MUNICIPAL BIODIESEL PRODUCTION: Foundations and Best Practices

Warren Nevad, Municipal Management Consultant
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THE UNIVERSITY of TENNESSEE
MUNICIPAL TECHNICAL ADVISORY SERVICE

In cooperation with the Tennessee Municipal League



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I. INTRODUCTION

Biodiesel is an alternative fuel derived from various feedstocks such as soybeans, other oil crops, waste vegetable oil and animal fats that can be used as a renewable fuel alternative to petroleum-based diesel fuel. Other potential next-generation feedstocks include algae and jatropha. Biodiesel contains no petroleum. It is biodegradable, nontoxic, and nonvolatile. Biodiesel is produced through a chemical process called transesterification in which methanol and sodium or potassium hydroxide are mixed with the feedstock. The process leaves behind two products: glycerin (a valuable co-product used primarily in soaps and in many cosmetic and other related products) and methyl esters (biodiesel). The methyl esters, after being carefully washed to remove all remaining catalyst, alcohol and glycerol, comprise the biodiesel and can be used as a fuel in diesel engines. The esters are good solvents and cleaning agents. Biodiesel also reduces greenhouse gases. Used in its pure form, biodiesel reduces emissions of carbon dioxide by 78 percent, carbon monoxide by 40 to 50 percent and particulate matter by 50 percent. Biodiesel also helps us become more energy independent by using renewable, American resources and can be a boost to the local economy through job creation and savings in operational costs.

Biodiesel offers other services to communities seeking to minimize their energy related costs. It can be used in any public works diesel equipment such as dump trucks, service trucks, mowers and tractors. This fuel can be used for building heating systems if the buildings have oil burners in their furnaces. Government buildings with steam radiators are good candidates to use biodiesel. It is possible to change out a natural gas burner for an oil burner, add an oil storage tank and use biodiesel for heating. Glycerin generated from production of biodiesel can be used to produce car wash soap to clean the vehicle fleet.

II. FOUNDATIONS OF MUNICIPAL BIODIESEL PRODUCTION

Small-scale production of biodiesel is possible when an appropriate source of oil is secured, appropriate storage and processing equipment and labor are available, and an acceptable off-take of the glycerin byproduct is developed. Interest in small-scale production of biodiesel by municipalities has grown considerably in recent years due to the high cost of fuel and a desire to implement programs that can prevent improper disposal of used cooking oils to municipal wastewater systems. In effect, biodiesel serves a dual role in reducing both fleet transportation costs and wastewater line clogs generated from household and restaurant grease (not to mention all the good it does for America). Another advantage in producing biodiesel is that it serves as insurance during natural disasters by ensuring that fleets have adequate supplies when fuel terminals are shut down. In 2005, Hurricane Katrina caused many communities to be stranded without diesel.

Today, several municipalities in Alabama and Tennessee have developed and implemented

recycling programs for both residential and commercial used cooking oils. These progressive, proactive communities obtain the waste vegetable oil (WVO) then process it into biodiesel that is used in municipal vehicle fleets. Gadsden and Hoover, Alabama, have become national models of municipal biodiesel recycling production systems. The Southern Alliance for Clean Energy (SACE) in partnership with the University of Tennessee Institute of Agriculture and the Tennessee Department of Environment and Conservation (TDEC) recently opened a Knoxville community-based biodiesel production facility. Built with an Alternative Fuels Innovations Grant from TDEC, the biodiesel production unit aims to convert waste fryer oil from local restaurants and other sources into useable fuel. Full production, double-shift capacity for the mobile unit is approximately 380,000 gallons of biodiesel per year. SACE collects waste fryer oil from participating restaurants, and the new facility converts the waste oil into ASTM specification biodiesel. The environmentally friendly fuel displaces corresponding volumes of petroleum-based diesel fuel.

The city of Clarksville, Tennessee, recently was awarded a Congestion Mitigation Air Quality grant to begin a municipal biodiesel recycling program. The cities of Crossville, East Ridge and Sweetwater, Tennessee, also are making plans to produce their own biodiesel for city vehicles and equipment. This technical publication examines some of the issues to be evaluated when municipalities consider initiating their own recycling and biodiesel production programs.

