

Next Generation

Biobutanol: On the Road to Overtaking Ethanol

Ethanol's long neglected cousin, butanol that is derived from biological sources, is poised to emerge from the shadows. New fermentation techniques combined with current high petroleum prices are spurring renewed interest in the decades-old fuel. In time, it may race ahead of ethanol as a motor fuel.

"There are a lot of potential reasons why a fuel company or a petroleum company might be more willing to use biobutanol as a fuel instead of ethanol," says Andy Aden, a senior research engineer at the National Renewable Energy Laboratory. For starters, it has a higher energy content and a higher octane rating than ethanol, so vehicles get better fuel mileage.

Biobutanol also can be burned in higher concentrations, possibly up to 100%, without having to modify vehicle engines. Since it has a lower vapor pressure than ethanol, it's safer and easier to blend with gasoline or diesel fuel. And unlike ethanol it can be transported through

FUEL PROPERTIES			
	Butanol	Ethanol	Gasoline
Energy content Btu/gal.	110,000	84,000	115,000
Motor octane rating	94	92	96
Flash Point* (°F)	95	55	-45
Reid vapor pressure** (100°F)	0.3	2.3	8-15
Water solubility at 70°F	9%	100%	Negligible
Transportation infrastructure	Existing	Segregated	Existing
Feedstock	Same as ethanol	Sugar or starch crops	Crude oil
Production costs	Not expected to differ from ethanol	About \$1.30/gal.	Variable
Availability	Available in commercial quantities post-2010	Available now	Available now
* Fuels with higher flash points are less flammable than fuels with lower flash points. ** Vapor pressure is an indication of a liquid's evaporation rate. Sources: ButylFuels, LLC, Department of Energy, BP, DuPont, Kiplinger			

existing petroleum pipelines, because it's less corrosive and doesn't easily mix with water. Finally, biobutanol production also yields some valuable coproducts, such as hydrogen, acetone and even ethanol itself.

Biobutanol can be made from the same feedstocks as ethanol—both the grains used today and cellulosic feedstocks expected to be used in the future. What's more, not only can existing ethanol plants be retrofitted to produce biobutanol, biobutanol reactors can be attached to existing ethanol plants to coproduce the two fuels, using the distillers grains left over from ethanol production as the biobutanol feedstock.

For years, higher production costs have kept biobutanol out of favor, and no U.S. companies make it on a commercial scale currently. Traditional "ABE" fermentation technology, yielding acetone, butanol and ethanol, results in less

fuel per bushel of corn than ethanol fermentation does. And until recently, relatively low oil prices have made petroleum-based butanol, produced now and used chiefly as a solvent rather than as a fuel, a more attractive proposition than biobutanol.

But with oil near \$70 a barrel, biobutanol is now "definitely competitive," says Hans Blaschek, a professor of microbiology at the University of Illinois and director of the university's Center for Advanced BioEnergy Research. "Biobutanol can be produced competitively at this point, and certainly it can be produced cheaper than petrochemically derived butanol."

More promising, Blaschek and others are hard at work paring production costs. Blaschek, for example, has partnered with technology investment firm IllinoisVentures LLC to

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launch **Advanced Biofuels, Inc.** The new company is nearing completion of an 80-gallon bioreactor test facility using technology Blaschek developed and patented over 25 years of research. Blaschek aims to cut production costs from something over \$2 a gallon now to under \$1.30 a gallon, roughly equal to the cost of making ethanol. Following the July start-up of the bioreactor, located near the UI Urbana-Champaign campus, Blaschek will experiment with scalability, testing various modifications to the reactor. He believes the company will be able to produce biobutanol at a much lower cost—possibly just half the \$1.35 per gallon cost of the current petrochemical-based approach.

ButylFuel, LLC in Blacklick, Ohio, has also begun work on a pilot fermentation production facility using technology that founder David E. Ramey says will produce biobutanol from corn for about \$1.20 a gallon. With corn at \$2.50 a bushel and taking into account the higher Btu content of butanol, that translates into 105,000 Btu per dollar for butanol and 84,000 Btu per dollar for ethanol, says Ramey. He expects ButylFuel's test reactor to be up and running in six months.

