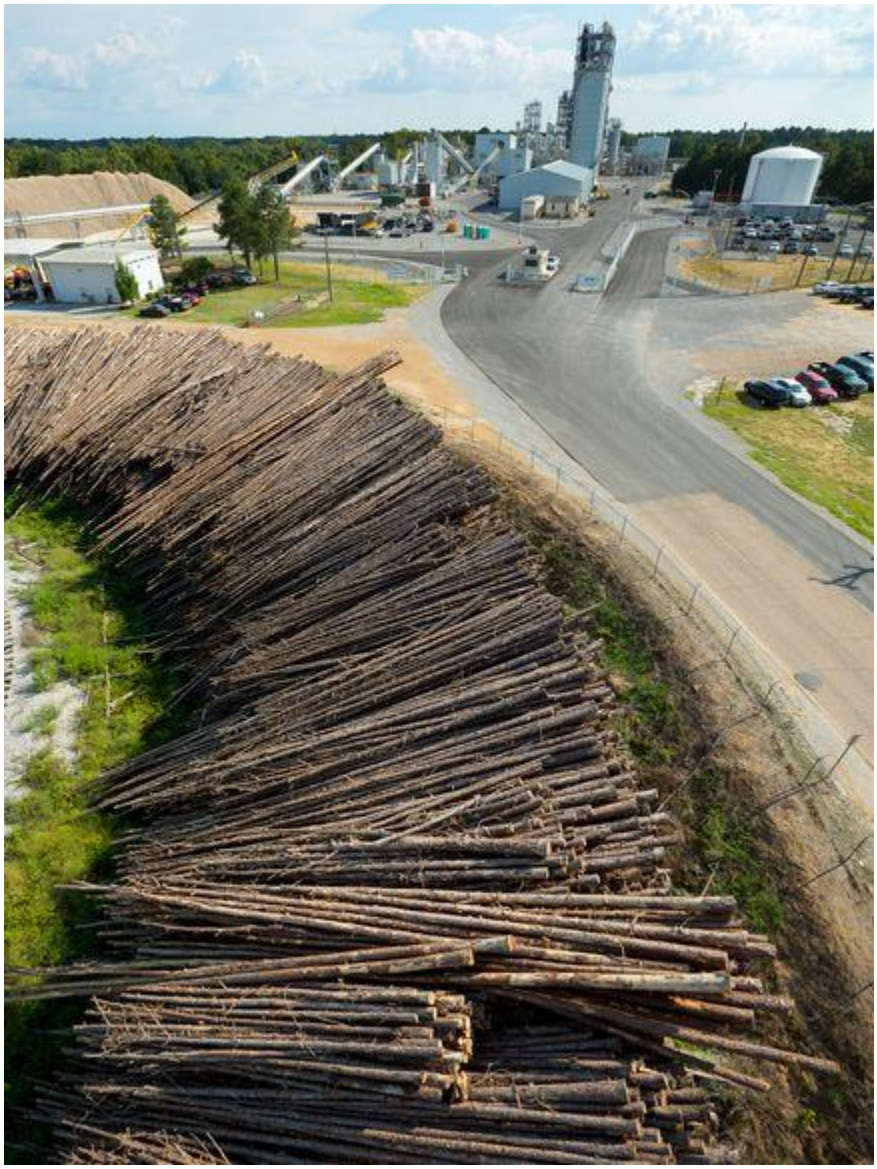
National Geographic/Daily News

http://news.nationalgeographic.com/news/energy/2013/06/130626-drop-in-biofuels-making-gasoline-from-plants/

Beyond Ethanol: Drop-In Biofuels Squeeze Gasoline From Plants



Cut southern yellow pine trees are stacked up outside the first commercial cellulosic biorefinery, KiOR's plant in Mississippi. The wood that once fed paper mills will be chipped up, as seen below, and converted directly into gasoline and diesel fuel in a process its advocates say will be more sustainable than corn ethanol.

Photograph courtesy KiOR

Photograph courtesy KiOR

Patrick J. Kiger and Marianne Lavelle

For National Geographic

Published June 26, 2013

Fred Cannon was working at a Dutch chemical company when he had a conversation with a chemist about the movie *Back to the Future*—in particular, the scene near the end in which Doc Brown refuels his time-travel car with household garbage.

Corn distilled into ethanol was touted as a way to reduce civilization's dependence upon fossil fuels, but it required different pipelines—and only a specially equipped car could run on a mix of fuels made mostly of ethanol. (See related quiz: What You Don't Know About Biofuel.)

Wouldn't it be better if you simply could take waste material, or biomass, and transform it into fuel?

Not quite a decade later, that fantasy may be starting to become reality. Cannon is now chief executive of the alternative energy start-up KiOR. A few weeks ago, the company produced and shipped what it says is the world's first commercial volume of cellulosic diesel fuel from its new biorefinery in Columbus, Mississippi. KiOR's product, made from pine wood chips, is chemically identical to the petroleum-based fuel it is designed to replace, the company says. (Vote and comment: "Are Biofuels Worth the Investment?")

KiOR's breakthrough is one part of a wide-ranging effort by a number of companies and government-supported researchers to develop and perfect "drop-in" biofuels—fuels so similar to their petroleum-based counterparts that they could be pumped through the same pipelines and

used to power the engines of cars and trucks without any modifications. Drop-in biofuels proponents say they could help free modern civilization from its dependence upon petroleum, without requiring extensive rebuilding of the fuel-supplying infrastructure or the junking of vast numbers of existing vehicles.

"Globally, we've invested trillions of dollars into our transportation infrastructure—our refineries, pipelines and distribution systems, our cars—so we need biofuel solutions that 'drop-in' to this infrastructure," Cannon said. "And today that infrastructure is made for hydrocarbon-based fuels. So what that means is that drop-in biofuel must be a hydrocarbon—molecularly indistinguishable from the gasoline, diesel, and jet fuel making the world mobile today."

Before drop-in biofuels become the transportation energy source of the future, there are still significant technological, economic, and environmental hurdles to overcome. Producers would need to be able to manufacture large quantities of drop-in biofuels at a cost that's competitive with gasoline and other petroleum products, and without expending excessive amounts of energy in the process. Some critics warn that drop-in biofuels would still release carbon into the atmosphere and contribute to climate change; they argue that electric cars powered by renewable energy provide a cleaner path to alternative fuel for transportation.

But biofuel believers point out that as long as coal—the most carbon-intensive fuel—generates 40 percent of U.S. electricity, greenhouse gas emissions remain a problem for electric cars.

"One of the things we have to do is get real," said clean technology investor Vinod Khosla, whose Khosla Ventures is controlling shareholder of KiOR. "Biofuels . . . even with [today's] inefficient engines, can do something like an 80 to 85 percent reduction in carbon emissions with very little increase in cost. It's the cheapest way to get carbon reduction in transportation at scale." More from Khosla in the video below:

Mimicking Fossil Fuels

Since the oil in the ground came originally from ancient living things, it might seem that creating its equivalent from biomass wouldn't be that much more difficult than, say, turning corn into alcohol, the process that produces today's most widely used biofuel, ethanol. (Related: "Ethanol Future Looking For More Fuel") Not so, according to Bill Brady, chief executive of Massachusetts-based alternative fuel company Mascoma (another firm in which Khosla has invested). "Ethanol is a simple molecule," he said. "How do you make a complicated molecule like what you have in gasoline? That's a lot more difficult." (See related: "Whisky a Go Go: Can Scotland's Distillery Waste Boost Biofuels?")

