The Collaborative Biodiesel Project

STAFF PHOTOS

Closing the biodiesel loop through recycling and renewable energy.

By Richard Freudenberger

Proponents of biofuels have always maintained that sourcing energy from domestic renewables such as plant biomass and bio-based wastes reduces our dependence on imported petroleum, diversifies our energy base, and offers cleaner end-use emissions. One particular biofuel—liquid biodiesel derived from soybeans, waste cooking oil, or animal fats—has received prominent national attention and enough investment that the number of commercial production facilities has grown from 65 in mid-2006 to 145 in June of this year.

But critics aren't so convinced. Their concern is that biodiesel fuel is not sustainable on a large scale. First, they question whether the energy invested in growing, harvesting, and processing soybean feedstocks will surpass or even approach the energy available from the finished product. Further, they hold that the by-products of manufacture—glycerin and wash water from the fuel-cleaning process—have limited value and are essentially contributing to the waste stream themselves.

Appstate Appropriate Technology

For Jeremy Ferrell, a graduate student in the A-T Department at Appalachian State University, biodiesel is far more than an academic topic of discussion. After completing his undergraduate studies in1999, he went to work for the U.S. Park Service, then served a three-year stint in the Peace Corps, working with subsistence farmers in Paraguay on agroforestry, apiary, and tilapia projects. Subsequent permaculture studies in Brazil exposed him to farm-scale biofuels potential and laid the groundwork for his ensuing interest in renewable fuels back home.

Ferrell and an interdisciplinary team of ASU students began the biodiesel project with the goal of "closing the loop"—designing the entire production facility to be self-contained and wholly sustainable so that every by-product either found a use within the system or had marketable value outside of it. To carry this through to completion, they had to develop a solar thermal hot water system for heat processing and rely on photovoltaics to run the pumps, lighting, and system controls.

How the System Works

The process begins with 80 gallons of waste vegetable oil collected each week from the ASU cafeteria. It's a mixture of soy, peanut, and canola (a low-acid rapeseed oil) and comes to the facility in five-gallon carboys.

The containers are stowed in covered storage outside a 280-square-foot greenhouse, where the initial processing begins. The first step is to empty the waste oil into the collection barrel, a 55-gallon drum fitted with a 400-micron drumhead filter, recessed to capture solids and thwart spillage. From there, the strained oil is pumped into two 120-gallon storage and settling tanks linked in series. Here, excess water can be drawn off and the oil sent through a 30-micron filter before being moved on through an insulated chase to a 120-gallon processor tank in the adjacent processing shed.

A grid-tied PV system provides power for pumps and lighting. Four solar thermal panels on the processing shed at right heat the oil.

The processor tank is one of several purchased at a salvage yard. (Stainless steel dairy equipment often finds its way to auctions and scrap yards and has proved ideal for biodiesel production.) This tank is equipped with an internal heat exchanger to heat the oil and was modified by adding a lid to seal the reactor chamber. This prevents the escape of methoxide fumes and also allows for methanol recovery through vacuum distillation as part of the recycling process.

To achieve the necessary reaction temperature of 130°F, a series of four solar thermal collectors mounted on the processing shed—144 square feet of total surface—supply a superinsulated 30-gallon water tank in the lab below. A 60-watt pump circulates the water through the thermal system. Individual valves control where in the process heat needs to be distributed by feeding exchanger coils built into the tanks. A backup hydronic oil-burner, operating on either biodiesel or clean vegetable oil, can be called into use when needed.

A smaller 35-gallon HDPE conical mix tank next to the processor allows for safe and consistent blending of the methyl alcohol and potassium hydroxide catalyst. Methanol from a 55-gallon drum is pumped into the methoxide tank through a stainless steel funnel that holds the potassium hydroxide (KOH) flakes. They dissolve in the filling process, and the resulting methoxide mix is transferred to the oil-filled processor tank through a mixing tube to start the biodiesel reaction. The mixing itself is carried out over one and a half hours using a stainless steel centrifugal pump, which is the most workable choice for a closed container system.

The liquid is then pumped into a 120-gallon settling tank, where it's kept for at least 48 hours to allow the glycerin to separate from the biodiesel fuel. Glycerin can be drawn off at both the processor and settling stages. Eighty gallons of raw biodiesel will yield about 16 gallons of glycerin by-product.

