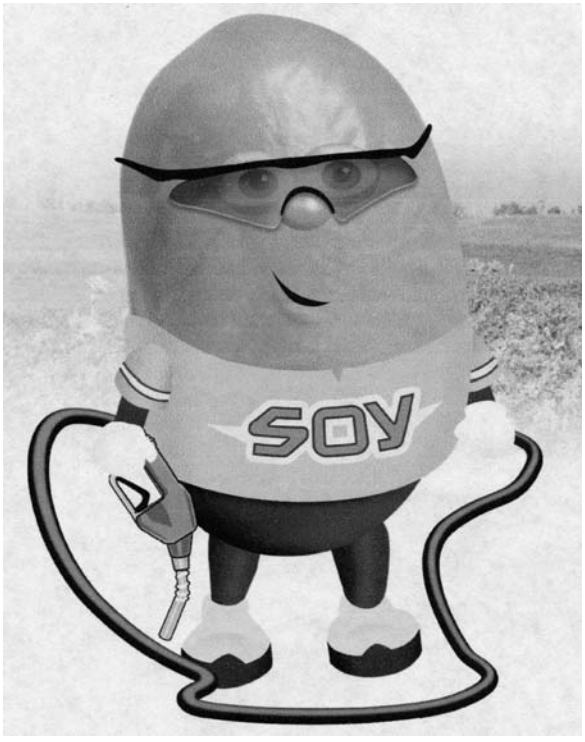
TCRP
SYNTHESIS 72

TRANSIT COOPERATIVE RESEARCH PROGRAM

Use of Biodiesel in a Transit Fleet



A Synthesis of Transit Practice

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TRANSIT COOPERATIVE RESEARCH PROGRAM

TCRP SYNTHESIS 72

Use of Biodiesel in a Transit Fleet

A Synthesis of Transit Practice

CONSULTANT
JOHN J. SCHIAVONE
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SUBJECT AREAS
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Research Sponsored by the Federal Transit Administration in Cooperation with
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WASHINGTON, D.C.
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TRANSIT COOPERATIVE RESEARCH PROGRAM

The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems. Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the transit industry. The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it.

The need for TCRP was originally identified in *TRB Special Report 213—Research for Public Transit: New Directions,* published in 1987 and based on a study sponsored by the Federal Transit Administration (FTA). A report by the American Public Transportation Association (APTA), *Transportation 2000*, also recognized the need for local, problem-solving research. TCRP, modeled after the longstanding and successful National Cooperative Highway Research Program, undertakes research and other technical activities in response to the needs of transit service providers. The scope of TCRP includes a variety of transit research fields including planning, service configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

TCRP was established under FTA sponsorship in July 1992. Proposed by the U.S. Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA, the National Academy of Sciences, acting through the Transportation Research Board (TRB); and the Transit Development Corporation, Inc. (TDC), a nonprofit educational and research organization established by APTA. TDC is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Committee.

Research problem statements for TCRP are solicited periodically but may be submitted to TRB by anyone at any time. It is the responsibility of the TOPS Committee to formulate the research program by identifying the highest priority projects. As part of the evaluation, the TOPS Committee defines funding levels and expected products.

Once selected, each project is assigned to an expert panel, appointed by TRB. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, TCRP project panels serve voluntarily without compensation.

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The TCRP provides a forum where transit agencies can cooperatively address common operational problems. The TCRP results support and complement other ongoing transit research and training programs.

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Cover figure: "Lean, Clean, Bean Machine." (*Source:* Central Ohio Transit Authority, Columbus, Ohio.)

FOREWORD

By Staff
Transportation
Research Board

Transit administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to the transit industry. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire transit community, the Transit Cooperative Research Program Oversight and Project Selection (TOPS) Committee authorized the Transportation Research Board to undertake a continuing study. This study, TCRP Project J-7, "Synthesis of Information Related to Transit Problems," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute a TCRP report series, *Synthesis of Transit Practice*.

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

This synthesis will be of interest to transit agency managers, maintenance and operation staffs, and other professionals involved in developing a program to actively manage the implementation of biodiesel fuel and its use in a bus transit fleet. It documents a full range of benefits offered by biodiesel with the thought that once the subject is understood, transit agencies can make informed decisions regarding its use. Successful implementation of biodiesel requires agencies to improve their understanding of how biodiesel differs from diesel, and the various steps needed to avoid problems resulting from these differences and components of transit agency development guidelines. Topics covered include engine manufacturer requirements and warranty considerations, maintenance implications, emissions testing results, cold weather operations, fuel specifications and procurement considerations, fuel storage, and delivery.

The synthesis includes findings from an extensive literature review, incorporates survey responses from 43 transit agencies, and closely examines biodiesel implementation at two transit agencies as case studies.

John J. Schiavone, Technical and Corporate Communications, Guilford, Connecticut, collected and synthesized the information and wrote the report, under the guidance of a panel of experts in the subject area. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

CONTENTS

USE OF BIODIESEL IN A TRANSIT FLEET

SUMMARY

The use of biodiesel, made primarily from soybeans and other organic products, merits serious consideration as an alternative fuel. As dependency on foreign oil escalates, use of any energy source that is both renewable and made domestically deserves further investigation. Biodiesel also provides a positive environmental effect, has no real handling or infrastructure considerations, mixes well with diesel, is safe to use, and in some cases is less costly to operate than diesel alone. Nevertheless, successful implementation of biodiesel requires agencies to improve their understanding of how the fuel differs from diesel and the various steps needed to avoid problems resulting from those differences. This synthesis provides readers with the full range of biodiesel benefits and the potential downsides, and offers recommendations for effectively managing the successful implementation of biodiesel. Once the subject is fully understood, agencies can make an informed decision regarding its use.

One of biodiesel's biggest downsides is more of a perceptual one; not so much with biodiesel itself, but the base fuel it is blended with: diesel. Although few understand how clean diesel engine emissions have become over the past 20 years, few have forgotten the sight of buses belching black smoke in the years before regulation. Diesel emissions reductions are impressive. For every 100 pounds of particulate matter generated from a diesel engine in 1988, fewer than two pounds are emitted from a comparable 2007 engine. Adding biodiesel made from soy beans and other organic feedstocks can make diesel emissions even cleaner. Although reductions in hydrocarbons, carbon monoxide, carbon dioxide, and particulate matter emissions are not disputed, studies regarding the effect of biodiesel on nitrous oxide emissions show a variety of results and require additional research to be conclusive. In particular, research is needed to quantify the level of emissions generated from newer engines currently equipped with diesel particulate filters, and from engines fitted with nitrous oxide reduction devices needed to meet 2010 emissions requirements.

The advantage of being able to order biodiesel, load it into existing storage tanks, and operate diesel buses as normal is actually one of biodiesel's biggest risks. In actuality, the successful implementation of biodiesel requires a well-conceived management approach that needs time and resources to properly execute. Given the time and resources required to implement other alternative fuels, the considerations needed for biodiesel use are minimal.

This synthesis includes findings from an extensive literature search into biodiesel, incorporates the responses of 43 transit agencies to a survey questionnaire, and examines the biodiesel implementation of two transit agencies as case studies. To summarize the findings, using higher concentrations of biodiesel bring with it greater potential for both rewards and problems. The higher the biodiesel concentration, the more effective it is at reducing harmful emissions, lowering dependency on foreign oil, and providing jobs domestically. Higher biodiesel concentrations are more susceptible to cold weather problems because of its ability to freeze or gel at higher temperatures than diesel, and are more likely to cause fuel contamination problems because of the fuel's cleansing effect and incompatibility with certain materials.

The good news is that all of the potential problems associated with biodiesel can be resolved through an active fuel management program. The majority of steps needed to successfully

implement biodiesel are up-front tasks that, when done properly, result in using biodiesel much like traditional diesel fuel with minimal intervention.

Recommendations for the successful implementation of biodiesel include:

- Learning about the fuel and its characteristics;
- Dedicating the necessary time and resources to developing a thorough biodiesel management plan;
- Locating a local biodiesel supplier and ensuring that it has adequate quality control measures for blending and delivery;
- Using a biodiesel specification that incorporates recognized performance and quality standards;
- Using additives as appropriate to control bacteria growth;
- Periodically testing fuel deliveries to ensure quality;
- Contacting engine and facility fueling representatives to determine warranty coverage and their recommendations for material compatibility;
- Choosing a biodiesel percentage based on local climate and operating conditions, and consider changing percentages during different seasons;
- Starting with a small test fleet with smaller biodiesel concentrations (preferably in the spring and summer), and monitoring various vehicle and fuel dispensing conditions; and
- Promoting agency use of biodiesel and its benefits with the local community.

CHAPTER ONE

INTRODUCTION

PROJECT BACKGROUND AND OBJECTIVES

Made from domestically produced soybeans and other organic products, biodiesel can provide both transit agencies and the nation with several significant benefits that include reduced dependency on foreign oil and improved energy security. Biodiesel blends well with petroleum diesel fuel, is safe to use, increases the lubricity of diesel fuel, and requires little if any infrastructure modifications. Biodiesel's positive effect on the environment can also enhance transit's image.

Obtaining benefits from biodiesel, however, requires transit agencies to become more knowledgeable about the fuel and the steps needed to ensure a trouble-free transition. Some transit agencies are currently using biodiesel in their buses, whereas others are interested in exploring its use but are unsure of how to proceed. This report synthesizes material obtained from a variety of sources—including those with biodiesel experiences—to provide transit agencies with the information needed to make informed decisions regarding implementation of this relatively new fuel option. Topics covered by this study include engine manufacturer requirements and warranty considerations, maintenance implications, emissions testing results, cold weather operations, fuel specifications and procurement considerations, fuel storage, and delivery.

TECHNICAL APPROACH

The approach to this project began with a teleconference with members the Oversight Panel to obtain their comments and input regarding how to structure the report and present the material. From that discussion a work plan was developed, which included a draft report outline and survey questionnaire. Once the work plan was finalized based on written feedback from the Panel, the survey questionnaire was circulated to agencies with and without biodiesel experience. A literature search was also conducted to obtain information from a variety of sources.

Material obtained from the literature search provided essential background information regarding biodiesel, including how the fuel is made, blended, stored, and delivered to the end user. The material also provided more detailed information concerning the full range of benefits offered by the fuel, its unique features, and the areas of its use that must be managed to avoid drawbacks. Information obtained from the transit agency surveys identified those specific areas of biodiesel use that required special focus and provided actual agency experiences from which others considering the fuel could learn. Agencies with biodiesel experience responding to the survey represent a combined fleet of 5,959 biodiesel-fueled buses traveling 217,857,955 miles annually. Two of those agencies were selected as case studies for an in-depth presentation of the procedures they used to implement biodiesel and their resulting experiences.

REPORT ORGANIZATION

Chapter two provides a basic overview and understanding of biodiesel. Chapter three builds on this foundation with greater detail about the subject and is intended for agencies seeking greater understanding of biodiesel to assist them in making a decision regarding the fuel and its implementation. Chapter four begins with an overview of biodiesel use in the trucking industry as an introduction to transit agency experiences provided from the survey questionnaire. Chapter five takes an in-depth look at two transit agencies committed to biodiesel and includes their reasons for using the fuel, along with their experiences. The report concludes with a summary of study findings and a list of recommendations to assist those wanting to put biodiesel into operation. A suggested list of future biodiesel research topics is also provided (chapter six).

CHAPTER TWO

UNDERSTANDING BIODIESEL—THE BASICS

OVERVIEW

This chapter provides a general overview of renewable energy products collectively known as biomass and the fuels made from it, with a focus on biodiesel.

BIOMASS

Biomass is broadly defined as any organic material made from plants or animals. Examples include agricultural and forestry residues, municipal wastes, industrial wastes, and animal residues. In addition to "recycled" organic waste products, biomass has come to include crops grown exclusively for energy use. Although animal products play a role, the majority of biomass feedstocks come from plant-derived material—essentially all energy originally captured by photosynthesis. Photosynthesis is the process by which green plants use sunlight to synthesize carbohydrates from carbon dioxide (CO_2) and water.

Because it comes primarily from plants and animals biomass is renewable, unlike the fossil fuels that provide the vast majority of our current energy needs. Fossil fuels supply approximately 86% of the energy consumed in the United States, with the majority coming from foreign markets. Even more disturbing is that our dependency on foreign energy continues to grow. Because the U.S. economy is so closely tied with petroleum products and oil imports, small changes in oil prices or disruptions in supply can seriously affect our economy.

As a renewable energy source that can be produced domestically, biomass offers an alternative to conventional energy to help provide national energy security, economic growth, and environmental benefits (*1*). To assist with achieving these goals, the DOE is supporting the creation of a new bio-industry that expands the use of biomass as a supplement to fossil fuel-based petroleum (*1*).

As of 2000, biomass surpassed hydroelectric power to become the largest U.S. renewable energy source, supplying more than 3% of our nation's total energy consumption. Most of this energy is in the form of industrial heat and steam used by the pulp and paper industry.

BIOFUELS

Biofuels are produced from biomass and represent the only renewable alternative liquid fuel for transportation, a sector that strongly relies on imported oil. In most applications a percentage of biofuel is blended with traditional fuels. In other cases biofuel can be used as a direct, 100% replacement for fuels such as gasoline and diesel; however, this is the exception rather than the norm for several reasons. One is that original equipment manufacturers (OEMs) typically restrict the percentages of biofuels allowed in their engines for warranty purposes. Another is that certain biofuels, especially biodiesel, have characteristics that when used in higher concentrations present challenges that must be addressed to ensure successful implementation. Because of this, those considering the use of biofuels are strongly advised to learn more about the characteristics of these fuels and to consult engine OEMs for their position.

In addition to biodiesel, examples of other biofuels include ethanol, E-diesel, and dimethyl ether. Ethanol, also known as ethyl alcohol or grain alcohol, is currently the most widely used biofuel and lends itself as a supplement to gasoline. E-diesel is a mixture of ethanol and diesel along with additives that prevent the two fuels from separating at very low temperatures. Dimethyl ether, also called methyl ether and wood ether, is a colorless gas that can be made from natural gas, coal, or biomass as a clean-burning alternative to diesel, gasoline, and other fuels.

BIODIESEL

Overview

Biodiesel is another biofuel and the subject of this report. As with the others, it is renewable and sourced domestically. Europe is the largest producer and user of biodiesel, which uses rapeseed (canola) oil as the primary feedstock. In the United States, the second largest producer and user, biodiesel is typically made from soybean oil, other agricultural products, or recycled restaurant grease. Although biodiesel contains no petroleum, it can be blended at any level with petroleum diesel.

As with other biofuels, biodiesel is expressed as the percentage of the product contained in the fuel. For example, 100% biodiesel containing no petroleum diesel is expressed as B100, and is also known as pure or "neat" biodiesel. One popular blend for vehicle applications contains 20% biodiesel and 80% petroleum diesel, and is expressed as B20. Other percentages of biodiesel are referred to as B5, B80, and so forth.

Methanol, which had been used with mixed results as a motor fuel for transit buses in the 1980s and 1990s, plays a

critical role in the production of biodiesel. Also known as wood alcohol or methyl alcohol, methanol is primarily made from natural gas. In the manufacturing of biodiesel, oils from the feedstock (soy, canola, etc.) are reacted with methanol to produce methyl esters (the official term for what we call biodiesel) and glycerin (*2*).

For every 100 lb of biodiesel produced, approximately 10 to 15 lb of glycerin is also generated. Glycerin is an ingredient typically found in hand lotions and soaps. It is also being tested as an alternative feedstock for producing antifreeze (propylene glycol), which may help offset some of the costs associated with producing biodiesel (*3*).

The oils used in biodiesel are natural products and their composition and properties will vary according to their origin. Because of this, readers should note that any natural oil products that have *not* been formally processed into biodiesel should *not* be used in diesel engines. This especially holds true for raw or refined vegetable oil or recycled greases. Research shows that vegetable oil or greases used in these engines at levels as low as 10% to 20% can cause long-term engine deposits, ring sticking, lube oil gelling, and other maintenance problems that can reduce engine life (*4*). Before it can be used in diesel engines, biodiesel must conform to a specification developed by ASTM known as ASTM D6751. Use of this ASTM specification is critical to ensure that biodiesel provides optimal fuel performance. Additional information on this important specification is provided in chapter three.

As with ethanol, the production of biodiesel has increased sharply over the past several years. In 2002, 15 million gallons of biodiesel were consumed in the United States. By 2005, production had increased to 75 million gallons and in 2006 production tripled to approximately 225 million gallons (*5*).

Advantages

Biodiesel's many advantages are summarized here and will be expanded on in subsequent chapters.

Reduced Foreign Oil Dependency

As presented earlier, biodiesel's primary advantage is as a domestic and renewable energy source that can help reduce our dependency on foreign oil. According to the Energy Information Administration, the United States spends approximately $250 billion annually on foreign oil, which translates to approximately $475,000 per minute (*6*). The U.S. consumes approximately 20 million barrels of oil per day; by 2025, the demand is expected to rise to 26 million barrels a day, of which 60% is projected to be imported.

Given our growing dependency on foreign oil, increasing demands from other parts of the world, and the instability in the Middle East where much foreign oil is sourced, biodiesel and other domestically made fuels can play an important role in strengthening our nation's energy security. To put it in perspective, if just 5% biodiesel were added to the 37 billion gallons of on-road diesel used in the United States annually it would displace 1.85 billion gallons of petroleum diesel (*6*).

Positive Energy Balance

Many alternative fuels require more energy to produce than the fuel itself provides. This is not the case with biodiesel. Although estimates vary, even under a worst-case scenario, biodiesel made from soybeans is a net energy generator (*7*). Using the national average, for every one BTU (British thermal unit) of energy used in the production of soybean-based biodiesel, an average of 2.5 BTUs of energy output is realized (a 151% energy gain). When the best agriculture and oil processing practices in the United States are used, 3.24 units of energy are produced, yielding a 224% energy gain. According to the National Biodiesel Board (NBB), this represents the highest energy balance of any fuel. The calculations, which are based on a so-called "well-to-wheel" analysis, take into account all of the energy consumed during the production of biodiesel, including energy used for transportation, production of fertilizers and pesticides to grow the feedstocks, fuels used to produce steam and electricity, and the methanol used in the manufacturing process. Proponents of biodiesel point to the positive energy balance as a major factor in ensuring its longevity as a viable fuel option.

Simplicity

Biodiesel blends are simple to use in that they require no special handling considerations. Unlike other alternative fuels that can require substantial infrastructure investments, biodiesel blends of B20 and lower can be used in compression-ignition (diesel) engines with little or no vehicle or facility modifications. Blends over B20, however, typically require additional considerations.

Biodiesel is biodegradable and essentially free of sulfur and aromatics. A sample Material Safety Data Sheet (MSDS) provided by the NBB indicates that the potential heath effects of biodiesel are minimal (*5*). In essence, handling considerations are essentially the same as petroleum diesel fuel and carry similar risks. A sample MSDS for B100 is included as Appendix A. Biodiesel users should, however, obtain an MSDS from their fuel supplier to ensure it is appropriate to the specific fuel delivered.

Lower Emissions

According to the EPA report, *A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions*, B20 reduces total unburned hydrocarbons (HC) by 20% and carbon monoxide (CO) and particulate matter (PM) by 12% each (*8*). Use of biodiesel can also help meet national goals for the net reduction of atmospheric carbon. A study by the DOE found that

biodiesel production and use, in comparison with petroleum diesel, produces 78.5% less carbon dioxide (CO_2) emissions because crops such as soybeans used to make biodiesel actually consume CO_2 during the growing process (*9*). The same study, however, suggests that net CO_2 reduction may be lower owing to other factors.

The effect of biodiesel on nitrogen oxide (NOx) emissions, however, has created a controversy in that some testing has shown a slight increase in emissions, others a slight decrease, whereas one study shows no effect at all. The variability in testing results using a variety of duty cycles combined with the lack of testing on engines equipped with diesel particulate filters (DPF) and NOx emissions controls indicates that additional research is required regarding biodiesel and NOx emissions.

Aside from the NOx controversy, biodiesel's ability to lower emissions stems from the fact it contains 11% oxygen by weight, which provides more complete combustion of fuel in the engine. Detailed information on biodiesel exhaust emissions is contained in chapter three.

Added Lubricity

With the introduction of ultra-low sulfur diesel (ULSD) to meet 2007 EPA emissions regulations, the removal of sulfur has also reduced fuel lubricity. Lubricants are needed in diesel fuels to keep the engine's moving parts such as the fuel pump from wearing out prematurely. Fuel suppliers compensate for the lack of lubricity by including fuel additives to their ULSD fuels to meet ASTM standards. However, for those agencies seeking lubricity levels higher than the minimal requirements, use of biodiesel as low as B2 can enhance lubricity to the point where additional lubricity-enhancing additives (some of which may be toxic) are not required.

Higher Cetane

B100 that meets ASTM D6751 specifications typically has a cetane number (a measure of the combustion quality of diesel fuel during compression ignition) higher than 47, which compares with a cetane average of 43 for highway diesel fuel. Biodiesel's higher cetane number provides for easier engine starting and quieter engine operation.

Incentives

The use of biodiesel offers incentives at federal and state levels. On the federal level, biodiesel is considered an alternative fuel under the Energy Policy Act (EPAct), which through various amendments made since 1992, allows some vehicles operating on biodiesel to qualify for certain credits and benefits (*9*). EPAct was passed by Congress to reduce our dependency on foreign oil by requiring certain federal, state, and public utility fleets to acquire alternative fuel vehicles (AFVs) capable of operating on non-petroleum fuels. Provisions contained in EPAct allow some agencies to meet their AFV purchase requirements by using specified amounts of biodiesel. Individual states also offer credits and other incentives for biodiesel use. Additional information on biodiesel incentives is provided in chapter three.

Flexibility

The nature of biodiesel is such that depending on pricing and availability of diesel or biodiesel, agencies can increase or decrease their use of the fuel without having to make significant changes to the fleet or fueling infrastructure. In addition, for agencies operating diesel–electric hybrid buses or diesel-powered support cars and trucks biodiesel can be used in those vehicles as well.

Potential Downsides

Despite its many advantages, there are potential disadvantages associated with biodiesel that must be understood. Many of the drawbacks apply to B100 and may not be of consequence with lower blends such as B5, B10, and B20. Understanding the full range of potential downsides associated with B100 will help with the implementation of lesser concentrations. Once understood, the good news is that the drawbacks can be greatly minimized or even eliminated. Chapters four and five will provide actual agency experiences with various biodiesel blends and the steps being taken to make the fuel work for them.

It is important to note that any biodiesel blend is only as good as the base diesel from which it is blended. Many problems attributed to biodiesel are the result of poor quality diesel fuel; sometimes the distinction is difficult to make.

Lower Energy Content

The energy content of diesel fuel, expressed in BTUs, is a determining factor in fuel economy and the engine's ability to make power. The energy content of conventional diesel can vary up to 15% depending on the supplier and time of year, with No. 2 diesel fuel typically having higher energy content than No. 1 diesel fuel.

When compared with most No. 2 diesel, B100 has slightly lower energy content. Whereas No. 2 diesel has approximately 129,000 BTUs per gallon, B100 has approximately 118,000 BTUs, which amounts to about an 8% reduction per gallon. Although the difference is more pronounced with B100, a typical B20 blend of biodiesel will reduce power, torque, and fuel economy only about 2%, which in practice may be difficult to detect from day-to-day operations, even in closely monitored fleets (*5*).