ButylFuel's patented technology, developed by Ramey and others at Ohio State University, yields more biobutanol—about 2.5 gallons—per bushel of corn than ABE fermentation does. That process produces about 0.7 gallons of acetone, 1.3 gallons of butanol and 0.13 gallons of ethanol. ButylFuel's method produces no

acetone or ethanol coproducts, generating another potential fuel, hydrogen, instead. Taking that into account, the company claims it can produce 42% more energy from a bushel of corn than today's corn-to-ethanol plant—25% more from the butanol plus an 18% bump from the hydrogen coproduct.

A third pilot plant, operated by **Energy Quest, Inc.** (EQST) will take a different approach, gasifying biomass, lignite coal and cellulosic material into butanol. The company aims to build a small 8-12 million-gallon-a-year plant within two years. According to Wilf Ouellette, president and CEO of Energy Quest, production costs should be on a par with ethanol.

In addition to these pilot plants, other research underway promises to help bring biobutanol to the fore. **Membrane Technology and Research, Inc.** of Menlo Park, Calif., for example, is working on a hybrid membrane that would allow more efficient extraction of butanol during the distillation process. **Gevo, Inc.**, of Pasadena, Calif., is engineering novel microorganisms to efficiently convert biomass to butanol without generating byproducts. **Integrated Genomics Inc.** is developing a method to produce butanol from biomass.

At least two major corporations are also exploring biobutanol. **DuPont (DD)** and **BP (BP)** intend to build a biobutanol research and demonstration facility in Hull, England. Both companies have been working for over a year laying the groundwork for commercial manufacturing of biobutanol. DuPont, for example, says that over the past 18 months it has doubled the number of scientists it has working on biobutanol. Intended solely for market development and testing purposes, the facility, which is expected to open in 2009, will import small quantities of biobutanol from an existing facility in China. A much larger, commercial ethanol plant is also planned for the site—a joint venture of DuPont, BP and **Associated British Foods**, parent of British Sugar. The companies say that down the road, that plant may be converted to produce biobutanol.

One government obstacle that will have to be overcome for biobutanol to achieve its full potential involves environmental testing. At present, biobutanol/gasoline blends of up to 11.5% biobutanol can be sold under a special waiver of Clean Air Act rules granted by the Environmental Protection Agency on the grounds that the blend is substantially the same as a 10% ethanol blend. Mixtures with higher concentrations of biobutanol would, however, require additional testing and registration with EPA. That process could take several years.

In the meantime, blended at 11.5%, biobutanol's share of the 140-billion-gallon annual U.S. motor fuels market would be nothing to sneeze at. And a healthy tax incentive on the way from Congress should help spur it along. (See our related story on coming energy legislation on page 4.) ■

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Industry Consolidation

Ethanol Market Headed for a Soft Patch

By early next year, ethanol supplies are likely to outstrip demand—or, more precisely, to outstrip current capacity to blend ethanol with gasoline. Until more refiners develop the necessary infrastructure and logistics, suppliers will face a buyers' market and softer prices. And that is sure to spark more consolidation in the industry.

The likelihood of lower ethanol prices, at least over the short term, are dampening the expectations of current plant owners. As a result, price tags on existing ethanol production facilities are falling. Purchasing a plant just a few years ago typically cost \$4 to \$5 per gallon of capacity.

Not so today. In late May, for example, **US BioEnergy Corp.** (USB) of St. Paul, Minn., acquired closely-held **Millennium Ethanol, LLC** for about \$2.25 per gallon of annual production capacity. Millennium is constructing a 100-million-gallon-a-year ethanol plant near Marion, S.D. It's expected to begin production in the first quarter of 2008.

Increased construction costs also play a role. A few years ago, the average cost of building a new ethanol plant ran around \$1 per gallon of annual production capacity, and the buy vs. build debate for companies wanting to expand was a no-brainer. But increased costs for materials and labor make it a tougher call.

For example, **Aventine Renewable Energy, Inc.** (AVR) of Pekin, Ill., recently disclosed a contract with private construction firm **Kiewit Energy Company** of Houston to build two new ethanol plants, one in Mt.