III. BIODIESEL QUALITY

Biodiesel is one of the most thoroughly tested alternative fuels on the market. ASTM International, known originally as the American Society for Testing and Materials, is an international standards organization that develops and publishes consensus technical standards for biodiesel. Biodiesel producers that sell biodiesel at retail must meet these specifications. Cities that produce their own biodiesel for their own use are not subject to these guidelines; however, it is recommended that cities follow the ASTM guidelines. The specifications are available from ASTM at www.astm.org.

A number of independent studies — performed by the U.S. Department of Energy, the U.S. Department of Agriculture, Stanadyne Corp. (the largest diesel fuel injection equipment manufacturer in the U.S.), Lovelace Respiratory Research Institute, and Southwest Research Institute — have shown that biodiesel performs similarly to petroleum diesel with greater benefits to the environment and human health. The National Biodiesel Board has been active in setting quality standards for biodiesel for more than 15 years. ASTM specifications exist for diesel fuel and biodiesel fuel blends from 6 to 20 percent (B6 — B20 (D7467-09)), biodiesel blends up to B5 to be used for on- and off-road diesel applications (D975-08a), and home heating and boiler applications (D396-08b). ASTM approved the original specification for pure B100 (D6751) in December 2001. These ASTM specifications apply regardless of the fat or plant oil used to make the fuel.

One of the major advantages of biodiesel is that it can be used in most existing engines and fuel injection equipment in blends of up to 20 percent with little impact to operating performance. Biodiesel has a higher cetane number than U.S. diesel fuel. In more than 50 million miles of in-field demonstrations, B20 showed similar fuel consumption, horsepower, torque, and haulage rates as conventional diesel fuel. Biodiesel also has superior lubricity, and it has the highest BTU content of any alternative fuel (falling between #1 and #2 diesel fuel). All major U.S. automakers and engine manufacturers accept the use of at least B5, and many major engine

companies have stated formally that the use of high quality biodiesel blends up to B20 or even B30 will not void their parts and workmanship warranties. For a list of specific statements from the engine companies, please visit the National Biodiesel Board Web site at www.biodiesel.org/resources/oems.

IV. FEEDSTOCK METHODOLOGY

The first step in the production of biodiesel is obtaining a suitable vegetable oil or animal fat (feedstock). The potential sources are:

1. Used oil commonly called yellow grease collected from restaurants and households;
2. Animal fat collected from slaughterhouses and packing sheds;
3. Yellow grease or tallow purchased from an existing renderer;
4. Vegetable oil seeds bought by contract from local farmers and processors;
5. Clean seed purchased from an existing warehouse or seedsman; and
6. Vegetable oil purchased from an existing crushing plant.

Municipal biodiesel producers generally use the potential source #1 to produce the alternative fuel. If a city collects 1,000 gallons of used cooking oil, 1,000 gallons of biodiesel will be produced. The typical biodiesel production formula is:

100 lbs. of used vegetable oil or other feedstock
+ 20 lbs. of methanol = 100 lbs. biodiesel
+ 20 lbs. glycerin

The case study that follows is an analysis of biodiesel production in Gadsden, Alabama, from the publication *Producing Biodiesel for Municipal Vehicle Fleets from Recycled Cooking Oil* prepared by Mark Hall, Extension Energy Specialist, Alabama Cooperative Extension System; Sushil Adhikari, Assistant Professor, Biosystems Engineering Department; and Steve Taylor, Director, Center for Bioenergy and Bioproducts at Auburn University.

V. BEST PRACTICES OF MUNICIPAL BIODIESEL PRODUCTION: GADSDEN, ALABAMA

The City of Gadsden, Alabama, initiated a WVO recycling program and a biodiesel production program in the fall of 2007. Like many similar municipalities, Gadsen was faced with rising fuel costs. It also was faced with another common problem of municipalities: high maintenance costs for its wastewater treatment system due to grease that had been introduced into sewers from households and restaurants. After expressing its intention to start a recycling and biodiesel production program, the city was designated as an Auburn University Energy Partner. In this relationship, personnel from Gadsden's municipal fleet worked with personnel from Auburn University's Center for Bioenergy and Bioproducts and the Alabama Cooperative Extension System to establish the biodiesel production system. The city of Gadsden currently is recycling used cooking oils that are available from local restaurants and households to produce biodiesel, thereby minimizing fleet fuel expenditures and wastewater treatment system maintenance. Additional financial support for this program was provided by the Energy Division of the Alabama Department of Economic and Community Affairs.