Cleansing Action

Because B100 is a solvent it may dislodge sediments contained in diesel storage tanks, dispensing lines, and onboard vehicle fuel delivery systems. As a result of this cleansing characteristic, diesel fuel storage tanks may need to be cleaned in advance of introducing biodiesel and/or fuel filters checked more frequently to prevent them from plugging.

Cold Weather Operation

B100 begins to thicken or "gel" at higher temperatures than diesel, which must be considered by those operating in colder climates. The extent to which lesser blends of biodiesel begin to gel depends on the temperature, the quality of the base diesel fuel, the type of base diesel fuel (No. 1 vs. No. 2), the region where biodiesel is sold, and other factors. Gelling of any diesel-based fuel impedes its ability to travel through lines and filters, which in turn creates problems with facility and vehicle fuel delivery systems. Because this subject is of significant concern it is addressed in more detail in chapter three. Chapters four and five will discuss steps that some agencies take in winter, such as using fuel additives and changing to lighter biodiesel blends (e.g., from B20 to B5), to avoid potential cold weather problems.

Material Incompatibility

Biodiesel incompatibility with certain materials is another potential concern, which again strongly depends on the concentration of biodiesel used. B100 has a much greater effect, biodiesel blends of 20% or less a much lesser effect, whereas the effects are said to be virtually nonexistent with low-level blends such as B2. The types of materials affected by biodiesel and the methods to mitigate the effects are discussed in chapter three.

Fuel Blending Options

Biodiesel can be blended with any type of diesel fuel including kerosene, No. 1 diesel, and No. 2 diesel. Biodiesel can also be blended with heating oil used in home furnaces. As long as biodiesel is *thoroughly blended* with diesel fuel it generally remains together as a cohesive fuel over time. As will be noted in chapter three, however, temperatures at or below the freezing point of any diesel fuel will cause fuel delivery problems. However, without exception, biodiesel *cannot* be blended with gasoline.

Blending typically consists of mixing pure biodiesel (B100) with a petroleum diesel stock. How and where the two fuels are blended will affect the thoroughness of the mixing. The easiest way is to purchase fuel from a supplier that has premixed biodiesel into a finished product that meets all specification and quality requirements defined by the customer. The newness of biodiesel in certain areas, however, may make it difficult to obtain premixed blends to exact agency requirements. With time, preblended biodiesel should become more common.

There are three general methods for blending biodiesel with diesel: splash blending, in-tank blending, and in-line blending. With splash blending, B100 biodiesel is typically poured atop the existing diesel fuel. Mixing occurs naturally as the heavier B100 works its way downward through the diesel fuel within the storage tank, although the mixing may not be as thorough.

In-tank blending is much like splash blending; the two terms are often used interchangeably. However, in-tank blending includes some form of mechanical agitation to assist with the mixing process. In one example, B100 is poured or "splashed" into a tanker truck that already contains diesel fuel. The blending that takes place during transportation as the truck travels across various road surfaces is generally sufficient. Short trips and/or colder temperatures, however, can prevent the two fuels from becoming thoroughly mixed. In another example, diesel and B100 are poured into a tanker truck or agency storage tank one right after the other at high enough fill rates to provide in-tank mixing. Some tanker tucks and fuel storage tanks are also equipped with mechanical recirculation systems to ensure more thorough in-tank blending.

In-line blending is the most effective and involves adding biodiesel to the diesel as it flows through the distribution pipe. Additives are typically blended with fuels using this method. A form of in-line blending can also take place at an agency's facility if the tanker truck can carry B100 and diesel in separate containers and deliver the fuels simultaneously through a common "Y" connector. Additional information on biodiesel blending is provided in chapter three.

Locating Biodiesel Suppliers

Given the relative newness of biodiesel, finding a biodiesel distributor or retail outlet may be difficult in certain parts of the country. Owing to the number of biodiesel outlets and the frequent additions that occur, it would not be practical to list them all here. For a complete and current listing of biodiesel suppliers, distributors, and retail sites, readers can contact NBB at 800-841-5849 or at http://www.biodiesel.org.

CHAPTER THREE

A CLOSER LOOK AT BIODIESEL

This chapter provides additional detail regarding biodiesel use from the vehicle perspective in terms of emissions and engine characteristics and from the fuel management perspective in terms of procurement specifications, blending, delivery, storage, and incentives. The reader with a more casual interest in biodiesel may want to pass over this chapter and return to it when more detail is required.

EMISSIONS AND EPA COMPLIANCE

Emissions Overview

Biodiesel's ability to reduce emissions ranks among its greatest attributes. Emissions, however, is a difficult subject to fully comprehend because of the chemical formulas and the way they are expressed. Of critical importance is that diesel emissions have been reduced drastically since they were first regulated in the 1980s, although to many the term "clean diesel" is still considered an oxymoron. A brief overview of emissions will illustrate the reductions achieved and the context in which biodiesel contributes to further reductions.

Most emissions are generated from incomplete combustion of fuel within an engine. Despite significant steps taken to improve combustion efficiency, the stop-and-go nature of transit bus operations combined with other factors continues to generate some diesel emissions that can not be fully eliminated.

The four regulated emissions from a diesel engine are CO, HC, NOx, and PM. CO is a poisonous gas and HC is a greenhouse gas that contributes to smog. Diesel engines produce little CO or volatile HC, but NOx and PM emissions from diesel engines are targets of increasingly stringent regulations. NOx contributes to low-level ozone and photochemical smog, whereas PM, which is composed of very fine particles that settle in the lungs, is suspected of causing cancer.

Trucks and buses are prime contributors to NOx and PM. Reducing both simultaneously presents a challenge because of their inverse relationship; that is, attempts to reduce PM causes NOx levels to rise and visa versa. Engine manufacturers typically control NOx through in-engine modifications such as higher fuel injection pressures, improved air intake control, exhaust gas recirculation, and the use of sophisticated electronic engine controls. Reducing PM is typically done with after treatment devices. Placed in the exhaust stream and typically concealed inside the muffler, these devices "treat" the PM "after" exhaust gases leave the engine.

2007 Diesel Emissions-Reduction Technology

EPA regulations for 2007 reduce PM and NOx to extremely low levels. The primary PM-reduction technology consists of a DPF (also called a PM filter) used in conjunction with ULSD fuel. Both are needed to meet PM levels for 2007. An after treatment device, the DPF is contained within the muffler along with a catalyst. Although each brand has different operating characteristics, DPFs that are passive in nature typically work by trapping the solid PM contained in the exhaust. The increased backpressure resulting from the partial blockage of exhaust gases causes exhaust temperatures to rise. When temperatures reach a certain level the accumulated PM is burned off. The process of trapping the solid particulate and burning it off continues and is known as regeneration.

In systems that use active regeneration, a small amount of diesel fuel is periodically introduced into the DPF to assist with burning off the PM. In both cases, the ash that builds up over time within the filter requires periodic cleaning. According to one DPF manufacturer, there is no effect on filter regeneration from testing done with biodiesel in concentrations up to B20. There is, however, a concern that if the biodiesel does not conform to the ASTM specification, higher levels of potassium could cause catalyst contamination (M. Lassen, Johnson Matthey, personal communication, May 14, 2007).

Although passive DPFs typically require no engine modifications or control systems, active DPFs do require systems to control the periodic injection of diesel fuel into the DPF to stimulate regeneration. To prevent clogging, all DPFs require ULSD with a sulfur content of no more than 15 parts per million (ppm). Most on-road diesel fuel sold is now ULSD, which can also be used in older engines without modifications. The process of reducing sulfur, however, also reduces the fuel's lubricating characteristics. Although fuel suppliers use additives to compensate for the lack of lubricity, the use of biodiesel further increases lubricity.

2010 Diesel Emissions-Reduction Technology

The 2010 EPA requirements for NOx are even lower, although PM remains at 2007 levels. Before 2007, NOx emissions were

typically reduced with in-engine modifications; however, the apparent technology to meet 2010 NOx requirements is an after treatment device called selective catalytic reduction, which is used in conjunction with the PM filter. Another technology is NOx adsorbers, a type of catalytic converter coated with a precious metal called zeolite. Agencies are urged to follow these developments to determine which technology becomes the NOx solution to meet 2010 EPA requirements.

Putting Emissions Reduction in Perspective

Numbers alone make it difficult to appreciate the level of diesel emission reductions achieved by transit buses, which during the earlier years of diesel regulation had to conform to more stringent standards than trucks. Table 1 summarizes those reductions in grams per brake horsepower-hour (g/bhp-hr), the unit of measurement used by EPA to denote emissions output.

For every 100 lb of PM generated from a diesel engine in 1988, only 1.6 lb is emitted from a comparably sized 2007 engine. For every 100 lb of NOx emitted from a 1988 engine, only 11.2 lb are emitted from a 2007 engine. In 2010 when NOx requirements become more stringent, 2010 engines will emit only 1.8 lb of NOx compared with 100 lb from a 1988 engine. Figure 1 illustrates the steep reduction of PM and NOx generated from diesel bus engines from 1988 to 2007 as expressed in g/bhp-hr.

These comparisons are important, because so much information on emissions refers to percentages of reductions without mentioning the level from which the reductions are taken. For example, a 25% reduction in PM from a 1988 diesel engine with a level of 0.60 g/bhp-hr is much more significant in terms of overall reduction than a 25% reduction from a 2007 engine where the level is already down to 0.01 g/bhp-hr. Indeed, a 25% reduction of PM from a 2007 engine would be extremely difficult to accurately measure.

The intent here is not to downplay the importance of emission reduction. Given the number of diesel vehicles on the road today, every reduction is significant. However, when emissions reductions are given in percentages, it is important to understand the level from which the reductions are applied regardless of the technology.

Biodiesel and Emissions Reduction

Atmospheric Carbon Dioxide

Before addressing the regulated emissions of CO, HC, NOx, and PM discussed so far, it is important to note that biodiesel can also help meet national goals for reducing atmospheric carbon. As organic plant material, biodiesel naturally reduces the net amount of carbon CO_2 gas, which contributes to global warming.

Biodiesel, like other fuels, generates CO_2 when burned in an engine. Unlike petroleum fuels, however, soybeans and other plants used to produce biodiesel actually consume CO_2 during the plant's growing process. According to a DOE study, the recycling of CO_2 is not 100% because some fossil fuels are used in the production of biodiesel (*4*). The DOE study shows that substituting pure biodiesel (B100) for petroleum diesel reduces life-cycle CO_2 emissions by 78%, whereas B20 reduces CO_2 atmospheric emissions by approximately 16%.

Exhaust Emissions

Biodiesel is officially registered with the EPA and meets clean diesel standards established by the California Air Resources Board (CARB). Additionally, B100 has been designated an alternative fuel by DOE and the U.S.DOT. Biodiesel is said to be the first and only alternative fuel to have a complete evaluation of emission results and potential

TABLE 1
TRANSIT BUS DIESEL EMISSIONS REDUCTION SINCE 1988

Year	PM (g/bhp-hr)	NOx (g/bhp-hr)	HC (g/bhp-hr)	CO (g/bhp-hr)
1988	0.60	10.7	1.3	15.5
1991	0.25	5.0		
1993	0.10			
1995	0.05			
1998		4.0		
2004		2.5	0.5 (NMHC) (options)	
2007	0.01	2.5–0.2 (phase in) Average of 1.2	0.5–0.14 (NMHC) (phase in)	
2010	0.01	0.2	0.14 (NMHC)	Unchanged

NMHC = non-methane hydrocarbons.

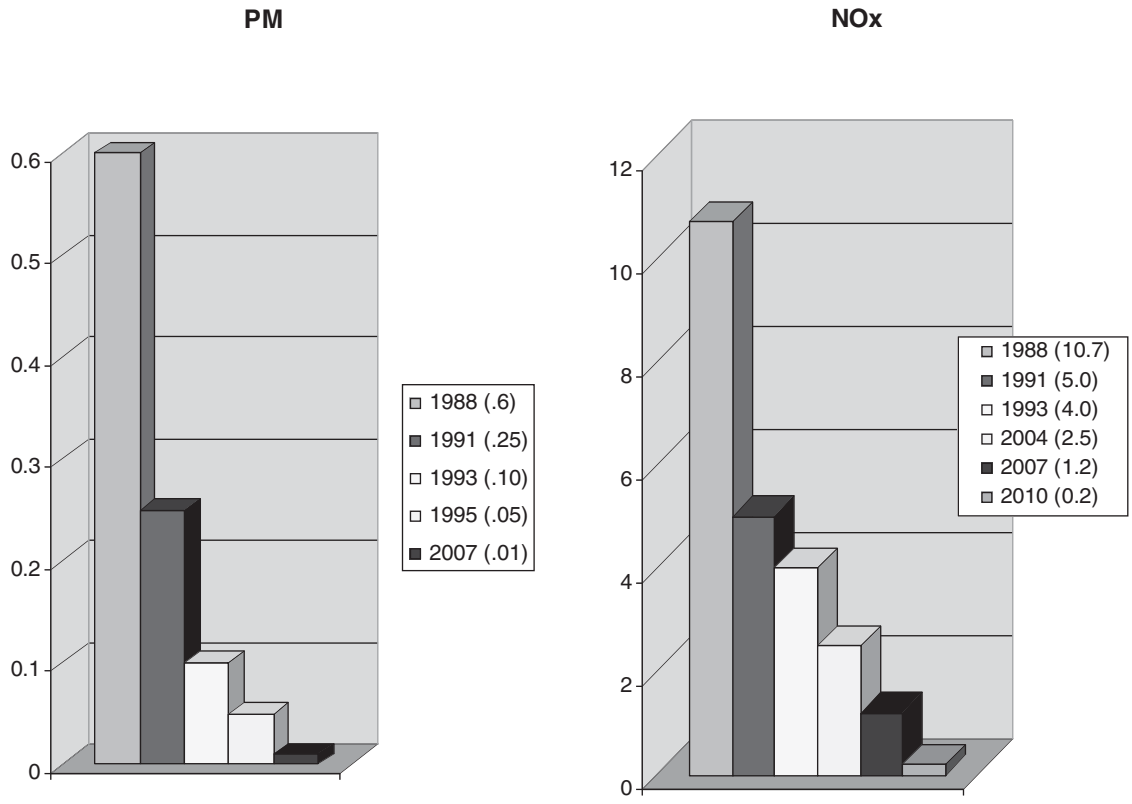

FIGURE 1 Putting diesel emission reduction in perspective. Measurements expressed as g/bhp-hr.

health effects submitted to the EPA under the Clean Air Act (*5*). Congress has also approved biodiesel as a strategy for complying with EPAct.

Most research shows that biodiesel reduces emissions of PM, CO, and HC, primarily because B100 contains 11% oxygen by weight. The presence of oxygen in the fuel allows it to burn more completely, resulting in fewer unburned fuel emissions.

Although reductions in PM, CO, and HC are generally accepted from biodiesel use, studies by the EPA, the National Renewable Energy Laboratory (NREL), and others show conflicting results for NOx emissions. The results of five biodiesel emissions studies follow.

EPA Study

The EPA conducted a comprehensive study of the impacts of biodiesel emissions on heavy-duty, on-highway engines (*8*). Although buses use heavy-duty engines and are considered on-highway vehicles, the stop-and-go nature of their operation gives them a unique operating characteristic. Nevertheless, EPA claims that its study depicts a statistically accurate relationship between biodiesel use and emissions for general highway applications.

Figure 2 summarizes the findings of EPA's study and shows that PM, CO, and HC emissions decrease as biodiesel concentrations increase, whereas NOx emissions actually increase with higher biodiesel concentrations. For B20, a popular biodiesel blend, the EPA reports that CO and PM emissions are reduced by approximately 12% each, HC emissions are reduced by approximately 20%, and NOx increases by approximately 2%. At full concentrations (B100), CO and PM emissions are reduced by approximately 48% each, HC emissions decrease by approximately 67%, and NOx increases by approximately 10%. The study also supports other findings that B20 biodiesel reduces fuel economy by 1%–2%.

It should be noted that EPA's testing included no engines equipped with exhaust gas recirculation, NOx adsorbers, or PM filters. In addition, approximately 98% of EPA's data was collected on 1997 or earlier model year engines. The EPA also reported that biodiesel emissions depend on the type of biodiesel used (soybean, rapeseed, or animal fats) and the type of base diesel fuel used to make the biodiesel blend. The most prominent test cycle the EPA used was the Urban Driving Dynamometer Schedule, which forms the basis of the Federal Test Procedure used for engine certification.

Houston Metro Study

Houston Metro commissioned an emissions study that focused exclusively on hybrid and B10-fueled transit buses (*10*). The study, conducted by the University of Houston, documents emissions and fuel economy data from two 280 horsepower

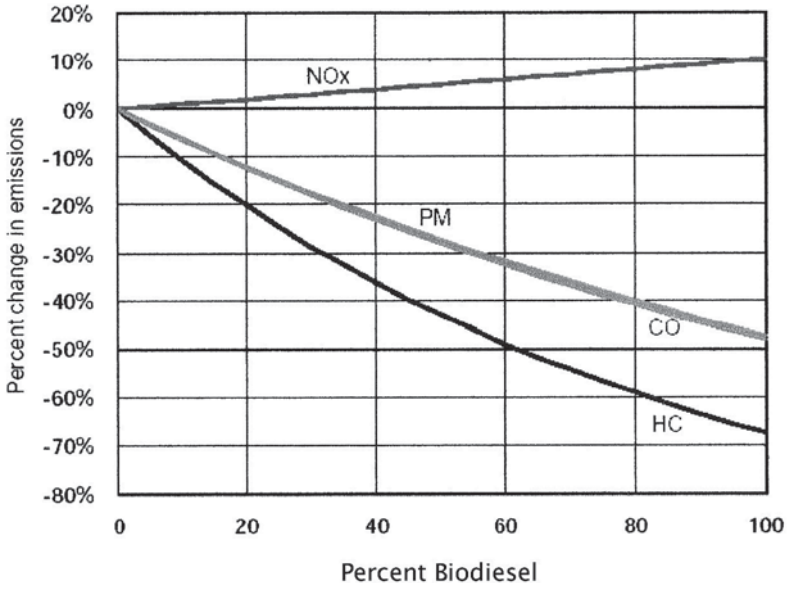

FIGURE 2 Average emissions impacts of biodiesel.

40-ft buses, one with standard diesel propulsion and the other with diesel hybrid-electric. Testing took place in October 2006 using a heavy-duty chassis dynamometer and two drive cycles: Orange County, California, and Houston Metro. Buses were also tested with two different fuels: ULSD and B10 biodiesel. Testing results were measured with air conditioning on and off. The Houston Metro study found that B10:

- Increased fuel consumption an average of 2.5%,
- Increased NOx emissions by 2%, and
- Reduced PM emissions by 11.5%.

When compared with EPA's study that was based on B20, Houston's findings for B10, which has half as much biodiesel as B20, are interesting. Despite the differences in biodiesel concentrations, both studies have PM reductions in the 11% to 12% range and NOx increases of approximately 2%. However, again using half as much biodiesel, the Houston study shows a fuel economy penalty of 2.5% for B10, in contrast to EPA's findings that B20 reduces fuel economy by 1% to 2%.

Differences between both studies could be the result of testing differences or differences between duty cycles. In presenting its findings, Houston Metro stated that additional testing is needed to validate the results (*11*).

Naval Study

An emissions study led by the Naval Facilities Engineering Service Center (NFESC) arrived at completely different findings (*12*). The report summarizes a three-year project to collect emissions data from ten Department of Defense (DoD) diesel engines, consisting primarily of buses and trucks, and portable generators. All testing was (1) performed with engines installed in the vehicles; (2) included the measurement of CO, HC, NOx, and PM; and (3) conducted in accordance with EPA testing standards and duty cycles.

Biodiesel blends from B20 to B70 were tested along with B100. All biodiesel blends were mixed with ULSD as the base fuel. Although several blends were tested, the project focused on B20, the primary blend used in military vehicles. Testing performed on B20 fuels showed:

1. No consistent trends over all engines tested;
2. No statistically significant emissions differences found between biodiesel fuels manufactured from yellow grease or soybean oil feedstocks; and
3. No statistically significant differences in HC, CO, NOx, or PM emissions between B20 biodiesel and CARB ULSD petroleum diesel.

NFESC's results are in direct contrast to those of the EPA and Houston Metro studies. In its report, the naval agency expects that its findings will be incorporated with previous EPA datasets to provide a more detailed and comprehensive database.

Despite its emissions findings, NFESC reported that use of B20, from a life-cycle cost perspective, is the most cost-effective method for DoD fleets to meet alternative vehicle requirements. Using B20 in place of petroleum diesel involved no new infrastructure requirements or additional environmental compliance costs. The only cost reported was the $0.14 higher cost per gallon to purchase the B20.

Denver RTD Study

A study presented in an SAE paper by the NREL, Denver Regional Transportation District (RTD), and the Cummins

Company evaluated nine identical 40-ft transit buses operating on diesel and B20 biodiesel in transit service by the Denver RTD (*13*). Test buses consisted of Model 2000 Orion V buses powered by Cummins ISM engines. The study evaluated the effects of biodiesel use on fuel economy, road calls, maintenance costs, and lubricants, the results of which are presented in chapter four. In addition to those tests, chassis dynamometer testing was also conducted on two of the test buses to evaluate exhaust emissions. The test driving cycle used was the City-Suburban Heavy-Vehicle Cycle.

Emissions testing revealed that B20 reduced the emissions of all regulated pollutants, including NOx. On a gram-per-mile basis, NOx was reduced by approximately 5%, HC by approximately 34%, CO by approximately 24%, and PM by approximately 19%.

NREL Study

A study conducted by NREL published in October 2006, focused on biodiesel emissions with an emphasis on NOx (*14*). The report supports other findings that oxygen in biodiesel reduces HC, CO, and PM. In particular, NREL wanted to take a closer look at EPA's 2002 report (summarized earlier) that showed a 2% increase in NOx emissions for B20. NREL noted that this small increase in NOx as stated by EPA was causing some to consider banning biodiesel.

NREL's study consisted of testing eight heavy-duty diesel vehicles, including three transit buses, two school buses, two Class 8 trucks, and one motor coach. Four of the vehicles met the 1998 heavy-duty emissions requirement of 4 g/bhp-hr NOx and four met the 2004 limit of 2.5 g/bhp-hr NOx + HC. The three transit buses tested were all model year 2000. NREL used driving cycles that simulated both urban and freeway driving. Each vehicle was tested on soy-derived B20 mixed with petroleum diesel. Only one of the vehicles tested (a school bus) was equipped with a DPF. As mentioned earlier, DPFs are needed to meet 2007 EPA emissions standards for PM.

NREL's study found that on average B20 caused a reduction in PM and CO emissions of 16% to 17% each, and a 12% reduction of HC emissions when compared with diesel. Emissions of these three regulated pollutants nearly always went down with the exception of the school bus equipped with a DPF, which did not show significant changes in emissions. This last finding is interesting in that it suggests the impact of biodiesel on 2007 and newer engines may not be as significant because emissions are already at extremely low levels, and also supports the case that additional research is needed.

When it came to NOx, the NREL study found the impact of B20 on emissions varied widely and depended on engine and vehicle technology and the driving cycle used. NOx emissions results ranged from a decrease of 5.8% to an increase of 6.2%. In summary, NREL concluded that the average NOx increase of 0.6% is statistically insignificant. When the results of NREL's own testing are combined with the B20 results from other recently published studies, the average change in NOx is 0.9% (±1.5%), which again NREL claims is statistically insignificant. NREL also found no discrepancy between engine and chassis testing studies regarding the effect of B20 on NOx emissions.