Vernon, Ind., the other in Aurora, Neb. Each will have a capacity of 113 million gallons and each will cost about \$2 per gallon of annual production capacity. Add in the benefit of not having to hassle with permits, the appeal of purchasing an existing facility is obvious.

Most of the companies doing the gobbling up are likely to be mid-sized "pure-play" ethanol producers—**Pacific Ethanol, Inc.** (PEIX), **VeraSun Energy Corp.** (VSE) and others that produce ethanol exclusively. Most of those being gobbled up will be small outfits with a single plant or two.

The largest firms with diversified interests, such as **Archer Daniels Midland Co.** (ADM), **MGP Ingredients, Inc.** (MGPI) and **Bunge** (BG), may be less inclined to beef up their stake in the ethanol market by buying existing plants, which for the most part coproduce ethanol and distillers dry grains (DDG). Sharply increased supplies and lower prices for DDG in coming years will curb the appeal.

To help you keep abreast of the biofuel industry's financial health, we've pulled together key financial data on a selection of publicly traded companies with significant interests in the field. The table, which will be a regular feature of Kiplinger's *Biofuels Market Alert*, includes recent share prices, market value, returns and price/earnings ratios, as well as a summary of analysts' recommendations. We'll look at a variety of different companies—from small to large, pure-play and diversified—over time. ■

		Analysts' Recommendations (June/3 months ago)					Key Facts for Selected Publicly Traded Biofuels Companies										
Company	Symbol	Strong Buy	Buy	Hold	Sell	Strong Sell	Share price (as of 6/29/07)	Market value (as of 6/29/07)	Earnings Per Share (last 4 quarters)	Revenue (last 4 quarters)	P/E ratio' (as of 6/29/07)	Total Returns %					
												Past 3 months	Past year	Past 3 years			
The Andersons	ANDE	1/3	2/2	4/2	0/0	0/0	\$45.33	\$821M	\$2.7	\$1.69B	18.80	4.10	9.40	442.80			
Archer Daniels Midland Co.	ADM	3/2	4/4	4/1	1/1	0/0	33.09	21.12B	2.4	41.68B	13.50	-10.00	-23.80	108.70			
Aventine Renewable Energy	AVR	2/1	3/5	7/8	1/0	1/0	16.97	656M	1.3	1.68B	16.60	-9.50	-60.10	NA			
Bunge	BG	0/0	3/3	6/5	0/0	0/0	84.50	9.84B	4.0	29.74B	18.90	1.20	68.07	115.40			
Dyadic Int'l	DIL	0/0	0/2	2/0	0/0	0/0	5.33	158M	NA	NA	NA	-15.30	1.30	-15.20			
Green Plains Renewable Energy	GPRE	2/2	1/1	0/0	0/0	0/0	17.57	103M	0.1	0	34.40	-17.10	-50.94	-85.48			
Pacific Ethanol	PEIX	2/2	1/3	6/6	1/0	2/1	13.20	519M	0.1	343.9M	46.70	-17.90	-50.00	NA			
US BioEnergy Corp.	USB	1/1	2/0	2/2	0/0	0/0	11.36	753M	1.0	474.4M	21.60	-3.30	NA	NA			
VeraSun Energy	VSE	2/4	2/1	9/11	2/1	3/0	14.48	1.03B	0.8	607.1M	34.30	-47.30	-3.00	NA			
Verenium Corp.	VRNM	1/1	1/1	1/1	1/1	0/0	4.88	246M	-0.1	52.9M	NA	-34.80	-40.90	-55.90			
							Source: Thomson One Analytics via Yahoo Finance					*Based on the current year's earning estimate.			Source: Thomson One Analytics		

More Help Coming from Congress

The comprehensive energy legislation Democratic congressional leaders envisioned earlier this year is dead, done in by fighting within the party's ranks. But one way or another, the biofuel industry is likely to come out of this congressional session singing hosannas. Odds are lawmakers will OK a slimmed down version of an energy bill, including more goodies for biofuels by early fall. But even if that fails, an extension of current tax credits for the industry, due to expire in 2010, will be wrapped into tax legislation that becomes law by the end of the year.

