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Aquatic Biomass in the Gasification Equation

Utilizing a technology developed at the U.S. DOE's Pacific Northwest National Laboratory, Utah-based Genifuel Corp. is working to gasify aquatic biomass into natural gas for use in pipelines and power generation.

by Anna Austin

In the world of biofuels, algae are typically associated with biodiesel production. While numerous companies are working to break barriers associated with commercial-scale algal biodiesel production, Pacific Northwest National Laboratory and Genifuel Corp. have embraced algae, or aquatic biomass, for a different purpose—natural gas production.

The companies are working to perfect a catalytic gasification process, which PNNL recently granted Genifuel an exclusive license for, and to develop a technique to efficiently grow and harvest aquatic biomass for use as a feedstock.

The companies think their process, which was originally developed as a technique to clean up industrial and food processing waste as an alternative to incineration, will be more efficient than other methods of gasifying biomass.

Now, it's just a matter of maintaining funding while fine-tuning and scaling up the system to prove it can be commercially viable.

A Different Application
PNNL's research began with a slightly different impetus than other algae projects—to develop an organic wastewater treatment/clean-up system, says Doug Elliot, the PNNL scientist who invented the gasification process.

"When we started trying to do biomass gasification the intent was to look at the mechanisms and capture intermediates in the catalytic gasification," he says. "We found that when we ran in this direction, rather than capturing water solutions for the organic intermediates, we actually did a pretty effective gasification."

The PNNL team then spent a number of years working on a wet biomass gasification system, but lost funding and continued to work on different organic wastewaters for the clean-up system. The important component of the system is that it's a simple one-step catalytic process, but it's also somewhat complex because it's a high-pressure hot water system, according to Elliot. "We pump solutions of organics and waters, sugars or slurries—solid biomass ground into a fine particle size— into the catalyst bed," he says. "Water comes out the other side, and the organic material is broken down through the catalyst into methane and carbon dioxide. In a short version, that's about it—a hot slurry solution is pumped at high pressure through a catalyst bed, and out comes clean water and fuel gas."

Elliot points out that when using biomass, while there are clean organics in the water, there are also mineral components—in some cases sulfur in the biomass proteins—which can contaminate the catalyst. "An incorporation of preliminary steps for mineral matter removal and sulfur trapping are built into the system, as part of the heat-up process before the organic material and water go into the catalyst bed to be gasified," he says.

The PNNL gasifier runs at relatively low temperatures—350 degrees Celsius (662 degrees Fahrenheit)—in a stainless steel reactor.

Scale-Ups, Yields and Challenges
PNNL tested the system at several scales, ranging from a 30-milliliter reactor used for long-term testing

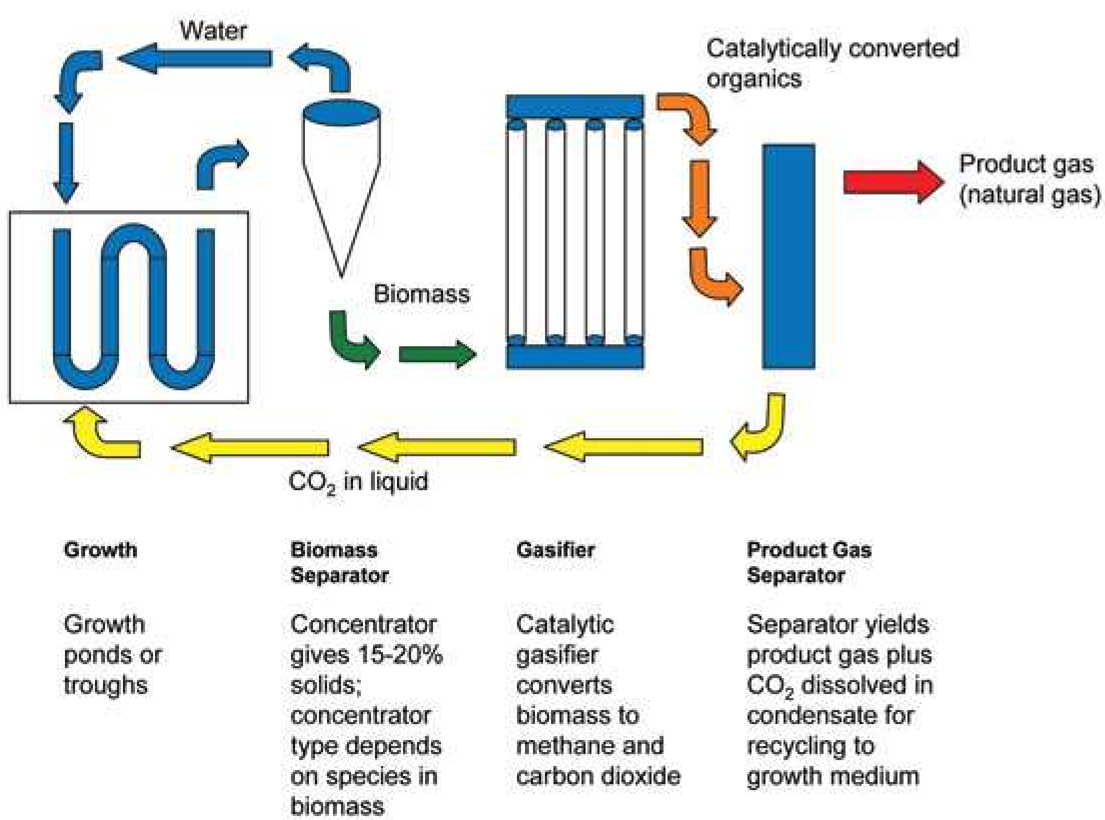
and catalyst lifetime proofing, to a bench-scale unit with a 1-liter catalyst bed and to a mobile, 4.4-liter trailer-mounted unit which can be taken on-site for testing to process approximately a quarter-ton of slurry per day.