PROGRAM INITIATION. At the start of the program, the biodiesel processing equipment and associated oil collection and processing equipment were procured by the city. This equipment included these major items:

- Biodiesel processor capable of producing 55-gallon batches of biodiesel (manufactured by Biodiesel Logic, Inc.);
- Four 275-gallon chemical storage "totes" for storing WVO before processing;

- Two 150-gallon fuel tanks, pumps, and meters for storing and dispensing finished biodiesel;
- Twenty 55-gallon steel drums for collecting WVO at restaurants;
- 4,500 one-gallon plastic jugs for residential WVO collection;
- Seven collection bins for residential WVO jugs;
- Miscellaneous lab supplies for titration of WVO; and
- Expendable supplies for biodiesel production (methanol, sodium hydroxide catalyst).

The collection bins for residential WVO jugs were fabricated in house by personnel in Gadsden's fleet management group. Other municipalities have purchased similar commercially available units. The one-gallon jugs were fitted with preprinted labels that provide information on procedures for recycling the WVO.

PROGRAM OPERATION. As the program started, 55-gallon drums were distributed to participating restaurants. Fleet management personnel checked the drums once each week and generally picked them up when the drums contained about 35 gallons, or every other week, whichever came first. A clean drum was left at the restaurant when the full drum was picked up.

The residential WVO jugs were placed in the storage bins, which were located at seven community centers in Gadsden. While other cities have chosen to place the collection bins at grocery stores, Gadsden chose to use its network of community centers. The bins are configured so that empty, clean containers are placed on the top shelf, while full containers are placed on the bottom shelf. Also, the bins are designed so that larger containers of WVO (such as those two-gallon containers used for turkey frying, etc.) can be placed on the bottom shelf.

Once the oil is picked up and transported to the fleet management facility, it is poured (in the case of the one-gallon jugs) or pumped (in the case of the 55-gallon drums) into the chemical storage totes. If water is detected in the WVO, the oil is heated then allowed to cool to separate the water from the oil. Since there are several of these 275-gallon totes, there is a rotating procedure whereby the oil is allowed to settle for nearly one week before being used for biodiesel production. The WVO is pumped from the top portion of the tank through a filter and into the biodiesel processor.

After the oil is pumped into the biodiesel processor, minimal labor is required to perform the transesterification process. The processor used by Gadsden is a relatively self-sufficient processor that conducts most of the transesterification process automatically. Before starting the transesterification reaction, the WVO is heated to 140 degrees F, and a sample of oil is removed for the titration procedure in order to determine how much catalyst is required to produce biodiesel. After the titration process is complete, methanol is added to a separate methanol tank, and the catalyst is poured into a methyl/oxide mixer drum. Once the reaction process starts, it takes approximately one and one-half hours for glycerin to begin separating from the biodiesel and another one and one-half to two hours for the glycerin to be completely separated. The system uses a dry wash process that requires another three hours to complete. After being allowed to cool, the finished biodiesel can be filtered through a five micron filter and pumped into the fuel storage tank. Biodiesel is splash blended with petroleum-based diesel to create blends of B10 or B20 for various fleet vehicles and machines.

Glycerin that results from the process is drained from the reactor vessel into a clean 55-gallon drum for later disposal. Disposal options include composting and transferring to a nearby business that manufactures soaps.

PROGRAM RESULTS. During the first year of operation, approximately 2,000 gallons of biodiesel have been produced successfully. The fleet manager reported that much more fuel could be produced (as much as one 55-gallon batch each day) if more WVO were available in the community. The fleet manager also reported that the collection and processing operations do not place any undue burden on fleet personnel.

