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Best Practices for Implementing a Biodiesel Program

by

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A University Transportation Center Program at Missouri University of Science & Technology

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16. Abstract

This report gives recommendations on best practices for implementing a biodiesel program. Year round operability, pricing and availability, and fuel efficiency were the specific objectives that were studied. The study was accomplished by contacting other state DOTs seeking information on their biodiesel programs, practices, and lessons learned. A list of best practices was then complied, with added inputs from literature review. An electronic survey was sent out to the contacts to prioritize these best practices. Upon the receipt of the responses to the survey, a tool called the Analytic Hierarchy Process (AHP) was used to determine the relative importance of the alternatives for year round operability. ASTM D 6751 standard compliance for B100 and BQ-9000 accreditation are the two most important best practices for a successful biodiesel program. Other important practices include effective blending, fuel filter inspection and replacement, winter additives and kerosene blending, and a regular tank cleaning program. Block heaters in the vehicle and underground storage tanks further help smooth operation in cold weather. Implementing these best practices will also ensure the availability of good quality fuel year round.

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Best Practices for Implementing a Biodiesel Program

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EXECUTIVE SUMMARY

Implementing the use of biodiesel has been a challenge to the Missouri Department of Transportation (MoDOT). Issues related to pricing, availability, fuel quality, and winter operability have made it difficult to meet the state legislature's requirement that 75% of MoDOT diesel is B20. In addition, fuel efficiency and impact on equipment were additional areas that needed to be addressed.

Thus, the objective of this study was to establish best practices for implementation of biodiesel programs. Specifically, the recommended practices address:

1. ensuring fuel quality and year-round operability,
2. best practices for pricing and availability, and
3. documentation on fuel efficiency, impact on equipment (including reported vehicle problems due to biodiesel), and general maintenance guidelines.

The study was accomplished by contacting other state DOTs seeking information on their biodiesel programs, practices, and lessons learned. A list of best practices was then compiled, with added inputs from literature review. An electronic survey was sent out to the contacts to prioritize these best practices. Upon the receipt of the responses to the survey, a tool called the Analytic Hierarchy Process (AHP) was used to determine the relative importance of the alternatives for year round operability.

ASTM D 6751 standard compliance for B100 and BQ-9000 accreditation are the two most important best practices for a successful biodiesel program. Other important practices include effective blending, water traps at fuel filters of the storage tanks, use of biocides, fuel filter inspection and replacement, winter additives and kerosene blending, and a regular tank cleaning program. Block heaters in the vehicle and underground storage tanks further help smooth operation in cold weather. Implementing these best practices will also ensure the availability of good quality fuel year round.

This is a condensed version of the final report submitted to the Missouri Department of Transportation under grant RI04-045. This project was done in conjunction with the Missouri Transportation Institute.

TABLE OF CONTENTS

Page

1.0 INTRODUCTION

Biodiesel is a clean burning diesel replacement fuel that can be used in the regular compression-ignition (CI) engines; and is manufactured from renewable sources like soy, canola, animal fat, and restaurant waste grease. Its major benefits include reduction of exhaust emissions, zero greenhouse gas emissions, increased lubricity, reduced dependence on imported oil, and use of renewable sources for its production. Several states in the United States (US) have already started using biodiesel at various levels, including attempts to satisfy mandates to use a certain percentage of biodiesel in state fleets. However, biodiesel offers significant challenges in terms of price, availability, quality, cold weather properties, and some maintenance issues. Thus, this study was carried out to determine the best practices for implementing a biodiesel program.

1.1 Background

There are many drivers for the biodiesel industry in the US. Unlike other alternative energy options like hydrogen, the technology is readily available for immediate use. It also reduces harmful exhaust emissions by approximately 50% and, since it is made from renewable sources, helps reduce the use of fossil fuels. It fosters the economic development of agricultural regions by providing jobs and creating wealth for the farmers[1].

In comparison to other fuels, biodiesel provides improved lubricity – particularly more important with the advent of Ultra Low Sulfur Diesel (ULSD), which typically has a lower lubricity. Biodiesel has a high cetane number, which is desirable for good ignition performance in a diesel fuel. For these reasons, more and more states are beginning to use biodiesel in their state fleets. There are also many state and federal incentives and tax credits being offered upon the use of biodiesel which further foster the acceptance of biodiesel in the US.

1.2 Study Objectives

Implementing the use of biodiesel has been a challenge to the Missouri Department of Transportation (MoDOT). Issues related to pricing, availability, fuel quality, and winter operability have made it difficult to meet the state legislature's requirement that 75% of MoDOT diesel is B20. In addition, fuel efficiency and impact on equipment were additional areas that needed to be addressed.

Thus, the objective of this study was to establish best practices for implementation of biodiesel programs. Specifically, the recommended practices address:

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3. documentation on fuel efficiency, impact on equipment (including reported vehicle problems due to biodiesel), and general maintenance guidelines.

[1] Biodiesel Experience and Use among State DOT Agencies, D.S. Humburg, T.J. Hansen, L.G. Schumacher, A.K. Mahapatra, G.L. Taylor, B.T. Adams.

2.0 WORK PLAN

The project began February 1st 2007 with an end date of October 1st 2007. A start-up meeting was held at MoDOT in Jefferson City on February 20, 2007. In the meeting, the specific goals and scope of the project were discussed and a detailed work-plan was created related to the three objectives: 1) Year Round Operability, 2) Pricing and Availability, and 3) Fuel Efficiency and Maintenance. Each of these is briefly discussed in the following sections.

2.1 Year Round Operability

Missouri currently regulates biodiesel and biodiesel blends, as well as proactively tests for fuel quality. Bordering states were initially studied due to the similarity in operating requirements. Five of the eight states bordering Missouri currently regulate biodiesel or biodiesel blends; however, only one currently proactively tests biodiesel quality. Further, a complete list of states with adopted fuel specifications, biodiesel quality regulations, and testing programs, including primary contact information for state fuel quality regulation was developed.

The NBB has an established fuel quality policy based on American Society of Testing and Materials (ASTM) specification ASTM D6751[2], which is used for 100 % biodiesel. In addition, National Biodiesel Board (NBB) has developed a certification (BQ 9000)[3] for marketers and producers, and, in conjunction with the National Renewable Energy Laboratory (NREL)[4], has established a fuel quality testing program to address the challenges of year-round operating capability. The above contacts and policies were used to establish related best practices.