These tests have indicated that the process is quicker and higher yielding than other biomass gasification methods, namely, anaerobic digestion. “What we’ve done is compare our conversion rates with anaerobic digestion to biological processing,” Elliot says. “Our system seems to run 300 to 400 times faster, but what you’re comparing is a small, high-pressure stainless steel reactor with a catalyst in it, to very large vats and tanks used in anaerobic digestion. The capital costs would be as much or more, but the footprint is much smaller.”

Another superior characteristic of the system is that with the catalysts and conditions used, nearly all of the aquatic biomass material is broken down. “In the water coming out the tail end of our process—some of the recent runs we were doing with lignocellulosic ethanol residues—the chemical oxygen demand was at about 200 parts per million,” Elliot says. “We can get 99 percent conversions of the organic material to gases coming out the other side, as opposed to 60 percent to 70 percent for an anaerobic system.”

The higher conversion rates can be attributed to the fact that the catalyst is not as selective as the biological systems, and can tear apart all types of organic functional groups. “It’s broadly applicable to chemical wastewater, as well as biomass, because we’ve shown that we can tear apart most chemical functional groups, certainly carbon, hydrogen and oxygen-containing materials,” Elliot says. “If there’s nitrogen in the structure, we’ve shown that it primarily comes out as ammonia in the water; sulfur we have to trap out so it doesn’t show up anywhere in the outlet streams.”

As is the case with the development of any new technology, there are challenges. In this case, it’s a matter of money. “We’ve gotten to a point where we thought we were ready to advance, to make a connection in an area—for example biomass—and move into continuous processing, but the government money went away,” he says. The biggest issue is the uncertainty of the process and because it’s an entirely new way of doing things, Elliot says. “On the biomass end, we’ve developed these pretreatment steps and we think we have these in hand now, so we’re moving forward,” he says. “It’s just been a matter of finding the right partners in the algae area—and now Genifuel is going to do that.”



Catalytic gasification of aquatic biomass with recycling of CO2 (no greenhouse gas emmissions)

Evaluating Cost
Determining the exact cost of a system isn't easy, according to Elliot, because it depends on varying factors—the specific application, what kind of feedstock is used and what concentration, as well as the intended use of the gas. "In 2004, we did a study and found that if we were to receive the residues from the spent grain from ethanol, a zero-cost feedstock, we would be able to produce a natural gas equivalency of about $5 per million Btu, and that was just barely interesting five or six years ago," Elliot says. "Of course, it looks a lot better now. We've done another study recently, in applying it to the lignocellulosic ethanol residues, and in that case we've predicted that our capital costs would be about 17 percent less than the capital required for the various pressing, drying and combustion systems that are drawn on paper for the lignocellulosic ethanol plants."

Elliot says the PNNL team is hopeful that they will soon be able to show the technology to people in the marketplace. "Application to chemical waste streams will probably come sooner because that's more of a question of disposal costs," he says. "A company we're working with now incinerates the water because it's too toxic for biological systems, yet only being about 10 percent organics in the water, you can probably guess it takes a lot of energy just to incinerate—to boil all the water—so our system is a better option for them. It's just a matter of getting over the risk; being the first one to build the plant is a tricky thing."

On the feedstock side, Elliot says cost is again an issue, and that's where Genifuel comes into play. For the past three years, the Utah-based company has been developing a low-cost system to grow and harvest aquatic biomass. "They're developing the algae part and we're doing the gasification—it's definitely a good partnership," Elliot says.

A Unique Approach
Genifuel CEO Jim Oyler says the company may seem relatively young, having been formed in 2006, but it is actually one of the earliest companies to start using nonagricultural crops to produce ethanol and biodiesel. "We're focusing on biofuels from nonagricultural products," he says.

