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Biodiesel Is Making Distributed Energy Green

Biodiesel is getting lots of attention these days. Here's a look at a pioneering effort at achieving the environmental benefits of fuels made from vegetable oils.

By Greg Northcutt

For some, the smell of French fries triggers an irresistible urge to gobble down those golden-brown slivers of hot potatoes. For Marty Borruso, it's the sweet smell of success in his quest to wean distributed energy (DE) systems off their dependence on natural gas and petroleum-based fossil fuels in favor of home-grown renewable energy sources.

He and his partner, David Landau, are now using B70, a blend of 70% biodiesel and 30% No. 2 petroleum diesel, to operate a 300-kW cogen system that provides primary power for an 87-family apartment building on New York City's Staten Island. "The odor of the exhaust from engines running on biodiesel fuel ranges from none to that similar to French fries," Borruso says. At the same time, the heat produced by this system provides hot water for the residents during the summer, eliminating the need to run the building's boiler. In the winter, the heat helps warm the building.

Borruso and Landau's company, Environmental Alternatives LLC, manufactures the biodiesel at their Staten Island facility from waste vegetable oil—mostly soybean, sesame, and rapeseed (canola) cooking oil gathered from New York City restaurants, and virgin soybean oil from other sources along the East Coast from Canada to Florida.

Since converting the apartment house cogen system from pure natural gas and No. 2 diesel fuel in June 2004, they've been gradually increasing the biodiesel content of the fuel from a 2% blend (B2) to the current 70% mixture. After 2,000 hours of continuous biodiesel operation, Borruso reports the fuel is proving to be a cost-effective alternative to petroleum diesel for fueling the building's primary power system.

The company's plans call for continuing to increase the biodiesel content of the fuel and monitoring performance of the cogen unit until reaching its goal of running the system on 100% biodiesel fuel (B100). "We're not aware of anyone else planning to use B100 in a prime power stationary engine application," Borruso says. "With the additives we developed we expect this intensive use of biodiesel will eliminate anti-gelling and cold weather problems that have plagued the biodiesel industry in the past

"Biodiesel is the most practical, simple-to-use alternative replacement fuel for boilers and diesel engines available in the United States today," he continues. "Currently, natural gas is the most common alternative fuel for diesel engines. However, converting to natural gas requires you to change out the entire system and build an infrastructure to accommodate compressing and delivering the fuel to the point of use. By contrast, converting to biodiesel is just a straightforward fuel substitution, which requires absolutely no changes to off-the-shelf diesel equipment."

"Today, biodiesel is giving our customers a real choice in buying fuel," says Bob Lindenbaum, the company's director of probabilities. "When compared to the cost of using other alternative fuels, biodiesel is quite economical."

Much of the economics of the company's approach to using biodiesel in DE applications hinges on a large local supply of waste oil and the ability to manufacture the fuel in-house. The company's experience to date demonstrates that the fuel is a viable option that offers a number of advantages over No. 2. diesel and other petroleum fuels for powering cogen

systems. Given ever-rising worldwide demand for petroleum fuels and the many uncertainties in the international market for these fuels, biodiesel is likely to become even more appealing in the future.

Other Applications

In addition to producing biodiesel for cogen systems, Environmental Alternatives also sells biodiesel for use in commercial truck fleets, heating-oil burners, and other applications by environmentally conscious private users, including a biodiesel-fueled motorcycle.

The company's B100 is being used by a neighbor, Fix-A-Dent Towing and Body Shop, to fuel its trucks. "According to initial reports, the trucks are running better than with No. 2 diesel," says Jim Crupi, owner of Fix-A-Dent.

"When the drivers work the flatbed controls they are not getting diesel fumes in their face, which makes their job much more pleasant," Borruso says. "Also, fuel consumption has been reduced dramatically. I'm not sure why, since biodiesel contains only 95% of the Btu value per gallon of No. 2 diesel. I expected fuel consumption with the biodiesel to be similar or a little higher. But, since biodiesel cleans out the fuel delivery system, perhaps the fuel is being handled more efficiently and the burn in the cylinder is more symmetrical and uniform for more efficient symmetrical combustion."

A Petroleum-Free Fuel

Because it's made from raw vegetable oil, biodiesel differs significantly from petroleum-based diesel fuel. In its pure form, biodiesel contains no petroleum. It can be used as is or blended with diesel fuel to power any diesel engine with little or no modification to the engine or fuel system and with little impact on engine performance, reports the National Biodiesel Board. "The higher cetane rating of biodiesel compared to most petroleum diesel will decrease the bottom end noise of diesel engines and reduce the preignition associated with petroleum diesel," Borruso says.