Of the 2,000 gallons of WVO collected, approximately 80 percent of it has been collected from restaurants and other food industries while 20 percent has been collected from residential sources. The restaurant program included approximately 10 restaurants during this period, and most of them were either new businesses or relatively small businesses that did not have existing contracts with WVO processors. The residential program has been successful; however, the fleet manager reports that there is a continuing need to educate the public on the opportunity to recycle their WVO. The mayor and fleet manager have both given presentations to civic groups and take the one-gallon jugs with them to pass out to citizens. Local news media also have been very willing to promote the program periodically. The fleet manager reports that any mention of the program in the media results in an increase in oil collected at the community center bins.

The fleet does not conduct formal fuel tests but has had no vehicle maintenance problems since initiating the program. They do conduct periodic fuel tank cleaning to prevent algae growth. Also, they will conduct the 3/27 test periodically to determine if there is any unreacted WVO in the biodiesel. The only problems they report have been with excess water in the WVO. This appears to have been the result of leaving the tops off of the 55-gallon drums while at the restaurants. Heating the WVO has been successful in removing water from the oil.

Handling the glycerin byproduct also has been successful. While initial phases of the program composted the glycerin, the city now has developed a relationship with a nearby company that produces industrial soaps. This business comes to the fleet maintenance facility and picks up the glycerin for further processing, thereby alleviating the need to dispose of the glycerin.

VI. FEASIBILITY MODEL: $45,000 CAPITAL OUTLAY/20,000 GALLONS OF ANNUAL PRODUCTION

Using 2009 dollars, the initial cost of a similar system (55-gallon biodiesel processor, storage tanks and bins, and WVO drums and jugs) is approximately $45,000. Note that the 55-gallon processor is capable of producing two batches per day. If this fixed cost is spread over a five year period, and if 20,000 gallons of fuel could be produced per year when the program is fully operational, the fixed cost is $0.45 per gallon of biodiesel excluding depreciation. With a production rate either higher or lower will lower or raise, respectively, the cost per gallon. The variable costs (methanol, sodium hydroxide, amberlite resin, and electricity) are listed in Table 1 and result in $0.96 per gallon of biodiesel. Therefore, a total cost of producing the fuel would be approximately $1.41 per gallon at the production rate of 20,000 gallons per year for five years. After five years, the cost to produce the biodiesel would be only the variable cost of $0.96 per gallon. The price per gallon of petroleum diesel as of October 19, 2009, was $2.86 per gallon. Using these figures, a city would save a minimum of $1.55 per gallon for a total savings of $31,000. Another way to explain the savings is that the biodiesel processor unit would pay for itself in approximately 18 months.

TABLE 1. VARIABLE COSTS OF BIODIESEL PRODUCTION

INGREDIENT	COST	COST, $/GAL BIODIESEL
Methanol	$ 2.75 / gal	0.55
Potassium hydroxide	$ 0.36 / lb	0.02
WVO	$ 0.00 / gal	0.00
Amberlite	$10.70 / lb	0.04
Electricity cost	$ 0.14 / kWh	0.35
Total cost		$0.96/gal + $0.45/gal fixed($1.41/gal)

Overall, the fleet manager, mayor, and city council have been very happy with the program. Benefits from this program include fuel and cost savings to the city (and taxpayers), improved local air quality from using the biodiesel, greater community involvement through the household used oil recycling program, and reduced sewer maintenance costs. The fleet manager is strongly committed to continuing and expanding the program into the future. For additional information in a video format, visit http://farmenergy.blogspot.com/.

VII. BIODIESEL PARTNERSHIP: TENNESSEE RENEWABLE ENERGY AND ECONOMIC DEVELOPMENT COUNCIL AND EAST TENNESSEE CLEAN FUELS COALITION

Cities may want to consider pooling their resources to create a shared biodiesel recycling program. The Tennessee Renewable Energy and Economic Development Council (TREEDC) and East Tennessee Clean Fuels Coalition (ETCFC) recently have begun seeking funding assistance for small cities and counties to share in the development of several statewide biodiesel recycling programs. In order to develop a viable and sustainable biodiesel recycling program among communities, an assessment of annual diesel should be conducted. This inventory serves a dual role as 1) a foundation to benchmark fossil fuel reductions and 2) information to help determine how much fuel will be needed based on the biodiesel blends that the community wishes to use. TREEDC and ETCFC plan to collaborate with communities on a regional basis to understand their fuel needs and develop a regional program to enhance local capacity to coordinate and build the necessary and appropriate infrastructure, logistics, and distribution systems for delivery of sustainable alternative fuels to new markets in Tennessee.