Additional Emissions Research Required

Variations on the effect biodiesel has on exhaust emissions, especially regarding NOx emissions, makes it clear that more definitive research is required in this important area. Table 2 summarizes the differences in average biodiesel emissions compared with diesel emissions for the five studies mentioned earlier.

Another study, conducted by Pennsylvania State University, found that biodiesel blends under low load conditions generally produced slightly less NOx compared with the baseline diesel fuel, whereas at high load conditions biodiesel blends produced evidently more NOx emissions (*15*). The study also concluded that NOx emissions increased as injection timing was advanced under single injection conditions. The findings may help to explain why the various testing conducted to date using different duty cycles has produced varying NOx emissions results for biodiesel, which strengthens the case for additional research.

TABLE 2
AVERAGE BIODIESEL EMISSIONS FINDINGS

	EPA	Houston	Naval	Denver	NREL
Biodiesel (%)	B20	B10	B20	B20	B20
NOx	2% increase	2% increase	No difference	5% reduction	0.6% increase
PM	12% reduction	11.5% reduction	No difference	19% reduction	17% reduction
HC	20% reduction	N/A	No difference	34% reduction	12% reduction
CO	12% reduction	N/A	No difference	24% reduction	17% reduction
Fuel economy	1%–2% reduction	2.5% reduction	N/A	2% reduction	N/A

N/A = not available.

In particular, additional emissions research is needed on engines equipped with DPFs installed to meet 2007 EPA standards, and NOx reduction technologies such as selective catalytic reduction, NOx adsorbers, and other such equipment needed to meet 2010 EPA standards. Additional testing with DPFs using standardized duty cycles may show less of an effect on PM emissions with biodiesel. Similar testing may also reveal that the NOx reduction equipment needed for 2010 is sufficient to neutralize any NOx increase resulting from biodiesel, even B100. This, however, could only be determined through additional testing.

ENGINE AND FUEL SYSTEM DETAILS

B20 Versus Higher Blends

The beneficial attributes of biodiesel combined with lower costs have caused some to consider using concentrations higher than B20. Before using these higher concentrations, however, there is the need to become thoroughly aware of the potential issues involved and the steps needed to resolve them.

As will be noted later in this chapter, the ASTM standard for biodiesel (D6751: Specification for Biodiesel Fuel Blend Stock) applies to B100 when used in blends of 20% by volume (B20) or lower because of potential concerns when greater concentrations are used. ASTM D6751 was developed through a standards development process that included participation from many organizations including vehicle, engine, and fuel injection equipment companies and biodiesel producers. A recommendation contained in ASTM D6751 states:

> A considerable amount of experience exists in the U.S. with [B20] . . . Although B100 can be used, blends of over 20% biodiesel . . . should be evaluated on a case by case basis until further experience is available.

According to guidance offered by the NBB, most engine and fuel injection equipment companies discourage the use of blends more than B20 owing to the impacts they may have on equipment and fuel systems (*5*). NBB also states that blends higher than B20 cannot be considered a direct replacement for petroleum diesel fuel and may require significant additional precautions, handling, and maintenance considerations, as well as potential fuel system and engine modifications.

Fuel-related problems, whether caused by diesel or biodiesel, are not considered manufacturing defects and generally are not covered by any engine or fuel injection equipment manufacturer's warranty. The following section will discuss specific engine manufacturer's positions regarding warranty and biodiesel use.

Warranty

All diesel engine manufacturers provide a warranty for their products. Although coverage varies, it typically includes defects related to materials and workmanship for a specified period of time. Each manufacturer recommends the types of fuels their engines were designed for, but do not warranty the fuel used in their engines whether that fuel is biodiesel or petroleum diesel. Therefore, the most important aspect regarding engine warranties and biodiesel is whether an engine manufacturer will void its parts and workmanship warranty when biodiesel is used, and whether the fuel producer or marketer will stand behind its fuels should problems occur (*5*).

According to NBB, some engine companies specify that the B100 contained in the various biodiesel blends must meet the standards of ASTM D6751 to be used in their engines, whereas others are still in the process of adopting it (*5*). NBB also reports that most major engine companies have stated formally that blends of up to B20 will not void their parts and workmanship warranties. However, each engine manufacturer has its own guidelines for biodiesel use and sets specific limits on biodiesel concentrations for warranty coverage. Given the importance of warranty, it is strongly recommended that agencies become familiar with warranty coverage offered by engine manufacturers *before* using biodiesel. It is also recommended that agencies determine if specific biodiesel or any other alternative fuel is approved by the EPA. The EPA provides alternative fuel information at http://www.epa.gov/otaq/consumer/fuels/altfuels/altfuels.htm. Agencies are also advised to periodically check with engine manufacturers to determine if any of the positions presented herein have been revised.

Cummins Engine Company

The Cummins Engine Company recently changed its position regarding the use of biodiesel. Cummins now approves B20 blends for use in its 2002 and later emission-compliant ISB, ISC, ISL, ISM, and ISX engines, including recently released 2007 products (*16*). Cummins is able to upgrade its position on the use of biodiesel fuel from B5 to B20 for the following three key reasons:

1. ASTM D6751 now includes an important stability specification for B100 biodiesel;
2. The availability of quality fuels from BQ-9000 certified marketers and accredited producers is growing rapidly; and
3. Cummins has completed the necessary testing and evaluations to ensure customers can reliably operate their equipment with confidence using B20 fuel.

Concerning warranty, Cummins covers failures that are a result of defects in material or factory workmanship (*17*). Engine damage, service issues, and/or performance issues determined by Cummins to be caused by the use of biodiesel fuel not meeting the specifications outlined in its Fuels Service Bulletin (3379001-11) are not considered to be defects in material or workmanship, and are not covered under Cummins

engine warranty. This policy is no different from Cummins' position with regard to regular diesel fuel. Cummins goes on to state that it is important to ensure when using diesel fuel or B20 with a Cummins engine that the fuel must meet industry acceptable quality standards.

Cummins also emphasizes that its engines must operate on registered fuels prescribed by the EPA and other local regulatory agencies such as CARB.

Detroit Diesel Corporation

The Detroit Diesel Corporation (DDC) recommends biodiesel fuels made from soybean or rapeseed oil. Other feedstock sources of biodiesel fuels such as animal fat and used cooking oils are not recommended by DDC. According to a 2005 DDC publication, biodiesel fuels meeting ASTM D6751 specifications before blending can be mixed up to 5% maximum by volume in petroleum diesel fuel (*18*). It is interesting to note that a previous publication issued in 2004 allowed 20% biodiesel (*19*). In all cases, however, DDC requires biodiesel to meet the fuel properties listed in a table provided on DDC's website at http://www.detroitdiesel.com.

DDC goes on to recommend that the cloud point (discussed later) of any diesel fuel should be 10°F (−12°C) below the lowest ambient temperature to prevent clogging of fuel filters. In addition, the filter plugging point temperature should be equal to or below the lowest expected fuel temperature. DDC notes that failures attributed to the use of biodiesel fuel will not be covered by DDC's product warranty; any engine performance problem related to the use of biodiesel fuel would not be recognized nor considered DDC's responsibility.

A May 2007 call to DDC revealed no change from the current biodiesel level of B5 maximum, and the company recommends that customers periodically check with DDC's website or with their local DDC representative to determine if the company's position on biodiesel has changed (Brent Calcut, DDC, personal communication, May 25, 2007).

Caterpillar

In its statement about biodiesel, Caterpillar, Inc., reminds customers that its engines are certified on only those fuels approved by EPA (*20*). As with other engine OEMs, Caterpillar states that it does not approve nor disapprove of the use of biodiesel, and that it is not in a position to evaluate its many variations and long-term effects on engines or emissions compliance.

For Caterpillar ACERT engine models that include C7, C9, C11, C13, and other models, the company's position is that biodiesel may be blended up to a maximum of 30% (B30) if the ASTM D6751 specification and other Caterpillar requirements are met. For Caterpillar 3003 through 3004, 3054, and 3056 engines, the company allows up to a 5% biodiesel blend assuming that similar requirements are met. Failures resulting from not complying with these recommendations are not covered under Caterpillar's warranty.

Ford Motor Company

The Ford Motor Company states that fuels containing no more than 5% biodiesel may be used in its diesel-powered vehicles as long as its definition for biodiesel is met, which includes compliance with ASTM D6751 (*21*). Ford's position also includes a list of some unresolved technical concerns with the use of biodiesel, which can be reviewed at Ford's website at http://www.fleet.ford.com.

Cold Weather Operation

As indicated in chapter two, biodiesel does have the potential to cause operational problems in cold weather, which can be avoided if the fuel is properly managed.

Fuel Characteristics

The characteristics of diesel fuel—even without biodiesel—are unlike gasoline in that diesel thickens or "gels" as temperatures get cooler. Those involved with diesel engines are already very familiar with this characteristic. It is not uncommon for long-haul diesel truckers to let their engines idle throughout the night to prevent diesel from gelling in their tanks. Diesel fleets operating in cold environments also take other steps such as storing vehicles inside and adding fuel heaters and special fuel additives to prevent gelling.

As with gasoline, diesel fuel is made through the refining and distillation of crude oil, the components of which range from lighter methane and propane to heavier components such as asphalt. Diesel fuels are on the heavy end of the processing, which provides higher energy content and power. The heaviness of diesel fuel, however, also causes it to gel at temperatures around 41°F (5°C). When fuel begins to gel the resulting solids get trapped in the fine mesh of fuel filters and causes them to clog. Whereas diesel fuel can start to gel at 41°F (5°C), B100 can gel at temperatures as high as 54°F (12°C), which exacerbates the gelling issue.

Cloud Point

The word gelling used so far technically refers to three terms that characterize the low temperature operability of diesel and biodiesel fuels. The least severe condition is cloud point, defined as the temperature where small solid crystals first form as the fuel cools and the fuel appears cloudy to the eye. Cloud point is a critical indicator for agencies to become aware of because it represents the first indication of more

serious conditions that will develop as temperatures fall. Concerning biodiesel use, it is essential to remember that the actual temperature of the fuel and the ambient air temperature remain above the cloud point assigned to the fuel. Failure to do so will cause the biodiesel to thicken or gel.

The second term is cold filter plugging point, the temperature that causes a fuel filter to become plugged. At this stage engine performance is severely diminished or the engine may stop running. A third term is pour point, where the temperature is so low the fuel essentially becomes a solid and will no longer flow.

It is interesting to note that neither the ASTM specifications for diesel (D975) or biodiesel (D6751) include a specific requirement for the maximum cloud point. The reason being that the cold flow properties of diesel-based fuel not only depend on where in the country the fuel is being used, but also the time of year. For example, the cloud point requirement for Florida in summer months is much different than the cloud point requirement for Alaska during the same summer months.

All transit operators should already be familiar with the cloud point requirements of their existing No. 1 or No. 2 diesel fuel. Given that biodiesel gels at temperatures higher than diesel, agencies using or planning to use biodiesel are strongly urged to obtain both cloud point and the cold filter plugging point information from their suppliers.

Additives and Other Cold Weather Solutions

Fuel additives are used to mitigate the effects of cold weather on diesel fuel. Doing the same for biodiesel can be more challenging. According to a DOE study, some additive manufacturers claim to reduce the pour point of a B100 by as much as 30°F, but the treat rate required is more than 10,000 ppm (*4*). This level of treatment can be expensive. In reality, B100 produced in the United States is extremely difficult to manage with current cold flow additives alone. Unlike rapeseed oil-based biodiesel produced in Europe, the saturated fat contained in U.S. B100 is too high for most cold weather additives to be effective. The use of cold flow additives is much more successful with biodiesel blends. According to NBB, blends of less than 20% biodiesel into existing diesel fuel have demonstrated little or no negative effect on the cold flow properties of the finished blend (*5*).

The best way to minimize the effects of cold weather when using biodiesel blends is to follow the same general guidelines for using No. 2 diesel fuel:

- Start with diesel fuel that possesses low cloud and cold filter plugging point values,
- Use the appropriate ASTM and fuel quality specifications,
- Blend fuel with kerosene,
- Use cold flow enhancing additives as appropriate,
- Continually monitor and test fuel to ensure suitability for temperature,
- Use fuel line heaters if necessary, and
- Store vehicles inside or near a building.

It is important to note that not all diesel fuel delivered to the engine is used by the engine. Unused fuel, which has been warmed by the engine as it travels through the pump, is returned back into the vehicle's tank. This warming of the fuel that occurs, especially when combined with indoor vehicle storage, may lessen the amount of cold weather additives required and may also allow the use of higher biodiesel concentrations.

Material Compatibility

Another potential concern is biodiesel's incompatibility with certain materials, which can be eliminated through gaining an understanding of the materials involved and by taking appropriate steps to ensure compatibility.

A materials compatibility study commissioned by the U.S. Army using ASTM test procedures revealed that B100 may degrade some hoses, gaskets, seal elastomers, glues, and plastics with prolonged exposure (*22*). Soft materials used for gaskets and seals, such as natural or nitrile rubber compounds, polypropylene, polyvinyl, and Tygon materials, are particularly vulnerable to B100. Teflon, Viton, and Nylon, however, were found to have very little reaction to biodiesel.

When it comes to the harder materials found in engines and fuel delivery systems, brass, bronze, copper, lead, tin, and zinc may accelerate oxidation of B100 biodiesel, creating solids. Lead solders and zinc linings should be avoided, as should copper pipes, brass regulators, and copper fittings. Affected equipment such as lines and fittings should be replaced with stainless steel, carbon steel, or aluminum.

Biodiesel blends of 20% have been shown to have a much smaller effect on these materials, although these effects are virtually nonexistent in low-level blends such as B2. Most engines made after 1994 have been constructed with gaskets and seals that are generally biodiesel resistant. Earlier engines or rebuilds that contain older gasket and seal materials may present a risk of swelling, leaking, or failure. Additionally, fuel pumps may contain rubber valves that may fail.

Once again, agencies are strongly urged to contact their engine and bus representatives to determine specific policies regarding biodiesel and the effects the fuel may have on engine and other onboard fuel systems. Once these polices are understood, agencies can then revise their preventive maintenance inspection (PMI) program and fuel island procedures to address potential material compatibility concerns. If needed,

agencies could also establish campaigns to replace affected components.

FUEL MANAGEMENT

Introduction

This section will address steps needed to ensure that the procurement, delivery, storage, and use of biodiesel are managed effectively to deliver optimum results.

Biodiesel Costs

As with petroleum diesel the cost of biodiesel is constantly changing, making it difficult to provide real-time comparisons. Chapters four and five provide biodiesel costing information from the survey results and case studies. A good source for comparing biodiesel with traditional diesel (and other fuels) is the *Clean Cities Alternative Fuel Price Report*, which is published on a periodic basis by the DOE, Energy Efficiency and Renewable Energy (*23*). At the time of this writing, the most current issue was dated October 2006.

The 2006 data show biodiesel prices for low-level blends (B2–B5) on an energy equivalent basis higher than regular diesel by approximately 14 cents per gallon, B20 higher by approximately 9 cents per gallon, and B100 higher by approximately $1.02 per gallon. Table 3 shows the average prices for B20 compared with regular diesel grouped by regions throughout the United States. Given the constantly changing landscape with regard to fuel pricing, agencies are urged to check with their local fuel suppliers and read the latest issue of DOE's *Clean Cities Alternative Fuel Price Report* at http://www.eere.energy.gov/afdc/resources/pricereport/price_report.html (*24*).

Biodiesel Quality and Specifications

Recognized standards (specifications) exist for most motor fuels to ensure an acceptable level of fuel performance. The specification for petroleum diesel fuel is ASTM D975, whereas ASTM D6751 serves as the standard for B100 biodiesel. As ASTM works to develop a separate specification for biodiesel blends up to B20, the Engine Manufacturers Association (EMA) has offered one for consideration. Although essential in defining fuel performance characteristics, neither the ASTM nor EMA specifications address quality control measures after the biodiesel has been blended with diesel. That task falls on the National Biodiesel Accreditation Program and its BQ-9000 specification. This section will describe the various fuel specifications in more detail.

ASTM D6751

ASTM standards are universally recognized in the United States. The process to develop the ASTM D6751 specification for biodiesel included representation from engine and fuel injection equipment companies, fuel producers, and fuel users.

ASTM D6751 applies to B100, which is then used as the source to produce other biodiesel blends. It does not, however, apply to the finished blend. ASTM is working to develop specifications for finished biodiesel blends up to B20, but none have been finalized. Until these specifications are established, biodiesel procurements should contain language that the B100 used in the blending process to meet ASTM D6751, and the base diesel to meet ASTM D975. The ASTM D6751 specification is summarized in Table 4 (*4*).

Whereas compliance to ASTM D975 can be confirmed through fuel testing, it is extremely difficult to determine the quality of B100 after it has been blended. In addition, ASTM D6751 does not address the specific raw materials or the manufacturing process used to produce the biodiesel. To remedy this, the following definition for biodiesel should also be included in biodiesel specifications: Biodiesel, a fuel composed of mono-alkyl esters of long-chain fatty acids derived from vegetable oils or animal fats, designated B100 (*4*).

As with other fuels, ASTM's biodiesel specification allows manufacturers to use several feedstocks and processes to produce the finished biodiesel product. Because biodiesel can be produced from several feedstocks, such as animal fats, vegetable oils, and recycled greases, the characteristics of the fuel, although meeting minimum ASTM requirements, will differ in properties according to the feedstock used. Properties affected include the cetane number and cloud point. The

TABLE 3
BIODIESEL (B20) AVERAGE PRICES BY REGION FROM CLEAN CITIES SOURCES

	Biodiesel (B20) Information Reported by Clean Cities ($ per gal)		Diesel Information Reported by Clean Cities ($ per gal)	
Region	Ave. Price/Standard Deviation of Price	Approximate No. of Stations	Ave. Price/Standard Deviation of Price	Approximate No. of Stations
New England	$2.55/—	2	$2.67/0.07	18
Central Atlantic	—	—	$2.67/0.13	30
Lower Atlantic	$2.64/0.09	40	$2.58/0.08	46
Midwest	$2.41/0.04	3	$2.57/0.10	95
Gulf Coast	$2.60/0.27	3	$2.51/0.10	35
Rocky Mountain	$2.71/0.16	4	$2.62/0.11	26
West Coast	$2.78/0.25	13	$2.74/0.19	66
National Ave.	$2.66/0.16	65	$2.62/0.15	316

TABLE 4
REQUIREMENTS FOR BIODIESEL (B100) BLEND STOCK AS LISTED IN ASTM D6751-03

Property	ASTM Method	Limits	Units
Flash point	D93	130.0 min.	°C
Water and sediment	D2709	0.050 max.	% vol.
Kinematic viscosity, 40°C	D445	1.9–6.0	mm^2/s (centistokes)
Sulfated ash	D874	0.020 max.	% mass
Sulfur*	D5453	0.0015 max. (S15) 0.05 max. (S500)	% mass
Copper strip corrosion	D130	No. 3 max.	
Cetane number	D613	47 min.	
Cloud point	D2500	Report to customer	°C
Carbon residue†	D4530	0.050 max.	% mass
Acid number	D664	0.80 max.	mg KOH/g
Free glycerin	D6584	0.020 max.	% mass
Total glycerin	D6584	0.240 max.	% mass
Phosphorus content	D4951	0.001 max.	% max.
Distillation temperature, 90% recovered (T90)‡	D1160	360 max.	°C

*Sulfur content of on-road diesel fuel to be lowered to 15 ppm in 2006.

†Carbon residue shall be run on the 100% sample.

‡Atmospheric equivalent temperature.

max. = maximum; min. = minimum.

determining characteristic is the fatty acid chains contained in biodiesel feedstocks, which are saturated, monounsaturated, or polyunsaturated (*4*). Because of the effect feedstocks have on biodiesel properties, agencies are urged to obtain from their fuel supplier specific information regarding the cloud point and cetane number before ordering a specific biodiesel product. This advice cannot be overstated.

EMA Biodiesel Test Specification

As ASTM works on a specification specifically for mixed blends of up to B20, EMA released its own test specification for B20 in June 2006, entitled Test Specification for Biodiesel Fuel (*25*). The specification is intended to jump start the testing and evaluation process. According to EMA, establishing a baseline B20 blend can be helpful for further testing and evaluation. A copy of the test specification is located at the EMA website at www.enginemanufacturers.org. Although EMA encourages vehicle owners to use the test specification along with BQ-9000, it is careful to note that the specification is not an approved national fuel standard.

Comparison of Selected Fuel Properties

Table 5 compares some properties of ASTM D6751 for B100, ASTM D975 for both No. 1 and No. 2 diesel, and the test specification being developed by EMA.

BQ-9000

NBAP is a cooperative and voluntary program for the accreditation of producers and marketers of biodiesel fuel (*26*). Defined as BQ-9000, the program combines the ASTM D6751 specification for biodiesel with a quality program that includes storage, sampling, testing, blending, shipping, distribution, and fuel management practices. The BQ-9000 program is available to any biodiesel manufacturer, marketer, or distributor in the U.S. and Canada.

The BQ-9000 program helps biodiesel companies reduce the likelihood of producing or distributing inadequate fuel. To receive accreditation companies must pass a rigorous review and inspection of their quality control processes by an independent auditor. Accreditation is available to both producers and marketers and is valid for only two years, at which time a company would need to recertify. The inclusion of a procurement requirement that biodiesel meet the BQ-9000 standard ensures that the finished fuel product as delivered to your agency conforms to nationally recognized quality standards regarding biodiesel production and distribution.

Delivery

The delivery of biodiesel is typically the responsibility of the fuel supplier. However, agencies may want to include lan-

TABLE 5
COMPARISON OF SELECTED FUEL PROPERTIES

Property	ASTM D6751 B-100	ASTM 975 No. 1 Diesel	ASTM 975 No. 2 Diesel	EMA Test Spec. B-20
Flash point	266ºF min. (ASTM D93)	100ºF min. (ASTM D93)	125ºF min. (ASTM D93)	100ºF min. No. 1 125ºF min. No. 2 (ASTM D93)
Water and sediment	Less than 0.05% by volume (ASTM D2709)	Less than 0.05% by volume (ASTM D2709)	Less than 0.05% by volume (ASTM D2709)	Less than 0.05% by volume (ASTM D2709)
Kinematic viscosity, 40º C	1.9–6.0 centistokes (ASTM D445)	1.3–2.4 centistokes (ASTM D445)	1.9–4.1 centistokes (ASTM D445)	1.3–4.1 centistokes (ASTM D445)
Sulfur content	Max. 15 ppm	Max. 15 ppm	Max. 15 ppm	Max. 15 ppm
Copper strip corrosion	No. 3 rating (ASTM D130)	No. 3 rating (ASTM D130)	No. 3 rating (ASTM D130)	No. 3 rating (ASTM D130)
Cetane number	47 min. (ASTM D613)	40 min. (ASTM D613)	40 min. (ASTM D613)	43 min (ASTM D613)
Cloud point	Report to customer—seasonal (ASTM D2500)	Report to customer—seasonal (ASTM D2500)	Report to customer—seasonal (ASTM D2500)	Report to customer— seasonal (ASTM D2500)
Carbon residue	Max 0.05% (ASTM D4530)	Max. 0.15% (Ramsbottom ASTM D5240)	Max 0.35% (Ramsbottom ASTM D5240)	Max. 0.15%—No. 1 Max 0.35%—No. 2 (Ramsbottom ASTM D5240)
Acid number	Less than 0.80 mg KOH/g (ASTM D664)	N/A	N/A	Max. 0.3 mg KOH/g (ASTM D664)
Phosphorus content	Less than 0.001 wt% mass (ASTM D4951)	N/A	N/A	Less than 0.001 wt% mass (ASTM D4951)
Lower heating value	118,170 BTU/gal (approx.)	N/A	129,050 BTU/gal (approx.)	N/A

N/A = not available; Max. = maximum; min. = minimum.

guage in their specifications to ensure that biodiesel be transported in such a way that it does not present a problem to the end user. As with much of the material provided here on biodiesel, delivery of B100 is more critical than lower blends. The most critical aspect is that fuel and air temperatures be kept above biodiesel's cloud point to prevent gelling during transportation.

