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Out Of The Labs

Biofuels Battle: Chemistry Versus Biology

Jonathan Fahey, 04.29.09, 06:00 AM EDT

What's the best way to turn plants into fuel?

There are 1,865 biofuels companies out there, and sometimes it seems that there are at least 1,865 different ways of turning every manner of biological material into fuel for a car, truck, train or plane.

A big part of the reason, of course, is that petroleum is, basically, old biological gunk. Changing new biological stuff into old biological stuff is relatively easy to do in a lab, at least.

The problem is finding a way of doing this alchemy on the scale of millions of gallons a year at a cost that comes somewhere near the price of gasoline without leveling the world's forests, sucking the world's fresh water supply dry or starving the world's humans.

The race is starting to shape up.

The contest: Take some type of agricultural waste, easy-to-grow non-food crop or just sunshine; add water and carbon dioxide and turn it into some type of fuel, like ethanol, butanol, gasoline, diesel or jet fuel.

The entrants: enzymes, algae, yeast, bacteria and plain old chemistry.

The winners will be the methods that use the least amount of energy to produce a fuel that stores the most amount of energy, at the best cost. Since the beginning of 2007, $1.8 billion has been invested worldwide in the race to these so-called next generation biofuels, according to Ethan Zindler, an analyst at New Energy Finance.

Despite all the hope, the finish line is not close. Helena Chum, a research fellow at the National Renewable Energy Laboratory, estimates that next-generation biofuels now cost anywhere between $5 and $1,000 a gallon, with a median of about $25. That won't work, even in a Prius.

"But we know a lot today compared with what we knew 10 years ago," Chum says. "There is a possibility this nut can be cracked."

What's going on is a rearrangement of molecules. The elements of biology--carbon, hydrogen and oxygen--are being reshuffled to create fuels based on alcohol, such as ethanol, or hydrocarbons, such as gasoline.

"Each company has a different way of connecting the dots on the feedstock, on the pretreatment, on the fuel," Chum says. Comparing the approaches at this point, she adds, is difficult because we don't have enough data.

But we can still dissect the chemistry and biology at work to find out the advantages, disadvantages and progress of a few approaches.

Current generation biofuels work because yeast likes the same food we do. Yeast thrives on the loads of sugar found in corn kernels and sugar cane, and they happily turn out lots of ethanol as a waste product.

But the hope is that the parts of plants that aren't so easy to digest can be turned into fuel. Cellulose, which comprises cell walls; hemicellulose, polymers found in plant walls; and lignin, the stiff stuff in cell walls that gives plants, such as trees, their support.

All the methods (except for the algal approach) first require that the plant matter be busted up, usually violently. This is called pretreatment. It is done with a mild or strong acid, or heat and pressure.

Then the long chains of cellulose, hemicellulose and the lignin must be chopped up into ever smaller bits, so they can be built back up into the molecules we want.

Cellulose is tough to break down, but yields only glucose, a sugar that is easy handle. Hemicellulose is easier to break down, but yields two types of sugars, so-called C6 sugars, like glucose, and C5 sugars, like xylose. This complicates things, requiring specialized enzymes, bugs or processes. Lignin is almost impossible to deal with. In most cases, the plan is to separate it out and perhaps burn it to provide energy for the refinery.

The approach that is most straightforward, and furthest along, is to use a mild acid to pre-treat the plant material, then use enzymes to break down the constituents, then use yeast to ferment the sugars, then distill the output into ethanol.

Companies like Iogen, POET, **Verenium** (VRNM - news - people) and Abengoa are working on pilot plants to develop this method. The enzymes are the trick here, and companies like Novozymes and Codexis are developing specialized enzymes to perfect the process. (See "Shell's Brash Biofuels Partner.")

Companies like Range Fuels and Virent have a different approach. They cut the bugs out. Range Fuels uses heat and pressure to gasify the plant material into hydrogen and carbon monoxide, then run the gas over chemical catalysts which turn the gas into ethanol.

Virent takes a slurry of sugars from broken-down plant matter and, like an oil refinery, uses metal catalysts to create hydrogen. The hydrogen is used to remove oxygen from the mixture, which yields hydrocarbons instead of alcohols. The hydrocarbons can be made into more traditional fuels like gasoline, diesel or jet fuel.

Randy Cortright, Virent's chief technology officer, says that while his process requires more sugar, it saves energy by not requiring distillation. Also, his process can produce gasoline, which holds one-third more energy than ethanol. "We're producing a real drop in replacement for fossil fuels," he says.

Then there are companies like LS9, Amyris, Mascoma and Qteros, which are trying to pull off some particularly tricky science. They are trying to engineer bacteria and yeast that will chew up the broken-up plant material and spit out ethanol, gasoline or diesel.

This is called consolidated bioprocessing. "This is the golden dream," says NREL's Chum. "All of the processes in one super-organism. That would be the lowest cost possible." It's also, however, furthest from success.

Finally, there's algae. The algae people argue that growing a plant just to break it down is a waste of energy. Algae don't have to grow leaves or stalks; they can be trained to just turn out ethanol (the approach that the company Algenol takes) or diesel (Solazyme).

These specialized algae, though, require special care. They must be kept in contained, and expensive, "bioreactors" for example, so they won't be out-competed by wild algae. Extracting the fuel can also be difficult.

So who's going to win? Certainly not all 1,865 companies. And maybe none will. Maybe the science will be too hard to scale up cheaply. "There has never been as much science and engineering done," Chum says. "We do not have a simple solution. But the conditions for making it work are there."

http://www.forbes.com/2009/04/28/biofuels-ethanol-virent-technology-breakthroughs-biofuels.html