
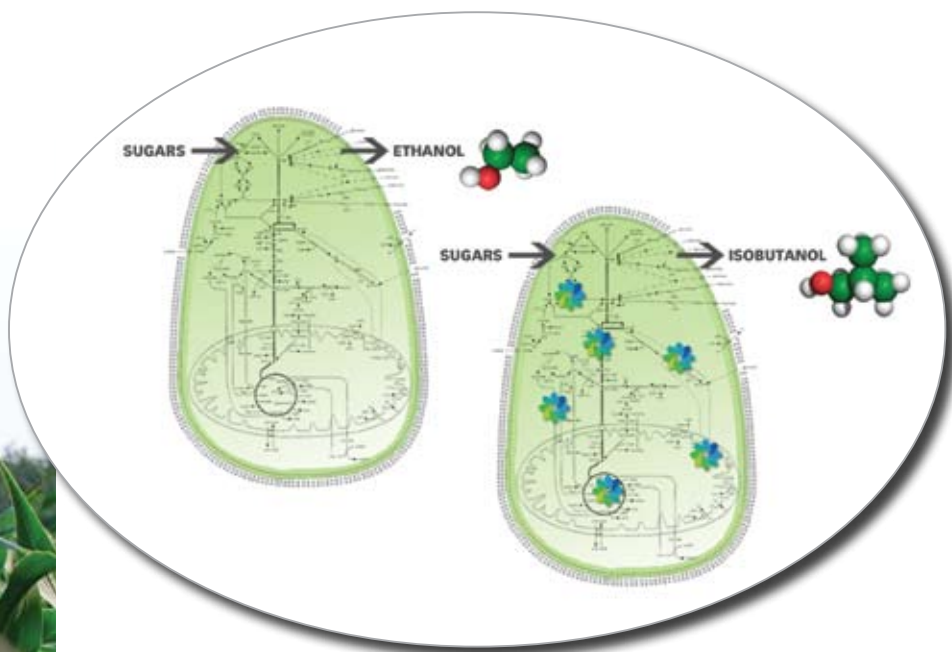


Target For Transformation



Tools for Transformation Butanol producers seeking to transform the ethanol industry are employing a variety of production methods. Gevo Inc.'s method, shown in the diagram above, utilizes biotechnology to replace metabolic pathways in a robust yeast biocatalyst to produce isobutanol instead of ethanol.

DIAGRAM: GEVO INC.



Can biobutanol provide ethanol producers new paths towards diversification?

BY KRIS BEVILL

Given the steady stream of adaptations and advancements made by ethanol producers just since the renewable fuel standard was updated in 2007, attempting to pinpoint one 12-month period as particularly transformational could be futile. Consider, however, the nonexistence of a blenders tax credit for the first time in 30 years, combined with an industry at a blendwall, and it doesn't take much crystal ball gazing to predict that 2012 could be the turning point—the year the industry begins to transform into its future self.

Diversification has been a topic of interest for some time now, but this is the year producers need to move toward incorporating alternative revenue streams into their operations. High on the list of contenders is biobutanol. It offers producers the opportunity to squeeze another product out of existing corn-ethanol facilities or to entirely convert their operations to produce a fuel with chemical and transportation applications. It's not likely to push ethanol out of the transportation fuels market anytime soon, if ever, but it has potential as a gasoline additive or in the chemicals market. Several companies poised to aggressively court the ethanol industry this year say the time is right for ethanol producers to welcome this four-carbon fuel into their stable and transform their facilities from ethanol plants to advanced fuel biorefineries.

Playing Host

Rather than building free-standing facilities, several biobutanol companies would prefer to piggyback on the existing infrastructure, workforce and feedstocks offered by ethanol producers.

The BP and DuPont joint venture, Butamax Advanced Biofuels LLC, has formed an Early Adopters Group for existing ethanol producers who sign on



PHOTO: GEVO INC.

First Converter Gevo Inc.'s first commercial-scale butanol production facility is a former ethanol plant located in Luverne, Minn. The facility is expected to begin production this year.

to collaborate on isobutanol retrofits. Its first taker was Lamberton, Minn.,-based Highwater Ethanol LLC, which signed a letter of intent in December to potentially retrofit its 50 MMgy corn ethanol plant. Calling biobutanol “the next step in biofuels,” Highwater CEO Brian Kletscher said shortly after the announcement that butanol has the potential to be a drop-in fuel that can be utilized nationwide and will allow Highwater to remain a leader in renewable fuels production. His company signed with Butamax because it offers new technology and the engineering resources necessary to complete retrofit operations, Kletscher said. It will be 2013 before retrofitting begins, but Butamax suggests it could produce at a commercial scale in 2014.