The other critical issue with the delivery of biodiesel is that it does not become contaminated during transportation. As with the transportation of diesel, suppliers are required to follow certain procedures that include:

- Transport tanks be inspected and washed out as needed (obtain washout certificate);
- Diesel fuel is generally the only acceptable residual;
- No residual water is allowed; and
- Hoses and seals must be clean and compatible with B100.

Blending

Biodiesel must be *thoroughly* blended to maximize fuel performance and minimize problems. As noted in chapter two, splash blending occurs when B100 is poured atop the diesel and the heavier biodiesel mixes naturally with the existing diesel fuel in the tank as it falls downward. In-tank blending uses some form of agitation to facilitate the blending, and in-pipe blending mixes the two fuels simultaneously.

A simple method is to have the supplier use a suitable blending method and deliver the fuel as a finished product. An increasing number of petroleum terminals are installing in-pipe equipment to thoroughly blend biodiesel at the rack and deliver it ready for use. There are also a growing number of public filling stations that carry premixed biodiesel. Some fuel suppliers will also fill individual vehicles at the agency's site with premixed biodiesel from tanker trucks. The process is

known as "wet hose" filling. The last two options can provide benefits to agencies wanting to test biodiesel in a select number of buses before introducing it to their bulk storage tanks.

Although buying premixed biodiesel provides an attractive way to start using the fuel, lack of availability may force some to purchase B100 and do the blending themselves. Agencies may also prefer to do their own blending to ensure proper mixing and concentrations. The procedure is not difficult if you remember (1) that the mixing must be thorough, and (2) biodiesel is slightly heavier than diesel (*4*).

Because the specific gravity of B100 is heavier than diesel (0.88 for B100 compared with 0.85 for No. 2 diesel and 0.80 for No. 1), B100 should never be poured into an empty tank because the weight will keep it at the bottom. Problems may not occur in summer months when temperatures are above the fuel's cloud point; however, colder weather will cause the heavier biodiesel to gel and clog filters. Because tanks typically draw from the bottom, the more concentrated biodiesel could also create material compatibility problems with fuel dispensing seals and gaskets that would normally not occur if the fuel was blended at lesser levels. Highly concentrated biodiesel at the tank bottom may also start to dissolve sediments, whereas lower levels would not.

The best method for self-blending is to add B100 to a tank that already contains diesel. The B100 could be splash blended atop the diesel, allowing the added weight of the B100 to do the mixing as it works its way through the diesel. Some other means of mechanical agitation can also be used to facilitate the in-tank blending, such as immediately adding diesel after the biodiesel. Agencies could also purchase mechanical blending equipment, but this involves additional costs and can be complicated for smaller fleets.

In all cases where the agency does its own blending, it needs to start by measuring the diesel content already contained in the tank and calculate the amount of B100 and petroleum diesel needed to achieve the desired blend (e.g., B5 and B20). A popular method for measuring fuel content is to "stick" the tank by inserting a long wooden rod into the tank to check the fuel level. If improper blending is suspected, there are tests that can be performed. One involves taking samples from the top, middle, and bottom portion of the storage tank using ASTM standard practice D4057 (Standard Practice for Manual Sampling of Petroleum and Petroleum Products). Each sample can then be tested for density or specific gravity to determine the biodiesel percentage. There are also several relatively inexpensive and simple-to-use measuring devices available. Information on where to obtain this equipment is available from the NBB at www.biodiesel.org. Another testing method involves placing the three fuel samples described earlier in a freezer and periodically noting when each batch begins to crystallize. If the samples are not within 5°F–6°F (3°C) of each other, the biodiesel blend will need further agitation.

Regardless of where the blending takes place, colder winter temperatures present the biggest concern because of the biodiesel's tendency to gel at higher temperatures than petroleum diesel. As noted throughout this study, agencies need to become familiar with the cloud point of the biodiesel they are using and must monitor air and existing fuel temperatures at time of delivery.

To prevent cold weather gelling, some suppliers will also mix in a 50/50 ratio of kerosene with B100. Agencies will need to know this in advance to obtain the desired final biodiesel blend. For example, 60% diesel blended with 40% 50/50 mixture of biodiesel and kerosene will yield B20 (not B40).

Fuel Storage

Many of the same properties that affect engine and onboard bus fuel systems with biodiesel use also apply to facility storage. Some concerns may be amplified by facility storage because bulk fuel generally remains in tanks for longer periods of time. Other concerns, such as cold weather operation, may be minimized by underground tank storage.

According to the NBB, standard storage and handling procedures used for petroleum diesel can also be used for biodiesel (*5*). NBB also states that existing storage tanks and dispensing equipment can be used for the most part. Fuel should be stored in a clean, dry, dark environment. Acceptable storage tank materials include aluminum, steel, fluorinated polyethylene, fluorinated polypropylene, and Teflon. Copper, brass, lead, tin, and zinc should be avoided. As discussed here, many of the issues related to biodiesel storage depend on the percentage of biodiesel contained in the fuel, temperature, fuel specification, and fuel quality.

Fuel Stability and Storage Life

Most transit agencies turn over their diesel fuel quickly, generally in 2 to 4 months. Given this rapid use, the stability of biodiesel (whether B20 or B100) should not be problematic. ASTM standard D4625 (Standard Test Method for Distillate Fuel Storage) states that B100 could be stored for up to 8 months, with lower percentages lasting for a year or more. NBB recommends that B100 be stored no more than 6 months.

Over time, biodiesel as with other liquid fuels will start to break down and deteriorate. The primary concern is oxidation, which over time can lead to high acid numbers, high viscosity, and the formation of gums and sediments that eventually clog filters. ASTM D6751 establishes limits for biodiesel stability. As with diesel fuel, periodic fuel monitoring and testing are highly recommended. The use of antioxidant additives can significantly improve the stability and storage life of biodiesel. Before using any additive, however, contact your fuel and engine supplier for recommendations.

Storage Temperatures

The bigger concern with B100 storage is its tendency to gel more quickly relative to diesel and other biodiesel blends. Whether B100 or a blend, the temperature at which the fuel can be safely stored without gelling depends on the local climate. In general, any biodiesel blend should be stored in tanks where the fuel temperature will remain at least 5°F to 10°F above the cloud point of the fuel. A storage temperature of 40°F to 45°F should be adequate for just about all biodiesel blends. Although underground tank storage should not be a concern because temperatures are normally above 45°F, it is recommended that agencies monitor temperatures to make certain. For aboveground storage tanks, B20 is generally regarded as the limit, and temperature monitoring is again highly recommended. In some cases additional precautions may be needed to prevent gelling, such as extra tank insulation, equipment to agitate the fuel, and auxiliary heating systems. The same holds true for piping and dispensing equipment exposed to the elements.

Glycerin Content

A byproduct of manufacturing biodiesel is a form of sugar called glycerin. Makers of automotive coolant are testing glycerin as a substitute ingredient in the production of antifreeze. If successful, the new market created for glycerin may help reduce some of the costs associated with manufacturing biodiesel.

Although the vast majority of glycerin is removed from the biodiesel manufacturing process, levels that exceed those set by ASTM D6751 can cause filter plugging and other fuel related problems. As shown in Table 4, ASTM D6751 calls for a maximum of 0.020% free glycerin and a maximum of 0.240 total glycerin.

Biological Contamination

One area not yet addressed is the biological growth that occurs in biodiesel caused by the presence of water. Although some water is typically present in petroleum diesel, biodiesel is more susceptible to water contamination problems. As a result, biocide additives are generally needed to control the growth of bacteria, algae, and other microorganisms. These microorganisms usually grow at the fuel–water interface, and if left untreated can promote corrosion of fuel system components. The same products used to treat biological growth in petroleum diesel can also be used in biodiesel. The additives typically work by drying up water and killing the microorganisms. Fuel suppliers and engine OEMs should be consulted before using any fuel additive.

In addition to additives, there are steps that agencies can take to reduce water levels in biodiesel (and other petroleum) fuels:

- Make sure the caps on all fuel tanks are in place and in working condition, especially gaskets.
- Keep tanks full of fuel to minimize condensation buildup inside the tank caused by large temperature swings.
- Insulate aboveground storage tanks (double wall) and provide shade if possible to moderate temperature swings and the formation of condensation.
- Check for the presence of water and other signs of contamination when measuring tank levels.
- Periodically drain a small amount of fuel from the bottom of storage tanks to remove any water accumulation.
- Avoid prolonged exposure of fuel to light, which can induce bacterial growth (aboveground fiberglass tanks should be painted and/or placed in shaded areas).

Cleansing Effect

As discussed in chapter two, biodiesel has a cleansing effect on the components it comes in contact with. The same methyl esters found in biodiesel have been used for years as cleaners and solvents. As a result, biodiesel can dissolve and dislodge accumulated sediments that have formed over time in diesel tanks, fuel delivery systems, and other areas where fuel makes contact. Once dissolved, sediments can plug filters and create fuel injector and other fuel system-related problems and failures.

The level of biodiesel's cleansing action depends on two factors: (1) the amount of sediment that has formed within the fuel system over time, and (2) the concentration of biodiesel used. The ideal scenario is one where both buses and storage tanks are new and therefore free of sediment, although this is rare. Anyone using B100 will need to have tanks and fuel systems cleaned (flushed) before using the fuel, although those using lesser concentrations should consider cleaning on a case-by-case basis.

Although tank cleaning is generally not required for B20 and lower blends, a program to check and replace fuel filters (both vehicle and facility) is advisable when first using biodiesel. Filters used in fuel storage systems should be at least as fine as those on the vehicles.

Informing bus operators of possible filter plugging caused by biodiesel will help them to better diagnose drivability problems. Any filter plugging problems that do occur should disappear after the first few tanks of fuel. Agencies should, however, be aware that moving from B20 to higher concentrations will dislodge sentiments that the weaker blend was not strong enough to remove. Any biodiesel splashed onto the vehicle or engine should immediately be wiped off. The cleansing effect of the fuel can damage paint and any decals or graphics. As with diesel, rags containing biodiesel need to be safely stored in a metal container and properly disposed of.

Material Compatibility

The same material compatibility concerns discussed earlier for engines also apply to facility fuel storage and dispensing equipment. As with engines, most of the compatibility issues involve the use of B100; B20 and lower blends are not as serious. Most fuel storage tanks designed for diesel fuel should be adequate for storing up to and including B100. Acceptable materials used in storage tanks and fuel dispensing equipment include steel, aluminum, polyethylene, polypropylene, Teflon, and most fiberglass compounds. (See the previous section on material compatibility for engines and chapter two for a complete description of soft and hard materials affected by biodiesel.)

Agencies need to monitor tanks, dispensing equipment, and fuel filters more closely when using biodiesel to ensure that there are no leaks, seepage, filter plugging, or seal deterioration caused by potential material incompatibility.

Facility and Infrastructure Requirements

One of the biggest advantages of biodiesel compared with other alternative fuels is that special facility and infrastructure requirements are virtually nonexistent. Any equipment changes needed as a result of using biodiesel have already been addressed. Agencies may require equipment to blend and/or agitate the fuel if premixed is not available and splash blending proves insufficient. Modifications may also be needed to fuel dispensing and storage equipment if B100 is used, or material compatibility becomes an issue with lesser concentrations. Agencies will also need an extra supply of fuel filters (facility and vehicle) when first introducing biodiesel because of the fuel's cleansing action.

Most of the facility changes involve procedural steps to ensure a trouble-free transition. These steps are summarized in chapter six under Recommendations.

INCENTIVES AND LOCAL REQUIREMENTS

Tax Incentive

In October 2004, Congress passed a biodiesel tax incentive as part of legislation known as the American Jobs Creation Act of 2004. The incentive is a federal excise tax credit given to the blender (petroleum distributor). Most of this blender's tax credit is passed down to the end user as a way of reducing biodiesel cost, although some may be applied to offset the supplier's infrastructure costs. The credit equates to one penny per gallon for each percent of biodiesel content (e.g., a 20 cent per gallon credit for B20) for blends made from agricultural products like vegetable oils, and one-half penny per gallon for each percent of recycled oil content. Set to expire at the end of 2008, the biodiesel tax incentive is expected to be extended to 2017.

Regardless of tax incentives, biodiesel is taxed at the same rate as diesel fuel unless the agency is exempt from paying fuel tax. Some states have also passed legislation that reduces fuel excise taxes or provides grants and other incentives. Agencies are urged to contact their local tax authorities for specific information regarding any fuel tax relief that may apply to their area. The DOE through its Clean Cities Program maintains a website that summarizes state and local laws and incentives related to all alternative fuels including biodiesel (www.eere.energy.gov/cleancities/vbg/progs/laws.cgi). The site includes a map of the United States where users can "click" on their state for detailed information. The NBB also provides information on tax benefits and other incentives at www.biodiesel.org.

Other Incentives

One of the most significant benefits of biodiesel use is contained in the Biodiesel Fuel Use Credit Interim Final Rule that became effective in January 2001 (*27*). The ruling gives fleets that are otherwise required under EPAct to purchase AFVs the option of purchasing and using biodiesel. Credits for biodiesel use are given, which organizations can then use to offset 50% of their annual AFV acquisition requirements under EPAct.

One biodiesel fuel use credit, which is counted as one AFV acquisition, is allocated to fleets for each purchase of 450 gallons of neat biodiesel fuel (B100). No credits are granted for the petroleum portion of biodiesel fuel blends, and biodiesel credits cannot be traded or banked. When it comes to biodiesel blends such as B20, a fleet may only count the biodiesel portion of the blend toward the allocation of a biodiesel fuel use credit. The rule applies to vehicles with a gross vehicle weight rating in excess of 8,500 lb. Credits offered under this program can only be claimed in the year in which the fuel is purchased. The ruling has created significant impetus for biodiesel use by those affected by EPAct. Users can find additional information from the EPAct web page at http://www.eere.energy.gov/vehiclesandfuels/deployment/fcvt_epact.shtml.

The Congressional Budget Office and the U.S. Department of Agriculture have confirmed that biodiesel is the least-cost alternative fuel option for meeting EPAct compliance requirements. Because it works with existing diesel engines, biodiesel offers an immediate and seamless way to transition existing diesel vehicles into a cleaner burning fleet (*5*).

Local Requirements

States and local governments have various requirements for using biodiesel and other alternative fuels. As mentioned, the DOE has a website that summarizes the various requirements and incentives pertaining to alternative fuels (www.eere.energy.gov/cleancities/vbg/progs/laws.cgi). The NBB also

provides information on tax benefits and other incentives at www.biodiesel.org.

Although each state has various requirements, New York is used here as an example of how the use of biofuels is being encouraged. New York has issued two executive orders that promote AFVs and biofuels. Executive Order 111 involves both buildings and vehicles. Agencies are required to reduce energy consumption in buildings by 35% by 2010 relative to 1990 levels, must procure more AFVs, and must reduce petroleum consumption and emissions by using alternative fuels.

Executive Order 142 addresses the use of biofuels in state vehicles and buildings. Agencies are required to use E85 ethanol fuel when feasible. They are also required to use biodiesel at an increasing rate starting with B2 in 2007 and reaching B10 by 2012. New York State agencies that operate medium- and heavy-duty vehicles can also substitute biodiesel to offset the number of light-duty AFVs required. For example, the use of 450 gallons of B100, 2,250 gallons of B20 or 9,000 gallons of B5 can be used to substitute the purchase of one AFV.

CHAPTER FOUR

EXPERIENCES WITH BIODIESEL

AMERICAN TRUCKING ASSOCIATION

The ATA, representing more than 37,000 members of the trucking industry, supports the use of biodiesel in blends up to 5% (B5) that meet quality standards (*28*). With the introduction of ULSD, ATA believes that B5 will help maintain adequate fuel lubrication. ATA also believes that biodiesel represents an important part of a long-term energy plan designed to increase the nation's fuel supply and reduce dependence on foreign oil.

In supporting the use of B5, ATA makes it clear that it favors the adoption of a federal fuel standard, and vigorously opposes any state-mandated "boutique" diesel fuels. ATA believes that until biodiesel is incorporated into the federal fuel standard and its quality is assured, the marketplace rather than law should dictate whether such fuels are used by trucking companies. ATA also supports a generous federal tax credit to keep biodiesel competitively priced with petroleum diesel. ATA is working with the biodiesel industry to avoid any problems associated with using the fuel.

BIOTRUCKER

A website dedicated exclusively to biodiesel use in trucking is located at http://www.biotrucker.com. The site includes listings for public filling stations that offer biodiesel. In addition, a telephone number is available to help find biodiesel locations (1-866-BIODIESEL). Agencies can also use this information to locate public sites if they are interested in testing biodiesel on a limited number of buses before implementing onsite bulk storage.

The BioTrucker website also includes a form letter truckers can use to encourage engine OEMs to support truckers wanting to use B20. As mentioned in chapter three, some OEMs limit biodiesel use to just 5%. Various testimonials from truckers using biodiesel are also listed on the site.

MINNESOTA AND PORTLAND BIODIESEL MANDATES

Minnesota was the first state to mandate the use of biodiesel, requiring that all diesel fuel sold in the state contain at least 2% biodiesel made from soybeans beginning in 2002. Within a few months as temperatures got colder, the requirement was temporarily suspended owing to reports by truckers of fuel filter plugging. Given the low percentage of biodiesel, officials were not clear if problems were caused by inferior biodiesel, high glycerin contained in the biodiesel, improper blending techniques, or if the fault rested with the base diesel fuel. Following Hurricane Katrina when diesel fuel supplies ran low, suppliers drained their tanks and refilled them with whatever fuel they could find. Running the tanks so low stirred up sludge at the bottom, which alone could have clogged fuel filters.

Unlike centrally fueled fleets, over-the-road truckers must rely on a variety of independent filling stations for fuel. As a result, adequate fuel quality and blending are not assured and the likelihood of developing biodiesel-related problems is greater. Five years after biodiesel was first mandated, the Minnesota Trucking Association reported that the problems originally associated with biodiesel have been resolved, and the state continues to have a minimum 2% biodiesel requirement (John Hausladen, Minnesota Trucking Association, personal communication, May 23, 2007).

In another example, the Portland (Oregon) City Council approved an ordinance that will require all diesel fuel sold in the city to contain a minimum blend of 5% biodiesel, and all gasoline sold in the city to contain a minimum blend of 10% ethanol, beginning July 1, 2007. Minnesota and Portland are just two examples of localities throughout the country mandating or planning to mandate the use of biofuels as a way of reducing petroleum fuel consumption.

TRUCK AND BUS BIODIESEL EVALUATIONS

A paper presented by the U.S. Postal Service, DOE, and Battelle late in 2005 at an SAE conference summarized a comparison of eight truck engines and fuel systems operating on B20 and diesel (*29*). The test included four 1993 Ford cargo vans and four 1996 Mack tractors (two of each running on B20 and two on diesel).

Engines and fuel system components were disassembled, inspected, and evaluated to compare wear characteristics after 4 years and more than 600,000 miles of operation. The study showed little difference in operational and maintenance costs between the B20 and diesel-fueled trucks. No significant differences in wear or other issues were noted during the engine

teardown. Mack tractors operating on B20 did, however, show higher frequency of fuel filter and injector nozzle replacement. Biological contaminants may have caused this filter plugging. A sludge buildup was noted around the rocker assemblies in the Mack B20 engines. The sludge contained high levels of sodium, possibly caused by the accumulation of soaps in the engine oil from out-of-specification biodiesel. Similar issues were not observed with the Ford cargo vans.

Although the Mack and Ford engines used similar pump-line nozzle fuel injection systems, a much larger volume of fuel is recirculated in the larger Mack engines. Along with differences in duty cycle and engine loading, this may have accounted for the difference in performance of the two engine types operated on B20. In any case, the issues did not result in significant cost increases. The study noted that differences in fuel and engine system maintenance costs between the two vehicle types were not attributed to biodiesel-related issues. The study concluded that further research and analysis is needed to determine how different engine and vehicle types would react to B20.

Concerning transit buses, a similar evaluation was provided in an SAE paper presented by the DOE, Denver RTD, and Cummins at SAE's Powertrain and Fluid Systems Conference late in 2006 (*30*). The paper summarized the findings of nine identical 40-ft transit buses operating on B20 and diesel for 2 years. Each bus accumulated approximately 100,000 miles. The 2-year study found no difference in on-road average fuel economy between the buses operating on diesel or B20; each group averaged 4.4 mpg. Laboratory testing performed on the same buses, however, revealed a nearly 2% reduction in fuel economy for the group of B20 buses.

Engine and fuel system-related maintenance costs between the two groups of buses showed an increase of only $0.02 per mile for the biodiesel-fueled buses compared with diesel-fueled buses. The increase was attributed to fuel injector and cylinder head replacements on one bus (it is not known if biodiesel caused these failures) and occasional fuel filter plugging likely caused by the use of out-of-specification biodiesel fuel. There was no significant difference in miles between road calls, and oil analysis results showed no additional wear metals from the use of B20. Soot levels contained in the lubricant, however, were significantly lower for the B20 buses. In addition, laboratory chassis testing found that B20 reduced emissions of all regulated pollutants, as described in chapter three.

TRANSIT AGENCY SURVEY RESPONSES

Forty-three transit agencies responded to a survey questionnaire, of which 18 (42%) operate biodiesel buses and 25 (58%) do not. The 43 responding agencies operate a total of 15,291 diesel buses, 5,959 (39%) of which run on biodiesel. The combined biodiesel fleet represented in this survey travels 217,857,955 miles annually. All survey responders (grouped by those using and not using biodiesel) are listed in Appendix B. Responses to all survey questions are summarized on the original survey form included as Appendix C.

The survey responses indicated a good collective understanding of biodiesel regardless of whether agencies are using the fuel or not. Those with biodiesel experience exhibited a solid knowledge of the benefits associated with the fuel along with the corrective actions needed to overcome the drawbacks. Most (67%) use a specification to procure biodiesel and almost half are using B20 or higher blends, which indicate that they feel confident in their ability to address the challenges associated with the higher blends. All but three using biodiesel have verified warranty coverage with their engine manufacturer. There were, however, areas where those using biodiesel could take more initiative. Only half of those responding make use of marketing material to inform the public of their biodiesel use and its benefits; many were unaware of the cost reductions being passed down to them by the blender's tax credit, and of a new study showing that NOx emissions is not as significant as once believed. Agencies using biodiesel were very generous in offering information and recommendations based on their experiences.

Those agencies not currently using biodiesel had plans to switch in the near future, were pursuing other emission reduction strategies, or were not allowed to use diesel in their area (e.g., Southern California). Gauging by the number and quality of responses to the question on what areas they would like the synthesis to cover, virtually all responders showed sincere interest in learning more about biodiesel.

