact the biodiesel industry. HB 868, passed in the 2001 session, authorizes the incremental costs of B20 to be a reimbursable expense for Missouri school districts. Funds would need to be appropriated in a subsequent session for this program to be initiated. *In addition, a significant supply side incentive exists to attract production capacity in the state.*

6.3 Oklahoma

The state of Oklahoma has created a supply side incentive that provides a $.20/gallon income tax credit for biodiesel production facilities. The credit is available through 2011 and may be claimed for 60 months but not later than 12/31/2011. Beginning January 1, 2012, a biodiesel facility can receive a $0.075/gallon credit for new production for a period not to exceed 36 consecutive months.

6.4 Texas and the Texas Low Emission Diesel Program

The Texas Low Emission Diesel Program (TxLED) was developed as a way to improve air quality in 110 select counties throughout the state. The program is administered by the Executive Director of Texas Commission on Environmental Quality (TCEQ) and was started October 1, 2005. The goal of the program is to lower emissions of diesel fuel and in particular nitrogen oxide (NOx). The major regulations imposed by this legislation require a 10% hydrocarbon cap by volume and a minimum cetane number of 48 for diesel fuel.

The TxLED program requires producers of any blend of fuel involving diesel fuel to pay for the testing of their fuel formulations. Since the program is a diesel program, anything added to diesel fuel is considered an additive and must be tested. Pure biodiesel, B100, is not regulated in any way by this program.

Background

The air quality in approximately 110 east Texas counties is out of compliance with the federal Clean Air Act’s standard for ground-level ozone. In response, the State of Texas revised its compliance plan to do a number of things including a change in the formulation (physical properties) of diesel fuel offered for sale in those non-attainment counties. The goal of these changes is to reduce NOx emissions and other pollutants from diesel-powered vehicles and non-road equipment. The new low emission diesel fuel is commonly referred to as “TxLED”.
The counties covered by the TxLED requirement are: Houston area (Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, Waller); Beaumont/Pt. Arthur area (Hardin, Jefferson, Orange); Dallas/Ft. Worth area (Collin, Dallas, Denton, Tarrant, Ellis, Johnson, Kaufman, Parker, Rockwall), Anderson, Angelina, Aransas, Atascosa, Austin, Bastrop, Bee, Bell, Bexar, Bosque, Bowie, Brazos, Burleson, Caldwell, Calhoun, Camp, Cass, Cherokee, Colorado, Comal, Cooke, Coryell, De Witt, Delta, Falls, Fannin, Fayette, Franklin, Freestone, Goliad, Gonzales, Grayson, Gregg, Grimes, Guadalupe, Harrison, Hays, Henderson, Hill, Hood, Hopkins, Houston, Hunt, Jackson, Jasper, Karnes, Lamar, Lavaca, Lee, Leon, Limestone, Live Oak, Madison, Marion, Matagorda, McLennan, Milam, Morris, Nacogdoches, Navarro, Newton,

Nueces, Panola, Polk, Rains, Red River, Refugio, Robertson, Rusk, Sabine, San Jacinto, San Patricio, San Augustine, Shelby, Smith, Somervell, Titus, Travis, Trinity, Tyler, Upshur, Van Zandt, Victoria, Walker, Washington, Wharton, Williamson, Wilson, Wise, and Wood counties. Counties not listed above are not covered by the TxLED requirements and biodiesel and biodiesel blends are not required to be approved by TCEQ as being TxLED equivalent in order to be sold.

Industry Testing

In order for a biodiesel blend to be approved as having an emissions profile equivalent or better than TxLED, emissions testing must be conducted according to protocols established by TCEQ. The rule requires that diesel fuel as defined under 30 TAC §114.6 produced for delivery and ultimate sale to the consumer –for both on and nonroad use – must contain less than 10 percent by volume of aromatic hydrocarbons and must have a cetane number of 48 or greater. Some compliance options are allowed.