2.2 Pricing and Availability

The review of best practices for pricing and availability began by reviewing other state-level programs. According to the Database of State Incentives for Renewable Energy[5] (DSIRE), 23 states and the District of Columbia have implemented state-level programs to assure continued support for renewable energy resources, energy efficiency initiatives, and low-income support programs; more than half of these include funding for biomass projects. The National Association of State Energy Offices[6] (NASEO) provides contact information for state energy offices, which, along with individual state DOTs, were used as initial sources for state policies related to biodiesel programs (Appendix A).

[2] www.biodiesel.org/pdf_files/fuelfactsheets/BDSpec.PDF
[3] www.bq-9000.org
[4] www.nrel.gov
[5] www.dsireusa.org
[6] www.naseo.org

As of July 07, the NBB indicates that there are eight member producers/marketers of biodiesel in Missouri, none of which are currently BQ 9000 certified (see Figure 4); however, there are four BQ 9000 certified producers in bordering states. These contacts were used to establish a visual representation of potential biodiesel supply to assist with basic pricing and availability analysis.

2.3 Fuel Efficiency

The Alternative Fuels Data Center sponsored by DOE Energy Efficiency & Renewable Energy (EERE) provided the primary methodology for comparison of fuel efficiency and no additional testing was required. The data center contains a number of links to related sites, studies, and other analysis tools/methodology. Specifically, the site has a section on fuel efficiency for alternative fuels. In addition, a number of other studies were researched that are available to be used as potential benchmarks for comparison of fuel efficiency.

Upon the completion of the initial literature review and gathering some starting information, we focused on the objective of year round operability in greater detail and developed a methodology to arrive at the best practices.

3.0 METHODOLOGY

We focused on the objective of determining best practices for year round operability with biodiesel. This work essentially consisted of two parts as follows-

1. a questionnaire sent to the state agencies to gather information on their state biodiesel programs, practices and related issues, and
2. a survey sent to the contacts for prioritizing the list of best practice for implementing a biodiesel program.

The list of contacts (see Appendix A) were approached with questions pertaining to the biodiesel implementation in their state including policies, lessons learned, and current practices. Many of these contacts referred us to other points of contact in order to get the most relevant information. A second list was prepared from the state Department of Transportation (DOT) websites and these contacts were also approached with the same questions. Thus, a comprehensive contact list was prepared. The questions are summarized in Table 1 and transcripts of the responses are provided in Appendix B.

Table 1: Preliminary Questionnaire

No.	Questions
1	What was the requirement for the biodiesel program in your case? Was there any legislature requirement? If yes, then what was it?
2	Where do you use the biodiesel – what are the fleets run?
3	Do you procure the biodiesel from a single source or multiple sources?
4	Did you have to go through a process of RFQ for purchasing the biodiesel?
5	Are your suppliers BQ9000 certified?
6	How do you ensure the quality? Do you insist on ASTM D6751compliance?
7	Have you had any issues with the quality at any time?
8	Do you use the biodiesel all year round in your fleets? Have there been any issues in winter?
9	Is your fuel choice different in winter?
10	Have you investigated the fuel efficiency of biodiesel? Have you collected data pertaining to this?

Analysis of the responses and a progress meeting with MoDOT, initiated follow-up questions as summarized in Table 2.

Table 2: Additional questions supporting the preliminary questionnaire

No.	Questions
1	Are the storage tanks underground? With heaters?
2	Any modifications to the fuel system of the vehicles?
3	How do you ensure effective blending?
4	Any issues with biodiesel storage stability?
5	What have been the primary issues that your state faced with the biodiesel usage and how were these overcome?

Based on the questionnaire responses and an extensive literature review, a list of best practices for year round operability was assembled as shown in Table 3.

Table 3: List of best practices for Year Round Operability

No.	Alternative / Best Practice
A	Vary the % of blend throughout the year
B	Require BQ-9000 compliance
C	Require ASTM D 6751 compliance for B100
D	Establish a periodic tank maintenance program
E	Implement underground storage
F	Heat the storage tanks containing B-100
G	Check the fuel filters regularly for plugging and replace if necessary in the initial days of biodiesel usage
H	Incorporate a water trap into the storage tank fuel filters
I	Require the distributor to deliver pre-blended fuel
J	Use cold flow additives and kerosene blending in winter
K	Heat the fuel system’s fuel lines, filters, and tanks

L Use biocides to prevent microbial growth in storage tanks
M Keep the fuel tanks as full as possible to minimize condensation
N Check for the compatibility of the % blend with engine components and change if necessary

These alternatives were then prioritized in order to aid the decision making process. To do so, an electronic survey (see Appendix C) was created and sent to the participating contacts. The contacts were asked to compare alternatives on a pair-wise basis to establish the relative importance of each criterion related to year round operability. The Analytic Hierarchy Process (AHP) was used as an initial step toward developing a prioritized list of alternatives.

Details of the survey findings and analysis of the results are provided in the next sections.

4.0 FINDINGS

The findings from the responses to the questionnaire sent to the contacts, from the responses to the electronic survey sent to the contacts, and from literature survey are all described in the following sections.

4.1 Year Round Operability

This work consisted of two sections – a questionnaire sent to the various contacts asking about their state biodiesel programs and a survey sent to the contacts to prioritize the list of best practices for year round operability. The next two sections highlight these findings.

4.1.1 Findings from the Questionnaire Responses

Thirty-six of 49 states (Missouri was not questioned) responded to the questionnaire – a response rate of 73.5% as of July 07. Figure 1 provides a visual of the response. Of special importance are the responses from the neighboring states of Missouri that have similar climatic conditions as that of Missouri.