AGENCIES NOT USING BIODIESEL

Those Without Short-Term Plans

Nineteen of the 25 agencies (76%) not currently using biodiesel indicated that they have no near-term plans to use the fuel. Twelve are pursuing other alternative fuels or emissions-reduction strategies, with hybrids mentioned most often (six responders). Fourteen of the 19 agencies without near-term plans stated that they were either unsure of the benefits or disadvantages of biodiesel or stated that there is no compelling reason to do so at this time. Five agencies reported that biodiesel is not available locally in their area.

Other reasons given for not using biodiesel include a concern with fuel consistency (three responders), cold weather concerns (two responders), possible increase in NOx emissions (two responders), uncertainty about biodiesel's effects on engines (two responders), higher costs associated with biodiesel, and the uncertainty of using biodiesel on a diverse fleet. Two of those agencies with no near-term biodiesel plans had actually used the fuel in the past, but switched back to conventional fuel because of costs, problems encountered

with the fuel, and the unknowns associated with biodiesel. One of those agencies will switch back to biodiesel because of a state requirement, but is asking for a waiver to conduct limited testing. Three agencies with no near-term plans did, however, indicate they would have an interest should the benefits become more evident and no long-term problems develop for those currently using biodiesel.

Those with Short-Term Plans

Six of the 25 agencies not using biodiesel (24%) indicated that they do have near-term plans to use it. Five of the six plan to convert shortly or within the year, with the sixth planning to try biodiesel when it becomes available in their area. One of the six agencies that will try biodiesel is currently setting up a pilot program to test biodiesel in its trucks and school buses before introducing it to their transit bus fleet.

Perceived Advantages

When asked about reasons for wanting to try biodiesel and their perceived benefits of it, the overwhelming reason cited was the environmental advantages of the fuel, its renewable nature, and the need to reduce dependency on foreign oil. Three agencies are motivated by increased lubricity and cetane. Other reasons include public relations benefits, that biodiesel is "better" than compressed natural gas, local regulations, reduced fuel taxes, and the need to support local farming interests.

Perceived Disadvantages

When asked what they see as the primary disadvantages to biodiesel, this group of six with short-term biodiesel plans cited:

- Higher costs and reduced fuel economy (six responders),
- Increased NOx emissions (four responders),
- Engine and warranty concerns (four responders),
- Fuel quality and cold weather concerns (four responders),
- Plugged fuel filters (two responders),
- Material incompatibility (two responders),
- Algae (bacteria) growth and the need for increased biocides (two responders),
- Substantial emissions reductions only possible with higher biodiesel concentrations (two responders),
- Long-term maintenance of fuel storage tanks, and
- Fuel unavailability.

Report Areas to Address

When asked what they would like to see addressed in the synthesis, those not currently using biodiesel collectively cited:

- Emissions and environmental impacts (four responders),
- Cold weather problems and other technical issues (three responders),
- Use with ULSD (three responders),
- Fuel quality and specifications (two responders),
- Warranties (two responders),
- Additives (two responders),
- Blending and dispensing (two responders),
- Cost, and
- Lack of availability.

AGENCIES WITH BIODIESEL EXPERIENCE

Overview

The 18 agencies responding to the survey that are using biodiesel have a combined fleet of 7,353 diesel buses, of which 5,959 (81%) are operating on biodiesel. Table 6 shows these agencies, along with their location, biodiesel fleet size versus total bus fleet, percentage of biodiesel used (under B20 in one group, B20 and over in another), and the tenth percentile minimum ambient air temperature (TPMAAT) for the month of January. This temperature classification, based on a U.S. Army study, is used in the ASTM D975 diesel specification for estimating expected temperatures for a given region when determining appropriate cloud point temperature properties for diesel fuels (Standard Specification for Diesel Fuel Oils, D975). TPMAAT is defined as the lowest ambient temperature that will not go lower on average more than 10% of the time. In other words, the daily minimum ambient air temperature would on average not be expected to go below the monthly TPMAAT more than 3 days for a 30-day month. The TPMAAT for the month of January was used in various tables in this chapter because it typically represents the coldest winter month.

As indicated in Table 6, 10 (56%) of the 18 agencies using biodiesel use concentrations under B20, whereas the remaining 8 agencies use B20 or greater. When asked if their use stems from a requirement to use biodiesel, 14 (78%) reported that they are not required to use biodiesel, whereas 4 agencies each cite a specific state requirement.

Test Buses

Biodiesel use on a limited test fleet can help identify problems in advance of widescale implementation. However, only seven (39%) of the agencies using biodiesel began with an initial test on a limited number of buses.

Of these seven agencies that began biodiesel use with a limited test, five have since converted their entire fleet to biodiesel. Table 7 shows the breakdown of buses first used as an initial biodiesel test compared with the total number of diesel buses in their fleet.

Use of Biodiesel Specifications

The use of specifications to procure biodiesel is essential. Twelve of the agencies using biodiesel (67%) follow some type

TABLE 6
BIODIESEL USER PROFILE—AGENCIES USING BIODIESEL

	Agency	Biodiesel Total/ Diesel Total	Biodiesel (%)	January TPMAAT (°F)
Using B20 or Greater				
1	Mass Transportation Authority (Flint, MI)	10/10	20	–9
2	NAIPTA, (Flagstaff, AZ)	14/14	20	1
3	CATO (Columbus, OH)	234/234	20–90	1
4	Toledo Area Regional Transit Authority (TARTA) (OH)	24/174	20	1
5	Bi-State Development Agency (Metro) (St. Louis, MO)	130/426	20	3
6	Sun Tran (Tucson, AZ)	43/110	20	25
7	King County Metro (Seattle, WA)	639/1,273	20	19
8	Central Florida Regional Transportation Authority (LYNX) (Orlando, FL)	4/248	20	37
Using under B20				
1	Minnesota Valley Transit Authority (Burnsville, MN)	108/108	2	–29
2	Roaring Fork Transportation Authority (Aspen, CO)	79/79	10	–22
3	Metro Transit (Minneapolis/St. Paul, MN)	830/830	5	–29
4	Ames Transit Agency (CyRide) (Ames, IA)	63/63	2–10	–15
5	Pace Suburban Bus Service (Arlington Heights, IL)	700/700	10	–6
6	Connecticut Transit (Hartford, CT)	398/398	5	1
7	Madison County Transit (Granite City, IL)	111/111	2	1
8	Utah Transit Authority (Salt Lake City, UT)	500/500	2–10	0
9	TriMet (Portland, OR)	825/825	5	19
10	Metropolitan Transit Authority (Houston, TX)	1,250/1,250	10	27

TPMAAT = tenth percentile minimum ambient air temperature; NAIPTA = Northern Arizona Intergovernmental Public Transportation Authority; COTA = Central Ohio Transit Authority; TriMet = Tri-County Metropolitan Transportation District of Oregon.

TABLE 7
BREAKDOWN OF BUSES USED IN INITIAL BIODIESEL TEST

Biodiesel Test Fleet	Total Diesel Fleet	% of Test Fleet to Total Fleet	Current Biodiesel Fleet
232	398	58	398 (100%)
230	1,273	18	639 (50%)
75	825	9	825 (100%)
10	234	4	234 (100%)
10	426	2	130 (30%)
6	830	<1	830 (100%)
3	14	21	14 (100%)
Total	4,000		3,070 (77%)

Note: Agencies that began biodiesel use with limited test fleets.

of specification to purchase biodiesel. Nearly all that use a specification (10 responders) either use ASTM D6751 (5 responders) or ASTM D6751 plus the BQ-9000 quality requirement (5 responders). Although it is encouraging that so many reported using specifications, all agencies should be doing so when procuring fuel whether the fuel is diesel or biodiesel.

Procedures and requirements used by these agencies to procure biodiesel include:

- Establish a good relationship with the supplier; know the raw product.
- Require tanker truck compartments sealed after filled at terminal.
- Require proof of insurance.
- Provide delivery time frame.
- Require discount from biodiesel rack average price for contract length.
- Initiate random monitoring of fuel quality once per month; retain samples.
- Require biocide and "Tank Dri" to prevent bacteria growth.
- Require delivery temperature and time, and process for blending on site.

Cost and Incentives

The agency cost for biodiesel averaged $2.06 per gallon, eight cents higher than the average of $1.98 per gallon reported for ULSD. The range of $1.68 to $2.75 per gallon for biodiesel compared with a range of $1.67 to $2.45 paid for a gallon of ULSD.

Tax breaks or other incentives for using biodiesel were reported by 8 of the agencies (44%) using biodiesel. The incentives came in the form of a blender's tax credit (four responders), tax-exempt status (two responders), and grant money. One agency reported that lower biodiesel cost was a benefit. Although only four agencies reported the blender's tax credit as an incentive, all biodiesel blenders do receive a credit, of which agencies may not be aware.

Cold Weather Problems

Table 8 classifies agencies with biodiesel experience under the TPMAAT in degrees Fahrenheit for the month of January in three categories: Below 0°F, 0–19°F, and above 19°F. Without listing agencies by name, the table indicates which had problems associated with biodiesel delivery, storage, or vehicle-related problems organized by TPMAAT temperatures for January.

Ten of the 18 agencies using biodiesel (55%) reported having some type of vehicle-related problem, although the frequency decreases for agencies with warmer January temperatures. When it came to storage, 6 of the 18 (33%) reported problems, whereas 7 (39%) reported problems with delivery (specific problems are presented in the following sections categorized by delivery, storage, and vehicle). Agencies in climates with TPMAAT for January above 19°F reported the fewest number of problems in all three areas.

Delivery

Specific delivery problems and the resulting action taken by those experiencing delivery problems are summarized in Table 9 according to temperature. Three of the seven agencies that reported problems (43%) were related to cold

TABLE 8
PROBLEMS BY JANUARY TPMAAT

Maximum Biodiesel	Delivery Problems	Storage Problems	Vehicle Problems
January TPMAAT Below 0°F			
2%	Yes	Yes	Yes
10%	Yes	Yes	Yes
5%	Yes	No	Yes
10%	Yes	No	No
20%	No	No	No
10%	Yes	No	Yes
5%	No	No	No
January TPMAAT 0°F to 19°F			
90%	No	No	Yes
20%	No	Yes	Yes
2%	No	No	No
10%	Yes	No	No
20%	No	No	Yes
20%	No	Yes	Yes
January TPMAAT Above 19°F			
20%	No	No	No
20%	Yes	Yes	Yes
5%	No	No	Yes
10%	No	Yes	No
20%	No	No	No

TABLE 9
DELIVERY PROBLEMS BY JANUARY TPMAAT

	Delivery Problem	Action Taken
	January TPMAAT Below 0°F	
1.	B100 used to blend at the rack did not meet cold weather specification; vendor and terminal were not monitoring it	Changed vendors; terminal increased frequency of testing B100 (we use the same terminal but different vendors).
2..	Cold weather mixing continues to be a problem	Vendor must mix load inside or discontinue splash blending when temperature is below 20°F.
3.	There have been times when the blend is inconsistent	Held discussions with fuel supplier and determined that mixing/blending issues can be attributed to the loading sequence or method of loading the delivery truck. If the ULSD fuel is loaded into our tanks from a separate compartment on the tanker truck then the blending process is only accomplished during the unloading drop. This results in inconsistencies in the blend once it is in the storage tank. However, if biodiesel is premixed with diesel into the tanker truck and then delivered to our tanks the fuel is sufficiently agitated. This method is by far the better of the blending options.
4.	Fuel dispensing filter plugging after pumping approximately 4,000 gallons. Originally would last 30,000 plus gallons	Changed to a small 30 micron filter (just to protect metering device), and added a very large 10 micron external filter. Have had great results, now fuel is filtered three times before it reaches the pump or vehicle.
5.	Fuel dispensing filter plugging in cold weather	Required supplier to have improved cold weather additives.
	January TPMAAT 0° to 19°F	
6.	Insufficient biodiesel supply at various times to meet delivery needs	
	January TPMAAT Above 19°F	
7.	Received some loads high in glycerlin and/or moisture content. This has been caught in fuel island filters and has not affected the bus. Hydrosorb filters are very sensitive to moisture content and sometimes give a false-positive indication. When we have seen high moisture it has not manifested into the bus fleet; however, we still change out filters more frequently on the fuel island	We have the fuel delivery contractor retain a quart sample of each delivery. They withold a quart of ULSD, a quart of B100 and a quart of B20. These are held for 7 months. All of our deliveries are a full truck and trailer load, 8,000 to 9,000 gallons at a time. This is part of the contract terms.

weather; all of which are located in areas with a minimum January TPMAAT of below 0°F.

Storage and Dispensing

A majority of the agencies using biodiesel (78%) have replaced their entire diesel supply in bulk storage, whereas the others use separate biodiesel storage tanks and dispensers or "wet hose" dispensing where a tanker truck fills all buses individually.

Twelve of 18 agencies using biodiesel (67%) reported no storage problems. The problems that do exist do not appear to be related to the percentage of biodiesel used. Of the 10 agencies using under B20 only three had storage-related problems. Likewise, of the eight agencies using B20 or higher only three reported storage-related problems.

Table 10 groups reported storage problems by temperature. Three of the six that reported problems (50%) were related to cold temperatures, whereas the remaining three were related to high levels of algae (bacteria), water, or glycerin. It is interesting to note that cold weather-related storage and dispensing problems were reported in all three temperature classifications.

Handling and Infrastructure

Twelve of the 18 agencies using biodiesel (67%) reported handling procedures or requirements that differ from traditional diesel handling; six agencies reported no changes in their procedures. All of the changes are procedural in nature and include:

- Place placards on dispensers to reflect biodiesel content.
- Store biodiesel in separate tanks during initial test program.
- Additional testing/monitoring was in place during initial test of B20.
- Blend biodiesel at the rack (pipe blended), not on a truck or in underground tanks.

TABLE 10
STORAGE PROBLEMS BY JANUARY TPMAAT

	Storage Problem	Action Taken
	January TPMAAT Below 0°F	
1.	Algae (bacteria) growth in underground tanks	Killed the algae (bacteria), changed vendors, terminal improved its testing frequency.
2.	Algae (bacteria) growth in underground tanks	Annual tank cleaning; each fuel load is treated with a biocide and Tank Dri. " Vendor is required to cover all clean-up costs associated with bad fuel. Agency pays for annual tank cleaning cost (approximately $5,000).
3.	Filter freeze ups	N/A
	January TPMAAT 0°F to 19°F	
4.	Gelling problem when temperatures got down to 15°F and we switched to ULSD. The only change from four previous winters of no gelling was ULSD. We think refineries cannot get emissions where they should be because of the winter additive. At this point we have not received any good answers	Diluted with No. 2 diesel for the remainder of the winter from B20 to B5.
	January TPMAAT Above 19°F	
5.	Received some loads high in glycerine and/or moisture content	We have the fuel delivery contractor retain a quart sample of each delivery. They withhold a quart of ULSD, a quart of B100 and a quart of B20. These are held for 7 months. All of our deliveries are a full truck and trailer load, 8,000 to 9,000 gallons at a time. This is part of the contract terms.
6.	Cold weather related	Decreased biodiesel concentration for winter.

N/A = not available.

- Temperature of biodiesel when delivered must be above 40°F/50°F (two responders).
- Install filters with water block media on fuel islands to remove moisture from biodiesel (two responders).

Vehicle-Related Experiences

Table 11 shows the vehicle-related problems grouped by temperature and the percentage of biodiesel used. Of those 10 agencies using under B20, 5 reported problems, whereas the other 5 did not. For the eight agencies using B20 and greater, six reported problems and two did not.

Of the 15 vehicle-related problems, 8 (53%) were related to clogged fuel filters, whereas 5 (33%) were related to decreased fuel economy. Clogged fuel filters were reported in all of the temperature ranges in vehicles with blends as little as B2. Those with clogged filters corrected the problems by:

- Changing fuel supplier,
- Monitoring filter sight glass at fuel island daily,
- Changing filters more frequently (five responders),
- Adding secondary fuel filters (two responders),
- Cleaning fuel storage tanks,
- Reevaluating fuel treatment and mixing procedures, and
- Increasing fuel testing for bacteria.

As expected, there was no corrective action listed for reduced fuel economy.

TABLE 11
VEHICLE PROBLEMS BY JANUARY TPMAAT

	Vehicle Problem	Action Taken	Biodiesel (%)
	January TPMAAT Below 0°F		
1.	Clogged fuel filters	Changed fuel vendors; added second filter on one group of buses	2
2.	Clogged fuel filters	Reevaluated fuel treatment and mixing procedures; increased fuel testing for bacteria; reduced fuel filter replacement interval; installed pre-filters before transfer pump on certain engines	10
3.	Reduced fuel economy	None	10
4.	Increased failures of transfer pumps on certain engines; other engines not affected	Check vehicle tank for algae (bacteria) when excessive filter plugging occurs	10
5.	(Problems not specified)		5
6.	Clogged fuel filters	Changed more frequently	10
7.	Reduced fuel economy	None	10
	January TPMAAT 0°F to 19°F		
8.	Clogged fuel filters	Changed more frequently	20
9.	Reduced fuel economy by 0.5%	None	20–90
10.	Clogged fuel filters	Unknown	20
11.	Reduced fuel economy	Unknown	20
12.	Clogged fuel filters	Monitor filter sight glass at fuel island daily, change filter when needed	20
	January TPMAAT Above 19°F		
13.	Clogged fuel filters	Cleaned out dirt in in-ground tanks; localized to one of four locations	20
14.	Fuel filter clogging on about 20% of fleet	Unknown	5
15.	Reduced fuel economy	None; ULSD and biodiesel both have slightly less energy than petroleum diesel	5

Warranty

Ten of agencies using biodiesel (56%) reported that the percentage of biodiesel they use conforms to engine manufacturers' recommendations, whereas seven (39%) reported their biodiesel use does not conform. Fifteen of 18 agencies (83%) have verified warranty coverage with the engine manufacturer; three have not. Thirteen of the agencies using biodiesel use percentages above B5.

Although policies regarding warranty coverage have changed since this survey was conducted, it appears that many agencies are not informed of the actual warranty policy, have chosen to risk warranty coverage owing to the benefits of using higher biodiesel blends, or have received special warranty coverage from their engine supplier.

Lubricity

Five agencies have experiences to share concerning lubricity of biodiesel and failures related to certain engine fuel pumps have ceased.

Biodiesel and Ultra Low Sulfur Diesel

Seven agencies reported experiences with ULSD to share:

- No problems encountered, and the use of ULSD is a non-issue (five responders).
- Supplier has not been able to reduce the gel (cloud) point to pre-ULSD levels.
- Biodiesel (B2) enhances the lubricity of ULSD (five responders).

Preventive Maintenance Inspections

Thirteen of the responding agencies (72%) reported that PMI procedures have not changed because of biodiesel use. Four reported that procedures have changed:

- Change fuel filters much more frequently (two responders).
- Add secondary fuel filter.

Emissions Experiences

Five agencies (28%) reported having experiences or testing results concerning exhaust emissions and use of biodiesel.

- West Virginia University testing done in 1995.
- Emissions testing with B10 performed by University of Houston (Texas) resulted in an average of 2.5% increase in fuel use, a 2% increase in NOx, and an 11% decrease in PM emissions.
- Samples were taken to measure PM; and comparisons were made. Results were mixed. More studies are needed, because information is inconclusive.
- Supplier conducts emissions testing per our agreement.

Marketing and Public Awareness Efforts

Only 9 of the 18 agencies (50%) developed marketing material to promote biodiesel to the public. Given all the negative publicity generated over diesel use before current emissions reduction technologies, promoting the use of biodiesel can do a great deal to overcome this and improve transit's image.

Metro Transit (Minneapolis, Minnesota) has produced a flier entitled *Metro Transit's "Go Greener" Initiative*, which includes the agency's use of biodiesel as one of several approaches taken to fulfill its commitment to improving the environment. Central Ohio Transit Authority (COTA, Columbus, Ohio) also has a relevant flier entitled *Lean, Clean Bean Machine*. Both fliers are included as part of Appendix D.

Areas That Report Should Cover and Other Information

Survey responders were clear about those areas the report should cover. All suggestions, which included fuel quality, adverse effects of biodiesel, storage issues, blending, cold weather use, warranty issues when using blends of higher than B5, and emissions, were taken into consideration and have been addressed by this synthesis.

Responders with biodiesel experience were also generous in offering advice that would benefit their peers concerning the use of biodiesel. Those comments are summarized at the end of Appendix C and have been incorporated into the recommendations included in chapter six.

CHAPTER FIVE

CASE STUDIES

ROARING FORK TRANSPORTATION AUTHORITY

Agency Profile

The Roaring Fork Transportation Authority (RFTA), Aspen, Colorado, operates 84 heavy-duty transit buses, including 7 hybrids, all powered by diesel engines. Collectively, the agency buses travel approximately 3.5 million miles per year, with 4.1 million passenger boardings. RFTA consumed approximately 621,000 gallons of diesel fuel in 2006.

RFTA's service area ranges from 5,000 to 9,500 ft above sea level. Temperatures range from −20°F to 105°F; in the winter it is common for low temperatures to range from 0°F to −20°F. The average winter low in Aspen is 9°F. Keeping any diesel fuel from gelling at these temperatures is challenging. The majority of RFTA's route profile (duty cycle) is typically commuter with some central business district operation. All buses are fueled and serviced at one of two maintenance facilities.

Reasons for Biodiesel Use

In the fall of 2004, RFTA began using biodiesel in response to an RFTA Board policy to use a phased approach to convert the transit fleet to alternative propulsion technologies as a means of reducing the environmental impact of transit operations on the community and RFTA's dependence on foreign oil by moving toward sustainable and renewable forms of energy.

The RFTA Board refused to fund an alternative fuels program or purchase any new propulsion technologies if it would compromise planned service levels and operational sustainability. Once this was understood, RFTA began working with a citizens group and others to develop partnerships. As a result of these partnerships, RFTA's entire fleet now operates on 10% renewable fuels (biodiesel and ethanol). Although the implementation of biodiesel presented challenges, RFTA hopes the lessons they learned can benefit others.

Biodiesel Delivery and Blending

RFTA uses a soy-based biodiesel, purchased as B99 and splash blended by the supplier owing to the lack of automated pipe-blending equipment. Biocide and water dispersant additives are added to the agency's storage tanks just before biodiesel delivery. The program initially started with a B5 blend, which was increased to B10 in December 2006. At the same time, RFTA also began using an E10 gasoline blend in all of its gasoline-powered vehicles. RFTA now replaces approximately 67,000 gallons of petroleum fuel products with renewable biofuels each year. The incremental cost of RFTA's Biofuels Program is $68,000 to $72,000, based on an overall fuel budget of approximately $1.7 million (a 4.25% increase).

Initial Investigations

RFTA's initial investigation focused on three areas:

1. Initial funding: In 2004, RFTA received two biodiesel demonstration grants totaling approximately $25,000 to offset the incremental cost of B5 over diesel. Once RFTA spent the initial grant funds, it absorbed the added cost of biodiesel in its operating budget and continues to do so today.
2. Cold weather storage and operation: After consulting with other agencies using biodiesel, RFTA became aware of major fuel gelling problems that occurred in vehicles and aboveground storage tanks during extreme cold weather.
3. Fuel Blends and Engine Specifications: Initially, RFTA was urged to test B20. After further research, however, two issues arose that led to the use of B5 for the demonstration project. First, there was limited experience with regard to biodiesel use in cold weather, high-altitude operations. Second, the engine manufacturer would only allow the use of B5 in 14 buses covered under warranty.