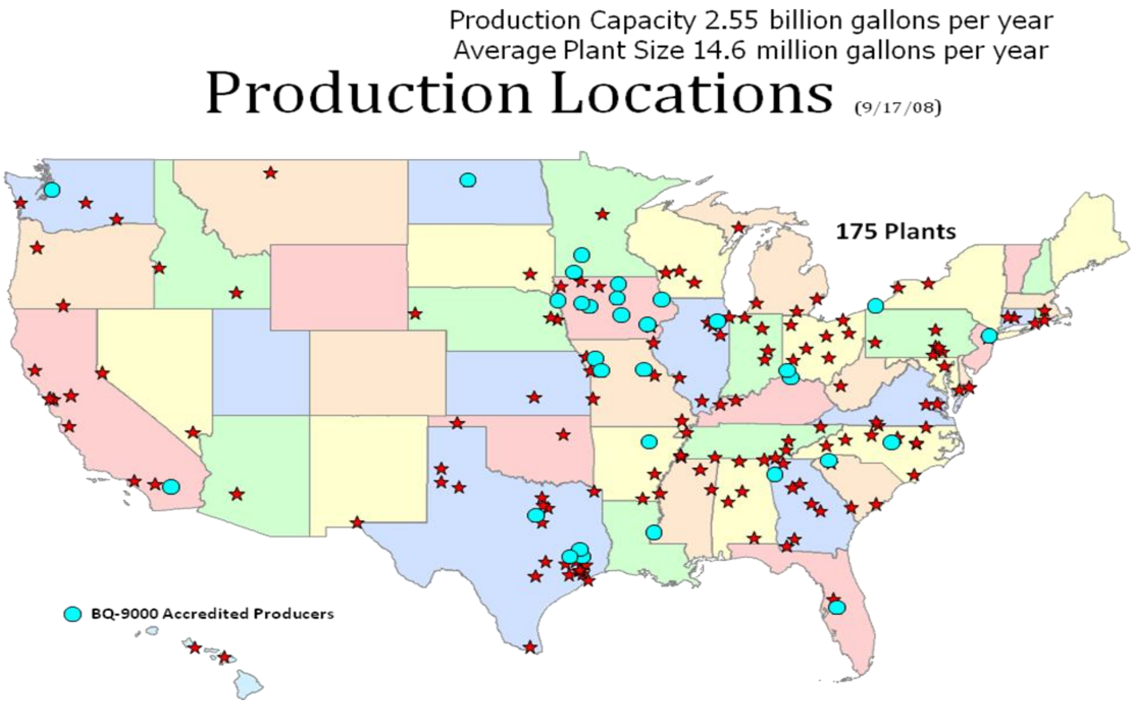
2008 Approved Formulations

TCEQ has approved blending% of ASTM D6751 with any TxLED Diesel (B5) without additive after NBB testing demonstrated equal or better NOx emissions when compared with 48/10 fuel. For biodiesel blends from B6-B20, there have been two additives approved and a third is soon to be announced, which also demonstrate equal or better NOx emissions. Since these are the same additives that are approved for producing TxLED diesel and are priced competitively, this provides a market-neutral option for biodiesel. For specifics see TCEQ website: Approved Alternative Diesel Fuel Formulations. Blends above B20 are not permitted for sale in these counties, until more additive testing can determine a NOx neutral solution.

Blender / Producer Reporting Requirements

All diesel producers and importers that sell or supply diesel fuel into the 110 Texas counties affected by the TxLED regulations are required to register with the TCEQ in accordance with 30 TAC §114.314. For biodiesel, this applies to anyone who produces or blends biodiesel with diesel. These producers and importers are required to register with the TCEQ at least 30 days before they begin to sell or supply diesel fuel into any of the 110 counties affected by the TxLED regulations. For Registration and Reporting see TCEQ website: Registration Requirements.

Appendix C: Location of Domestic Commercial Biodiesel Production Plants



Appendix D: Transit Operator Feedback Form

Transit Operator Feedback for Information on Biodiesel

(please print clearly)

1. Name and Company:

2. Contact email or telephone number:

3. Location (city & state):

4. Fleet size (number of buses): ____

5. Do you currently fuel with biodiesel? ____ yes ____ no

6. If yes, what number of buses currently run on biodiesel: ____

7. Number of buses using both biodiesel and particulate filters: ______

8. Concerning biodiesel, please rate (check the box) the following as they apply to your transit fleet/operation:

	Extremely Important	Important	Somewhat Important	Not Important
Sourcing biodiesel				
Compatibility with ULSD				
Fuel quality				
Sustainability				
Air quality benefits				
Economics/price				
Lubricity benefits				
Human health/safety benefits				
Cold weather operation				
Engine maintenance/ repair				
Compatibility with particulate filters				
Results of fleets currently using biodiesel				
Type of biodiesel feedstock				
Engine warranties				
More research on biodiesel use in all fleets				

9. Please circle one or more of the following you would like addressed:

- General technical assistance from the NBB
- ASTM specification and BQ-9000
- Proper blending techniques
- On-site storage and handling
- Fleet demonstrations
- Other: ______________________

10. How would you like to receive future information concerning biodiesel? Circle all that apply.

E-mail   Mailings   Written Material   National Webinars   Workshops

Thank you for your input from the National Biodiesel Board

Appendix E: Metric Conversion Chart

SYMBOL	CONVERT FROM	MULTIPLY BY	TO FIND	SYMBOL
mi	miles	1.61	kilometers	km
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
°C	Celsius	1.8C+32	Fahrenheit	°F

Bibliography

1000 Hours of Durability Evaluation of a Prototype 2007 Diesel Engine Using B20 Biodiesel Fuel. Southwest Research Institute, 2007. Written by Imad A. Khalek, and Michael D. Feist, Southwest Research Institute Report Project No. 03.13090. 2007.
http://www.biodiesel.org/resources/reportsdatabase/reports/gen/20080601_gen-395.pdf

B20 Demonstration Project – Kansas City Area Transportation Authority (KCATA). Written by the National Biodiesel Board, Jefferson City, Missouri. 2008.
http://www.biodiesel.org/buyingbiodiesel/guide/

Biodiesel Emissions from Heavy-Duty Engines. McCormick, Robert and Yanowitz, Janet. National Renewable Energy Laboratory, 2009.

