Cover Story

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Cellulosic Scale-Up

DOE-backed ethanol producers encounter difficulties converting waste streams to commercially viable fuel

Melody Voith

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Cellulosic Ethanol

Six DOE-backed projects show mixed results

Interactive Map by Monica Gilbert and Tchad Blair/C&EN

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IN FEBRUARY 2007, the Department of Energy selected six cellulosic ethanol projects to receive up to $385 million in grants. Authorized by the Energy Policy Act of 2005, the funding was part of an effort by the Bush Administration to end the U.S.'s "addiction to oil" and enhance the nation's energy security.

The money was intended to further two of President George W. Bush's goals: to make ethanol out of nonfood biomass, including billions of pounds of agricultural waste, at a cost competitive with gasoline by 2012 and to increase the use of renewable and alternative fuels to 35 billion gal per year by 2017. In all, more than $1.2 billion was to be invested in the six biorefineries.

Poet

WASTE NOT Ethanol maker Poet wants local corn growers to gather their cobs to use as feedstock for the company's new plant.

Two years later, none of the projects has been built, although one is under construction. Two were canceled right out of the gate. Hitches in the plans have turned up in numerous places. From securing feedstock to financing construction to finding a ready market, the experiences of the awardees illustrate that the nascent cellulosic ethanol industry faces several daunting hurdles.

The chosen projects represent technologies including enzyme hydrolysis, acid hydrolysis, and gasification. They were to be located in the Midwest, Southeast, and West and were planning to use feedstocks ranging from corncobs to wood chips. The companies advancing the projects had little in common other than having a plan to turn cellulosic waste into ethanol.

The designers of the DOE program envisioned that the grant money would be invested over four years, with the companies contributing 60% of the plant costs. When fully operational, the six facilities were expected to produce more than 130 million gal of cellulosic ethanol per year.

DOE managers say it is too early to judge whether any of the plants will make cost-competitive ethanol from cellulose. But it is not too early to start learning from the first attempts, they say. And challenges relating to scaling up the ethanol processes, rather than the particulars of any one technology, are keeping costs higher than the market will now accommodate. In the long run, the agency would like to see cellulosic ethanol projects become attractive to private investors.

"We're finding nuances to our integrated approach and scale-up issues that add a bit to the cost and make it more challenging," acknowledges Larry Russo, technology manager of DOE's integrated biorefinery program.

Project leaders at the companies give DOE high marks for being involved partners in getting their facilities ready to produce commercial quantities of ethanol. But they have serious concerns about other aspects of federal policy that influence the demand for their product. For example, the gasoline sold in filling stations can contain no more than 10% ethanol. The so-called blend wall will be in place until the Environmental Protection Agency has determined that higher blends will not increase tailpipe emissions. "If there is not a blend-wall increase, we are not quite sure where the path will be for cellulosic ethanol," observes Jim Sturdevant, project officer at Poet, one of the six companies.

One of the canceled projects was to be built by Alico, a publicly traded land management firm. That project called for a facility in LaBelle, Fla., that would convert yard, wood, and vegetative waste to ethanol. But in a June 2008 press release, the company wrote that the "risks associated outweigh any reasonably anticipated benefits for Alico."

Canadian enzyme producer Iogen had planned to build a plant in Shelley, Idaho, that would process agricultural waste such as wheat straw and corn stover. Iogen operates the world's only large-scale demonstration facility in which cellulosic ethanol is made from agricultural residues. The plant, located in Ottawa, uses up to 33 tons of feedstock per day.

But according to Mandy Chepeka, director of communications, "Iogen suspended its operations in Idaho to focus our development efforts on our most advanced project, which is in Saskatchewan." Chepeka says the firm has not yet made a final decision to build at the Saskatchewan site.