Biodiesel Introduced

At the start of the 2004 ski season, RFTA surreptitiously began using B5. Because employees were unaware of any changes, the agency believed that any comments or opinions received would therefore not be biased. After one month of use, RFT asked operations and maintenance personnel in a very generic manner how things were going. When no one reported any noticeable changes in the fleet, RFTA publicly announced that it had been using B5 for about one month.

No Problems . . . Then Fuel Contamination

The biodiesel program ran very smoothly until mid-September 2005, when the agency began to experience problems with engines shutting down in six of the buses. The problems persisted even after replacing the fuel filters. The problem was initially diagnosed as failing or failed fuel transfer pumps. However, after replacing the pumps, the new pumps also failed within a few weeks. The agency realized something else was the cause.

Maintenance personnel disassembled one of the failed pumps and found a creamy-colored slime inside, which they traced to bacteria growth. Sampling confirmed that they had both water and bacteria in their fuel. The agency quickly learned that when biodiesel comes in contact with water it provides an excellent medium for bacteria and algae growth. Further investigations by the agency confirmed that bacteria growth is a common problem with untreated biodiesel, although this issue was not widely discussed or known at the time.

Tank Treatment Needed

Once the bacteria problem was identified, RFTA's fuel supplier arranged to have the underground tanks pumped out and treated with a biocide and water dispersant. The biocide prevents bacteria growth, whereas the water dispersant keeps water in solution to avoid creating a medium where bacteria can grow.

All loads of biodiesel were treated with the same combination of chemicals and steps were taken to prevent additional water from entering the tanks. Follow-up fuel testing (now performed on a quarterly basis) revealed no evidence of bacteria or algae growth since the initial problem.

More Tank Problems Develop

After treating their storage tanks for water and bacteria, RFTA began having problems with fuel dispenser filters plugging, which lasted for almost a year. When filters were examined the agency found a black slime similar to what was found earlier with vehicle filters even though the tanks tested negative for bacteria. Research found that a school system using biodiesel had experienced similar problems, which were addressed by cleaning its tanks on an annual basis.

In September 2006, RFTA cleaned its tanks at a cost of approximately $5,000, which then eliminated the filter plugging problem. It is important to note that RFTA is not completely sure that all of these problems could be directly attributed to the cleansing action of the biodiesel. One belief is that the contamination was caused by refineries scrubbing their diesel tanks in preparation for ULSD. Regardless, RFTA will continue to monitor its tanks for contaminates and clean them as needed.

Vehicle Treatment and Remediation

The bacteria/algae problem that first appeared in six buses operated almost exclusively in a low-speed, stop-and-go duty cycle. Once bacteria were found, RFTA drained the vehicle fuel tanks and refilled them with treated fuel. RFTA added a spin-on fuel filter between the fuel tank and transfer pump to catch any residual slime and bacteria before it could damage the pump. Over time the problems diminished.

RFTA extended their search to other buses in the fleet, but did not find any visible bacteria growth in any other tanks. The agency speculates that engines equipped with suction side filters catch bacteria and debris before it can do damage. They also believe that gear-driven mechanical fuel pumps are much more durable than electric transfer pumps. Regardless of the engine type, however, RFTA did use up many more fuel filters during that time (see Parts Usage below).

Important Lesson Learned

In hindsight, RFTA believes that they would have not have had problems if they were aware of the:

- Bacteria problem in advance, treated the fuel accordingly, and conducted ongoing fuel sampling for bacteria; and
- Cleansing action of the biodiesel, and had vehicle and storage tanks cleaned in advance of using the fuel.

Increase to B10

By summer 2006, RFTA believed that it was through the steepest part of its learning curve with biodiesel. They were treating all fuel with biocide and a water dispersant, conducting regular bacteria testing, and modifying their PMIs as needed. At the same time, the city of Aspen had adopted the Canary Initiative in an effort to take a proactive stance against Global Warming (www.canaryinitiative.com/), and the state of Colorado passed legislation requiring utility companies to move toward purchasing at least 10% of its energy from renewable sources. In response, RFTA increased its use of biodiesel from B5 to B10. The agency was aware that it was risking warranty coverage and discussed the decision with their local engine distributor.

Cold Weather Blending Problems

In late 2006, Colorado experienced unusually cold temperatures. Following their normal splash-blending procedures, RFTA's fuel supplier loaded 750 gallons of B99 into its tanker truck when the outside temperature was –20°F and the B99 was heated to approximately 120°F. The truck was driven approximately 35 miles, and when the driver started loading fuel into the agency's storage tank, unbeknownst to the agency, the biodiesel portion had already started to

thicken. As a result, the mixing that was to occur during the splash-blending process had not taken place. The poorly mixed, more concentrated fuel was then dispensed into several buses during the daily refueling process.

With night temperatures at –10°F to –20°F, RFTA parked many of its buses inside heated storage areas. The vehicles with concentrated biodiesel (unknown at the time) left early the next morning showing no signs of problems. However, after being in service for about an hour and exposed to the colder outdoor temperatures they began running rough. Mechanics traded out the vehicles and brought them back to the heated shop. When the mechanic checked the buses, they ran fine. The next morning the same rough running problem developed. Once aware of this pattern, the agency inspected fuel filters and took a fuel sample from their underground tank. They found no signs of bacteria, but did find that biodiesel settled at the bottoms of the sample jars; therefore, RFTA realized they had a poorly mixed load of biodiesel fuel.

RFTA immediately contacted their biodiesel supplier to discuss the problem. The first challenge was dealing with the bad fuel in the buses and underground storage tanks. The second challenge was to develop additional procedures to prevent this from occurring again.

The agency calculated that it had only 750 to 1,500 gallons of poorly blended biodiesel to contend with. They also discovered that when the samples were agitated the biodiesel remained in solution and did not settle back out. RFTA's fuel delivery system indicated an in-ground fuel temperature of 38°F; well above the cloud point for even marginally mixed biodiesel.

RFTA hoped that if it could remix the fuel, the biodiesel would return into solution somewhere less than a B10 blend. The agency added a load of straight diesel into the tanks, hoping it would provide enough agitation to remix the biodiesel. RFTA replaced fuel filters on the affected buses and refueled the units. Buses were also stored indoors until just before their scheduled pullout. The ambient temperature started to rise and after a few days everything returned to normal.

Another Important Lesson Learned

It was clear that during milder weather splash blending worked fine for small demonstration projects. However, the fuel distributor needs a much more advanced mixing system to dispense properly mixed biodiesel at cold temperatures. Such a system became operational at the end of March 2007. Until that time, RFTA's fuel supplier agreed to provide only B10 when splash blended with diesel at ambient temperatures above 20°F. This procedure generally requires that fuel be blended midday during the winter months.

Financial Impacts

Using Denver Rack Pricing (i.e., the price of fuel at the distribution point excluding transportation costs) over the previous 18 months, the incremental cost for B5 ranged from about 3 to 7.9 cents per gallon, and the incremental cost for B10 ranged from about 3 to 16 cents per gallon.

Parts Usage

The use of fuel filters from December 2004 through January 2007 increased by 33 filters for the 6 buses affected by the bacteria and poor mixing problems. The total cost of parts was less than $300 spread over 810,000 miles. A more significant cost was the fuel transfer pumps. However, it is difficult to determine if the cost of replacing these pumps was strictly the result of the use of biodiesel. RFTA estimates that three to five transfer pump failures may have been directly related to the bacteria problem.

Service Interruptions

RFTA attributed 15 to 20 road calls between November 2004 and January 2007 to the use of biodiesel. This count, however, may be slightly lower than the actual road calls created by biodiesel, because the actual cause of problems may not have been known when road call coding was assigned. In any case, the total labor costs charged to biodiesel-related road calls was about 73 h. Only five reported road calls for biodiesel were a result of an actual breakdown; the others occurred in bus changes during scheduled layovers.

To put road calls in perspective, RFTA operated close to 8 million miles during this period and the rate of occurrences was extremely low. However, when failures began to occur they were at times frequent and overwhelming.

Partnerships Matter

RFTA's fuel supplier had a vested interest in ensuring that biodiesel worked for the agency and absorbed many of the costs resulting from the biodiesel problems. Concerning the fuel transfer pumps, the agency chose not to take a hard line with the engine OEM because it was not certain that biodiesel was the cause. Instead, the agency shared the risks and costs associated with the pumps because it believed that it was more important for the project to continue.

RFTA believes that it is important to establish realistic expectations before embarking on any biofuels program by clearly identifying the risks the agency and its partners are willing to take. If all parties can come to an agreement in advance, the authority believes that any issues that do arise can be resolved more quickly and in an amicable manner.

Employees Matter Even More

According to RFTA, the real success of a biodiesel program rests largely with the employees, most notably the maintenance staff. RFTA's maintenance staff is comprised of loyal, dedicated employees that rose to the challenges of using biodiesel and made it work. As problems arose, innovative solutions were devised and proactive steps were taken steps to minimize disruptions of service. Good communications and quick reactions substantially reduced the extent of biodiesel-related problems.

Concluding Thoughts and Opinions

RFTA is quick to note that their biofuels program is part of a much broader vision that has been developing in the Roaring Fork Valley over the past 15 years. Global warming, energy conservation, and livable communities are topics of constant local discussion. When Aspen was classified by the EPA as a nonattainment area and gridlock became a common occurrence, RFTA was asked to play a key role in mitigating these problems. The communities that support RFTA saw firsthand the difference public transit can make, and strong political and community support grew as a result. So did expectations to move toward a cleaner and more environmentally friendly transit system.

All involved understood there would be costs associated with moving toward a greener fleet. Sales taxes generated in the local communities were expected to enable RFTA to spend approximately $70,000 in 2007 to offset the additional cost of replacing 67,000 gallons of petroleum-based fuel with agricultural-based renewable fuels. RFTA's partners help to fund the incremental costs of green technologies knowing they are still in testing stages.

Operationally, RFTA recognizes that environmental programs are fraught with challenges. When asked about the economics of their hybrid and biodiesel programs, RFTA's standard answer is that they do it because they believe it is the right thing to do. Biodiesel is a domestically produced renewable fuel, and in terms of greenhouse gas emissions, the CO_2 absorbed by the plants grown to produce the biofuels feedstock virtually offsets all carbon emissions generated when biofuel is burned.

RFTA believes that biodiesel will become a mainstream product in the near future and is looking forward to a new local biodiesel mixing station to improve the quality of biodiesel. This new station will be capable of providing B2 to B10 blends that will be properly mixed and treated so that future users will not be burdened with the same challenges that RFTA experienced. The agency has also been advised that when this station comes on line they should see a 50 cent per gallon drop in the price of B100.

In conclusion, RFTA believes that it is important to revel in your successes with biodiesel, acknowledge your problems, and thank those who got you through them. The agency points out that support of upper management and the RFTA Board was critical.

Recommendations for a Successful Biodiesel Program

RFTA offers the following recommendations:

- Clearly identify the goals of the program
  - Identify needed resources and potential partners, and
  - Take a conservative approach—do not oversell the program.
- Identify potential risks and costs
  - Determine what risks each partner is willing to accept,
  - Develop a 3 to 5 year budget that includes:
    - Incremental cost for fuel,
    - Additional fuel sampling,
    - Biocide and water dispersant,
    - Increased fuel filter and fuel system-related costs, and
    - Tank cleaning and disposal costs.
  - Include contingencies for unexpected events, and
  - Present findings to the agency board and public.

If support is in place and you decide to proceed:

- Commit to the project wholeheartedly
  - Review NBB publication, *Fuel Quality and Performance Guide* (*31*).
  - Specify ASTM D6751 biodiesel from a BQ-9000 certified producer and accredited fuel marketer,
  - Avoid splash blending in colder climates, and
  - Treat all fuel with an approved biocide and water dispersant.
- Sell program to the employees
  - Stress the importance of the programs' success,
  - Acknowledge that there will be challenges, and
  - Cultivate the employees' commitment and dedication to help ensure the success of the program.
- Sample fuel weekly for the first 12 months
  - Document all results.
- Develop a good reporting process for unusual conditions, including
  - Slow fuel delivery at dispensing nozzles, and
  - Rough idling or dying engines.
- Train maintenance staff on what to look for
  - Drain filters into a clean container.
  - Cut open filters to inspect them closely.
  - Sample from bottom of fuel tanks, and
  - Document everything: Save samples and take photographs.
- Provide regular feedback to staff, partners, and Board
  - Identify successes,
  - Acknowledge problems,
  - Recognize those who make the program work.

- Review goals
  - Quantify reductions in petroleum-based fuels,
  - Relate results to U.S. agricultural benefits, and
  - Identify green house gas emissions reductions.
- Grow the program as you gain experience
  - Increase to B5, B10, and possibly B20; and
  - Consider ethanol for gasoline vehicles.

CENTRAL OHIO TRANSIT AUTHORITY

Agency Profile

The Central Ohio Transit Authority (COTA) in Columbus, Ohio, operates all of its 234 diesel buses on biodiesel, which collectively accumulate approximately one million miles of travel annually. The agency blends its own fuel in various percentages depending on the time of year and consumes approximately 965,000 gallons of B100 biodiesel annually, which represents about 48% of their total annual fuel consumption. The remainder is ULSD.

COTA's service area covers about 534 square miles and includes some hills. The average bus speed is 14 mph; the average winter low temperature is 22.7°F. All buses operate from two garages, with four underground diesel tanks. All vehicle storage is indoors.

Reasons for Biodiesel Use

The maintenance department initiated COTA's use of biodiesel in 2005 when Hurricane Katrina disabled many southern refineries, causing an escalation of fuel prices. Biodiesel costs were higher than diesel costs; however, after Katrina, COTA's maintenance department began to look at biodiesel more as an economic benefit. Including the blender's tax credit, B100 was priced at $1.82/gallon compared with approximately $2.35 per gallon for ULSD shortly after Katrina. The more the agency looked into it, the more biodiesel made sense from a fuel availability and environmental benefit standpoint. In addition, biodiesel added lubricity to ULSD.

Solid Biodiesel Specification

Developing a solid specification is one of the reasons COTA can claim success for its biodiesel program. In developing the specification, the maintenance manager researched many publications, including those from NREL, ASTM, and the NBB. Calls were placed to fuel suppliers, the local university (Ohio State University), and those using biodiesel. Information from research on cloud point, water, glycerin, sulfur, cetane, and other topics prepared the agency to write its specification in a knowledgeable fashion. Key aspects of the specification include ensuring compliance to ASTM D6751 and BQ-9000, and establishing specific requirements for blending and delivery. COTA so completely developed the specification that it has not changed from the original version.

Since it began using biodiesel, the agency has not experienced any fuel separation or quality issues. The problems encountered, however, have more to do with the ULSD petroleum diesel. COTA periodically took fuel samples. Results showed a low cetane count, high sediment, high water content, higher than specification sulfur, and cross-contamination with other fuels. COTA believes that most reported biodiesel problems from other agencies are actually related to the ULSD base fuel.

Cost

Since first purchasing B100 in December 2005, COTA has seen the price increase from approximately $1.83 per gallon to $2.10, plus $0.07 per gallon for delivery. The agency was on a fixed-price schedule through June 2007. The cost of the base ULSD is currently $1.80 per gallon, which includes delivery.

COTA claims the use of biodiesel saves the agency approximately $534,000 annually. The cost savings comes from what the agency projected to spend on fuel over the entire year of 2006; the first 6 months was projected at $2.45 per gallon delivered, and the last 6 months at $2.75 per gallon. The differential between projected cost and actual blended cost per gallon constitutes COTA's savings.

Different Blends Throughout the Year

To maximize use of biodiesel and avoid problems associated with the cold weather experienced in Columbus, COTA's fuel management program includes maintaining the following four different biodiesel blends throughout the year:

- December through April—B20
- May—B50
- June through September—B90
- October through November—B50.

B90, which is the highest biodiesel blend used by any agency responding to the survey questionnaire, is used 4 months of the year when temperatures are mild, B20 is used 5 months annually during the coldest period, and B50 is used between seasons.

Fuel Management Plan

COTA strongly believes that a thoroughly developed fuel management plan is essential to a successful biodiesel program. Its plan is designed around the seasonal mean temperatures in Columbus, the cloud point for each fuel blend, and fuel tank temperatures in the storage tanks. The program also involved contacting vehicle and facility fuel dispensing

OEMs to identify which component materials in their products were not compatible with B100.

Although the OEMs raised no fuel compatibility issues, the agency put in place a proactive program to monitor fuel pumps, lines, seals, gaskets, and other components for leaks and degradation to ensure that there were no compatibility issues. The monitoring program included cutting open fuel filters to examine them closely for contamination and examining gaskets for leaks.

Despite the claims by OEMs that all materials were compatible, as biodiesel concentrations were increased, COTA anticipated and did discover some residual materials inside the filters. As soon as the problems were discovered, the agency contacted each component OEM to obtain further information on replacement parts (gaskets, fuel lines and hoses, fuel pumps, injector seals, etc.) that would be compatible with higher biodiesel concentrations.

Based on information provided by the OEMs and other research, COTA put in place a campaign to change all affected components for a one-time cost of $17,000. The replaced parts included lift pumps, fuel lines, auxiliary heater lines, and primary/secondary fuel filter gaskets for 234 buses for a per-bus average of about $72 for parts. Given the annual savings of approximately $534,000, the agency believes that the one-time cost was well worth the effort and expense. The retrofit campaign involved, among other procedures, changing to Teflon seals, stainless steel lines, and special fittings. In most cases, replacement components were available through traditional suppliers; in other cases, COTA had to make its own fittings, lines, and gaskets. By understanding that B100 could have compatibility issues with some materials and actively monitoring for signs of deterioration, the agency was able to prevent major problems. According to COTA's maintenance manager, the issues did not prevent the agency from providing scheduled bus service. Regarding road calls, performance actually improved. In January 2007, COTA averaged 6,900 miles between service interruptions, the best record in the agency's history.

Delivery and Blending Procedures

COTA has four 25,000 gallon underground tanks. COTA purchased B100 biodiesel from the supplier according to a fuel specification described earlier. The supplier delivered B100 to COTA's tanks in specified amounts, along with alternating loads of diesel to achieve the desired concentration. Calculating the concentrations is not a problem according to the agency. Each tank holds 22,500 gallons and calculations are made as to how much diesel and biodiesel fuels are needed based on the existing concentration and amount of fuel in each tank. COTA orders truckloads of fuel with diesel delivered first, followed by biodiesel, followed by diesel again; each load is calculated to a specified gallon amount to achieve the desired biodiesel concentration.

Staggering the fuel deliveries (with biodiesel between the two diesel loads) assists with in-tank blending. Given that COTA uses four different biodiesel concentrations throughout the year, tanks are prepared with the desired concentration level in advance of the need, which also provides additional time for the fuels to blend more thoroughly.

COTA is well aware that cold weather could cause problems with the delivery of B100. Tanker trucks making the deliveries are equipped with in-tank fuel heaters and a temperature gauge, and the temperature of B100 delivered must be in the 42°F–48°F range or higher according to the agency's specification and contract term. COTA is also aware of the cleansing effect of biodiesel, and although storage tanks were only 4 years old, they were inspected and cleaned before using the biodiesel. A biocide is also added to the fuel by the supplier based on COTA's contract requirements. COTA's preparations have averted any fuel delivery or storage problems.

Test Buses

COTA began its biodiesel program with 10 buses using B20. After 30 days without experiencing problems, they added another 20 buses to the test program. As they continued to experience no problems, they converted the entire fleet to B20. The test period ran from January 15 through March 4, 2006. Test buses were fueled using two of the agency's four tanks that contained the B20 blend, and their fuel doors were labeled with a special BIODIESEL decal to route them to the correct pump and fuel island.

Warranty and Maintenance

Although COTA understood that one of its engine suppliers only allowed up to B5 for warranty purposes, the agency decided that the benefits of higher biodiesel concentrations outweighed the risks. Given that the agency uses much higher concentrations on average, COTA fully understood that the engine OEM would not warranty the fuel system portion of the engine, but must warranty other parts of the engine not affected by biodiesel use. According to COTA, replacing the entire fuel delivery system on its engines is worth the risk.

To date, COTA has not had any warranty issues regarding the use of higher biodiesel concentrations in any of its diesel engines. Based on collected failure and repair data, the cost to maintain engines operating on biodiesel is not significantly greater than operating the engines on ULSD alone. Additionally, rebuilding of engines revealed less carbon on internal engine parts because of biodiesel's cleansing characteristics.

Preventative Maintenance Procedures

After changing fuel hoses, lines, gaskets, and other parts to be compatible with B100 during the initial retrofit campaign, COTA's preventative maintenance remains unchanged.

Secondary fuel filter life was extended from 6,000 to 12,000 miles because the primary fuel filters were effective at trapping what little contaminates were left in the fuel system.

Emissions

An emissions study was conducted in Columbus using federal EPA modeling that calculates emissions outputs based on specific engines. The study revealed that the agency's current program to use maximum levels of biodiesel according to each season is reducing PM emissions by more than 17 tons annually. COTA is also working with Ohio State University on a physical emissions study to help validate the EPA model, as well as the NOx issues related to the use of biodiesel.

Marketing

To promote its biodiesel use, COTA produced a flier entitled "Lean, Clean, Bean Machine" (*32*). The flier promotes the agency's use of biodiesel as a renewable fuel that is:

- Made from Ohio-grown soybeans,
- Cleaner than diesel,
- Non-toxic,
- Able to reduce diesel emissions, and
- Able to save the agency approximately $534,000 annually.

The flier is attached as Appendix D.

Recommendations for Successful Implementation

Based on its experiences, COTA offers the following recommendations to assist others in successfully implementing biodiesel:

- Do not begin a biodiesel program unless you are willing to do the necessary research and up-front work to ensure success; understand that storage and use of biodiesel is not the same as for diesel.
- Successful biodiesel implementation is all about management. Biodiesel needs to be managed like a special fuel; you have to be aware of its limitations.
- Start with purchasing biodiesel through a specification that meets ASTM and BQ-9000 standards to ensure fuel performance, quality, and consistency.
- Conduct random testing to verify that fuel delivered meets all specification requirements.
- Examine your operation to assess:
  - Existing fuel management program,
  - Vehicle storage (indoors or outdoors),
  - Ambient temperature conditions,
  - Geographic location (depending on concentration, biodiesel will cause loss of power on hills),
  - Fueling infrastructure and biodiesel availability to determine how fuel will be blended and stored,
  - Condition of fuel storage tanks to determine if cleaning is required,
  - Compatibility of biodiesel with materials used in bus and facility fuel delivery and storage systems (seals, gaskets, pumps, valves, etc.), and
  - Engine OEM position concerning maximum biodiesel concentrations.
- Develop a fuel management program that takes into consideration and anticipates all issues associated with biodiesel use.
- Take actions based on your management program to monitor and identify potential problem areas, and respond appropriately. Key actions include:
  - Start with a small test program,
  - Clean storage tanks if needed,
  - Consult with OEMs and replace bus and facility component materials if needed to be compatible with biodiesel,
  - Monitor fuel filters carefully to identify potential contamination and fuel gelling issues in advance of developing into problems,
  - Ensure biodiesel is properly heated during cold weather months during delivery,
  - Pay particular attention to fuel storage gelling problems if aboveground tanks are used, and
  - Inform engine OEMs of biodiesel use to determine warranty coverage; decide if benefits and other factors are worth using concentrations above recommended levels.

