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Municipal Biodiesel Production Programs (2011)

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THE UNIVERSITY of TENNESSEE

MUNICIPAL TECHNICAL ADVISORY SERVICE

In cooperation with the Tennessee Municipal League

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MUNICIPAL BIODIESEL PRODUCTION PROGRAMS: Foundations and Best Practices

I. INTRODUCTION

Biodiesel is an alternative fuel derived from various feedstocks such as soybean, 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 is biodegradable, nontoxic, and nonvolatile. It is produced through a chemical process called transesterification where methanol and sodium or potassium hydroxide are mixed with the feedstock. The process leaves behind two products: glycerin (a valuable co-product primarily used in soaps and in many cosmetics) and methyl esters (biodiesel). The methyl esters, after carefully washing to remove all remaining catalyst, alcohol and glycerol, are the biodiesel and can be used as a fuel in diesel engines. The esters are good solvents and cleaning agents. In addition to its other attributes, biodiesel 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 leads to energy independence 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 diesel public works equipment such as dump trucks, service trucks, mowers and tractors. It can be used to develop heating systems if buildings have oil burners in their furnaces. Government buildings with steam radiators are good candidates to use biodiesel. It is possible to change out the natural gas burner for an oil burner and 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 by-product is developed. Interest in small-scale production of biodiesel by municipalities has grown considerably in recent years due to high costs of fuel and a desire to implement programs that prevent improper disposal of used cooking oils to municipal wastewater systems. Biodiesel serves a dual role in reducing fleet transportation costs and wastewater line clogs generated from household and restaurant grease (not to mention all it does for America). Another advantage in producing biodiesel is that it serves as good insurance during natural disasters, when fuel terminals are shut down, by ensuring that fleets have adequate supplies. 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), and process it into biodiesel that is subsequently used in municipal vehicle fleets. Gadsden and Hoover, Ala. 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 will collect waste fryer oil from participating restaurants and the new facility will convert the waste oil into biodiesel. The environmentally friendly fuel replaces volumes of petroleum-based diesel fuel.

The City of Clarksville recently received a Congestion Mitigation Air Quality grant to begin a municipal biodiesel recycling program. The cities of Crossville, East Ridge and Sweetwater also are making plans to produce their own biodiesel for city vehicles and equipment. This technical publication will examine 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, originally known as the American Society for Testing and Materials, is an international organization that develops and publishes consensus technical standards for biodiesel. Producers who sell biodiesel must meet these specifications. Cities that produce biodiesel for their own use are not subject to these guidelines, however, it is recommended that cities follow them. Copies of 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 similar to petroleum diesel with greater benefits to the environment and human health. The National Biodiesel Board has set 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 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 demonstrations, B20 showed fuel consumption, horsepower, torque, and haulage rates similar to conventional diesel fuel. Biodiesel also has superior lubricity, and it has the highest BTU content of any alternative fuel (falling in the range 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 listing of specific statements from the engine companies, please visit the National Biodiesel Board website 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) Collection of used oil commonly called yellow grease from restaurants and/or households;
2) Collection of animal fat from slaughter houses and packing sheds;

3) Purchasing yellow grease or tallow from an existing renderer;
4) Contracting production of vegetable oil seeds from local farmers or processors;
5) Purchasing clean seed from an existing warehouse or seedsman; and
6) Purchasing vegetable oil from an existing crushing plant.

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

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

A program analysis of producing biodiesel will be reviewed in the Gadsden, Ala. case study 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, ALA.

The City of Gadsden initiated a WVO recycling program and biodiesel production program in the fall of 2007. Like many municipalities, it was faced with rising fuel costs. It was also faced with another common problem of municipalities: high maintenance costs in the wastewater treatment system due to grease 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 the Gadsden 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. Gadsden is currently recycling used cooking oils that are available from local restaurants and households to produce biodiesel, and as a result 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 bought by the city. This equipment included the following 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;
- 20 55-gallon steel drums for WVO collection 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 built by personnel in the fleet management group in Gadsden. Other municipalities have purchased similar commercially available units. The one-gallon jugs were fitted with pre-printed labels that have information on procedures for recycling the WVO.

Program operation. When 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 drum contained about 35 gallons, or every other week, whichever came first. When the full drum was picked up, another drum was left at the restaurant.