Colorado-based Gevo Inc. has partnered with ethanol engineer-

ing masters ICM Inc. to also take the total retrofit approach. Gevo expects to begin producing isobutanol this summer from a 22 MMgy corn-ethanol plant in Luverne, Minn., purchased in 2010. Once the retrofit is complete, the facility will have a butanol capacity of 18 MMgy, but isn't expected to approach full-scale production until the second half of this year. Gevo has also signed a joint development agreement with South Dakota's 50 MMgy Redfield Energy LLC and is retrofitting that facility to produce 38 MMgy of isobutanol when complete. Gevo anticipates beginning production there sometime in 2013.

U.S.-based Green Biologics Inc., the newly announced merger between Ohio's butylfuel Inc. and UK-based industrial biotechnology company Green Biologics Ltd., is taking a slightly different approach to the ethanol-butanol relationship. It is seeking to partner with ethanol producers to either retrofit their plants or to bolt its n-butanol production capabilities onto existing facilities. The company had not yet announced ethanol partners as of late January but Joel Stone, president, North American, and global vice president of engineering, says several ethanol producers have shown a “high degree of interest” in the concept because it would allow ethanol production throughout the bolt-on process, rather than requiring a temporary shutdown for retrofits. Ethanol producers will be allowed to determine what amount of ethanol and butanol output they would like from the finished plant. For example, a 100 MMgy ethanol plant could choose to produce 90 MMgy of ethanol and divert between 10 and 20 percent of its corn intake to the butanol stream, lessening pressure on the ethanol blendwall and adding diversity to the plant's revenue streams, he says.

The co-located butanol facility would license Green Biolog-

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ics' technology, which Green Biologics would own, operate and serve as marketer. Stone says that is another benefit for ethanol producers if they participate as an investor. They don't have to learn a new market or product; they'd be required only to supply feedstock and serve as the host facility. Green Biologics is also exploring building its own facilities, but Stone says they will be aggressively courting ethanol producers to host butanol facilities first.

Plus Side

Developers are more than willing to share the benefits of butanol compared to ethanol. While the ethanol industry is still struggling to make E15 legally available for sale, butanol can currently be blended at up to 12.5 percent by volume. At this level, it is defined under the Clean Air Act as being "substantially similar" to gasoline, which means it can

be used in gasoline infrastructure, including pipelines and retail dispensers, without modifications. Additionally, because the Energy Independence and Security Act of 2007 declared that isobutanol has 30 percent more energy than ethanol, producers generate 1.3 renewable identification numbers (RINs) per gallon of isobutanol compared to 1 RIN per gallon of ethanol.

One of ethanol's most well-known, albeit not insurmountable, flaws is its affinity for water. This phase separation issue is nonexistent for butanol, according to companies like Gevo, which, in a white paper addressing many of the differences between the two fuels, stated that butanol acts more like a hydrocarbon when introduced to water in a fuel blend, thereby avoiding any dilution of the gasoline's octane and reducing or entirely eliminating any operational issues related to water content.



PHOTO: GREEN BIOLOGICS LTD.

Existing Example Green Biologics Limited is currently retrofitting three facilities in China to produce n-butanol using a variety of feedstocks.



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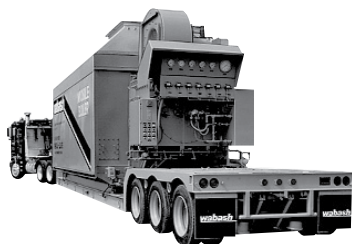
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| | ETHANOL | ISOBUTANOL | GASOLINE |
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| Blend Octane (R+M)/2* | 112 | 102 | 87 |
| Blend RVP (psi)* | 18-22 | 4-5 | 7-15 |
| Oxygen Content (%) | 3.5% | 2.7% | 0% |
| Net Energy (% of gasoline) | 65 | 82 | 100 |
| Compatible with pipelines, gasoline pumps, and all engines | NO | YES | YES |

*Blend values were measured at 10% ethanol in gasoline and 12.5% isobutanol in gasoline.

What's the Catch?