TREEDC and ETCFC will work with participating local governments, transportation systems and utility companies to profile their current and past fuel usage and procurement practices for gasoline, diesel and natural gas. TREEDC will collect information from participating communities on fuel use by government, police, fire departments, emergency and regular service, utilities, schools and transportation systems. The Council then will compile regional renewable fuel market information and coordinate shared biofuel purchases and distribution.

ETCFC is the East Tennessee arm of the U.S. Department of Energy's Clean Cities program and serves the majority of the eastern half of Tennessee. The Clean Cities program contributes to the energy, environmental, and economic security of the United States by supporting local deci¬sions to reduce our dependence on imported petroleum. Established in 1993 in response to the Energy Policy Act of 1992, the partnership provides tools

and resources for voluntary, community-centered programs to reduce consumption of petroleum-based fuels. Clean Cities has 90 coalitions where regional government agencies and private companies come together voluntarily under the umbrella of Clean Cities. The partnership helps all parties identify mutual interests and meet the objectives of reducing the use of imported oil, developing regional economic opportunities, and improving air quality. The ETCFC is a regional nonprofit that is housed within the University of Tennessee's Institute for Secure and Sustainable Environment. It reaches out throughout the region to serve as a catalyst for greater use of alternative fuels by fleets and individuals.

VIII. CONCLUSION

Small-scale production of biodiesel by municipalities has been conducted successfully by several cities in Alabama and appears to be a concept that can be duplicated in other municipalities across the state and nation. These programs use recycled WVO as their primary feedstock for biodiesel. The WVO can be obtained from the food service industry and from local citizens. Organizations such as the Tennessee Renewable Energy and Economic Development Council and the East Tennessee Clean Fuels Coalition can assist local governments with implementing sustainable small-scale biodiesel production systems.

By using commercially available biodiesel processors and relatively simple oil collection and storage equipment, the municipal fleet management team can produce high-quality biodiesel for use in municipal vehicles and equipment. While there are technical issues to overcome in any such program, challenges such as WVO quality assurance, fuel quality assurance, and glycerin offtake all have been overcome successfully by municipal fleet operators.

The most important aspect of these programs is the successful involvement of local businesses and citizens in creating a community-based recycling and biofuel production program. Such programs alone will not solve our nation's energy security problem; however, they serve as a small step toward energy independence by producing renewable fuels from local resources while building community awareness for environmental protection. In short, these programs allow local citizens to have a part in producing renewable fuels in their own community.

(Acknowledgments: Hoover, Gadsden, Alabama, Jonathan Overly, ETCFC)

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Hall, M., Adhikari, S.,Taylor, S., 2008. Producing Biodiesel for Municipal Vehicle Fleets from Recycled Cooking Oil. Auburn University.

ADDITIONAL INFORMATION ON BIODIESEL PRODUCTION OR BIOENERGY

National Biodiesel Board: http://www.biodiesel.org/

Auburn University Natural Resources Management & Development Institute: http://www.nrmdi.auburn.edu/

Alabama Department of Economic and Community Affairs, Energy Division: http://adeca.alabama.gov/Energy/default.aspx

Alabama Department of Agriculture and Industries, Center for Alternative Fuels: http://www.agi.state.al.us/alternative_fuels

Alabama Clean Fuels Coalition: http://www.alabamacleanfuels.org/

Southern Alliance for Clean Energy: http://www.cleanenergy.org

East Tennessee Clean Fuels Coalition: http://www.etcfc.org/

INFORMATION ON BIODIESEL TESTING

Fleet Biodiesel Testing: http://www.fleetbiodiesel.com/

Wilks Infraspec Analyzer: http://www.wilksir.com/vfa-spectrometer.htm

Biodiesel water test: www.utahbiodieselsupply.com/biodieselwatertestkit.php



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