Oyler says the feedstock Genifuel grows can more accurately be described as aquatic biomass, rather than algae. "It seems like a real technical difference, but there are a variety of aquatic species that can supply the biomass," he says. "For example, cyanobacteria, which are not actually algae but a bacterium, and there are other aquatic materials such as diatoms. We refer to it as aquatic biomass, though most call it algae."

Genifuel's technology platform involves the outdoor growth of aquatic biomass, in what the company calls "Genifarms." "These kind of aquatic species grow anywhere, in any climate," he says. To achieve the best and cheapest growth, however, consideration of cost-related economics is critical when choosing where to grow aquatic biomass. "You'd actually like a warm, humid climate with relatively easy access to water supplies, and so it probably is not optimum to grow aquatic biomass in the Northern U.S. or Canada; it's more optimum in the Southern U.S.," he says. "We're currently growing and harvesting [aquatic biomass] outdoors, on a relatively small scale, but we're growing enough to make some substantial runs with the gasifiers that PNNL developed. We do that to gather additional data, and make design improvements to the gasifiers."

Genifuel tried using algae to make biodiesel but soon gave up. "It's a very difficult process with a lot of problems—all of which can be solved, but all of which make it expensive," Oyler says. The company concluded that algae-based biodiesel wasn't going to be profitable because it's difficult to harvest. "The biodiesel approach requires algae that can make oil, which can then be converted into diesel fuel," Oyler says. "The species that make algae oil are very small cells. They are all unicellular, on the order of five microns, which is small and therefore hard to harvest. With our approach, we're not trying to make oil or biodiesel. We're gasifying the entire biomass to try to make natural gas."

By not worrying about extracting the oil, a huge restraint is removed, Oyler says. "That allows us to select bigger species that are easier to harvest, with very simple technology and machinery, or even by hand," he says.

Key Considerations
When growing algae outdoors, the focus must be on high growth rates and low costs, Oyler says. "If you're going to try to make fuel, you have to have low costs. One of the well-kept secrets of alternative energy in general—and it doesn't matter if it's wind, solar or biofuels—is that technologies are more

expensive than in fossil energy, and usually by a factor of two times, or even five times," he says. "The only way today to make any alternative energy viable is to have government involvement, either through subsidies or tax credits, or raising the price of other energy."

The cap-and-trade legislation being developed today has the effect of raising the cost of fossil energy, but alternative energy is more expensive than fossil energy and therefore emphasizes the importance of further reducing the cost of alternative energy, from Oyler's perspective.

Cost is critical if biofuels are going to make a significant contribution to the energy economy of the future. "Some people attempting to make biofuels from aquatic biomass or algae are using closed, indoor systems or artificial lights or photobioreactors," Oyler says. "In our experience, that's never going to work. It's way too expensive." He says the most cost efficient and simplest way is using open outdoor ponds or channels of water.

It's also important to economically get as much oil from the algae as possible. Algal oil typically yields 20 percent to 30 percent oil. "Some people talk about yields twice that high, but it's not economic," Oyler says. "You usually get 20 or so percent, maybe 30 percent oil, where our system gets almost a 100 percent conversion. When we realized this route, we decided to look for a way to get higher yields from our aquatic biomass, and found this project that Elliot had developed. After we began working with them to test their gasification process with our aquatic biomass, we found that not only did it work, but it worked very well."

Moving Ahead

The next step for PNNL and Genifuel is to reach large-scale production, and Oyler says the companies are well along that path. "We've already scaled up several times with PNNL, and plan to continue that process until we reach commercially significant volumes," he says. "One factor that has to play into our commercialization is the position and actions of the government in relation to biofuels and alternative energy. Those policies are fairly well-established for windmills, and there are subsidy programs and tax/production credits and financing alternatives for wind; there are emerging subsidies for solar, and the subsidies in place for corn ethanol are well known. We need the same kind of established actions to be in place for aquatic biomass and gasification technologies."

Another way to look at it, according to Oyler, is that if fuel prices go back to what they were last summer, about $12 or $13 per thousand cubic feet of natural gas, the technology could be economic without government involvement. "Today, it's $4 per thousand cubic feet," he says. "That kind of swing is impossible for a new technology to deal with; you have to have some stability."

Besides high efficiencies, natural gas is the cleanest burning fuel other than hydrogen, which is difficult to deal with, Oyler adds. "Methane or natural gas is everywhere—and we can use existing infrastructure; all of the pipelines that exist today, we can directly feed it into them, so we don't need new infrastructure or technology like you would with hydrogen. It's a clean fuel and a clean feedstock that is used as a fundamental feedstock for literally thousands of other chemicals. It's an exceptionally important type of biofuel."

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