Biodiesel is biodegradable, nontoxic and essentially free of sulfur and polycyclic aromatic hydrocarbons (PAH). Chemically, biodiesel consists of mono alkyl esters (mostly methyl esters) of fatty acids derived from renewable vegetable and animal lipid sources. It's produced by a process called transesterification, in which vegetable oil or animal fat reacts with methanol in the presence of a catalyst. This yields methyl esters—the biodiesel—and glycerin, which can be used to make soaps and other products.

To be sold and distributed as a legal motor fuel for diesel engines in the US, biodiesel must meet American Society for Testing and Materials specifications. The fuel is legally registered with the EPA as a pure fuel or as a fuel additive. The manufacturer must also be registered with the EPA.

Nationwide, soybean oil accounts for about 90% of all biodiesel production. Other feedstocks include vegetable oil from such crops as rapeseed and sunflowers, and animal fats. In Europe most biodiesel is based on rapeseed oil, commonly known as canola oil in the US.

The Case for Biodiesel

As the National Biodiesel Board points out, biodiesel offers a number of benefits in distributed energy applications.

Fewer and Lower Emissions

Biodiesel is the first alternative fuel to complete the health effects testing requirements of the Clean Air Act. Since biodiesel is oxygenated, it results in more complete combustion than petroleum-based fuels. As a result, when used in a conventional diesel engine, biodiesel reduces emissions of unburned hydrocarbons, carbon monoxide, and particulate matter. (See Table 1.) Depending on duty cycles and testing methods, biodiesel either reduces slightly or increases slightly emissions of nitrogen oxides (NOx). Soy biodiesel cuts carbon dioxide emissions by 78% on a life-cycle basis, reducing the major pollutant contributor in greenhouse gases. Also, because it contains no sulfur, it produces no sulfur dioxide, a major contributor to acid rain.

The non-toxic fuel is also less irritating to the eyes, nose, and throat, and reduces PAH, the compounds linked with cancer by 80%–90% compared to petroleum diesel.

Table 1: Average Biodiesel Emissions Compared to Conventional #2 Petroleum Diesel Fuel in Industrial Engines

Emission Type	B100	B20
Regulated		
Total Unburned Hydrocarbons	-67%	-20%
Carbon Monoxide	-48%	-12%
Particulate Matter	-47%	-12%
NOx	+10%	+2%

Non-Regulated		
Sulfates	-100%	*-20%
PAH (Polycyclic Aromatic Hydrocarbons)**	-80%	-13%
nPAH (nitrated PAH's)**	-90%	-***50%
Ozone potential of speciated HC	-50%	-10%

* Estimated from B100 result
** Average reduction across all compounds measured
*** 2-nitroflourine results were within test method variability
(Note: NOx can be significantly reduced and operation of the engine improved if the injection timing is retarded 2% to 4%. This should only be done with the advice and approval of the engine manufacturer)

More Domestic Energy Security

Imported oil accounts for more than half the petroleum-based fuel consumed in the US. Supply and prices are becoming more and more out of our control; with new markets, developing countries are taking more and more of the supply, leaving us short on fuel and with prices higher than ever.

"Using renewable fuels grown by American farmers can reduce US dependency on foreign oil supplies," Borruso says. "In fact, biodiesel has the highest energy balance of any fuel. For every unit of fossil fuel used to make biodiesel, you gain 3.2 units of energy. Since petroleum diesel has a negative energy balance of .88, every gallon of biodiesel can add four gallons to our petroleum reserves."

He sees increased use of domestically produced biodiesel exerting a stabilizing influence on the entire national and international fuel marketplace. "The natural gas industry has done a wonderful job of finding new markets and uses for its product," Borruso says. "But this success may be the industry's undoing. Prices of natural gas are at historic highs while availability is at historic lows. Interest in importing liquefied natural gas is also increasing. The last thing this country needs is another imported fuel."

Compatible with Conventional Engines

In more than 50 million miles of in-field vehicle operation, fuel consumption, horsepower, torque, and haulage rates of B20 were similar to conventional diesel fuel. What's more, biodiesel has superior lubricity and the highest Btu content of any alternative fuel, falling between No. 1 and No. 2 diesels.

Easy on the Environment

In tests at the University of Idaho, biodiesel samples degraded faster than sugar. At the end of 28 days, biodiesel was 95% degraded. Diesel fuel was about 40% degraded by that time. Blending with biodiesel increases the rate at which No. 2 diesel degrades. A 20% biodiesel blend degrades twice as fast as No. 2 diesel.

Safer to Use

In its pure form, biodiesel ignites at 260°F. That compares to the much lower flash point of 125°F for No. 2 diesel. Because it's considered non-flammable, it can be stored in areas where petroleum fuels would pose a safety hazard. "That's especially important when storing fuel in densely populated areas like New York City," Borruso notes.

Lower Engine Maintenance Costs

"Fewer particulate emissions extend the life of engine lubricating oil," Borruso says. "With diesel it's common to change oil in generators every 250 hours. But, when using the cleaner-burning biodiesel, you can run the engine 500 hours between oil changes with little or no degradation in oil quality."