Biodiesel Fuel Management Best Practices for Transit. Written by the National Biodiesel Board. FTA Report no: FTA-MO-2607009.2007.1. November 27, 2007.
http://www.biodiesel.org/resources/reportsdatabase/reports/tra/20071127_tra-56t.pdf

Economic Contribution of the Biodiesel Industry. Urbanchuk, John. LECG. December 2008.
National Biodiesel Board, OEM Information / Standards and Warranties
http://www.biodiesel.org/resources/oems/

National Biodiesel Board. Biodiesel Basics http://biodiesel.org/resources/biodiesel_basics/

St. Louis Metro Biodiesel (B20) Transit Bus Evaluation. 12-Month Final Report. Written by R. Barnitt, R.L. McCormick, and M. Lammert. National Renewable Energy Laboratory Technical Report 540-43486, July 2008.
http://www.biodiesel.org/resources/reportsdatabase/reports/tra/20080701_tra-57.pdf

Transit Cooperative Research Program. TCRP Synthesis 72. Use of Biodiesel in a Transit Fleet – A Synthesis of Transit Practice. Transportation Research Board of the National Academies. Washington, DC.
National Biodiesel Board, Materials Compatibility -
http://www.biodiesel.org/pdf_files/fuelfactsheets/Materials_Compatibility.pdf

References

1. 1000 Hours of Durability Evaluation of a Prototype 2007 Diesel Engine Using B20 Biodiesel Fuel. Southwest Research Institute. 2007. http://www.biodiesel.org/resources/reportsdatabase/reports/gen/20080601_gen-395.pdf

2. St. Louis Metro Biodiesel (B20) Transit Bus Evaluation. 12-Month Final Report. July 2008. http://www.biodiesel.org/resources/reportsdatabase/reports/tra/20080701_tra-57.pdf

3. B20 Demonstration Project – Kansas City Area Transportation Authority. 2008. http://www.biodiesel.org/resources/reportsdatabase/reports/tra/20081017_Tra-58.pdf

4. Biodiesel Fuel Management Best Practices for Transit. Written by the National Biodiesel Board. FTA Report no: FTA-MO-2607009.2007.1. November 27, 2007. http://www.biodiesel.org/resources/reportsdatabase/reports/tra/20071127_tra-56t.pdf

5. Specification for Biodiesel (B100)- ASTM D6751-09. National Biodiesel Board. Nov 2008. http://www.biodiesel.org/pdf_files/fuelfactsheets/BDSpec.PDF

6. Biodiesel Emissions. National Biodiesel Board. http://www.biodiesel.org/pdf_files/fuelfactsheets/emissions.pdf

7. Energy Contract. National Biodiesel Board. http://www.biodiesel.org/pdf_files/fuelfactsheets/BTU_Content_Final_Oct2005.pdf

8. American Public Transportation Association: *2010 PublicTransportation Fact Book, Appendix A: Historical Tables*, Washington, DC, April, 2010. p.33. http://apta.com/resources/statistics/Documents/FactBook/2010_Fact_Book_Appendix_A.pdf

9. Environmental Protection Agency: *Regulations Requiring Onboard Diagnostic Systems on 2010 and Later Heavy Duty Engines Used in Highway Applications Over 14,000 Pounds; Revisions to Onboard Diagnostic Requirements for Diesel Highway Heavy-Duty Applications Under 14,000 Pounds. Regulatory Announcement*, EPA420-F-06-058, December 2006. http://www.epa.gov/obd/regtech/420f06058.pdf

10. B20 Demonstration Project: Kansas City Area Transportation Authority. http://www.biodiesel.org/resources/reportsdatabase/reports/tra/20081017_tra-58.pdf

11. Buy Biodiesel- Guide to Buying Biodiesel. National Biodiesel Board. 2010. http://www.biodiesel.org/buyingbiodiesel/guide/

12. *Best Fuel Management Practices for Transit.* Department of Transportation. Federal Transit Administration. November 27, 2007. http://www.biodiesel.org/resources/reportsdatabase/reports/tra/20071127_tra-56t.pdf

13. Transit Cooperative Research Program. TCRP Synthesis 72. *Use of Biodiesel in a Transit Fleet – A Synthesis of Transit Practice*. Transportation Research Board of the National Academies. Washington, DC.

14. Materials Compatibility. National Biodiesel Board. http://www.biodiesel.org/pdf_files/fuelfactsheets/Materials_Compatibility.pdf

15. *Biodiesel Emissions from Heavy-Duty Engines*. McCormick, Robert and Yanowitz, Janet. National Renewable Energy Laboratory, 2009.

16. The National Biodiesel Board. "Biodiesel Emissions." http://www.biodiesel.org/pdf_files/fuelfactsheets/emissions.pdf

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