One of the projects that is still active has hit a snag. BlueFire Ethanol, in Irvine, Calif., sold DOE on the idea of using a concentrated acid hydrolysis process to turn municipal cellulosic waste such as lawn clippings and tree prunings into ethanol. But it has yet to secure a site for its facility. BlueFire's first planned site, the El Sobrante Landfill in Corona, Calif., fell through when the current occupant, a waste treatment plant, did not vacate the location.

The three remaining projects appear to be moving forward. The first large-scale production plant will be operated by Range Fuels in Soperton, Ga. The project is the only one of the six that uses gasification technology. The feedstock, mainly wood chips, is heated under pressure to create a synthesis gas (mainly carbon monoxide and hydrogen) that is then passed over a catalyst to make ethanol. Venture-capital-backed Range has begun construction on the plant and says it will start producing ethanol in 2010.

Privately held Poet plans to have a cellulosic ethanol facility operating by 2011 in Emmetsburg, Iowa. Built adjacent to a larger corn ethanol plant, Poet's plant will use enzymes to break the cellulose in corncobs into sugars and then ferment those sugars into ethanol.

If all goes according to plan, the third DOE-backed facility to come on-line will be run by Abengoa Bioenergy, a Spanish ethanol firm. It will use enzymes to break down the cellulose in the inedible parts of the corn plant and other agricultural residues. The company says it will start construction in Hugoton, Kan., in 2010 and be in production at the end of 2011. Abengoa is also investigating thermochemical production methods.

POTHOLES ABOUND on the road to commercializing cellulosic ethanol. Iogen's Chepeka says her company recognizes six discrete steps. The first task is to show successful operation of a demonstration-scale plant. Then the company must select a commercial plant site and sign contracts for feedstocks. The firm needs to be able to purchase the land and get government support to help share the financial risk. Finally, the company needs to attract enough government and private investment to finance construction of the actual ethanol-producing plant.

To get the DOE grants, the six projects had to demonstrate that their technology was the strongest of the applicants, according to independent merit reviewers. To that end, all six companies were able to show that they had operated successful pilot facilities.

It is not yet clear if any of the contenders have found a workable formula for the next stages: selecting a commercial plant site and ensuring ready supplies of feedstock at a reasonable cost. According to Gene Petersen, project manager at DOE's Golden, Colo., field office, even seemingly free feedstock, such as agricultural waste, isn't really free. "The feedstock budget has gone up by a factor of 10," he says, because companies' plans did not account for the full cost of the supply chain, including getting feedstock to the plant site. Particularly problematic, Petersen says, is transporting lightweight corn stover in a cost-effective manner.

Although corn stover surrounds Poet's facility in Iowa, Sturdevant says it is too lightweight to be cost-effective in the firm's process. "Cobs are denser than the rest of the corn crop residue," he says. "When you have to haul biomass, it's more economical to haul a load of cobs than a load of leaves, husks, and stalks."

Sturdevant is optimistic that Poet can find a way for farmers to easily gather cobs when they harvest corn. The company is working with 12 farm machinery manufacturers, including John Deere, to make cob harvest equipment. The farmers would pile the cobs on the edge of their fields for collection by Poet or a third party. "No cob left behind is our motto," Sturdevant says.

Some projects are designed to take advantage of centrally located sources of cellulosic waste, such as timber operations or landfills, by locating their operations nearby. Range Fuels' chief executive officer, David Aldous, points to his company's acquisition of land near Soperton as a strategic choice. Soperton is near two major interstates and is surrounded by timber forest. "The key thing for us is there is an abundance of feedstock. Our simplified wood feedstock chain is a big advantage, although ultimately, we see ourselves using other feedstocks in addition to wood chips," Aldous says.