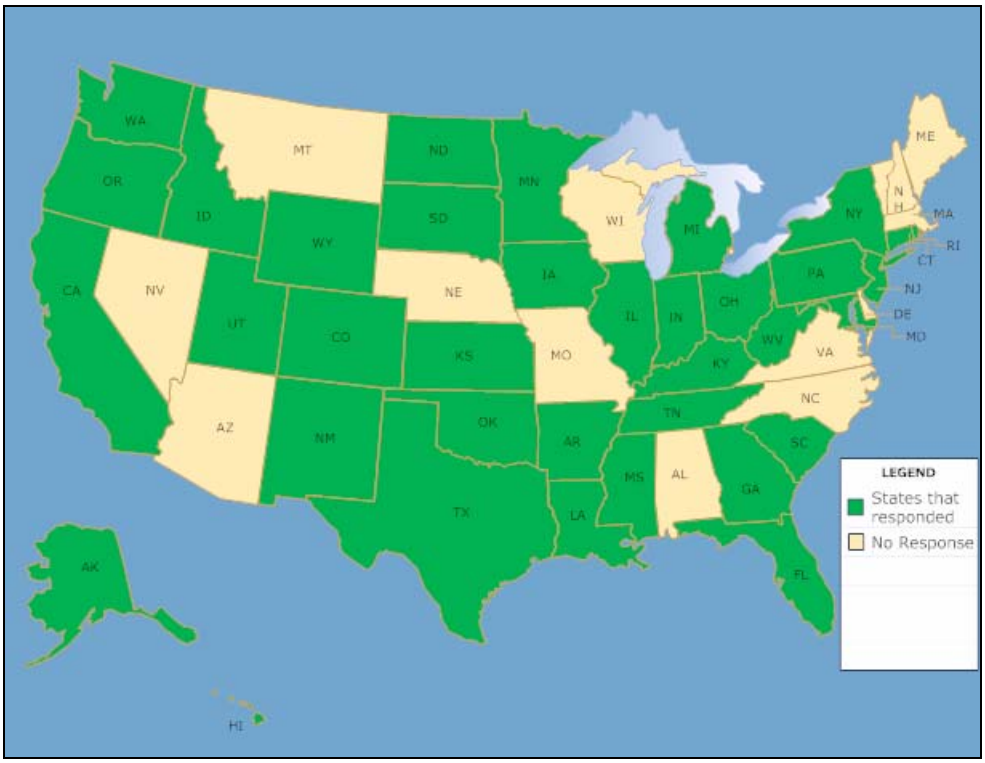

Figure 1: States that responded to the questionnaire

1. <u>Biodiesel usage among states:</u>

   Most states have some form of biodiesel implementation. At the state program/DOT level, 20 of the 36 (55.6%) states that responded have a state funded biodiesel program. Figure 2 summarizes the biodiesel initiatives among various states.

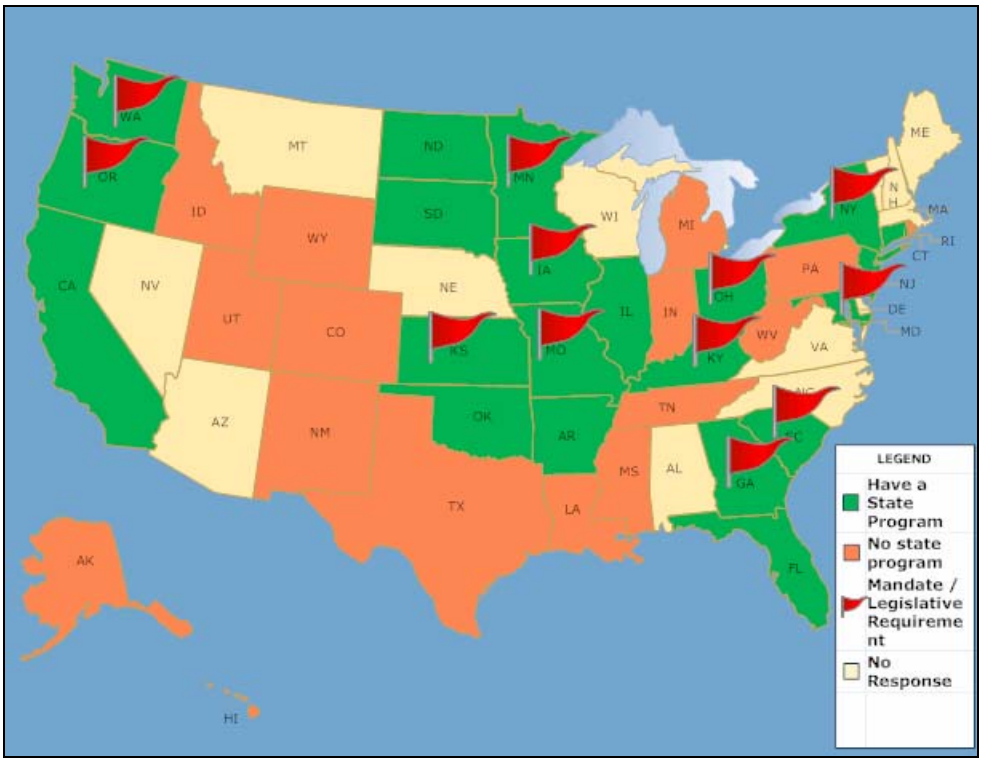

Figure 2: State Biodiesel Programs

Some states have mandates or executive orders requiring a certain percentage of biodiesel in the state fleets. Of the 19 states that responded positively for a state biodiesel program, 12 (63.2%) have a legislative requirement. These are summarized in the Table 4.

Table 4: State legislative requirements for biodiesel usage

No.	State	Policy	Requirement
1	Georgia	Executive Order	Prioritize the procurement of high fuel efficiency and flexible fuel vehicles.
2	Iowa	Executive Order # 41	Minimum of 5% of biodiesel to be purchased annually.
3	Kansas	Statute KSA 75-3744a	Minimum 2% blend to be used in state fleets as long as the price difference is no greater than 10 cents per gallon compared to regular diesel.
4	Kentucky	Executive Order	B-10 requirement
5	Maryland	Senate Bill 54	50% of diesel usage in state fleets be of at least a B-5 blend
6	Minnesota	Mandate	All diesel sold must be B-2
7	Missouri	Mandate	75% of all diesel used in state fleets must be B-20.
8	New York	Executive Order # 142	Minimum of B-2 as of 2007, gradually increasing to B-10 by 2012
9	Ohio	Ohio revised code 125.834	B-5 requirement
10	Oregon	Energy Action Plan	Encourage demonstration projects and create a program to use B-20 in the entire school fleet.
11	South Carolina	Legislation	B-5 in all state owned fleets
12	Washington	Executive Order 05-01	Replace standard diesel with B-20 by September 1 2009.

B20 is the preferred blend amongst most states with the exceptions of Indiana (B5), Kansas (B5), Louisiana (B2), Minnesota (B2, B5), Nebraska (B2), and South Dakota (B2, B5).