CHAPTER SIX

PROJECT RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

SUMMARY AND CONCLUSIONS

After reviewing the literature and experiences of those using biodiesel, it is apparent that biodiesel is a viable complement to petroleum diesel for use in buses. Biodiesel offers too many benefits for transit agencies to ignore. Unlike petroleum diesel, biodiesel is a renewable energy source produced domestically that can both reduce dependency on foreign oil and provide greater energy security. These factors alone make biodiesel worth considering.

Biodiesel also provides significant environmental benefits. The plants used to make biodiesel displace atmospheric carbon dioxide through the natural growing process, and the higher oxygen content of biodiesel reduces emissions by providing more complete combustion. Studies regarding NOx emissions, however, present various findings. Some show a slight increase in NOx, others a slight decrease, whereas one study shows biodiesel having no effect on emissions at all. The variations highlight the need for more conclusive research, especially focused on 2007 and newer diesel engines equipped with particulate filters, and engines fitted with NOx reduction equipment needed to meet 2010 EPA requirements.

Unlike other alternative fuels, biodiesel has virtually no safety or handling concerns other than those normally associated with diesel, nor any extensive infrastructure requirements. Biodiesel does, however, have a series of characteristics and related potential issues that must be understood and actively managed to achieve a trouble-free transition.

The ease with which biodiesel can be ordered, poured into existing diesel fuel storage tanks, dispensed into buses, and easily used in those buses is one of its biggest downsides. Because biodiesel can be used so easily as an additive to diesel, it is also easy to overlook the steps needed to prevent difficulties. Troubles may manifest quickly, over time, or not at all. Agencies should not, however, just hope for the best. None of the procedures needed to prevent problems associated with the use of biodiesel are especially difficult to put in place, and pale in comparison to the efforts needed to implement other alternative fuels. Overlooking these basic procedures, however, could result in problems. Worse yet, ignoring the relatively simple implementation procedures could give biodiesel a reputation it does not deserve.

The most significant conclusion drawn from this study is that users must actively manage biodiesel to be effective. Given the complexities associated with advanced bus technologies and the host of other issues that maintenance managers continually face, managing the implementation of biodiesel becomes yet another task added to an already long list. However, if an agency decides to move forward with biodiesel it must become thoroughly familiar with the fuel and the implications associated with its use, and commit the appropriate effort and resources.

The areas of biodiesel use that need to be managed to ensure its successful implementation have been discussed in detail throughout this synthesis. They are summarized here, followed by a section on recommendations to assist agencies with their implementations.

- B100 Versus Lower Blends

B100 is pure biodiesel, which can be used as is or mixed with diesel to form various blends. The higher the biodiesel content the greater the benefits in terms of reducing dependence on nonrenewable and foreign-based petroleum diesel, reduced emissions, added fuel lubricity, and so forth. However, the greater the biodiesel percentage the more actively the fuel implementation needs to be managed in a fleet environment to avoid potential facility- and vehicle-related problems such as voiding engine warranty, cold weather issues, material compatibility issues, problems related to the cleansing action of the fuel, fuel economy penalties, and potential vehicle performance impacts.

- Warranty

All engine manufacturers provide warranty coverage based on using fuels and lubricants that conform to recommended characteristics. This applies to traditional diesel as well as biodiesel. When it comes to biodiesel use, engine original equipment manufacturers typically have very explicit requirements for the fuel specification and the amount of biodiesel blended with diesel. Some limit biodiesel to B5, whereas others approve B20 and higher levels.

Agencies that do not keep abreast of developments and fail to conform to engine requirements risk losing warranty coverage. This applies to the fuel delivery system and other components if the manufacturer can prove the fault is related

to biodiesel use. Agencies therefore must consider the benefits of using biodiesel against potential warranty risks.

- Biodiesel Specifications and Quality

Biodiesel is not officially biodiesel unless it meets the ASTM D6751 specification. Although this specification defines acceptable fuel characteristics and performance for B100, and ASTM D975 provides the specification for petroleum diesel, neither address the blends created (e.g., B10 and B20) when the two are mixed. ASTM is, however, developing a standard for mixed biodiesel blends, though it is not yet finalized. In an attempt to help further this process, the Engine Manufacturers Association has released its test specification for B20, which could be used by agencies in the interim. It is important to note that any biodiesel fuel that does not meet ASTM D6751 should *not* be used in diesel engines, period!

Neither ASTM specification D6751 or D975 addresses quality control measures after biodiesel is produced. This is however done by the National Biodiesel Accreditation Program, and is known as the BQ-9000 standard. The standard addresses quality control measures for storing, sampling, testing, blending, shipping, distributing, and fuel management, and is to be used as a companion to ASTM D6751.

- Blending, Delivery, and Storage

Depending on availability, biodiesel can be pipe-blended by the supplier and delivered as a premixed, ready-to-use product similar to diesel fuel. Until biodiesel becomes more popular and readily available as a ready-mixed product that meets individual agency requirements, users will needs to blend biodiesel inside the tanker truck that delivers the fuel or within the agency's storage tanks. Splash blending is where heavier B100 is poured atop diesel fuel already contained inside the tank, with gravity doing the mixing as the B100 disperses to the tank's bottom. In-tank blending is similar to splash blending (the terms are often used interchangeably), but involves some form of external agitation to achieve the desired concentration. In-tank blending agitation could be achieved by:

- Mechanical blending means such as a rotating device placed inside the tank,
- Splash blending B100 into a tanker truck containing diesel and letting the movement of the truck during delivery mix the two fuels, or
- Alternating the delivery of the two fuels into the storage tank so that the force of the fuels entering the tank one after the other does the in-tank blending.

In no case should B100 be poured first into an empty tank, because its heavier weight will cause it to remain at the bottom and not mix well with the lighter diesel above it.

Biodiesel can be stored in the same bulk storage tanks as diesel, in separate tanks, purchased and dispensed at off-site retail filling stations, or delivered and filled directly to individual buses onsite by the supplier (wet hose method). Biodiesel's increased ability to grow bacteria in the presence of water typically requires additives to control this. Additionally, biodiesel's higher cloud point (ability to freeze or gel at higher temperatures than diesel) may require additional procedures. Although more consistent temperatures offered by underground storage tanks mitigate many of the cold weather issues, biodiesel still needs to be delivered warm enough to the site to prevent gelling when the fuel is exposed to ambient air temperature while being poured into the storage tank.

- Cold Weather Operation

The characteristic of biodiesel to freeze or gel (thicken) at higher temperatures than diesel gives it the potential for cold weather problems not only with delivery, storage, and dispensing, but with vehicle drivability. Typical cold weather problems occur when biodiesel is delivered or stored at temperatures near or below the fuel's cloud point. When this occurs, the thickened fuel will cause dispensing filters to clog, which can slow down or stop the fuel from flowing. The same could occur with the bus, which can cause the vehicle to run poorly or even shut down.

Users can eliminate all of these potential problems by keeping the temperature of the biodiesel safely above its cloud point. This can be managed by cold weather additives, adding kerosene to the biodiesel, switching to No. 1 diesel as the base fuel, or by switching to a lower percentage of biodiesel (e.g., B5 or B10) in the winter, all of which effectively raise the cloud point of biodiesel to prevent gelling. The temperature of biodiesel during delivery, however, may need to be monitored depending on ambient temperature.

- Materials Compatibility

Biodiesel, especially B100, is known to be incompatible with certain materials found in facility fuel storage and dispensing equipment, and with bus onboard fuel delivery systems. Soft materials used to make gaskets and seals such as natural or nitrile rubber compounds and other materials are particularly vulnerable to B100, whereas Teflon, Viton, and Nylon have very little reaction to biodiesel. Harder materials such as brass, bronze, copper, lead, tin, and zinc may be oxidized by biodiesel to the point where it creates solids that can contaminate fuel delivery systems. Stainless steel, carbon steel, and aluminum are generally not affected.

Biodiesel blends of 20% and lower have much less effect on these materials; information and advice concerning material compatibility is available from engine and facility fueling manufacturers. Agencies should remember that biodiesel accidentally spilled in the engine compartment or elsewhere on the vehicle may degrade hoses, wiring, and other components not designed to come in contact with fuel. Workers should immediately clean up any biodiesel spilled on these

components or on paint and decals during daily fueling to avoid potential damage.

- Cleansing Effect

Biodiesel is a natural solvent that will dissolve and dislodge accumulated sediments formed over time in both vehicle and facility fuel delivery systems. Once dissolved, the sediments can travel within the fuel to clog dispensing filters. These sediments can also wreck havoc with fuel injector and other bus fuel system components. The problem is exacerbated if the fuel begins to gel in colder weather, creating two potential sources for fuel delivery problems.

The level of biodiesel's cleansing action depends on two factors: the amount of sediment that has formed in the fuel system over time, and the amount of biodiesel blended with the diesel fuel. Higher biodiesel concentrations have a greater cleansing action; older vehicle and facility fueling systems tend to have a greater buildup of sentiments. This combination is sure to present problems if not managed.

Again, users can effectively manage these potential problems monitoring fuel filters for debris and, if needed, cleaning or flushing fuel systems to remove sediments. Once removed, biodiesel will generally keep the sediment from reappearing. Agencies should note, however, that increasing to stronger concentrations can cause additional debris to be dislodged.

- Costs

As with diesel, the price of biodiesel is constantly changing. In most cases, biodiesel is priced slightly higher than diesel. Biodiesel also has slightly less energy content than diesel, meaning that vehicles with B20 will use up to 2% more fuel than 100% diesel. The October 2006 issue of the *Clean Cities Alternative Fuel Price Report* included calculations on an energy equivalent basis; B2 to B5 was priced higher than regular diesel by approximately 14 cents per gallon, B20 higher by approximately 9 cents per gallon, and B99 to B100 by approximately $1.02 per gallon. Other costs associated with biodiesel include:

- Tank cleaning if required,
- More frequent replacement of fuel filters if required,
- Biocide and other additives if required,
- Retrofitting vehicle and facility fuel system equipment with compatible materials if required,
- Periodic fuel testing if required, and
- The extra labor needed to effectively manage the biodiesel program.

Costs can be offset by tax reductions, grants, and other incentives that may make biodiesel close to or even less expensive than traditional diesel.

- Incentives

In 2004, Congress passed a federal excise tax credit for biodiesel given to the fuel distributor, which is generally passed down to the end user as a way of reducing biodiesel costs. Set to expire at the end of 2008, the tax incentive is expected to be extended through 2017. Another incentive offered by biodiesel allows fleets required to purchase alternative fueled vehicles under the Energy Policy Act of 1992 the option of purchasing and using biodiesel instead. The Congressional Budget Office and the U.S. Department of Agriculture have confirmed that biodiesel is the least-cost alternative fuel option for meeting Energy Policy Act of 1992 requirements. Other incentives are also available.

- Local Requirements

Certain states and local governments have their own requirements for using biodiesel and other alternative fuels. In New York, for example, certain buildings and vehicles are required to use biofuels such as biodiesel to reduce petroleum consumption and emissions. Agencies need to become aware of these requirements and incorporate biodiesel as appropriate. As mentioned earlier, the DOE has a website that summarizes the various requirements and incentives pertaining to biodiesel and alternative fuels at www.eere.energy.gov/cleancities/vbg/progs/laws.cgi.

- Public Awareness

The EPA first began regulating diesel emissions about 20 years ago, a move long overdue. The black soot and other emissions emanating from exhaust pipes of unregulated diesel engines presented a valid environmental concern. The problem was most visible with transit buses that operated in congested city traffic. Because of this, the EPA established more stringent emissions standards for transit buses than their heavy-duty truck counterparts. In the 1990s, EPA's Retrofit Rebuild Program required transit buses to meet more strenuous emissions standards when their engines were rebuilt or replaced; the same requirements were never passed down to the much larger trucking industry.

Because most transit agencies are unaware of just how clean diesel bus engines have become, the use of biodiesel gives these agencies an ideal opportunity to highlight the emissions and energy independence benefits offered by biodiesel. Several transit agencies have done this through public relation campaigns and other efforts.

RECOMMENDATIONS

There are several recommendations regarding the use of biodiesel. The most significant is that agencies avoid the temptation to simply order biodiesel and start using it. Instead, agencies must first become knowledgeable about the fuel, and develop a program to actively manage its implementation and use.

The following recommendations are based on the synthesis findings and are offered as a checklist of sorts to assist agencies with their implementation and use of biodiesel.

- Locate a suitable biodiesel supplier to determine availability and cost. Also determine:
  - If the B100 used to make blends meets the ASTM D6751 specification.
  - If the petroleum diesel portion meets ASTM D975 and local agency fuel requirements.
  - The various cloud points for the pure biodiesel (B100) and other popular biodiesel blends such as B2, B5, or B20.
  - If the supplier is BQ-9000 certified.
  - How the fuel is blended: Is it premixed (pipe or rack blended), tank blended, or splash blended?
  - What level of assurances and safeguards are provided by the supplier to ensure that the biodiesel will be properly blended (assuming the supplier does the blending).
  - The level of after-sales support provided by the supplier in terms of fuel-related warranty and other support.
  - How the supplier will protect against cold weather issues: Will the biodiesel be warmed above the cloud point of the fuel at the time of delivery?
  - If references from other biodiesel customers are available.
  - If there are additive recommendations to control bacteria growth and to increase cloud point levels.
  - How supplier tanks are cleaned to prevent contamination of biodiesel during delivery.
- Contact engine and vehicle representatives to determine:
  - Allowable maximum biodiesel concentrations for use in engines and vehicle fuel systems to maintain warranty coverage.
  - Exactly what the manufacturers will and will not cover regarding warranty and biodiesel use.
  - The level of risk the agency is willing to take during and after the warranty period if biodiesel is used in concentrations higher that those allowed by vendors.
  - What materials in the engine and fuel delivery systems are not compatible with various levels of biodiesel; obtain their recommendations for procedures to make materials compatible.
  - Additive recommendations to control bacteria growth and to increase cloud point levels (prevent fuels from gelling).
  - If policies concerning biodiesel use and warranty coverage have changed or been updated (check periodically).
- Contact facility fuel dispensing equipment representatives to determine:
  - Allowable biodiesel concentrations for use in storage tanks and dispensing equipment.
  - What materials in the fuel storage and delivery systems are not compatible with various levels of biodiesel; obtain their recommendations for procedures to make the materials compatible.
  - What additives they recommend to control bacteria, algae, and other microorganisms, and to increase cloud point levels.
- From the previous items, you will know how the fuel will be delivered, either premixed by the supplier in the proper concentration, or as B100 and then tank or splash blended at the agency's site. Regardless of the blending, you will need to develop (or modify existing) fuel specification and contract requirements that include:
  - Use of ASTM D6751, ASTM D975, and BQ-9000 standards.
  - A definition for biodiesel to the specification: a fuel composed of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats, designated B100.
  - Consider using the Engine Manufacturers Association's test specification for B20.
  - Check with ASTM periodically to determine if their specification for B20 and other blends has been released; use that specification as appropriate.
  - Include provisions to have the supplier ensure the biodiesel is not contaminated.
  - Include the appropriate fuel additives for controlling bacteria and water, and to prevent gelling.
  - Ensure the contract gives you flexibility to increase or decrease the biodiesel percentage if needed.
  - Provisions for the supplier to provide the cloud point for B100 or each biodiesel blend delivered; specify that the temperature of the fuel be at least 10°F above its cloud point when delivered.
  - If delivered premixed by the supplier, include assurances that the blend will be homogeneous when delivered, and that the supplier will stand behind the mixture if found to be not uniform.
    - If delivered as B100, the agency will need to have procedures in place to ensure that the fuel will be adequately blended onsite using proven splash- or tank-blending techniques. Splash bending relies on gravity to do its work; in-tank blending involves some form of agitation such as mechanical mixing or alternate pumping of the fuels (i.e., diesel first followed by B100 followed by diesel).
- Based on these findings:
  - Begin with a conservative approach. Consider first testing biodiesel on a limited number of buses. Initiating the project with lower biodiesel concentrations during warmer months may be more appropriate to gain initial experience; work up to the final blend concentration in increments (i.e., B5 to B10 to B20).
  - Instead of replacing all facility bulk storage with biodiesel for the initial test, consider dedicating a certain tank(s) for biodiesel, installing temporary storage tanks, having the supplier fill vehicles on site (wet hose), or filling at a public filling station if available. Monitor fuel filters and vehicle performance during the initial test.

  - Depending on test results:
    - Institute a campaign to replace vehicle fuel system components with compatible materials. For low levels of biodiesel concentrations (e.g., B2, B5, or B10) this may not be needed.
    - Institute a campaign to install additional vehicle fuel filters including those with improved water separation, if needed. Again, for low levels of biodiesel concentrations this may not be needed.
  - In preparation for having biodiesel stored in existing facility storage tanks, test the fuel tanks for water and sediment, and clean them if needed. Also determine if any facility fuel storage and dispensing equipment materials not compatible with biodiesel will need to be changed or modified. Change out materials as needed.
- As experience is gained with biodiesel use:
  - Modify facility preventive maintenance inspection program. Monitor:
    - Fuel filters for contamination and blockage; add filters and/or adjust change-out frequency as needed.
    - Fuel storage temperatures to ensure they are safely above the fuel's cloud point; aboveground tanks may require additional fuel heating and/or insulating measures.
    - Water content, bacteria growth, and sediment deposits when periodically checking tank levels (i.e., when sticking tanks); drain water from tanks and adjust fuel additive package as needed; aboveground tanks may require additional procedures because of greater temperature fluctuations and tendency to develop more water and bacteria growth.
    - Fuel quality; take samples (one gallon) after each fuel delivery (B100 or blended fuel) and retain until current batch shows no signs of problems; avoid long-term storage to prevent degradation, use biodiesel within 6 months.
  - Modify vehicle preventive maintenance inspection program.
    - Monitor fuel filters for contamination and blockage; add filters and/or adjust change-out frequency as needed.
    - Take other measures as recommended by engine manufacturer.
  - Once program proves successful, publicize biodiesel use throughout local community.

FUTURE RESEARCH

The following research topics are suggested as a result of this study:

- Follow-up on biodiesel experiences as more information is gained.
- Examine engine longevity, maintenance, and rebuild experiences associated with biodiesel use.
- Conduct additional testing of regulated emissions (e.g., particulate matter, nitrogen oxide, carbon monoxide, and hydrocarbons), especially nitrogen oxide, to determine level of emissions reductions from 2007 and newer diesel engines equipped with particulate matter filters, and from engines with nitrogen oxide emissions controls.
- Examine the long-term effects of biodiesel on diesel particulate filters and other emissions control equipment.
- Conduct testing of emissions that are not currently monitored to determine if biodiesel combustion creates other harmful pollutants.
- Examine effective procedures for blending biodiesel.
- Conduct an education program to impart how much cleaner diesel has become over the last 20 years and how biodiesel contributes to diesel's viability as a clean motor fuel.

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ABBREVIATIONS AND ACRONYMS

AFV	Alternative fuel vehicle
B100	100% biodiesel, also known as pure or "neat" biodiesel
B10, etc.	Diesel blended with biodiesel at the prescribed percentage
BQ-9000	Biodiesel quality specification developed by the National Biodiesel Accreditation Program
CARB	California Air Resources Board
CO	Carbon monoxide
CO_2	Carbon dioxide
COTA	Central Ohio Transit Authority
D1	No. 1 diesel
DDC	Detroit Diesel Corporation
DME	Dimethyl ether
DoD	Department of Defense
DOE	Department of Energy
DPF	Diesel particulate filter, also called a PM filter
E10, etc.	Gasoline blended with ethanol at the prescribed percentage
E-Diesel	Fuel blend made of diesel and ethanol
EMA	Engine Manufacturers Association
EPAct	EPA Energy Policy Act
g/bhp-hr	Grams per brake horsepower-hour
HC	Hydrocarbons
MSDS	Material safety data sheet
NBAP	National Biodiesel Accreditation Program
NBB	National Biodiesel Board
NFESC	Naval Facilities Engineering Service Center
NOx	Nitrogen oxide
NREL	National Renewable Energy Laboratory
OEM	Original Equipment Manufacturer
PM	Particulate matter
PMI	Preventive maintenance inspection
PPM	Parts per million
RFTA	Roaring Fork Transportation Authority
RTD	Regional Transportation District
TPMAAT	Tenth percentile minimum ambient air temperature
ULSD	Ultra low sulfur diesel

APPENDIX A

Sample Material Safety Data Sheet

SAMPLE MATERIAL SAFETY DATA SHEET

1. CHEMICAL PRODUCT

General Product Name:	**Biodiesel (B100)**
Synonyms:	Methyl Soyate, Rapeseed Methyl Ester (RME)
Product Description:	Methyl esters from lipid sources
CAS Number:	Methyl Soyate: 67784-80-9; RME: 73891-99-3;

2. COMPOSITION/INFORMATION ON INGREDIENTS

This product contains no hazardous materials.

3. HAZARDS IDENTIFICATION

Potential Health Effects:

INHALATION:

Negligible unless heated to produce vapors. Vapors or finely misted materials may irritate the mucous membranes and cause irritation, dizziness, and nausea. Remove to fresh air.

EYE CONTACT:

May cause irritation. Irrigate eye with water for at least 15 to 20 minutes. Seek medical attention if symptoms persist.

SKIN CONTACT:

Prolonged or repeated contact is not likely to cause significant skin irritation. Material is sometimes encountered at elevated temperatures. Thermal burns are possible.

INGESTION:

No hazards anticipated from ingestion incidental to industrial exposure.

4. FIRST AID MEASURES

EYES:

Irrigate eyes with a heavy stream of water for at least 15 to 20 minutes.

SKIN:

Wash exposed areas of the body with soap and water.

INHALATION:

Remove from area of exposure; seek medical attention if symptoms persist.

INGESTION:

Give one or two glasses of water to drink. If gastro-intestinal symptoms develop, consult medical personnel. (Never give anything by mouth to an unconscious person.)

5. FIRE FIGHTING MEASURES

Flash Point (Method Used): 130.0 C or 266.0 F min (ASTM 93)

Flammability Limits: None known

EXTINGUISHING MEDIA:

Dry chemical, foam, halon (may not be permissible in some countries), CO_2, water spray (fog). Water stream may splash the burning liquid and spread fire.

SPECIAL FIRE FIGHTING PROCEDURES:

Use water spray to cool drums exposed to fire.

UNUSUAL FIRE AND EXPLOSION HAZARDS:

Biodiesel soaked rags or spill absorbents (i.e. oil dry, polypropylene socks, sand, etc.) can cause spontaneous combustion if stored near combustibles and not handled properly. Store biodiesel soaked rags or spill absorbents in approved safety containers and dispose of properly. Oil soaked rags may be washed with soap and water and allowed to dry in

well ventilated area. Firefighters should use self-contained breathing apparatus to avoid exposure to smoke and vapor.

6. ACCIDENTAL RELEASE MEASURES SPILL CLEAN-UP PROCEDURES

Remove sources of ignition, contain spill to smallest area possible. Stop leak if possible. Pick up small spills with absorbent materials and dispose of properly to avoid spontaneous combustion (see unusual fire and explosion hazards above).

Recover large spills for salvage or disposal. Wash hard surfaces with safety solvent or detergent to remove remaining oil film. Greasy nature will result in a slippery surface.

7. HANDLING AND STORAGE

Store in closed containers between 50°F and 120°F.
Keep away from oxidizing agents, excessive heat, and ignition sources.
Store and use in well ventilated areas.
Do not store or use near heat, spark, or flame, store out of sun.
Do not puncture, drag, or slide this container.
Drum is not a pressure vessel; never use pressure to empty.