Look for lawmakers to greatly expand biofuels production incentives, stipulating a new renewable fuels standard of 35 billion gallons—roughly 20% of the estimated U.S. motor vehicle fuels market—by 2022. Just two years ago, lawmakers embraced a standard requiring just 7.5 billion gallons of ethanol or biodiesel be used in U.S. vehicles by 2012.

In doing so, Congress will bet big that technological breakthroughs will allow much of the required renewable fuels to be something other than corn-based ethanol. To help jump start that process, coming legislation is likely to include an additional 50¢-a-gallon federal tax credit for cellulosic ethanol, made from switchgrass,

sawdust, waste or other lignin sources. The credit will be on top of the current 51¢-a-gallon credit for all ethanol.

In addition, a new \$1.10-a-gallon tax credit for biobutanol made from cellulosic sources will also get the nod. The biobutanol credit would sunset in 2010, along with its cousins. And as with its cousin credits for biodiesel and ethanol, an extension is all but certain.

Other alternative energies that are headed for approval by lawmakers: A two-year extension from 2008 to 2010 for various tax credits to build commercial wind, solar and fuel cells for sale to electricity utilities. A juicier tax incentive for solar, air and water heating systems, with the probable elimination of the current \$2000 cap on credits for solar, air or water heaters. In addition, both the solar energy credit and credits for the purchase of a hybrid vehicle can offset the alternative minimum tax.

Lawmakers are also enthusiastic about toughening up minimum auto fuel standards, raising them to an average for all vehicles of 35 miles per gallon. And they'll quit encouraging the purchase of large SUVs. After 2007, only vehicles weighing more than 14,000 lbs. will be eligible for the \$25,000 tax write-off. It now applies to SUVs weighing as little as 6000 lbs. ■

Playing Politics

Food Vs. Fuel Fight Heating Up

A new study on the impact of ethanol production on food prices is good news for the biofuel industry. Concluding that petroleum prices pack about twice the punch as an equivalent increase in corn prices, the study, by consulting firm LECG LLC, provides the ethanol community with valuable ammunition against attacks by critics.

While that's news to gladden the heart of ethanol devotees, it won't silence critics of the corn ethanol boom, who point out that rising feed prices have spurred producers to trim poultry flocks and livestock herds and that consumer prices are on the rise for milk, poultry and other products. With price hikes for food and beverages expected to accelerate a bit this year to about 4%, you can expect the rhetoric—and dueling studies—to escalate.

According to John Urbanchuk, the study's author, a 33% increase in crude oil prices, translating into a \$1-per-gallon increase in the price of conven-

tional regular gasoline, results in a 0.6 %-to 0.9% hike in the CPI for food. An equivalent jump in corn prices of \$1 a bushel (from about \$3 a bushel to \$4 a bushel) would cause the CPI for food to increase only 0.3%.

The study is just the latest foray in an increasingly heated public relations struggle between supporters of ethanol and those who argue that government ethanol production incentives are stunting the corn supply at the expense of livestock and poultry producers and others. They want to see a limit on how much ethanol made from corn or other grains is eligible for federal tax credits.

As it is, the study came out at a particularly useful moment for the biofuel industry, shortly before Congress tackled comprehensive energy legislation. The LECG study, which was commissioned by the Renewable Fuels Association, can be found at: kiplinger.com/biofuels/links/foodfuelstudy. ■

Closed-Loop Plants

Making More Green from Ethanol and Ethanol More Green

“Closed-loop” ethanol plants have a secret weapon. Not only can they make ethanol cheaper than today’s plants using conventional methods, they’ll also help the nation’s livestock industry comply with what are likely to be increasingly strict environmental regulations in coming years. Those two advantages could give operators of such plants a distinct edge, helping to make them commonplace in coming years.

One such plant is already in operation. At least four others are in the works. All rely on the same basic formula: Combining a livestock feedlot with a biogas production facility and an ethanol refinery in a system that generates its own power, creates much of its own livestock feed and produces ethanol for sale.