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 and allowed to cool to separate the water from the oil. Because there are several 275-gallon totes, a rotating procedure is used where 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 by the fleet management personnel to perform the process. The processor used by Gadsden is a relatively self-sufficient processor that will conduct most of the process automatically. Before starting the trans-esterification reaction, the WVO is heated to 140 degrees and a sample of oil is removed for the titration procedure, in order to determine how much catalyst is required for biodiesel production. 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. After starting the reaction process, it will take approximately one and a half hours for glycerin to begin separating from the biodiesel and another one and a half to two hours for the glycerin to be completely separated. The system uses a dry wash process that requires an additional 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 or machines.

Glycerin that results from the process is drained from the reactor vessel into a clean 55-gallon drum for later disposal. Disposal options have included 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 successfully produced. The fleet manager reported that much more fuel could be produced (as much as one 55-gallon batch each day) if more WVO was available in the community. The fleet manager indicated 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 was from restaurants and other food industries while 20 percent was from residential sources. Approximately 10 restaurants participated during this period, and most of these 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 WVO. The mayor and fleet manager both gave presentations to civic groups and took the one-gallon jugs with them to pass out to citizens. Also, local news media have been very willing to mention the program. 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 city does not conduct a formal fuel testing program on its fleet, but has had no vehicle maintenance problems since initiating the program. It does conduct periodic fuel tank cleaning to prevent algae growth. Also, it will conduct the 3/27 test periodically to determine if there is any unreacted WVO in the biodiesel. The only problem reported was 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 a successful method of removing water from the oil.

Handling the glycerin by-product has also been successful. While initial phases of the program composted the glycerin, the city has now 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 2011 dollars, the initial cost of a similar system (55-gallon biodiesel processor, storage tanks and bins, and WVO drums and jugs) is approximately $60,000. 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, this results in a fixed cost of $0.60 gallon of biodiesel excluding depreciation. Changing the production rate higher or lower will either 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 $0.99 per gallon of biodiesel. Therefore, a total cost of producing the fuel could be approximately $1.59 per gallon at the production rate of 20,000 gallons per year for five years. After five years, the costs to produce the biodiesel would consist only of the variable cost of $0.99 per gallon. The price per gallon of petroleum diesel as of November 28, 2011, was $3.63 per gallon. Using these figures, cities would save a minimum of $2.04 per gallon or a total annual savings of $40,800 during the first five years. 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	$0.50/lb	0.05
WVO	$0.00/gal	0.00
Amberlite	$10.70/lb	0.04
Electricity cost	$0.14/kWh	0.35
Total cost		**$0.99/gal + $0.60/gal fixed ($1.59/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) began 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) as 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 program to enhance local capacity to coordinate and build the necessary and appropriate infrastructure, logistics, and distribution systems to enable the 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 communities on fuel use by government, police, fire departments, emergency and regular service, utilities, schools and transportation systems. The council 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 (DOE) Clean Cities program and serves the majority of the eastern half of Tennessee.

Since 2009, three communities in Tennessee started their biodiesel production activities. These communities are Clarksville, East Ridge and Crossville. Clarksville's processor, which was funded by an EPA Congestion Mitigation and Air Quality Improvement grant, was damaged during heavy rains in May 2010 and East Ridge suspended its operations due to a change in city management. Since Spring 2010, Crossville has produced 1,600 gallons of biodiesel. It uses a 10 percent blend of biodiesel in backhoes and mowers. The city also uses its biodiesel facility as an educational tool at an annual sustainability fair. Crossville uses a 100 percent blend in a 1997 one-ton service truck. According to Public Works Maintenance Manager Steve Powell, the biggest challenge in the operation is to secure enough usable and clean used oil from local grocery franchise stores and donors. Tours at the Crossville Biodiesel Center can be arranged by calling (931) 484-7631.

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 successfully 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 or 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 the implementation of 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 vehicles and equipment. While there are technical challenges to overcome in any such program, challenges such as WVO quality assurance, fuel quality assurance, and glycerin offtake have all been successfully overcome by 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 the nation's energy security problem; however, they can be 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 the local citizens to have a part in producing renewable fuels in their own community.

(Acknowledgements: Hoover and Gadsden Ala., Jonathan Overly, ETCFC)

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November 10, 2011 Interview with Steve Powell, Public Works Maintenance Manager City of Crossville, Tennessee

ADDITIONAL INFORMATION ON BIODIESEL PRODUCTION OR BIOENERGY

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

Auburn University Natural Resources Management and 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

3/27 Biodiesel test: www.biolyle.com/doc/gc 3 27pass fail.doc

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

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