Drop-in biofuel pioneers are exploring a number of options. (See related "Electrofuels: Charged Microbes May 'Poop Out' a Gasoline Alternative.") For many years, biorefiners in the United States have turned soybean oil into drop-in biodiesel that can be used in any diesel engine; they rely on a chemical process called transesterification that separates the glycerin from the fat or vegetable oil. Another tried-and-true process used with plant material is called Fischer-Tropsch synthesis—gasification and a set of chemical reactions, long used by the South African company Sasol to make diesel fuel out of coal.

But soy oil biodiesel remains a niche product in the United States; the feedstock, a food crop, is expensive and the price at the pump is higher than any other alternative fuel tracked by the U.S. Department of Energy—about 30 cents per gallon more than petroleum diesel as of April. And Fischer-Tropsch processing is both expensive and energy-intensive. One company working in this area, Rentech, announced in March that it would shut down an $85 million research-and-development facility in Colorado, and end its efforts on Fischer-Tropsch synthesis.

The U.S. government is funding a number of drop-in biofuel projects, with the Pentagon taking a leading role in looking for petroleum alternatives for jets and ships. (See related stories: "As Jet Fuel Prices Soar, A Green Option Nears the Runway" and "First Green Supersonic Jet to Launch.") Major energy companies are also pushing ahead. Among them, Royal Dutch Shell* in February 2012 announced the construction of a pilot plant in Houston, using a process licensed from Wisconsin-based alternative fuel start-up Virent. In addition to the technology that Shell licensed from Virent, the oil giant is looking at a more exotic method-developing microorganisms that would ingest biomass and excrete hydrocarbons. (See related story: "Brazil Ethanol Looks to Sweeten More Gas Tanks.")

KiOR, which is based in Pasadena, Texas, maintains that its new proprietary technology will overcome the challenges of the other processes; its Biomass Fluid Catalytic Cracking involves treating plant matter, or biomass, with chemicals and heat. KiOR says it uses very little water compared to other biofuels production methods, and in fact, recovers and reuses water as part of the process. (See related story: "Water Demand for Energy to Double by 2035.") The U.S. government's energy analysts estimate that the production cost for this pyrolysis process (heating in the absence of oxygen) are much less than current biodiesel or Fischer-Tropsch methods, and could fall below $3 per gallon if production is scaled up.

Brady, of Mascoma, estimates that manufacturers of drop-in biofuels would need to reduce their production cost to no more than $1.75 or $2 a gallon to be competitive with petroleum-based fuels. "It will be a technical challenge," he conceded. But even so, he envisions that within a decade, drop-in biofuels will be a viable option at the filling-station pump.

The U.S. Energy Information Administration's forecast is more conservative: It foresees rapid growth in drop-in biofuels in the market only after 2030, when the price of petroleum fuels will have risen above the cost of drop-in biofuel production. (See related story: "Storage, Biofuel Lead $156 Million in Energy Research Grants.") Of course, the price of oil is a moving target—driven both by world events and policy. In its most recent annual outlook, the International Energy Agency said cellulosic biofuel of all kinds could be cost-competitive as early as 2015 if nations adopted policies aimed at stabilizing atmospheric carbon concentration at 450 parts per billion. (See related: "Climate Milestone: Earth's CO2 Level Passes 400 ppm.")

Biofuel or Electric Cars?

Not everyone agrees that drop-in biofuels are the best investment for addressing climate change. Dan Becker, director of the Washington, D.C.-based Safe Climate Campaign, is concerned that biofuels might get in the way of what he sees as a more environmentally beneficial solution-

switching to plug-in vehicles powered by electricity from wind, solar, and other non-carbon-burning generation methods.

Becker is skeptical of the carbon-reducing claims made for biofuels. Producing enough plants such as switchgrass to supply major quantities of fuel, he said, would require intensive, mechanized cultivation, which would add to the carbon output. "The problems don't go away just because it's drop-in," he warns.

But the U.S. Environmental Protection Agency administers current policy based on its analysis that there is a significant carbon emissions reduction difference between biofuels produced by traditional methods (the refining of corn into ethanol) and those from cellulosic sources—woody or fibrous plants or plant waste. EPA has faced challenges on its approach. But the theory is that if a fuel is created from low-maintenance plants that capture carbon from the atmosphere and are continually replanted, the net effect is a significant reduction in carbon output compared to petroleum-based fuels. (See related quiz: "What You Don't Know About Food, Energy, and Water.")

KiOR's products qualify as cellulosic fuels under EPA's life-cycle analysis, meaning the agency agrees they will achieve a 60 percent or more reduction in greenhouse gas emissions over their petroleum counterparts from production through burning in the fuel tank.

KiOR says its process would work with a variety of feedstocks, but its current aim is to produce fuel from wood chips culled from the large southern yellow pine plantations that were used to service paper mills throughout the South. As the use of paper has declined, those mills have shut down. KiOR hopes to step into that void, with both its $213 million initial plant that began producing in March in Columbus, Mississippi, and another biorefinery three times larger that it is constructing in Natchez, Mississippi.

The new biofuels plants will establish supply relationships with the same plantations and lumber companies that used to service the paper mills. The wood that once was processed into newspapers, magazines, and catalogs would be grown, harvested, and chopped into biomass for fuel.

"Clearly, it's the winning technology and very, very soon I expect if we build three, four, five plants, it will be cheaper, unsubsidized, than deep offshore drilling projects or oil sands projects," Khosla said. "We can return all those paper mills that have been shut down back into business in thriving communities and replace our gasoline with something that's 80 percent lower carbon or more while not paying more."

The company has strong backing from the state of Mississippi, with $75 million in low-interest loans (former Governor Haley Barbour was instrumental in the deal). And Condoleezza Rice, former U.S. secretary of state, who works in an advisory role to Khosla Ventures, sits on the KiOR board of directors (which is picked by Khosla Ventures as controlling shareholder).

Khosla maintains his optimism on biofuels as a clean energy solution, despite a number of high-profile setbacks and disappointments. He was a lead investor in Range Fuels in Soperton,

Georgia, which also aimed to use Southern wood as its feedstock (for making ethanol) before its bankruptcy in 2011. (See related, "Second Try: LanzaTech Grabs Failed Biofuel Refinery in Georgia Pine.")

Because of high hopes that Range and other cellulosic pioneers would be churning out high volumes of alternative fuel by now, Congress set ambitious renewable fuels goals in the 2007 energy law. The target was for U.S. drivers to be putting 500 million gallons of cellulosic biofuels into their gas tanks in 2012, up to 1 billion gallons in 2013, and 16 billion gallons by 2022. Instead, only 20,069 gallons of cellulosic biofuel were produced in the United States in 2012, according to U.S. EPA data.

In 2013, so far, only about 5,000 gallons of cellulosic diesel have been produced—at KiOR's plant in March. The EPA, which tracks biofuels sales, has recorded no new cellulosic diesel production since then. KiOR says it has no further operational data beyond the guidance it gave with its financial results in May: Adjustments were being made to the plant, and officials expected operating times to increase.

At this point, though, with far greater capital expenses than sales, KiOR's losses in the first quarter totaled $31.3 million. And the company's stock is trading some 80 percent below its high point soon after its initial public offering in late 2011.

It remains to be seen whether KiOR can meet its goal of producing 3 million to 5 million gallons of drop-in biofuel this year. Success would be just a small step toward replacing the 18.5 million barrels—777 million gallons—of petroleum products consumed *each day* in the United States. Although the numbers are daunting, Khosla, who made his mark as one of the cofounders of the pioneering tech company Sun Microsystems, believes that energy can be transformed just as communications were transformed by Internet technologies. Fuels that plug into the existing transportation infrastructure, he argues, have the potential to be the kind of revolutionary advance needed for cleaner energy.

"Things can change," he said, "and they can change very rapidly."

**Shell is sponsor of National Geographic's Great Energy Challenge initiative. National Geographic maintains autonomy over content.*