2. Winter Operation:

Most states that have a state program are able to operate year round as 14 of 19 states (73.7%) indicated that they use biodiesel all year round. However, many states lower the % of blend during winter, operating at as low as B2 or B5. States that do operate on B20 in winter are the ones that don't have a severe winter (the southern states like Florida and Georgia). It is important to note that Iowa and Ohio (that have similar winters as Missouri) have problems with B20 usage in winter. Year round operability was unclear for the states Arkansas, California, Illinois and New Jersey. Figure 3 summarizes these findings.

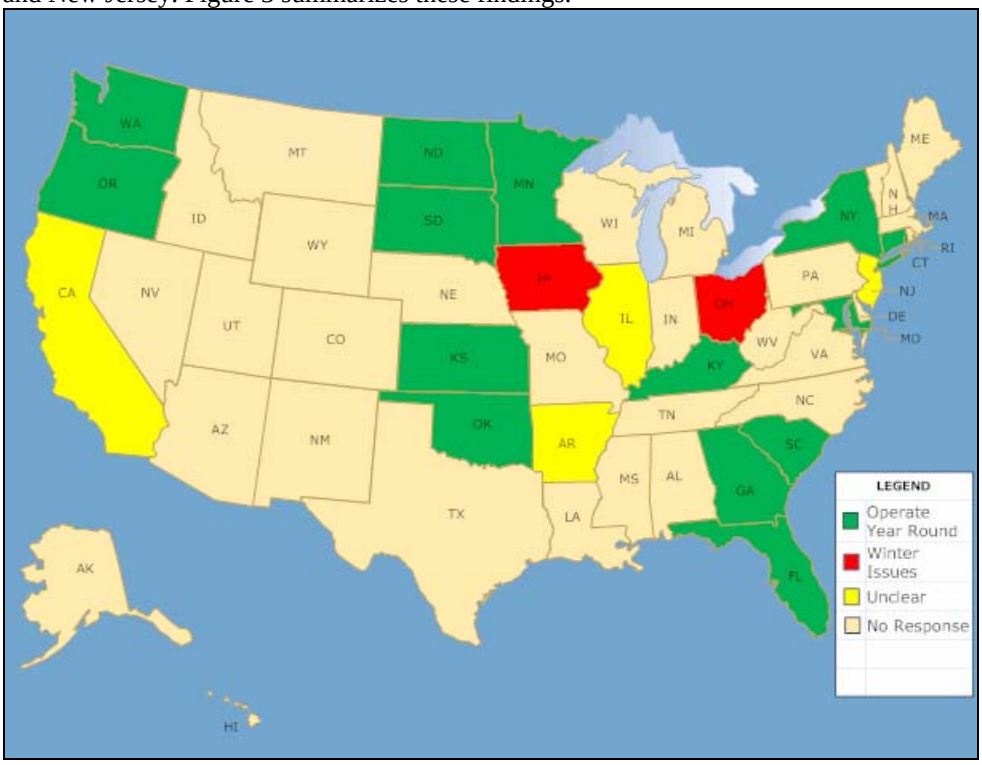

Figure 3: States that operate year round

Using biodiesel in cold weather presents some problems in terms of clouding and gelling. It is essential to keep the biodiesel warm. Connecticut, Florida, North Dakota, and South Dakota all have underground storage tanks. Also, it is a common practice to blend the biodiesel with kerosene and/or other additives to improve its cold weather properties. The states that reported to be following this were Connecticut, Iowa, Maryland, North Dakota, New York, and Oregon.

3. Fuel Quality:

Quality was the foremost issue that seemed to be considered important by all biodiesel users. Almost all of the states that have a state program said they ensure ASTM D 6751 compliance for the biodiesel that they procure, with a lone exception of Ohio which doesn't have a fuel standard. Requirement of the BQ 9000 standard is increasingly common among the states. Seven states (Connecticut, Florida, Kansas, Minnesota, Oregon, South Dakota, and Washington) have embraced BQ 9000 as a requirement, and three states (Iowa, Ohio, and Kentucky) have partial compliance with many new suppliers going for the certification. Georgia, Maryland, and South Carolina do not have BQ 9000 as a requirement yet. It should be noted here that BQ-9000 accreditation program is a relatively new effort and certification began in 2006. Many states are now trying to get certified. Figure 4 summarizes these facts.