The better lubricity of biodiesel compared with conventional diesel fuel reduces maintenance costs even more, especially in the fuel delivery system—the pumps and injectors that are influenced by the material it is pumping, Borruso notes. "More and more states across the country are requiring diesel fuel users to use ultra-low sulfur diesel fuel, which has a much reduced lubricity," he says. "Adding 1% biodiesel replaces this lubricity loss. Including 2% biodiesel also significantly reduces the particulate matter that escapes from the exhaust with diesel fuel and significantly reduces the amount of characteristic black diesel smoke from trucks and buses.

More Cogen Operation

In New York, state air-quality regulations limit the total annual amount of emissions produced by an engine, Borusso notes. "Using cleaner biodiesel can extend engine operating hours by as much as a third before reaching that emission limit for the year," he says.

He reports that biodiesel proponents are seeking exemptions from New York's emission limits for engines operated on biodiesel. "As more people learn about the benefits of this, we'll see wider use of it," he says. "Meanwhile, our company is gathering data and studying the performance of the material to identify any potential problems before the product becomes more popular. Usually, the limiting factor in diesel engine operation is NOx loading into the environment. But,

considering the high, double-digit reductions in other biodiesel emissions, the small amount of NOx increase in engine operation should not restrict use of the fuel."

Other Considerations

Over time, biodiesel in its pure form will soften and degrade certain types of natural or butyl rubber. "Biodiesel is compatible with components in most newer engines," Borruso says. "However, it could damage fuel hoses, fuel pump seals, and gaskets found on engines older than 10 years."

"The only problem we have seen is that biodiesel is a better solvent than No. 2 diesel and will dissolve sludge in fuel storage tanks and clog up filtration systems when it is first used in an old system," Lindenbaum says. "We view this as an advantage. Once the biodiesel dissolves all the sludge in the tank, the fuel will keep the system very clean. In fact, we recommend that anyone who stores and uses petroleum diesel to use at least an occasional charge of biodiesel to clean out their fuel system and keep it clean. The product also helps keep injectors clean and removes certain coatings and residuals in engines and burners which use standard petroleum products."

As with No. 2 diesel, biodiesel will gel in very cold temperatures. Blending with No. 1 diesel, or heating or storing the fuel in or near a building or warm area, will prevent this problem. "We have also developed other products and fuel-circulation systems used with biodiesel and with standard petroleum diesel to prevent gelling and other storage problems associated with liquid fuels," Lindenbaum adds.

Meeting the Challenges

Borruso's interest in biodiesel as an alternative fuel for DE stems from his role as president of Brooklyn Utility Management Inc., a New York City firm that designs and installs cogen systems. He says the decision to establish Environmental Alternatives and to switch from No. 2 fuel oil to biodiesel for operating cogen systems was three years in the making.

"Because we're not a large company, we couldn't afford to jump in with both feet first," he says. "We wanted to prove to ourselves that biodiesel was an economic alternative fuel in stationary applications for power generation. I like information, and a prime power operation is an intensive program which provides the means to study any problems with biodiesel. Since our site is under close control we can develop products and procedures to address these problems in the future."

In developing biodiesel as a practical fuel for cogen operation, the company faced three major challenges.

An Adequate Supply of Vegetable Oil

Much of the oil, which Environmental Alternatives processes is derived from soybeans. The market for soybean oil on the East Coast, Borruso notes, is limited. "There are no soybean fields in New York City's five boroughs," he says. "If you're not located in the Midwest, you're dependent on importing supplies. As members of the National Biodiesel Board, we were able to find various suppliers in this region, in addition to local sources of waste soybean oil from restaurants and food preparation establishments.

Consistent, High-Quality Biodiesel

Right now, consistency is the biggest issue for people who are using biodiesel, Borruso reports. He has interviewed numerous users from around the country who had tried operating trucks on biodiesel. "Each one, it seemed, had a horror story to tell related to poor fuel quality," he says. "Production of biodiesel is a hydrolytic process. Any water, glycerin, or other contaminants in the fuel can produce engine operational problems like poor power response and clogged filters.

"No diesel engine runs as intensely as one used to generate electricity. So, any fuel that's marginal in quality can cause a major problem quickly and acutely. Prime power applications, especially for a residential building, require a consistently high-quality fuel."

The solution to both the supply and quality problem was Environmental Alternatives.

"By manufacturing our own biodiesel, we can control the quality to meet our own specifications," Borruso says. "Tom Grossberger, a New York City consultant with extensive experience in the fatty acid oil business, has been instrumental in getting us up to speed in terms of quality and continuous improvement in techniques. Also, because the demand for our biodiesel can vary, we've established a network with other manufacturers, who also follow strict quality-control procedures, to balance each others' needs and commitments for biodiesel."

