Energy Feasibility Report for

Piedmont Biofuels

Pittsboro, NC

March 2007

Study conducted by the

National Center for Appropriate Technology

and

Piedmont Biofuels

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USDA Risk Management Agency

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Introduction

This energy audit for the Piedmont Biofuels Cooperative was conducted by the National Center for Appropriate Technology (NCAT), between November 2006 and March 2007.

One main purpose of the audit was to improve energy management at the co-op, including both energy efficiency improvements and opportunities for incorporating renewable energy into the co-op's operations.

Another purpose of the audit was educational. The co-op tries to model sustainability in all aspects of its operations and has earned a national reputation for its educational efforts. The co-op would particularly like to increase its capacity to provide energy-related demonstrations, programs, and information to area farmers.

Piedmont is collaborating with NCAT and the Center for Environmental Farming Systems (CEFS) to increase energy-related research and educational efforts at Cherry Research Farm, near Goldsboro, North Carolina. CEFS, NCAT, Piedmont Biofuels, and other partners are planning an energy risk management workshop for area farmers that will take place in July 2007.

Funding for this study came from the USDA Risk Management Agency (RMA), through a Cooperative Partnership Agreement with NCAT, as part of a project called "Managing Farm Energy Risk." RMA was an actively involved partner in all phases of this project. NCAT and Piedmont Biofuels would like to thank RMA for the agency's support and involvement in this project.

About Piedmont Biofuels Cooperative

A member-owned cooperative headquartered near Moncure, North Carolina, Piedmont provides surrounding communities with pure biodiesel and information on renewable biofuels. Piedmont offers weekly tours of its farm and biodiesel production facilities, showcasing numerous innovative energy ideas and approaches. These include solar water heating, photovoltaics, and passive solar design. Green building demonstrations include strawbale construction, cob construction, and Hebel walls, as well as the use of recycled materials. The co-op takes energy efficiency seriously, and has gone to great pains to calculate and improve the energy balance of all of its operations.

The co-op is strongly committed to working with local farmers and supporting sustainable agriculture. Piedmont's BioFarm sells organic produce to the local food co-op and farmer's market, and includes a greenhouse that is experimenting with burning vegetable oil for heat. Piedmont is also growing test plots of canola and rapeseed, two oilseed crops that can be made into fuel.

The co-op prides itself on its "open source" philosophy: openly sharing everything it knows with anyone who asks.

How the Co-op Uses Energy

The largest uses of utility-provided energy at the co-op are electricity and propane. Propane is used for water heating and clothes drying by people living on the premises. The co-op intentionally limits its use of electricity.

The biodiesel production process uses mostly solar energy (to heat water and other fluids), although some electric pumps run on conventional grid power. A small photovoltaic system powers one biodiesel dispensing pump. The other dispensing pump is hand crank-powered.

Solar thermal collectors generate heat for the biodiesel process. Nine roof-mounted solar thermal collectors heat a 500 gallon water tank – a “drainback” design.

Water comes from a 110-foot deep well, pumped with grid electricity and delivering around 35 gallons per minute.

The co-op uses wood for space heating, with members cutting and splitting the wood themselves. Vehicles, including a large pickup, are major energy users, although they use exclusively 100% biodiesel (B100) made from waste oil.

A separate building houses one person and has an electric water heater. The co-op has talked about taking this building off-grid.

Project Possibilities

Energy Analysis Procedure

Mike Morris of NCAT made an initial visit to Piedmont Biofuels in November 2006. During a second visit in January 2007, NCAT Energy Engineer Dave Ryan spent several hours taking photos and recording observations with a hand-held voice recorder.

NCAT and Piedmont subsequently held phone meetings about once per week from February through March 2007. During these calls, NCAT staff asked many follow-up questions and brainstormed project ideas. Most of the analysis was done by engineering staff in NCAT’s office in Butte, Montana.

Because the co-op is already sophisticated in its energy efficiency and use of renewable energy, NCAT staff did not review overall energy consumption or billing records. Instead, we focused mainly on a few areas of concern where Piedmont requested our help.

We evaluated projects for their feasibility but did not estimate costs or simple paybacks for recommended measures.

Project possibilities are briefly summarized below. Green shading means “recommended.” Yellow shading means “more research is required.” Orange means “not recommended.”

Grease Warming Zone (Grease Storage Area)

Totes full of waste oil are stored in this room, which uses passive solar heating and well-insulated walls (R-12 in the roof and R-30 in the 8-inch thick masonry walls) to keep grease as warm as possible. This system has generally worked well, but the co-op has had problems during the last couple winters, with the room dropping as low as 48º F. The co-op would like this room to stay above 55º F at all times.

1. Install night insulation in the windows in the Grease Warming Zone.

Discussion
We discussed three options: (1) adding water thermal storage; (2) painting the piping, ceiling, and walls black; or (3) Adding insulating shutters to the windows. The co-op quickly implemented the third option, making simple foam boards (the edges protected with duct tape) that can be pressed into the windows at night.

Book Store (Tchochkie Shop)

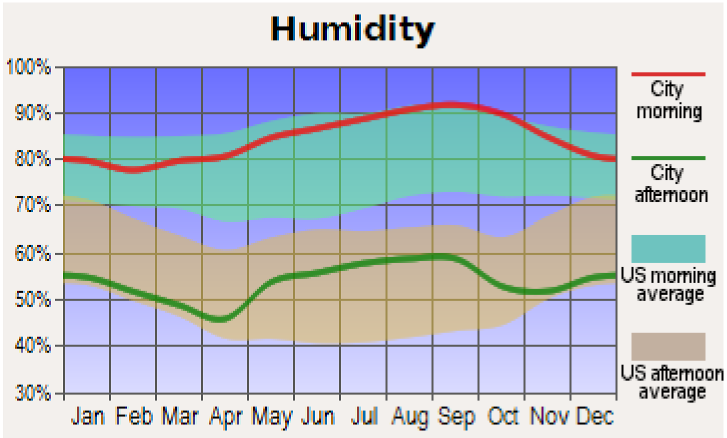
The co-op sells books at a small store with cob walls, but the pages of the books curl because of high humidity conditions in the summer months.

2. Install a simple dehumidification system, using silica gel dessicant and a small fan.

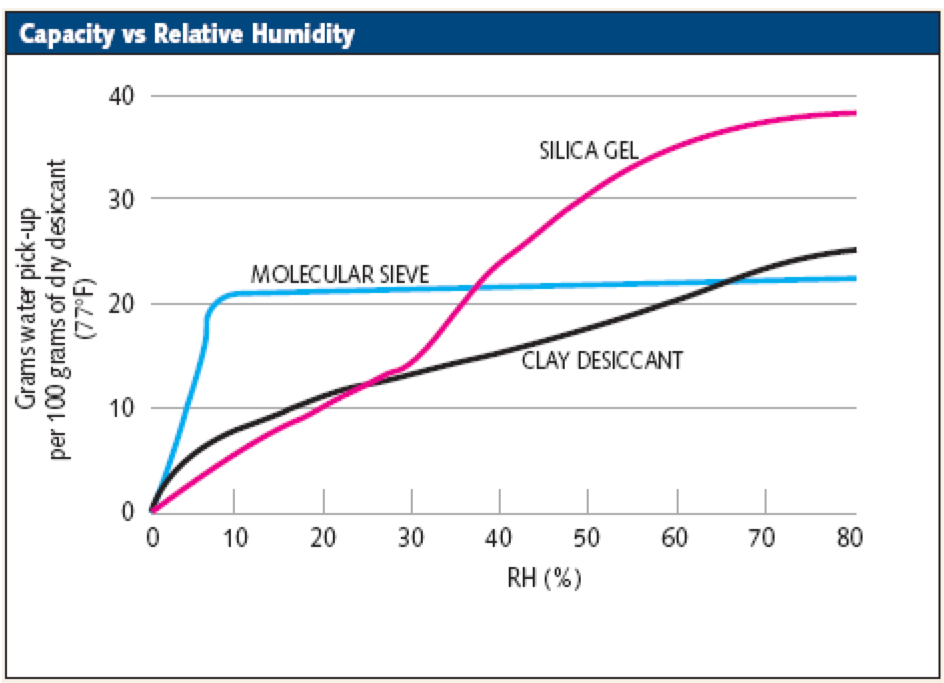
Discussion
Dehumidification is needed. According to http://dlis.dos.state.fl.us/barm/preservation/conservation/books/index.html, books should be stored at 40% relative humidity and 65º F. We are not going to get those conditions, but there may be ways to improve the current situation

We suggest a strategy of closing the building in the morning (when humidity is high) and ventilating in the afternoon (when humidity is low). We need to bring air into the store in the afternoon, and shut it up to keep the moist outdoor morning air out. We suggest making a tray that can be filled with silica gel dessicant, and mounting the tray such that it can be easily moved from the store out under a glass cover to dry out the dessicant in the afternoon. This may not be necessary. It may be adequate just to blow dry afternoon air through the building and keep the building shut up at night and into the morning to dry out the silica gel. Silica Gel will absorb up to 38% of its weight at 80% relative humidity.