A third pump moves the biodiesel fuel to the wash tanks, two vertically stacked stainless steel containers, each 210 gallons capacity. There, a three-stage water-washing procedure carried out over a period of several days removes remaining impurities (free methanol, glycerin soaps, fatty acids, etc.) that can lead to corrosion, sediment buildup, and injector blockage in a diesel engine. The washed biodiesel is then circulated through a perforated annular ring in the wash tank to evaporate out the last traces of moisture from the fuel, then the finished product is pumped one last time through a 5-micron filter and into a 55-gallon storage drum, where it's hand-pumped into Ferrell's 1985 Toyota diesel pickup or transported to the project's Fuel Sampling Partners to be used in various off-road applications such as farm equipment and home heating.

Reuse and Recycle

None of this is unique for biodiesel processing plants of this size. What makes the Appstate Collaborative Biodiesel Project distinctive is that the team has consciously sought practical end-use applications for the by-products that habitually have been difficult to dispose of, mainly wastewater from the washing cycle and glycerin from the transesterification reaction.

Wastewater is an issue especially in larger operations because the system produces too much volume over time to simply discard. To alleviate that, the ASU students have built an "ecological machine" within the greenhouse to treat the spent water for reuse. The living machine is a micro-ecosystem designed to treat a specific volume of influent through the use of biological organisms such as wetland plants, algae, plankton, and aquatic wildlife. Currently, a small wetland pond built just behind the polycarbonate glazing at the front of the greenhouse contains water hyacinth and azolla, more commonly known as duckweed fern. Future plans include the addition of cattails, mollusks, and possibly some water-loving trees such as figs and willows.

Water from the lab sink and the fuel-washing process is piped into two 350-gallon containers at the rear of the structure. A single solar thermal panel on top of the greenhouse preheats the water prior to introduction. The first stage is the treatment of 120 gallons with anaerobic bacteria to break down any solid material. Following that, an open aerobic tank of 150 gallons capacity further clarifies the water and removes objectionable odors. The final step is the wetland pond, where the water is purified by the plants and eventually is returned to wash subsequent batches of biodiesel. A 25-watt pump on a scheduled timer circulates the water at a rate of 100 gallons, or about 10 percent, every hour.

Glycerin from the reaction process has always been a question, even for home producers. Approximately 20 percent of the yield is a crude glycerin composed of free fatty acids, glycerol, excess methanol, and residual catalyst. That's 20 gallons of material for every 100 gallons of biodiesel made. Glycerin soap has typically been a marketable end product, and the Appstate group has been successful in finding applications not only for industrial cleaners but also in composting operations and as fire-starter briquettes, using wood chips as a substrate.

Part of the project's "loop" includes the use of renewable energy to run the various pumps. Ten 170-watt Sharp modules and a Sunny Boy inverter are the key components in the grid-tied system, which provides lighting and power for the controls as well. Conveniently, the pump motors are not required to operate simultaneously, so there's no large surge demand in the system, and with one-inch line and no appreciable elevation, no single pump is particularly large.

Where From Here?

In 2006, the Appstate team exhibited the project in Washington, D.C., as part of the Environmental Protection Agency's EP3 Student Design Competition for Sustainability. As one of the winners of the competition, the team was awarded further funding for continuing Phase 2 of the project, which includes continued research into biodiesel feed stocks such as algae and alternate oilseed crops, reaction and fuel-quality monitoring with near infrared spectroscopy, waste composting for CO_2 and methane production, and expanded educational and outreach programs.

Members of the program have also cast their eyes toward the area's farmers and its extension service in hopes that the growth of biofuels may be an opportunity for local growers to find new markets for feedstock material and oilseed by-products such as high-protein seed meal. The ongoing loss of tobacco crop has left many in the agricultural community searching for viable market alternatives.

In the meanwhile, the project is moving forward and taking advantage of the successes and interdisciplinary approach that has served it well thus far. Both the algae and composting research may well prove viable additions to the ongoing biodiesel loop.

For more information visit www.biodiesel.appstate.edu

A micro-ecosystem within the greenhouse treats system wastewater using wetland plants.