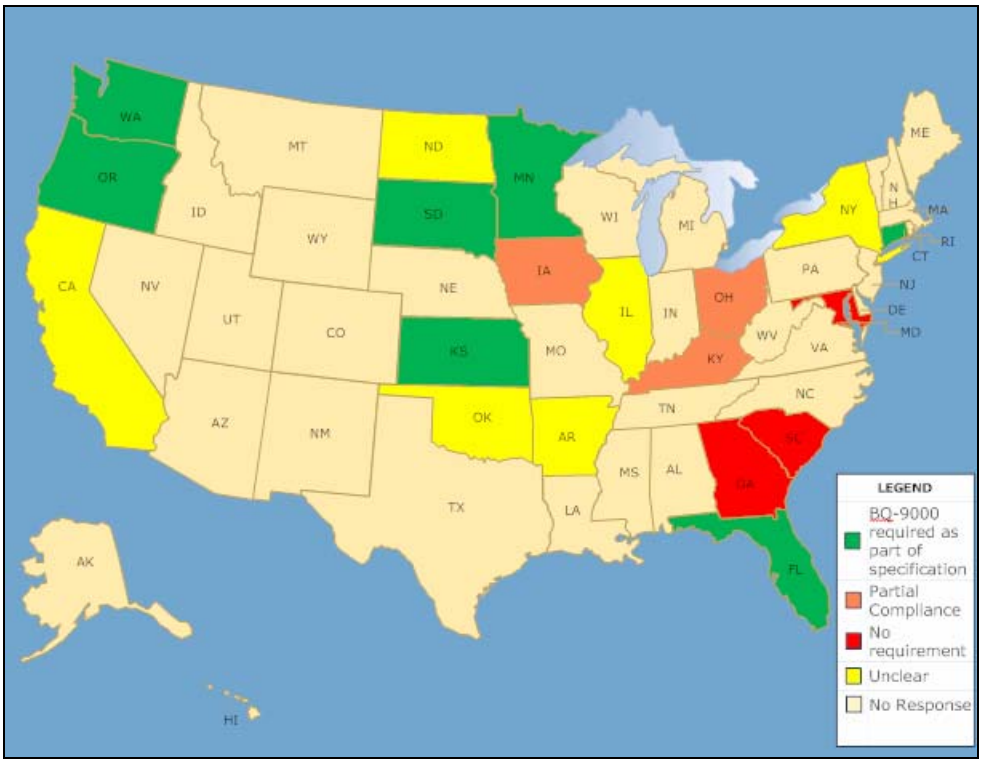

Figure 4: States having requirement for BQ-9000 accreditation

4. Maintenance Practices:

Maryland and North Dakota vary the percentage of biodiesel during summer and winter months in order to use the biodiesel year round. Since biodiesel has a solvent effect, it can clean the storage tanks and form deposits at the bottom that can choke the filters. Also, sediments could be formed due to microbial growth. Poor quality biodiesel can give rise to glycerin crystals depositing in tanks. Connecticut, Maryland, and North Dakota also have had to replace the fuel filters due to the solvent effect.

North Dakota, South Dakota, and South Carolina have established periodic tank maintenance programs to constantly monitor the health of the biodiesel tanks. South Dakota has a program wherein the biodiesel tanks are inspected periodically for sludge/sediments, bacteria, and sulfur. Their vendor uses a process called a 'Tank Snake' to pump the sludge out of the tanks. Disposal of this sludge requires compliance with applicable laws. North Dakota reported using an electronic monitoring system to monitor the presence of moisture in the tanks. At least once a year, usually in the fall, their facilities pump the bottom of the tank to remove any moisture or sludge that may have accumulated and dispose of any contaminated fuel

5. Deterrents:

Quality of the biodiesel has been the most critical issue for most states. The second common issue seems to the fuel filter clogging due to the solvent effect. Higher cost of the biodiesel compared to regular diesel has also been quoted as a deterrent. These are summarized in Table 5:

Table 5: Summary of major issues faced by the states with biodiesel usage

No.	State	Issues/Deterrents
1	Connecticut	Cost, Filter clogging due to a bad mixing batch
2	Florida	Cost
3	Iowa	Quality, improper blending in winter, poor equipment maintenance – all pre-date ASTM D 6751
4	Georgia	Filter clogging due to solvent effect, cold weather issues
5	Kentucky	Quality (presence of glycerin), price and availability
6	Maryland	Filter clogging due to solvent effect, winter clouding concerns

7	Minnesota	Quality (water contamination, dirt & sediments), shortage of #1 diesel for blending, and filter problems
8	North Dakota	Fuel gelling in winter, solvent effect in older storage tanks, and fuel filter clogging
9	Ohio	Fuel gelling at dispenser pumps, filter plugging due to solvent effect
10	Oregon	Cost, fuel filter clogging
11	South Carolina	Supply, Price
12	South Dakota	Filter plugging due to solvent effect, solvent effect in tanks, and winter operation.

Many of the quality issues occurred before the ASTM D 6751 standard and BQ-9000 accreditation. States following these guidelines are facing either minimal or no issues with quality. Fuel filter clogging due to solvent effect is usually addressed by periodic checks and replacing the filter as necessary. Solvent effect in storage tanks is addressed by cleaning the tanks before filling with biodiesel and also by establishing a periodic tank maintenance program. Fuel clouding and gelling in winter is addressed by blending the biodiesel with #1 diesel and/or some additives, and also by using a lower percentage of biodiesel blends.

4.1.2 Findings from the Survey

With the help of the responses to the questionnaire and literature review, we developed a list of best practices for year round operability. These are briefly discussed below.

a) Vary the % of blend throughout the year (Vary %)

B20 has somewhat poor cold weather properties and hence causes operating issues like gelling/clouding during winter operation. A higher % of biodiesel blend can be used in spring and summer (B20) whereas the % blend in winter can be reduced to B2 or B5 in order to achieve year round operability. However, we do not recommend this, since doing so will essentially defeat the whole purpose of this study.

b) Require BQ-9000 compliance (BQ-9000)

Presence of water and free glycerol in the biodiesel is highly undesirable. Water favors microbial growth which in turn causes plugging of filters. Suspended water is a problem in fuel injection equipment because it contributes to the corrosion of closely fitting parts in the fuel injection system. Fuel with excessive free glycerol will usually have a problem with glycerol settling out in storage tanks, creating a very viscous mixture that can plug fuel filters and cause combustion problems in the engine. BQ – 9000 is a quality compliance program initiated by the National Biodiesel Board to ensure good quality fuel (free of water, glycerol, sediments etc) ending up in the tank.

c) Require ASTM D 6751 compliance for B100 (ASTM)

This is an ASTM standard specifying the acceptable limits of sediments, free and total glycerin, sulfur, cloud point, flash point etc for pure (B100) biodiesel. Any biodiesel that is used for blending with petrodiesel to make varying % of blend must meet this ASTM specifications.

d) Establish a periodic tank maintenance program (Tank)

Biodiesel has a solvent property and hence has a tendency to clean deposits on the inner walls of a storage tank that has been previously used to store petrodiesel. These deposits settle at the bottom and may cause problems when the fuel is to be pumped out. Microbial growth can also lead to formation of sludge at the bottom. Excess free glycerin also settles down in the tank. Hence, it is important to have a regular tank cleaning program established.

e) Implement underground storage (Underground)

The cloud point and cold filter plug point of biodiesel is higher than the regular petrodiesel. Hence, biodiesel has to be stored at a temperature usually above 45F. The geothermal energy of earth can be used to advantage if the storage tanks are made underground so that it keeps the biodiesel warm.

f) Heat storage tanks containing B-100 (Heat Storage)

Pure biodiesel has lower cold flow properties compared to regular petrodiesel and hence it has to be stored at a temperature higher than the ambient temperature.

g) Check the fuel filters regularly for plugging and replace if necessary in the initial days of biodiesel usage. (Filters)

Due to the solvent effect of biodiesel, it tends to clean deposits on tank walls when it is first used in a tank that was previously filled with petrodiesel. This cleaning effect could plug the fuel filters; hence, it's important to check regularly for any plugging. With continued use though, this effect is no longer seen since biodiesel doesn't form any new deposits. However, if a tank is alternatively filled with biodiesel and then petrodiesel, regular inspection is a must.