A fan will add air movement and can be put on a timer. Adding a fan to the building will take more energy than the present system, but less than a compressive air conditioning system would require. The cob in the walls is probably acting like a sponge. It may be advisable to coat the inside of the cob structure to keep moisture from wicking out of the cob and into the air inside the structure.



At 90% relative humidity, there is 195 grains of water per pound of dry air, or .028 pounds of water per pound of dry air. There are 14.5 cubic feet of dry air per pound. The store is about six by eight by eight feet, 384 cubic feet, or 26.48 pounds of dry air. At 90% RH, we have 0.74 pounds of water in the air in the building. If silica gel can absorb 38% of its own weight in water at 90% RH, we need only about two pounds of silica gel to absorb the water. We suggest trying perhaps double or triple that amount, just to be sure that it will work. We have to dry the air back out in the afternoon, so the silica gel will have to go in a tray that can be removed and placed in a solar heater, or at least we will have to keep circulating air through the building during the afternoon.



Reactor Room

Biodiesel is made in one or two batches per week. Batches are 100 to 125 gallons each.

Warm vegetable oil is pumped into the reactor from the Grease Warming Zone. Methanol is pumped into a tank and mixed with potassium hydroxide to make methoxide. Methoxide is then pumped into the reactor with the vegetable oil and recirculated for about four hours. Glycerin, a byproduct, is drained out. Biodiesel is water-washed in a plastic tank and then pumped out to a finished fuel drum. Co-op members fill their vehicles from the drum, using a hand crank pump.

The co-op is currently disposing of about 50 gallons of glycerin per week, and this is an ongoing challenge. They have tried making soaps, composting it, feeding it to worms and goats, and using it as a dust suppressant and soil amendment. The co-op is looking for new ways to use glycerin.

Methanol recovery is another high priority for the co-op. The dollar savings would be modest, but worthwhile for environmental protection and demonstration value. Recovering methanol from glycerin is the main problem. Methanol recovery is well-understood and mature at large scale biodiesel plants, but small-scale producers as a rule do not recover methanol.

Piedmont's previous efforts to recover methanol have required large amounts of electric energy to achieve the necessary 147º F boiling temperature. Recovered methanol contains residual water. Recovered methanol is mixed to new methanol to get the water content down to the point that the methanol will react with the catalyst and oil.

3. Pull a vacuum to boil off methanol, with methanol vapors going into a condenser (distillation column) and methanol dripping out. Remove residual water from methanol with a molecular sieve.

<u>Discussion</u>

Creating a vacuum would reduce the boiling point of methanol, therefore reducing the energy required to reclaim the methanol. Piedmont already owns a vacuum pump and condenser, but has safety concerns, including methanol vapors potentially being released in areas visited by the public. We researched some questions about methanol recovery, but Piedmont staff had many additional questions and concerns, and we did not come up with a definitive solution or design.

NOTE: The reactor room needs to be better ventilated, for the safety of staff and visitors. A ventilation system designed by an engineer in North Carolina, familiar with state and local codes, should be installed.

4. Install a heat exchanger so that waste heat from Piedmont's portable 10KW generator will heat the reactor. Use electricity from the generator to power the mixing and recirculation pumps in the process.

Discussion

The co-op owns "CleanTech", a trailer-mounted system including a 10kW generator that is used for educational demonstrations and runs on biodiesel. This could be used to heat the biodiesel reaction vessel at times when not enough water is available in the solar reservoir, and might allow the co-op to stop using propane for water heating entirely. NCAT provided Piedmont with a conceptual drawing showing how heat reclamation from this generator might work. An existing heat exchanger in the water storage tank in the reactor room could be used, but the condition of this heat exchanger is not known. NCAT and Piedmont selected an appropriate heat exchanger for the heat reclamation system, and Piedmont expects to get this system installed.