8. EXPOSURE CONTROL /PERSONAL PROTECTION

RESPIRATORY PROTECTION:

If vapors or mists are generated, wear a NIOSH approved organic vapor/mist respirator.

PROTECTIVE CLOTHING:

Safety glasses, goggles, or face shield recommended to protect eyes from mists or splashing. PVC coated gloves recommended to prevent skin contact.

OTHER PROTECTIVE MEASURES:

Employees must practice good personal hygiene, washing exposed areas of skin several times daily and laundering contaminated clothing before re-use.

9. PHYSICAL AND CHEMICAL PROPERTIES

Boiling Point, 760 mm Hg:>200°C
Volatiles, % by Volume: <2
Specific Gravity (H_2O=1): 0.88
Solubility in H_2O, % by Volume: insoluble
Vapor Pressure, mm Hg: <2
Evaporation Rate, Butyl Acetate=1: <1
Vapor Density, Air=1:>1
Appearance and Odor: pale yellow liquid, mild odor

10. STABILITY AND REACTIVITY

GENERAL:

This product is stable and hazardous polymerization will not occur.

INCOMPATIBLE MATERIALS AND CONDITIONS TO AVOID:

Strong oxidizing agents

HAZARDOUS DECOMPOSITION PRODUCTS:

Combustion produces carbon monoxide, carbon dioxide along with thick smoke.

11. DISPOSAL CONSIDERATIONS

WASTE DISPOSAL:

Waste may be disposed of by a licensed waste disposal company. Contaminated absorbent material may be disposed of in an approved landfill. Follow local, state and federal disposal regulations.

12. TRANSPORT INFORMATION

UN HAZARD CLASS: N/A

NMFC (National Motor Freight Classification):

PROPER SHIPPING NAME: Fatty acid ester
IDENTIFICATION NUMBER: 144920
SHIPPING CLASSIFICATION: 65

13. REGULATORY INFORMATION:

OSHA STATUS:

This product is not hazardous under the criteria of the Federal OSHA Hazard Communication Standard 29 CFR 1910.1200. However, thermal processing and decomposition fumes from this product may be hazardous as noted in Sections 2 and 3.

TSCA STATUS:

This product is listed on TSCA.

CERCLA (Comprehensive Response Compensation and Liability Act):

NOT reportable.

SARA TITLE III (Superfund Amendments and Reauthorization Act):

Section 312 Extremely Hazardous Substances:

None

Section 311/312 Hazard Categories:

Non-hazardous under Section 311/312

Section 313 Toxic Chemicals:

None

RCRA STATUS:

If discarded in its purchased form, this product would not be a hazardous waste either by listing or by characteristic. However, under RCRA, it is the responsibility of the product user to determine at the time of disposal, whether a material containing the product or derived from the product should be classified as a hazardous waste,
(40 CFR 261.20-24)

CALIFORNIA PROPOSITION 65:

The following statement is made in order to comply with the California Safe Drinking Water and Toxic Enforcement Act of 1986. This product contains no chemicals known to the state of California to cause cancer.

14. OTHER INFORMATION:

This information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any other process. Such information is to the best of the company's knowledge and believed accurate and reliable as of the date indicated. However, no representation, warranty or guarantee of any kind, express or implied, is made as to its accuracy, reliability or completeness and we assume no responsibility for any loss, damage or expense, direct or consequential, arising out of use. It is the user's responsibility to satisfy himself as to the suitableness and completeness of such information for his own particular use.

APPENDIX B

Survey Responders

AGENCIES USING BIODIESEL		
Agencies Using B20 or Greater	**Location**	**Biodiesel (%)**
1. Bi-State Development Agency (Metro)	St. Louis, MO	20
2. Central Florida Regional Transportation Authority (LYNX)	Orlando, FL	20
3. Central Ohio Transit Authority (COTA)	Columbus, OH	20–90
4. King County Metro	Seattle, WA	20
5. Mass Transportation Authority	Flint, MI	20
6. Northern Arizona Intergovernmental Public Transportation Authority (NAIPTA)	Flagstaff, AZ	20
7. Sun Tran	Tucson, AZ	20
8. Toledo Area Regional Transit Authority (TARTA)	Toledo, OH	20
Agencies Using Under B20	**Location**	**Biodiesel (%)**
9. Ames Transit Agency (CyRide)	Ames, IA	2–10
10. Connecticut Transit	Hartford, CT	5
11. Madison County Transit	Granite City, IL	2
12. Metropolitan Transit Authority	Houston, TX	10
13. Metro Transit, Minneapolis	St. Paul, MN	5
14. Minnesota Valley Transit Authority	Burnsville, MN	2
15. Pace Suburban Bus Service	Arlington Heights, IL	10
16. Roaring Fork Transportation Authority	Aspen, CO	10
17. Tri-County Metropolitan Transportation District of Oregon (TriMet)	Portland, OR	5
18. Utah Transit Authority	Salt Lake City, UT	2–10

AGENCIES NOT USING BIODIESEL	
With Near-Term Plans	**Location**
19. Capital District Transportation Authority	Albany, NY
20. Chittenden Transportation Authority	Burlington, VT
21. Montgomery County (MD) Transit Services (Ride On)	Rockville, MD
22. Oahu Transit Services, Inc.	Honolulu, HI
23. Spokane Transit Authority	Spokane, WA
24. StarMetro	Tallahassee, FL
Without Near-Term Plans: Pursuing Other Strategies	**Location**
25. Altoona Metro Transit (AMTRAN)	Altoona, PA
26. Capital Metro	Austin, TX
27. Charlotte Area Transit System (CATS)	Charlotte, NC
28. Dallas Area Rapid Transit (DART)	Dallas, TX
29. Delaware Transit Corporation	Dover, DE
30. Everett Transit	Everett, WA
31. Fresno County Rural Transit Agency	Fresno, CA
32. Golden Gate Transit	San Rafael, CA
33. Greater New Haven Transit District	Hamden, CT
34. GRTC Transit System	Richmond, VA
35. Milwaukee County Transit	Milwaukee, WI
36. Niagara Frontier Transportation Authority	Buffalo, NY
37. Omnitrans	San Bernardino, CA
38. Orange County Transportation Authority	Orange, CA
39. Potomac and Rappahannock Transportation Commission	Woodbridge, VA
40. Port Authority of Allegheny County	Pittsburgh, PA
41. Santa Clara Valley Transportation Authority (VTA)	San Jose, CA
42. Southeastern Pennsylvania Transportation Authority (SEPTA)	Philadelphia, PA
43. VIA Metropolitan Transit	San Antonio, TX

APPENDIX C

Summary of all Survey Responses

SYNTHESIS QUESTIONNAIRE

Use of Biodiesel in a Transit Bus Fleet

Transit System Characteristics:

1. How many diesel buses are currently operating in your fleet?
   For those who reported biodiesel use: 7,353 (combined)

2. How many (approx.) miles do they travel annually?
   For those who reported biodiesel use: 217,857,955 (combined)

3. Are you currently operating any of your diesel buses with biodiesel?
   Yes: 18 No: 25

   If "No" please answer questions 4–7. If "Yes" please answer questions 8–29.

Agencies <u>Without</u> Biodiesel Experience:

4. Do you have near-term plans to use biodiesel?
   Yes: 6 No: 19

   If No, what reason(s) would you give for not using biodiesel? (Check all that apply.)

   6 There is no compelling reason to do so at this time

   8 We are not sure of the benefits or disadvantages associated with it

   5 Biodiesel is not available locally in our area

   12 We are pursuing other emission-reduction strategies (e.g., hybrids, alt fuels, etc.)
   Explain:
   - Hybrids (6)
   - Electric shuttles, ethanol, CNG, LPG, hydrogen (4)
   - Diesel engines not allowed (2)

   13 Other reason(s) for not using biodiesel (list/describe)
   - Diverse fleet
   - Unsure of benefits, effects on engines (2)
   - Possible increase in NOx emissions (2)
   - Cost
   - Cold weather concerns (2)
   - Fuel consistency (3)
   - Had used biodiesel but switched back due to problems, costs, and unknowns (2)

   If Yes, when do you plan to use biodiesel?
   - Shortly, within the year (5)
   - When available

   Why are you making the move to biodiesel?
   - Environmental benefits/reduced emissions and health risks (2)
   - Renewable energy and reduced dependency on foreign oil (4)
   - Better than CNG
   - Comply with local mandate
   - Greater fuel lubricity

5. What do you see as the primary benefits to using biodiesel in buses?
   - Environmental benefits/reduced emissions and health risks (10)
   - Renewable and reduced dependency on foreign oil (5)

- Greater fuel lubricity (2)
- Enhanced cetane
- Improved public relations
- Reduced fuel taxes
- May support local farm interests

6. What do you see as the primary disadvantages to using biodiesel in buses?
   - Increased NOx emissions (4)
   - Plugged fuel filter concerns (2)
   - Engine manufacturer concerns/limited warranty (4)
   - Fuel quality/blending/cold weather issues (4)
   - Higher costs/reduced fuel economy (6)
   - Material incompatibility (2)
   - Algae growth (2)
   - Unavailability
   - Long-term maintenance of fuel storage tanks

7. What areas of biodiesel use would you like the Synthesis Report to address?
   - Emissions/environment (4)
   - Cold weather problems/technical issues (3)
   - Use with ultra-low sulfur diesel (ULSD) (3)
   - Fuel quality/specifications (2)
   - Warranty (2)
   - Additives (2)
   - Blending/dispensing (2)
   - Cost (2)
   - Availability

Agencies with Biodiesel Experience:

8. What percentage of biodiesel is blended with your diesel?
   - B20 or greater: 8
   - Under B20: 10

9. Is your agency required to use biodiesel?
   Yes ___4____ No ___14___

   If Yes, which requirement applies to your agency?
   - State requirement (4)

10. Did you use a procurement specification to purchase biodiesel for the bus fleet?
    Yes ___12____ No ___6____

    If Yes, what specific areas does your biodiesel fuel specification address (i.e., fuel blending techniques, meeting ASTM requirements, cetane, additives, etc.)?
    - ASTM (5)
    - ASTM plus quality controls/BQ-9000 (5)
    - Engine provided fuel specification
    - Cold flow/energy content

    If Yes, would you be willing to share your biodiesel specification?
    Yes _12___ No ___0___

11. What is the current per-gallon agency cost for:

    $2.06 average for biodiesel/diesel blend per gallon

    $1.98 average for ultra-low sulfur diesel per gallon

12. Does your agency receive any tax breaks or other incentives for using biodiesel?
    Yes ___8____ No ___10___

If Yes, explain:
- Blenders tax credit (4)
- Tax-exempt status (2)
- Grant
- Biodiesel priced lower than diesel

13. Other than using a biodiesel specification, please describe any procurement procedures or requirements that your agency has in place that would assist others with their purchase of biodiesel.
    - Establish a good relationship with supplier; know raw product
    - Require tanker truck compartments sealed after filled at terminal
    - Require proof of insurance
    - Provide delivery time frame
    - Require biocide and "Tank Dri" to prevent algae growth
    - Require discount from biodiesel rack average price for contract life
    - Require delivery temperature and time, and process for blending on site
    - Random monitoring of fuel quality once per month; retain samples

14. Did you begin your use of biodiesel as a test on a limited number of buses?
    Yes ___7____ No ___11____

    If Yes, how many buses were involved in the initial test?

Biodiesel Test	Current Biodiesel Fleet	Total Diesel Fleet
3	14	14
6	830	830
10	130	426
10	234	234
75	825	825
230	639	1,273
232	398	398

15. How many buses currently operate on biodiesel? __5,959_ (combined)

16. Have you had any problems or issues associated with the delivery of biodiesel?
    Yes ___8____ No ___10____

    If Yes, explain:
    - Supplier lacks product at times to meet delivery needs
    - Received some loads high in glycerine and/or moisture content; change fuel filters on daily service lane
    - Inconsistent blending at times
    - B100 used to blend did not meet cold weather specification
    - Cold weather issues/filter plugging (4)

    What have you done to improve the delivery of biodiesel as a result of those issues?
    - Require supplier to retain fuel sample of each delivery for 7 months
    - Changed to new supplier who tests biodiesel more frequently
    - Require supplier to have improved cold weather additives
    - Supplier to mix inside or discontinue "splash blending" when below 20°F
    - Require supplier to provide improved (in-pipe) blending
    - Use two dispensing filters; small 30 micron filter to protect metering device and very large 10 micron external filter

17. How is biodiesel stored and dispensed at your agency?

    14 (78%) Biodiesel has replaced our entire diesel supply in bulk storage

    5 (28%) We use separate biodiesel storage tanks and dispensers

    2 (11%) We use "wet hose" dispensing where a tanker truck fills buses individually

    1 Other. Explain:
    We use tank blending method; diesel is dropped first, followed by biodiesel owing to specific gravity. Rotate tanks to allow blending time. Tanks temperature averages 46°F degrees or warmer year around.

18. Have you had any problems (e.g., gelling) associated with the storage of biodiesel?

Response from agencies using under B20:

Yes ___3___ No ___7____

If Yes, explain:
- Gelling in cold weather
- Algae growth (2)

What have you done to improve the storage of biodiesel as a result of those issues?
- Reduced percentage in winter
- Killed algae, changed vendors, required more frequent testing; treat each load with biocide and "Tank Dri," require supplier to cover all tank clean-up cost associated with bad fuel. Agency pays for annual tank cleaning cost (approximately $5,000/2,000 gal. tanks.)

Response from agencies using B20 or greater:

Yes ___3____ No ___5____

If Yes, explain:
- Received some loads high in glycerine and/or water content is high
- Filter freeze-ups
- Large gelling problem when temps got down to 15°F. Ultra low sulfur diesel is the problem. Did not have problem with biodiesel and pre-ULSD

What have you done to improve the storage of biodiesel as a result of those issues?
- Require supplier to retain fuel sample of each delivery for 7 months
- Dilute biodiesel with No. 2 diesel for the remainder of winter = B5

19. Describe any biodiesel handling procedures or requirements that differ from traditional diesel handling.
- None (6)
- Use placard: "Low Sulfur Diesel with 2% Bio Diesel Content"
- Additional testing/monitoring only during our test of B20 fuel
- Request blending at rack, not on the truck or in tank
- Require tank to be above 40°F when biodiesel is dropped in the tank
- Product is manually recorded as opposed to electronic metering

20. Describe any other infrastructure procedures or requirements that differ from traditional diesel facilities.
- None (8)
- Require supplier to keep biodiesel heated to 50°F for best blending
- Biodiesel is currently stored in a separate 500 gal. tank and dispensed only to the four buses being tested; limited use avoids Board approval
- Installed hydrosorb filters on fuel islands to extract moisture, which must be changed often, sometimes daily
- Same as diesel: inside fueling, garages heated to 55°F –60°F during winter; filter fuel at fill hose with filter that has a water block media

21. Has your agency experienced any vehicle related problems with biodiesel?

Response from agencies using under B20:

Yes ___5____ No ___5____

If Yes, indicate which problems apply and the corrective action taken:

__4___ Clogged fuel filters

Corrective action:
- Changed fuel suppliers; added second filter on one group of buses
- Change filters more often
- Reevaluated fuel treatment and mixing procedures; increased fuel testing for bacteria; reduced fuel filter replacement interval; install pre-filters before transfer pump
- Minor clogging on about 20% of fleet

___0__ Seal deterioration

Corrective action:

__3___ Reduced fuel economy

Corrective action:
– None (3)

__1___ Others:
– Increased failures of certain engines
Corrective action: Check vehicle tank for algae when excessive filter plugging occurs

Response from agencies using B20 or greater:

Yes ___6____ No ___2____

If Yes, indicate which problems apply and the corrective action taken:

__5___ Clogged fuel filters

Corrective action:
– Monitor filter sight glass at fuel island daily, change filter when needed
– Found dirt in in-ground tanks; did a thorough cleaning and corrected the issue
– Change filters more frequently

__0___ Seal deterioration

Corrective action:

__3___ Reduced fuel economy

Corrective action:
– (comment) After using almost a million gallons of biodiesel over the past ten months the average mpg has only increased by 0.5% compared to ULSD

__0___ Others:

22. Does the percentage of biodiesel (e.g., B10, B20, etc.) used at your agency conform to engine manufacturer's recommendations?

Agencies using under B20:

Yes ___7___ No ___3____

Have you verified warranty coverage with the engine manufacturer?

Yes ___8___ No ___2____

Agencies using B20 or greater:

Yes ___3___ No ___4____ Unknown __1___

Have you verified warranty coverage with the engine manufacturer?

Yes ___7___ No ___1____

23. Do you have any experiences to share concerning the lubricity of biodiesel?

Yes ___5____ No ___11____

If Yes, explain:
– Beneficial to certain engines; failures of the pump have ceased
– Provides lubricity lost with ULSD (4)

24. Do you have any experiences to share concerning the use of biodiesel with the new ultra-low sulfur diesel (ULSD)?

Yes ___7___ No ___11___

If Yes, explain:
– No problems encountered, a non-issue (5)
– Supplier has not been able to reduce the gel point to pre-ULSD levels
– Biodiesel (B2) is adequately replacing the lubricity lost with ULSD

25. Have preventive maintenance inspection (PMI) procedures changed as a result of biodiesel use in your bus fleet?
    Yes ___4____ No ___13___

    If Yes, what specific areas of your PMI have changed?
    - Changed fuel filters much more frequently; now it is not a problem
    - Reduced fuel filter replacement interval
    - Added secondary fuel filter

26. Do you have any experiences or testing results concerning exhaust emissions and the use of biodiesel?
    Yes ___5___ No ___13___

    If Yes, explain:
    - University of West Virginia testing done in 1995
    - Emission test with B10 performed by University of Houston resulted in an average of 2.5% increase in fuel use, a 2% increase in NOx, and an 11% decrease in PM emissions
    - Samples taken to measure particulate matter; comparisons made; results are mixed; more studies needed; information is inconclusive
    - Supplier conducts emissions testing per our agreement

27. Does your agency develop marketing material that promotes the use of biodiesel to the public?
    Yes ___9____ No ___9____

    If Yes, would you be willing to share press releases and other such materials?
    Yes ___9____ No ___0____

28. What areas of biodiesel use would you like the Synthesis Report to address?
    - Fuel quality
    - Adverse effects including storage, blending, cold weather use (7)
    - Warranty issues when using biodiesel blends of higher than B5 (2)
    - Emissions (2)

29. Please add anything else you feel would benefit your peers in using biodiesel.
    - Only use BQ-9000 certified suppliers.
    - Great PR—replaces petroleum, public thinks it is great on emissions.
    - B20 a non-issue in our hybrid bus fleet.
    - Preparation and maintenance of fuel storage/handling/pumping equipment becomes more critical with use of biodiesel.
    - Cold weather areas need to be very careful about the quality of the B100 and also have reliable suppliers.
    - Expect to change all your fuel filters in the first month.
    - Use a petrodiesel blendstock you have confidence in.
    - Even with relatively low concentration of biodiesel, we need to clean each storage tank and treat each tank at least yearly with a fungicide.
    - Biodiesel is a very temperamental fuel that does not have the quality controls (QC) in place to make it reliable (contrary to what the Bio industry says); unless issues are addressed biodiesel will not become a viable alternative.
    - Bus manufacturers or transit agencies will most likely need to make some minor design changes (i.e., heated pre-filters in the fuel system) to accommodate higher biodiesel blends in cold weather applications.
    - Areas with high humidity should look at things that could be done to to reduce the potential for algae growth in underground and vehicle tanks.
    - ULSD has many problems including gelling, lubricity, and emission issues, which can be offset with a very high-quality BQ-9000 biodiesel.
    - You will need to evaluate your infrastructure, and develop a cost and operational plan to incorporate biodiesel in your fuel management plan to achieve economic, environmental, and mechanical benefits. This can be accomplished within a short time frame and will help to reduce our dependency on foreign oil now and in the future.
    - Difficult to understand why engine manufacturers do not understand biodiesel and have very limited experience with the fuel. I think this needs to be addressed as we move to 2010 emissions standards.
    - Although the engine manufacturer does not warranty engines over B5, we are keeping them informed of our B20 test.
    - Have a procurement option with supplier should there be an interruption in the supply chain or a problem is discovered with the biodiesel.
    - Biodiesel has usually been readily available here, but we could not get it this winter.
    - We strongly feel that a sole supplier of biodiesel is needed to guarantee quality and protect the agency's investments.
    - We have had absolutely no problems with biodiesel. This spring we will be switching to a 15% blend, then anticipating no problems, we will be switching to 20% mid-summer. We will continue raising our blends by 5% until we feel we have reached the equilibrium considering cost of fuel, cost of maintenance, bio related problems, etc.

- We may be running biodiesel/diesel comparison for approximately 8 weeks.
- We ran 1970s era buses with mechanical engine controls, 1980s buses with mechanical engine controls, and 1990s engines with electronic controls all last year with B5 and had absolutely no problems at all.

Please Return the Completed Survey Questionnaire by January 26, 2007 to:

John Schiavone
32 State Street
Guilford, CT 06437
Telephone: 203-453-2728
Fax: 203-453-2728

E-mail address: JohnJSchiavone@cs.com

We encourage you to return your completed survey to John Schiavone via e-mail at JohnJSchiavone@cs.com. If you have any questions on the survey or the project, please do not hesitate to call John at 203-453-2728. Thank you very much for your participation in this important project.

APPENDIX D

Sample Biodiesel Fliers

COTA

Introducing the

LEAN, CLEAN, BEAN MACHINE.

COTA is fighting high fuel prices by using Bio-Diesel fuel made from Ohio-grown soybeans. It's cleaner and renewable!

Environmentally Friendly

- Cleaner air
- Up to 80% less soot emissions
- Biodegradable
- Non-toxic
- Renewable, non-fossil fuel
- Reduces diesel emissions and odor

Fiscally/Operationally Sound

- Saves an estimated $400,000 per year over diesel fuel
- Helps Ohio farmers and the economy
- Increases engine life

COTA will use up to 90% Bio-Diesel blend June through September, 2006

COTA

For more information, call (614) 228-1776 or visit www.cota.com

Accessible information available upon request. Please call (614) 308-4403.

Metro Transit's "Go Greener" Initiative

Advancing Metro Transit's commitment to a better environment

WHAT "GO GREENER" WILL DO: The plan will reduce the agency's tailpipe emissions, reliance on foreign oil and operating costs.

PLAN DETAILS: Over the next five years, Metro Transit will replace 314 buses with 150 hybrid-electric buses (20 expected in 2007) and another 164 buses that burn fuel more efficiently. The agency also will double the biodiesel content of its fuel supply from 5 percent to 10 percent in mid-2007.

ENVIRONMENTAL BENEFITS:

- Reduce emissions by 168 tons each year
- Replace 1.23 million gallons a year of non-renewable fossil fuel with soy-based biodiesel and hybrid technology.

OPERATIONAL BENEFIT: $652,000 (estimated) in annual fuel savings

Hybrid-electric buses will deliver 22 percent better fuel mileage and half the exhaust soot of the buses they will replace.

Metro Transit's leadership in environmental stewardship

- Incorporated three hybrid-electric test buses into its fleet
- Became first in the state to use ultra-low sulfur diesel, the cleanest available
- Took over management of the region's carpooling and biking efforts
- Modified bus transmissions for better fuel economy
- Implemented a strategy to reduce bus engine idling

Metro Transit **Hop on.**™
a service of the Metropolitan Council

06-071-01-06

Abbreviations used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation