



THE SUGAR MAKERS

Start-up firms target cheap sugars to make possible
COST-EFFECTIVE BIOFUELS and biochemicals

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AS OIL PRICES have edged up in recent years, numerous firms have developed processes for making biobased fuels and chemicals. But these products typically require sugarcane and corn-derived sugars as feedstocks. Use of such food-derived raw materials is economically questionable and politically fraught.

One long-term solution is to unlock the sugars found in waste biomass, which is composed of cellulose, hemicellulose, and lignin. At least three start-up firms—Renmatix, HCL CleanTech, and Comet Biorefining—and the engineering firm Chemtex are working on biomass-based ways to cost-effectively create sugars to sell to producers of biofuels and chemicals. Another solution is to dispense with biomass and depend on start-up firm Proterro's genetically engineered cyanobacteria to produce sugar.

Unlocking sugars from biomass is easier said than done. A recent report by the National Research Council points out that the U.S. is unlikely to meet a 2022 mandate to produce 16 billion gal of cellulosic biofuels (C&EN, Oct. 10, page 12). Today, such technologies are only at the demonstration scale, and no commercial cellulosic biofuel plants exist.

"Cheap sugar from waste biomass is a key trip point for the biochain," says Andrew

Soare, a clean technology analyst with Lux Research. A lot of development is needed to scale up production of these sugars so they are competitive with petroleum, he says.

Most biofuels and biochemicals today start with conventional sugarcane or corn. In the case of corn, amylase enzymes are required to break down cornstarch into sugar.

But making sugar from biomass such as wood chips and switchgrass requires additional costly pretreatment steps, notes James D. Stephen, a Ph.D. candidate at the University of British Columbia. Reducing pretreatment costs is a big challenge, says Stephen, the lead author of a recent study in *Biofuels, Bioproducts & Biorefining* (DOI: 10.1002/bbb.331) gauging the competitiveness of biomass-based ethanol.

Cane- and corn-derived sugars don't require expensive pretreatment, and as a result ethanol made from these feedstocks costs 30 to 40 cents per L, making them cost-competitive substitutes for petroleum, Stephen says. Pretreatment steps used today more than double the cost for cellulose-based ethanol to about 90 cents per L.

About 14 lb of sugar, whose price fluctuates, but now sells for about 30 cents per lb, are needed to make 1 gal of ethanol. The new sugar makers say their technology can lower this price, helping fuel makers meet federal cellulose-based fuel mandates and enabling

SWEET DREAMS
Renmatix' supercritical water process breaks down cellulosic biomass into sugars for fuels and chemicals.

a new generation of biobased chemicals. And they have high expectations for their processes.

Just as petroleum was the basis for a revolution in chemicals and fuels, "in the 21st

century, sugar is replacing petroleum as the raw material for those industries," said Mike Hamilton, chief executive officer of Renmatix, during a September press event at the firm's soon-to-open headquarters and research facility in King of Prussia, Pa.

The firm estimates that biofuels and biochemicals account for 3% of a \$5 trillion global chemicals and fuels market. It projects that the bio portion will grow to 17% of an \$8 trillion market by 2025. "Sugar water will change the world," Hamilton said.

Renmatix uses water to break down biomass to yield both glucose and xylose. Heated to supercritical temperatures, the water solubilizes the cellulose, allowing the firm to separate the valuable sugars.

Fred Moesler, vice president of process technology at Renmatix, explained that the firm's Plantrose process uses control of the supercritical water's pressure to tune pH conditions and efficiently recover the sugars. The lignin left over generates the energy needed to run the process. Excess energy can be sold to a local utility or used to help power a fermentation facility.

RENMATIX doesn't intend to ferment the sugars it makes but hopes to either license its process or partner with fuel and chemical users. Moesler suggested that Renmatix could collocate its sugar-making operation at a customer's site, providing it with both feedstock and power.

Renmatix also has the backing of well-known venture capital firm Kleiner Perkins Caufield & Byers. It counts among its board members John Melo, CEO of renewable fuels and chemicals maker Amyris.

Another firm pushing to commercialize a biomass-derived sugar process is Italy's Gruppo Mossi & Ghisolfi (M&G). Earlier this year the firm began to build a 40,000-metric-ton-per-year cellulosic ethanol plant in Crescentino, Italy. A key part of the project is to demonstrate at a commercial scale the firm's Proesa sugar process.