The generator should generate at least 34,130 Btus per hour of waste heat. There is a chance that Piedmont might be able to net meter the generator, although rural electric cooperatives are reluctant to do net metering in general, and the co-op's electric bills are already very low. Batteries could be charged while the generator is running, and the stored electric energy could be used when the generator is not running. Selling Renewable Energy Credits may be a possibility. This would require running the output through an AC-DC-AC "Grid-Tec" or equivalent inverter to make the electrical power match up to the utility, and would also require negotiating a Power Purchase Agreement with the utility.

5. Investigate burning glycerin in the waste oil burner in the greenhouse.

Discussion

It might be possible to drip glycerin into the waste oil-burning stove in the greenhouse for space heat. The stove should generate175,000 Btu hours at a1.25 gallon per hour fuel rate. At the time of this study, Piedmont had not yet used this waste oil heater successfully, and had concerns about potentially toxic emissions.

6. Try an anaerobic digester for waste water and glycerin. Generate methane, then compost any solids.

Discussion

Waste water from the biodiesel manufacturing process contains unreacted oils, soap, glycerin, and methanol. This waste water is generally released into typical waste water streams, and is of concern to Piedmont. The co-op does not want to release any waste streams, and would like to re-use the water if possible.

The co-op is already doing aerobic digestion in a series of tanks, but the current system does not have the capacity to lower the biological oxygen demand (BOD) of the waste water to acceptable levels. NCAT suggested adding an anaerobic digester as an additional step in the waste water treatment. Anaerobic bacteria will like the methanol, glycerin and soap in the waste water.

Anaerobic Digestion (AD) is done in closed tanks or stagnant ponds where the anaerobic bacteria can grow, and works best at temperatures around 95-105º F. Digestion of waste water will produce methane gas as a byproduct. The anaerobic digester could be kept in the Grease Warming Zone, where it will be kept warm and will by itself generate some heat. Or the co-op could build another cob structure to house the digester. The digester could be put into a compost bed to keep it warm.

Methane can be flared off initially. Later it may be possible to use the gas for lighting, heating, cooking or other purposes.

Piedmont intends to make a model digester from a five-gallon bucket. Waste water will be innoculated with waste water from the septic system. As in the making of a fine wine, an airlock will be installed and will be monitored as methane begins to start bubbling. A balloon can be put on the air lock to trap gas for analysis. BOD will be measured at the beginning of the batch and at the end of the bubbling to see what decrease in BOD is possible. BOD will be measured at the beginning, then after a month, after 2 months to see what BOD reduction is as a function of reaction time. The digester will be agitated from time to time.

House and Yard

The house contains a refrigerator, kitchen appliances, and a propane stove. All lighting is fluorescent – no incandescent lighting is allowed on the premises. Staff and interns use laptop computers (which use a fraction as much energy as desktop computers), and there is no air conditioning system.

7. Move solar thermal collectors off the roof to an unobstructed sunny location in the yard. Use solar hot water to reduce/replace propane and electric hot water heating.

Discussion

Although the solar water-heating system works extremely well for most of the year, shading and cool weather in fall cause water temperatures to drop severely – to as low as 80º F. The co-op believes that moving the solar collectors to a location with full sun might allow adequate heating with only a third to half as many collectors. We discussed options, and pointed out that this would require changing from current drainback system to a glycol system with a heat exchanger.

8. Use solar panels (photovoltaics) instead of grid power to pump well water.

Discussion

This appears prohibitively expensive. A one-horsepower pump would require at least 800W of solar panels, possibly costing as much as $5,000 to $7,000.

9. Reduce clothes dryer energy usage

Discussion
We suggest discouraging use of the clothes dryer by residents, including possibly posting signs suggesting use of a clothesline. A clothesline could be put up in the greenhouse for clothes drying in cool/wet weather.

Constructed Wetland

Piedmont is experimenting with recycling its wash water through a constructed wetland -- hoping to get to the point where the water can be reused in the biodiesel process.

Water runs out of a tote into series of vats and tubs to reduce the biological oxygen demand (BOD) of waste water. A 12-volt air pump with an air stone aerates the water.

10. Try using a fine bubble diffuser instead of the air stones. Use a one square foot fine bubble diffuser per tote.

Discussion
Put the bubbler at the top of the water in a tube to use convection to move water up from the bottom of the "aeration basin"

BOD of waste water 65,000 needs 2 pounds per square inch (psi) at 1 cubic foot per minute (cfm). The co-op has a small air compressor that might work. We suggest a Sweetwater linear air pump SL24 – about 1 cfm at 18 inches.