h) Incorporate a water trap into the storage tank fuel filters (Water Trap)

This is to prevent any carry-over of water particles into the fuel system of the vehicle.

i) Require the distributor to deliver pre-blended fuel (Pre-blend)

This will allow the user to know the exact % of blend rather than when blending is done at the point of use. Also, the blending must be done by an appropriate technique. Biodiesel is slightly heavier than petrodiesel and so has a tendency to settle down. Proper agitation and mixing is required so that the biodiesel is completely mixed in the petrodiesel. Splash blending, In-tank blending and In-line blending are the usual techniques adopted. In-line blending ensures complete blending before the mixture enters the tank.

j) Use cold flow additives and kerosene blending in winter (Additives)

Just like regular #2 petrodiesel, biodiesel should also be blended with #1 petrodiesel (kerosene) in winter to improve its cold flow properties. Other chemical additives are also available to serve this purpose.

k) Heat the fuel system's fuel lines, filters and tanks (Heat System)

Block heaters on the vehicle can be employed to prevent gelling/clouding of the biodiesel fuel in the fuel system of the vehicle during severe winters

l) Use biocides to prevent microbial growth in storage tanks (Biocides)

Microbial growth can lead to clogging of fuel filters because of the formation of sludge and sediments. This can be avoided by the use of biocides.

m) Keep the fuel tanks as full as possible to minimize condensation (Full Tanks)

Condensation of water in the tank is undesirable since water promotes the growth of microorganisms and also causes tank corrosion.

n) Check for compatibility of the % blend used with engine components and change if necessary. (Compatibility)

B100 will degrade, soften, or seep through some hoses, gaskets, seals, elastomers, glues and plastics with prolonged exposure. Nitrile rubber compounds, polypropylene, polyvinyl, and Tygon materials are particularly vulnerable to B100. There have not been significant material compatibility issues with B20 and lower % blends.

An electronic survey (see Appendix C) was sent to the contacts in order to assist with prioritization of these best practices. We used the Analytic Hierarchy Process (AHP) to compare the alternatives listed in Table 3 in a pair-wise with regard to importance for year round operability. The AHP is a basic approach[7] to decision making. It is designed to cope with both the rational and intuitive to select the best from a number of alternatives evaluated with respect to several criteria. In this process, simple pair-wise comparisons are made which are then used to develop

[7] Models, Methods, Concepts & Applications of the Analytic Hierarchy Process, Thomas L. Saaty, Luis G. Vargas

overall priorities for ranking the alternatives. The alternatives are scored over one another using weighting factors shown in Table 6.

Table 6: Weighting factors for AHP analysis

Option	Weighting Factor
Left hand side alternative is **significantly** more important than right hand side alternative	3
Left hand side alternative is **moderately** more important than right hand side alternative	2
Left hand side alternative is **slightly** more important than right hand side alternative	1.5
Both alternatives are equal	1
Right hand side alternative is **slightly** more important than left hand side alternative	1/1.5
Right hand side alternative is **moderately** more important than left hand side alternative	1/2
Right hand side alternative is **significantly** more important than left hand side alternative	1/3

Thus, we developed a preliminary matrix of relative scores of the entire alternatives one over another as shown in Table 7. The elements of the matrix were then normalized (Table 8) and average values for each row were determined which indicates the relative importance for that particular alternative. The preliminary results are summarized in Table 9.

Table 7: Preliminary AHP matrix

	Vary %	BQ-9000	ASTM	Tank	Underground	Heat Storage	Filters	Water Trap	Pre-blend	Additives	Heat System	Biocides	Full Tanks	Compatibility
Vary %	1.00	0.81	0.56	0.87	1.00	1.21	0.56	0.73	0.96	0.79	1.17	0.88	1.02	0.75
BQ-9000	1.23	1.00	0.92	1.38	1.35	1.69	1.25	0.98	1.21	1.40	1.71	1.17	1.65	1.10
ASTM	1.78	1.09	1.00	1.42	1.73	1.85	1.31	1.35	1.50	1.75	1.85	1.44	1.69	1.58
Tank	1.14	0.73	0.71	1.00	1.52	1.35	1.04	1.19	0.98	1.31	1.29	0.96	1.48	0.90
Underground	1.00	0.74	0.58	0.66	1.00	1.48	0.83	0.83	1.00	1.06	1.44	0.88	1.42	0.69
Heat Storage	0.83	0.59	0.54	0.74	0.68	1.00	0.52	0.65	0.67	0.75	1.04	0.77	0.90	0.67
Filters	1.78	0.80	0.76	0.96	1.20	1.92	1.00	0.94	1.27	1.21	1.46	1.13	1.75	1.15
Water Trap	1.37	1.02	0.74	0.84	1.20	1.55	1.07	1.00	1.19	1.10	1.54	1.10	1.15	0.79
Pre-blend	1.04	0.83	0.67	1.02	1.00	1.50	0.79	0.84	1.00	1.35	1.33	0.94	1.35	1.15
Additives	1.26	0.72	0.57	0.76	0.94	1.33	0.83	0.91	0.74	1.00	1.13	1.02	1.08	0.96
Heat System	0.86	0.59	0.54	0.77	0.70	0.96	0.69	0.65	0.75	0.89	1.00	1.00	1.00	1.02
Biocides	1.14	0.86	0.70	1.04	1.14	1.30	0.89	0.91	1.07	0.98	1.00	1.00	1.31	0.90
Full Tanks	0.98	0.61	0.59	0.68	0.71	1.12	0.57	0.87	0.74	0.92	1.00	0.76	1.00	0.92
Compatibility	1.33	0.91	0.63	1.12	1.45	1.50	0.87	1.26	0.87	1.04	0.98	1.12	1.09	1.00

Table 8: Normalized Preliminary matrix

Additives	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.05	0.06	0.06	0.06	0.06
Heat System	0.05	0.05	0.06	0.06	0.04	0.05	0.06	0.05	0.05	0.06	0.06	0.07	0.06	0.08
Biocides	0.07	0.08	0.07	0.08	0.07	0.07	0.07	0.07	0.08	0.06	0.06	0.07	0.07	0.07
Full Tanks	0.06	0.05	0.06	0.05	0.05	0.06	0.05	0.07	0.05	0.06	0.06	0.05	0.06	0.07
Compatibility	0.08	0.08	0.07	0.08	0.09	0.08	0.07	0.10	0.06	0.07	0.05	0.08	0.06	0.07