Viable Economics

Sharply higher prices for natural gas and petroleum oil this past year have significantly improved the economic feasibility of biodiesel for distributed energy.

"We wanted to wait for economics to be right before switching to biodiesel," Borruso says. "Currently, the price of natural gas is double that of biodiesel. At the same time, biodiesel, which used to cost twice as much as No. 2. diesel fuel, now costs only a few cents more."

However, by manufacturing its own biodiesel from waste oil, Borruso reports, the company's fuel price becomes even more attractive—only slightly higher than No. 2 diesel.

Would he still use biodiesel produced from straight, unused vegetable oil? "Yes," Borruso says, "because of all its other advantages compared to No. 2. diesel fuel. "

Table 2 compares his cost of using various blends of biodiesel with the costs of other fuels to produce 657,000 kWh of electricity with a 300-kW generator set. Equipment and installation are amortized over five years.

Table 2: The Cost of Producing Electricity with Different Fuels*

Fuel Type	Capital Cost	Annual kWh Production	Price Per Gallon	Actual Real Costs Per kWh
Natual Gas (firm non-interruptible rate)	$360,00	657,000	$0.75	$0.1250
Diesel	$255,000	657,000	1.10	0.0767
Natural Gas-Diesel Bifuel Interruptible Gas	$255,000	657,000	0.75 gas 1.10 diesel	0.0630
B100	$255,000	657,000	1.65 biodiesel	0.1217
B80	$255,000	657,000	1.65 biodiesel 1.10 diesel	0.1127
B50	$255,000	657,000	1.65 biodiesel 1.10 diesel	0.0992
B20	$255,000	657,000	1.65 biodiesel 1.10 diesel	0.0857

*Actual real cost is based on capital cost at 7% for 5-year plant life amortization
Fuel cost is price per gallon of #2 equivalent
Heat rate of gas engines 12,600 Btu's per kWh
Heat rate of diesel and diesel variant 9000 btus per kWh

Borruso notes several other factors to consider in evaluating the merits of biodiesel for cogen systems.

One is the quantity of heat produced. He offers these comparisons.

Type of Fuel	Low Heat Value
Natural gas	930,000 Btu/dth
Diesel	129,000 Btu/gal
Biodiesel	122,000 Btu/gal

"Natural gas companies penalize customers who use non-interruptible gas with higher rates than interruptible supplies," Borruso says. "Also, capital and maintenance costs of spark-ignited natural gas cogen systems are much higher than with diesel engine units. Consequently, in comparison to natural gas purchased at firm, non-interruptible rates, biodiesel makes some sense.

"And, when you consider that biodiesel is a renewal product which reduces our dependency on foreign sources of oil and has far fewer environmental impacts than diesel, then biodiesel makes even more sense."

Producing the Fuel

The waste oil is collected from restaurants and delivered to Environmental Alternatives in 55-gallon barrels, 270-gallon totes, and six 12,000-gallon tank trucks. The company's 6,000-square-foot production facility includes a 7,000-gallon tank for storing the soybean oil, a 7,000-gallon processing tank that converts the oil into biodiesel and byproducts, and a lab for analyzing the fuel. "Customers mix the biodiesel with No. 2 diesel at their sites," Borruso says. "If they want to use biodiesel in a blend of less than 100%, they can blend right in their tanks because the two fuels are miscible in any concentration," Borruso says.

The facility can processes 7,000 gallons of oil into 7,000 gallons of biodiesel daily, Borruso reports. Strict quality-control procedures are followed in producing the fuel. "Our process features an extra polishing step, using 0.5-micron water coalescent filters to remove any free fatty acids, water, and any residual glycerin in the fuel," he says. "This is much finer than required by engines and helps prevent engine fuel filters from clogging."

Operation of the production facility is also ISO 9000 compliant, which assures consistent quality of the biodiesel. "Our customers know they'll get the same product quality every time," Borruso says.

The apartment building's DE system includes a primary and a backup generator set. Each complete set includes a 150-kW Marathon generator powered by a 220-horsepower John Deere 6068TI diesel engine. He reports the biodiesel has had no effect on the engine's horsepower rating.

The engine comes standard with a fuel recirculation system, Borruso notes. That plays a key role in preventing the biodiesel from gelling at temperatures below 30°F. "The engine's fuel pump draws biodiesel into the engine at the rate of 3 gal/min, but the engine only consumes 0.1 gal/min," he explains. "The remaining 2.9 gal/min is heated by operation of the engine and returns to the fuel tank, keeping the biodiesel in the tank warm."

Environmental Alternatives' approach to green DE may not fit most operations today. But, as the company's experience shows, the day when home-grown biodiesel is widely used to power cogen systems moves closer and closer with each bump upward in the price of petroleum fuels.

Topics: Fuels,Biomass,