Although the upfront costs of building such closed-loop plants are about 50% more than those of conventional plants, their operational costs are significantly lower. **E3 BioFuels**, a private company in Shawnee, Kan., which recently opened the first such plant, says that it cost nearly \$3 per gallon of annual production capacity. That compares with costs of roughly \$2 per gallon of capacity to build a conventional ethanol plant.

But the biogas made from the cattle manure eliminates the need to burn fossil fuels to make the ethanol. And locating feedlots, fuel facilities and biorefineries in close proximity both saves on transportation costs and allows the distillers grains coproduced with the ethanol to be fed to the cattle wet, cutting out the expense of drying the grains. “It’s those little efficiencies that when added together really make the difference between success and great success,” says Craig Scott, the vice president of capital markets for **Bion Environmental Technologies** (BNET).

Located in Mead, Neb., the 25-million-gallon E3 BioFuels plant has been producing ethanol since April, though it officially opened in June. The anaerobic digester, which processes manure from the operation’s 28,000 head of cattle, has been online since December 2006 and currently produces about 125% of the energy needed to run the plant. That saves the company about \$7 million in annual natural gas costs, according to company spokesman Nathan Dayani. “Right now, the biogas results have been very encouraging and we do not believe that fossil fuels are going to be needed for the production of ethanol,” he says.

Bion Environmental Technologies, based in New York, is banking not only on the economic advantages a closed-loop system builds in, but also on its environmental bene-

fits. The company has released detailed independent analyses of its proprietary system, which converts most of the organic matter in the manure into solids, or stabilizes it in particulate form. This microaerobic process prevents most of the pollutants from escaping into the air and water, while creating a solid fuel that can be burned on site or transported for use elsewhere.

With the EPA working on new, more stringent regulations to reduce the runoff from concentrated animal feeding operations, Bion’s technology or others like it should become even more appealing. EPA also is considering regulating for the first time feedlot air emissions, which include ammonia, methane, volatile organic compounds, hydrogen sulfide and particulates. Closed-loop systems can minimize such emissions.

Bion is negotiating with business partners and municipalities in upstate New York, Indiana, Nebraska and Oregon to build closed-loop ethanol plants, based on this technology, near beef and dairy cattle feedlots. The company says it’s at least a year away from opening its first plant.

A third company, **Panda Ethanol Inc.** (PDAE) of Dallas, Texas, is using gasification technology that employs a fluidized-bed gasifier. The cattle manure is fed into a bubbling sand bed, kept at a relatively low heat to accelerate the decomposition of the manure. As it decomposes, the organic material releases a synthetic

gas that rises to the top of the fluid-bed combustor and is burned for ethanol production. Panda plans four such closed-loop ethanol plants. The first, a 100-million-gallon-a-year plant under construction in Hereford, Texas, is slated to come online in the fourth quarter of this year.

XL Dairy Group of Phoenix, Ariz., has in mind an integrated ag-industrial complex on a 307-acre site about 100 miles west of Phoenix. In phase one, the company plans to use the waste from up to 7,500 dairy cows to produce 100 billion gallons of ethanol, 25 to 30 million gallons of biodiesel fuel and 21 million gallons of milk a year. XL Dairy Group expects to complete this first phase by the end of 2008. A second phase that would more than double the output could be running in about five years.

Further down the road, closed-loop plants could bypass the cattle manure method altogether, instead trapping methane gas from landfills. That would allow ethanol plants to be built closer to end users on the populous East and West coasts, further saving on transportation costs. ■

“It’s those little inefficiencies that when added together really make the difference between success and great success.”

BUSINESS BRIEFS

Mutual fund firm Calvert has launched a new fund dedicated to alternative energy investments and related services and technologies. The **Calvert Global Alternative Energy Fund (CGAEX)** was developed to accommodate investors' concerns about global climate change as well as their desire to profit from this developing sector over the long term.

Synthetic Genomics Inc. and **BP (BP)** have entered into a long-term research and development deal aimed at cleaner energy from traditional fossil fuels. Research will focus on the microbial communities in hydrocarbon formations like oil, natural gas and coal.