Table 9: Preliminary Results from the AHP Analysis

No.	Alternative/Best Practice	% Relative Importance for Year Round Operability
1	ASTM D 6751 Compliance	10.5
2	BQ-9000 Compliance	8.8
3	Fuel Filters inspection & replacement	8.4
4	Water Trap in storage tanks	7.7
5	Tank Maintenance Program	7.6

6	Compatibility of % blend used with engine components	7.5
7	Pre-blended fuel delivered by distributor	7.2
8	Biocides to prevent microbial growth	7.0
9	Underground storage tanks	6.6
10	Additives for winter operation	6.5
11	Vary % throughout year	6.0
12	Full Tanks to minimize water condensation	5.6
13	Heated fuel system in the vehicle	5.6
14	Heated storage tanks for B-100	5.1

Relative Importance of Best Practices

As can be seen from Table 9, quality of the fuel appears to the top priority in terms of best practices – with ASTM compliance and BQ-9000 compliance getting the highest relative importance. Also, fuel filter clogging during the initial days of biodiesel use is a very common issue and it appears to be the third most important best practice in terms of year round operability.

Additional Considerations

It should be noted that these percentages have been calculated based on the state responses. However, varying %, full tanks, heated fuel system, and heated storage tanks rank very low in terms of importance as per Table 10. Since heating the tanks containing B-100 is really a concern of the supplier and not that of MoDOT, we decided to take it off from the matrix. Also, the alternative of keeping the tanks full in order to minimize water condensation and hence microbial growth, is not very easy to implement. Moreover, if biocides are used in the tank and water traps are incorporated in the tank filters, keeping the tanks full is then not really that critical. Hence, this alternative was also discarded from the matrix. One of the ways year round operability can be achieved is to vary the % blend through the year, using lower percentage blends during winter. However, doing so defeats the main purpose of this project – to be able to operate year round at desired biodiesel blends. Hence, this alternative was also discarded. With this new set of 11 alternatives, AHP was again carried out.

4.2 Pricing and Availability

Most states procure their biodiesel through a state contract through a bidding mechanism. The cost of biodiesel will depend on the market dynamics, volume purchased and also on the local demand.

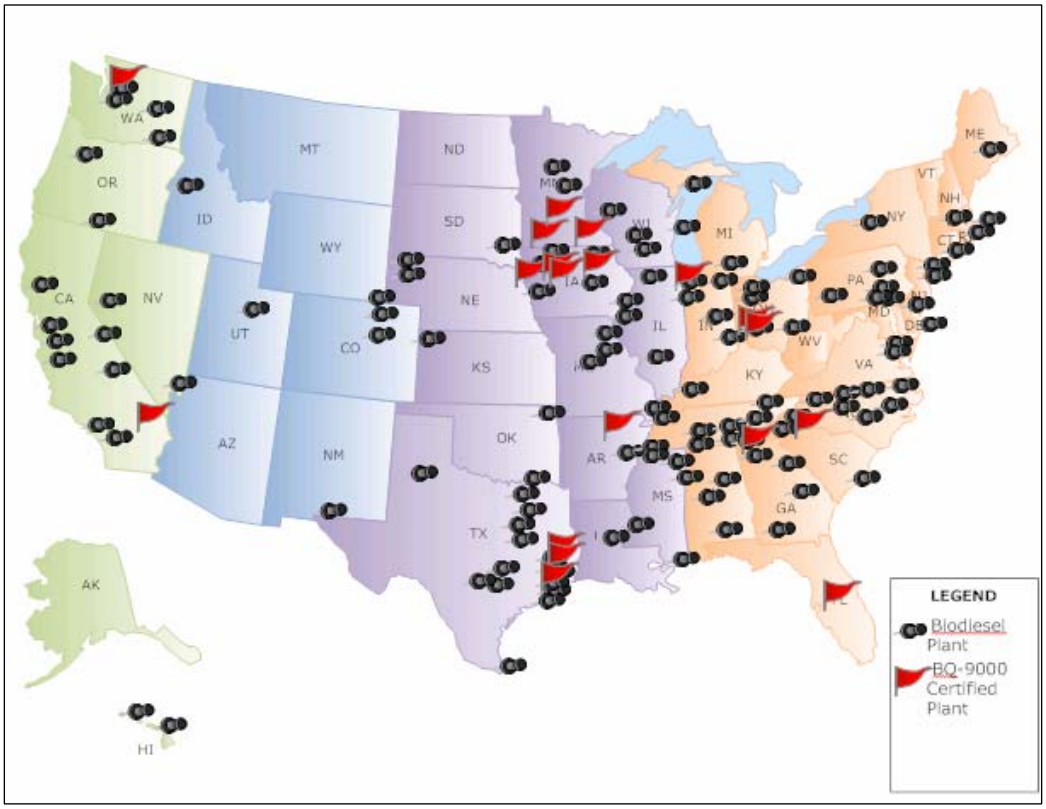

Figure 5: Biodiesel plant locations in US

Figure 5 above is a visual representation of location of biodiesel plants in the US and the ones that are BQ-9000 certified.

4.3 Fuel Efficiency and Maintenance

Only a few states of all that responded to the questionnaire admitted to formally investigating the fuel efficiency of the vehicles running on biodiesel. Amongst these were Florida, Georgia, New York, and South Dakota. Florida claimed to have gained 1 mile per gallon with the use of B20 in buses older than 1999. Rome school, Georgia has reported an anecdotal increase of about 10%. University of Georgia has seen a neutral or slightly positive effect on mileage. New York reported no difference in the mileage with the use of B20; however, it reported 1.6 – 2% reduction in energy content while using B20. As per the report, "Potential Impact of Biodiesel on SDDOT" submitted to the South Dakota Department of Transport, there was a very small reduction in the fuel economy (from 4.9 to 4.7 mpg) with the use of B5. As per the National Biodiesel Board's report, "Biodiesel Handling and Use Guidelines, September 2006"[8], B100 has 8% lesser energy content per gallon compared to #2 petrodiesel and B20 users experience a 1% loss in fuel economy on average and rarely report changes in torque or power.