For all of its benefits, there are also multiple issues left to be resolved before butanol can stake its claim as being a widely used gasoline additive. For example, as ethanol producers know, the U.S. EPA allows fuel containing 9 to 10 percent ethanol to exceed the 9.0 psi Reid vapor pressure (RVP) limit by 1 pound during summer months. Because the waiver strictly applies only to E9 or E10 blends, if butanol-blended fuel were to be added to a storage tank containing E10 in the summer months, diluting the overall ethanol content to less than E9, the fuel would violate EPA regulations if the RVP is greater than 9.0 psi. This puts would-be suppliers of butanol blends at a disadvantage because they would likely need to store that fuel and ethanol-blended fuel in separate tanks in order to avoid potential compliance issues. "If I go to my local fuel station and buy a truckload of E10 and the next day I buy a truckload of B12.5, I cannot pour that truckload of B12.5 into the E10 that's already in the tank because it will reduce the volume of ethanol in the tank to less than 9 percent," explains Glenn Johnston, vice president of regulatory affairs at Gevo. "Thus, even though the two fuels separately are perfectly legal in commerce, when you mix them together in an underground storage tank they would be illegal. It's a complexity in the compliance that we are working with EPA to resolve. It

has nothing to do with the emissions criteria or the cleanliness. It has everything to do with how the EPA enforces the fuel and fuel additives underneath the Clean Air Act in commerce."

Butanol producers also need to register their fuel with the U.S. EPA before it can be introduced for sale in the marketplace. The registration process requires the producer to disclose the fuel additive's chemical composition and to describe an analytical technique that can be used to detect the presence of the additive in the fuel. The applicant must also complete various tests to analyze evaporative emissions, to screen for potential health effects from emissions and to provide other scientific information related to the fuel. In October 2010, Gevo successfully registered its product as a small business and is working now on completing the Tier I and Tier II registration with the EPA. Butamax says it expects to complete the registration process on a timeline consistent with its plans to produce commercially in 2014.

Not Just a Fuel

Finally, butanol producers must overcome the cost of production in order to be a competitive player with ethanol. As with every second-generation biofuel, production costs are currently higher than for first-generation ethanol. However, while ethanol's mainstay is in the transportation fuels market, butanol

producers can easily venture into the chemicals market, where the cost of production suddenly becomes much more manageable. As a testament to this, Gevo has committed most of its production capacity for the next two years to Sasol Chemical Industries Ltd. Green Biologics will initially sidestep the fuels market entirely in favor of chemical production. "Why use butanol for a fuel when it can be marketed as a higher value chemical?" asks Stone. He says that while butanol holds great potential as a fuel, it still needs to overcome some of the same regulatory issues ethanol faces. Meanwhile, the chemical applications are well-known and represent a 10 billion-pound-per-year market for the n-butanol Green Biologics plans to produce. So, as is the case for many potential biorefiners, Stone says it is a wiser choice to produce butanol for chemical markets initially so that plants can capture the most profit while working to drive the price of butanol-for-fuel production down to more competitive levels. This will allow entry into the bio-fuels markets when demand and economics are matched, he says.

Niche Market

Gevo believes that while chemical markets represent a profitable venture for butanol production, there is also great potential for it to be used in segments of the transportation fuel market that currently hold issue for ethanol, namely marine and small engine equipment. Not all of Gevo's initial production volume will be sold to Sasol because it wants to have enough to also seed the marine fuel market and other specialty applications that have tested well using butanol. "I would anticipate that could be one of the first markets you'll see us in—a local marina, if you will—supplying an option for the marine market that would be better than their option of ethanol-blended gasoline," says Brant DeMuth, executive vice president of strategy and corporate development for Gevo. "The marine group has been very supportive because of their work on testing our blendstocks with E15 and the better performance, quite frankly, that they got out of isobutanol-blended fuel." Gevo supplied isobutanol for testing

on marine and small engines last fall that showed promising results. The National Marine Manufacturers Association and the Outdoor Power Equipment Institute both stated isobutanol-blended fuel performed better in those types of engines than E15 and indicated it could be a viable biofuel alternative.

Why Try?

Despite the regulatory hurdles and initial cost to produce, butanol producers are confident that the ethanol industry will agree its value is worth the effort. Stone even envisions a production model that would allow ethanol plants to produce their own 100 percent, bio-based E85 by replacing petroleum-based gasoline with butanol. "If you have a bolt-on butanol plant and you produce butanol using 15 percent of the corn volume, you could produce E85 with butanol and sell it directly to your regional distributor," he suggests.

Gevo executives say ethanol producers will likely relish the opportunity to produce a product that can be sold to markets without the same volatility experienced in the ethanol market. DeMuth says that was a selling point for the Redfield, S.D., plant. "They've made good money in good times and they've lost money in the challenging times, despite being one of the best operating plants in the U.S.," he says. "They looked at the isobutanol opportunity to reduce the volatility of their profit margin, but also to expand the profit margin. Even when split with Gevo, they have the opportunity to make more money selling into that specialty chemical market than they would otherwise have had selling into the fuel market. It opened up new markets, potentially higher margins and, equally importantly, less volatility of those margins, which is why they agreed to the joint venture terms that we have with them."

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