Pacific Ethanol (PEIX) is seeking SEC approval to sell up to \$250 million of stock. The company says the proceeds of this pending transaction will be spent on ethanol plant construction and acquisitions of ethanol production assets, as well as investment-grade, interest-bearing securities.

Earth Biofuels, Inc. (EBOF) and **Revolution Biorefining, LP** are planning a new venture, called Earth Revolution, which aims to produce cellulosic biofuels in commercial quantities. The venture intends to use a modular, portable refining system designed to bring the plant to the biomass source rather than the other way around. The partnering companies say the innovative production system will be cheaper and easier than figuring out the logistics of transporting and storing perishable biomass feedstocks. The deal was expected to be finalized at the end of May but remains open.

Kreido Biofuels, Inc. (KRBF) and **Vopak North America, Inc. (VOPKF)** have inked a long-term agreement for Vopak to provide transportation and storage of Kreido's biodiesel, glycerin and raw feedstocks. Vopak will also oversee construction of the liquids pipeline between Kreido's facility and Vopak's terminal located in the Port of Wilmington, N.C.

SE-Energy Technology, a California biodiesel company, is planning a new plant and storage facility on a 44-acre site near Norfolk, Va. With a production capacity of 320 million gallons a year, the plant would be the largest in the U.S. The plant, which will use jatropha oil as a feedstock, will operate as Virginia Point Biodiesel and is expected to open by March 2008. The site's location near major naval installations is intended to capitalize on the U.S. Navy's goal to use a blend of 20% biodiesel fuel. Cost for the plant plus the 42-million-gallon storage facility is estimated at \$532 million.

Panda Ethanol Inc. (PDAE) intends to sell \$140 million worth of senior notes that can later be converted into common stock. This offering will fund the development and construction of its ethanol plant in Yuma, Colo.

RESEARCH AND TECHNOLOGY

A new corn variety that produces its own enzymes for use in the fermentation process will allow the whole corn plant, including cellulosic material, such as stalks and other plant waste, to be used in ethanol production. **Agrivida**, the privately funded plant-engineering firm that developed the variety, says the enzymes remain dormant until harvest.

Biodiesel can be engineered to last longer by protecting the methyl ester bonds with a catalytic process, says **International Oil and Gas Holdings Corp. (IOGH)**. The company says that its process allows biodiesel to be stored and transported up to year longer than usual, depending on temperature conditions. The process also reduces microbial attack within the fuel.

Cookies made from distillers dried grains? U.S. Department of Agriculture researcher Kurt A. Rosentrater and his team are studying the feasibility of making human food from dried distillers grains with solubles (DDGS). Rosentrater says that, so far, their findings show that DDGS has promise as a flour substitute as well as a biodegradable filler and protein alternative. For more information, visit: kiplinger.com/biofuels/links/substitutes.

Researchers are hot on the trail of another biofuel. Scientists at the Pacific Northwest National Laboratory say they have developed a more effective way of converting glucose to 5-hydroxymethylfurfural or HMF, a primary building block for the production of fuels and plastics. The next step: Increasing HMF yield while preventing chemical separation and holding costs down.

Three new bioenergy research centers are coming, funded by \$125-million grants from the Department of Energy. Work will begin on the Bioenergy Science Center in Tenn., the Great Lakes Bioenergy Research Center in Wis. and the Joint Bioenergy Institute in Calif. in 2008. All are expected to be operational in 2009. A big focus of the centers is cellulosic ethanol—developing new ways of deconstructing cellulose, reducing cellular resistance to breakdown, developing new crops for use as biomass feedstocks and consolidated bioprocessing, among other things.

E. coli bacteria can turn glycerin into ethanol, say scientists at Rice University. They've identified a strain of the deadly bacteria that efficiently converts glycerin, a coproduct of biodiesel production, into an in-demand biofuel. The technology would help solve a growing glycerin glut. Many companies that used to be able to sell the chemical must now pay for its disposal, according to the Rice researchers. What's more, the technology they have developed allows the production of ethanol from glycerin at a cost that is 40% less than traditional production of ethanol from corn.