Most states that responded indicated presence of moisture, microbial growth, and sludge deposition at the tank bottom to be of utmost concern in terms of maintenance. Different practices are followed to keep the tanks free from these impurities. Biocides are used to prevent microbial growth. States such as North Dakota, South Dakota, and South Carolina have established periodic tank maintenance programs to keep the storage tanks free from moisture, bacteria, and sludge. In terms of vehicle maintenance, some states, e.g., South Dakota, indicated the use of water traps at fuel filters to prevent water from entering into the vehicle system. Almost all states that responded indicated that they have had to change clogged fuel filters in the initial days of biodiesel usage.

5.0 RECOMMENDATIONS

[8] Biodiesel Handling and Use Guidelines, DOE/GO-102006-2358, Third Edition, September 2006, US Department of Energy, Energy efficiency and Renewable Energy.

The recommendations for year round operability have been classified into two groups – primary and secondary. Primary recommendations are those that are of utmost importance to implementing a successful biodiesel program. In most cases, the implementation of these primary recommendations will not require excessive capital investments. Secondary recommendations either have less relative influence on the success of the program, or those that may incur high capital investments that would require financial justification. It is recommended that MoDOT should follow the primary recommendations immediately, and further investigate secondary recommendations based upon the availability of funds.

5.1 Primary Recommendations

P1: Fuel Quality

Procuring biodiesel of the best quality is the most critical step in implementing a state program. The biodiesel blend must have been made from B100 complying with ASTM D 6751 standard and the blend itself must comply with BQ-9000 accreditation program. Also, the biodiesel blend must be blended with #1 petrodiesel and other appropriate additives for smooth winter operation. The fuel must be pre-blended and delivered by the distributor in order to ensure effective blending of the biodiesel with petrodiesel.

P2: Maintenance

In order to prevent microbial growth in the storage tanks, biocides must be used. Presence of water can foster the growth of microbes, enhance corrosion of the tank material and reduce the efficiency of combustion in the engine; and hence, water traps must be used with the fuel filters at the storage tank to prevent water from entering into the vehicle system.

P3: Vehicle considerations

Fuel filters may get clogged during the initial days of biodiesel usage due to the solvent effect on the deposits inside the tanks. Hence, the fuel filters must be regularly inspected and replaced as and when necessary. Higher percentages of biodiesel blends (greater than B20) may not be compatible with the engine components. B100 will degrade, soften, or seep through some hoses, gaskets, seals, elastomers, glues and plastics with prolonged exposure. Nitrile rubber compounds, polypropylene, polyvinyl, and Tygon materials are particularly vulnerable to B100. Sometimes, engine manufacturers void the warranty for even B20 blends. Hence, it is very essential to work with the OEMs to ensure the compatibility of the blend being used with the engine components.

5.2 Secondary Recommendations

S1: Tank Maintenance Program

The solvent effect of biodiesel will clean the deposits on the inner walls of the storage tanks forming sediments that settle out at the bottom. This can plug the fuel filter at the tank and also in the vehicle. Older tanks are more prone to this problem. To overcome this, it is recommended that a regular tank maintenance program be established to inspect the health of the storage tanks regularly and clean them if necessary. If possible and economically feasible, older tanks could be phased out and new tanks could be installed. Also, it is recommended that biodiesel be stored in dedicated tanks since constant switching between petrodiesel and biodiesel in the same tanks aggravates the problem of sediment formation and thereby will give rise to added cost of fuel filter replacement and tank cleaning.

S2: Underground storage

It is advisable to keep the biodiesel at a temperature above its cold weather properties, and in this regard, having underground storage tank would help.

S3: Block Heater on the vehicle

Also, if economically feasible, block heaters can be installed on the vehicles to overcome any cold weather issues like fuel gelling and filter plugging.

5.3 Additional Recommendations Related to Pricing and Availability

In terms of availability, the two main issues are availability of BQ-9000 certified fuel and availability of good quality fuel in winter. More and more plants are going for the BQ-9000 accreditation program and hence availability of BQ-9000 certified biodiesel should not be a problem. However, availability of good quality biodiesel in winter requires implementation of the recommendations mentioned in section 4.1.3. Specifically, the quality of the fuel should be good to begin with (ASTM D 6751 and BQ-9000 compliance). Winter additives and kerosene blending must be utilized in winter to preclude any gelling/clouding issues with the biodiesel. Also of great importance is the blending method used to mix the biodiesel with the petrodiesel in cold weather. Even if the biodiesel is kept warm, if the petrodiesel is at ambient temperature (in winter), blending the two together will form snowy flakes. This can cause plugging of the filters. Though these flakes will eventually melt, it usually takes long. Other best practices like filter replacement, water traps, biocides, and tank cleaning will also further ensure availability of quality fuel in cold weather.

5.4 Additional Recommendations Related to Fuel Efficiency and Performance

In general, the loss in fuel economy of the vehicle running on B20 is not greater than 1-2%, and hence is not very significant. Quality of the biodiesel fuel is important with regard to vehicle performance. Excessive glycerin, water, and/or other sediments will have a detrimental effect on the fuel system in the vehicle. Hence, ASTM D 6751 compliance and BQ-9000 accreditation are important practices to be followed. Also, provisions must be made to preclude gelling of biodiesel in the fuel system of the vehicle in cold weather by the use of cold weather additives, blending with #1 petrodiesel, and by keeping the biodiesel warm. These practices, if followed, will prevent the performance of the biodiesel vehicle from deteriorating.

6.0 SUMMARY

This report gives recommendations on best practices for implementing a biodiesel program. Year round operability, pricing and availability, and fuel efficiency were the specific objectives that were studied. The study was accomplished by contacting other state DOTs seeking information on their biodiesel programs, practices, and lessons learned. A list of best practices was then complied, with added inputs from literature review. An electronic survey was sent out to the contacts to prioritize these best practices. Upon the receipt of the responses to the survey, a tool called the Analytic Hierarchy Process (AHP) was used to determine the relative importance of the alternatives for year round operability.

ASTM D 6751 standard compliance for B100 and BQ-9000 accreditation are the two most important best practices for a successful biodiesel program. Other important practices include effective blending, fuel filter inspection and replacement, winter additives and kerosene blending, and a regular tank cleaning program. Block heaters in the vehicle and underground storage tanks further help smooth operation in cold weather. Implementing these best practices will also ensure the availability of good quality fuel year round.

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