Dennis Leong, executive vice president of Chemtex, the engineering arm of M&G, explains that Proesa produces sugar in two steps. Steam and pressure start the process

of breaking down the biomass, and enzymes complete the job.

Chemtex has already licensed the Proesa process to the Colombian firm Colombiana de Biocombustibles Celulósicos, which will turn sugarcane waste into cellulosic ethanol at an 85,000-metric-ton-per-year plant to be built in Chitaraque, Colombia. Chemtex says it is also collaborating to build an “industrial scale” cellulosic ethanol plant in Brazil with GraalBio Investimentos.

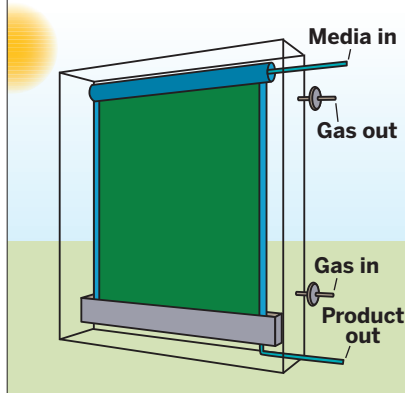
The Proesa process recently got a significant endorsement with a \$345 million investment from Texas-based private equity firm TPG Capital. The investment involved formation of a joint venture, Beta Renewables, that will own the Crescentino plant and license the Proesa technology to others.

HCL CLEANTECH also has strong backers. Venture capital firms Khosla Ventures and Burrill & Co. are investors in the company, which uses concentrated hydrochloric acid to extract sugars from biomass. The acid is then recycled. In June, the firm received a \$9 million grant from the Department of Energy to develop its process.

The firm operates a pilot plant at Southern Research Institute in Durham, N.C. It is also working with biotech firm Virent to convert sugars from the research institute plant to biofuels and chemicals. HCL claims it will be able to produce sugar at less than 8 cents per lb in a full commercial facility.

Two-year-old Comet Biorefining, in contrast, is mum on its backers. Andrew Richard, former chief technology officer of

PHOTOBIOREACTOR In this representation, water and nutrients trickle down a fabric supporting genetically engineered cyanobacteria (green). Exposed to sunlight and CO₂ gas, the organisms secrete a fermentation-ready sucrose solution.



ADAPTED FROM PROTERRA

biomass-to-ethanol developer Mascoma and now CEO of Comet, also isn't saying much about his company's technology. What he will say is that the Canadian firm's process uses fewer enzymes to break down biomass than in competing processes.

"We'll disclose more information in the future as we work with downstream customers," he says. For now, Comet plans to license its technology to producers of biofuels and chemicals.

Among the industrial sugar start-ups, perhaps the most intriguing but least advanced is Proterro. CEO Kef Kasdin says

the firm takes cyanobacteria known to express sugar and genetically engineers them to make more. Kasdin is also a general partner at venture capital firm Battelle Ventures, Proterro's principal backer along with Braemar Energy Ventures. The firm now grows the cyanobacteria, also known as blue-green algae, on a fabric backing in bench-scale photoreactors.

Like plant-grown biomass, the cyanobacteria thrive on sun, carbon dioxide, and nutrients, Kasdin points out. But unlike biomass, the cyanobacteria express ready-to-ferment sucrose. They don't require traditional biomass's time to grow or its expensive harvesting, storage, and extraction steps. She figures that scaled-up cyanobacteria photoreactors will be able to produce 10 times more of the firm's Protose-brand sugar per acre than biomass, at a cost lower than sugarcane-derived sugar.

"Our idea is to position our reactors at the front end of a fermentation facility," Kasdin says. Carbon dioxide generated during fermentation could be captured and used to make more sugar. Four-year-old Proterro has spoken to a number of potential partners, Kasdin says, and has raised \$5 million to advance its technology.

It will be several years before new sugar technologies become commercial, Lux Research's Soare cautions. Government policies, investors, and even big energy companies are backing the start-ups, banking on their success. But he predicts it will take decades before cellulosic sugars make a serious dent in the petroleum market. ■