In an effort to gain a similar advantage, BlueFire is busy negotiating the right to build on land about halfway between Palm Springs and the Salton Sea, in Southern California, its third attempt to find a site for a plant. John E. Cuzens, chief technology officer, explains that location is important to his firm's plan to use municipal waste as its feedstock. "We need to be adjacent to communities or their landfills, where this waste is generated," he

General Motors

HAPPY HOUR Patrons at a Chevron station in Tucson, Ariz., fill their E85 vehicles' tanks with fuel that is 85% ethanol.

says. "There is no room in Southern California for expanding landfills. We have to look for land that is close to the urban center. Then we also benefit because we don't have to transport the ethanol far to consumers."

Cuzens says BlueFire is anxious to settle on the site because the next step, getting the environmental permits required by the National Environmental Policy Act (NEPA), is time-consuming. Federal law requires that all construction projects funded by the federal government comply with NEPA's environmental impact review and permitting rules.

The NEPA process has also had a hand in slowing progress on the Abengoa plant in Kansas. Gerson Santos, the firm's director of R&D, estimates that it takes about 18 months to complete a NEPA review. For most of the projects, DOE supplied 10 to 20% of the grant up front to help the companies get through the permit and design phase.

Santos says his company will complete the process in January. "We've been diligently working with the Department of Energy, and they're being very supportive through the whole process. You have to generate quite a bit of information on the emissions and on the design. But so far, so good," Santos says.

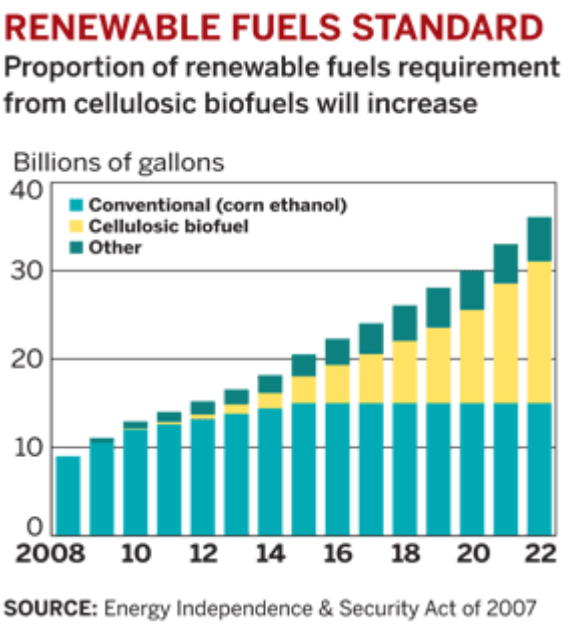
According to DOE, Range Fuels did not request an advance on its grant during the NEPA process. Moreover, the agency says the company was able to expedite the permits and receive them in about six months.

Range Fuels has also come out ahead of the other companies in obtaining financing for its facility. Aldous says the plant will cost less than $200 million to build. In addition to $76 million from the DOE cost-sharing grant, Range has more than $100 million that it raised in early 2008 from venture capital investors. In January 2009, Range announced that it was offered an $80 million loan guarantee from the Department of Agriculture.

For most of the projects, though, getting the financing needed for construction has been difficult. Poet will receive up to $80 million from DOE, and it expects to get an additional $20 million in grants, tax credits, and tax refunds from the State of Iowa. But the company still needs to bring in private capital for the $200 million plant. "We absolutely need a federal loan guarantee," Sturdevant says. Poet and the three other companies with active projects have all applied for DOE loan guarantees.

Private investors will require the loan guarantees because they are in no mood to invest in a "first of its kind" facility, given the overall weakness in the economy, says Laurence Alexander, a stock analyst at Jefferies & Co., where he covers the cellulosic ethanol industry. Because there has never been commercial production of cellulosic ethanol, investors can't determine what approach, if any, would be successful. "You need comparable projects up and running, and then you can debate which one is the better business model," Alexander explains.

By depending on the loan guarantees, cellulosic ethanol companies will have to do more than promise to make competitively priced ethanol. DOE's Petersen points out that the renewable energy loan guarantee program places a high priority on projects that significantly reduce emissions of greenhouse gases compared with nonrenewable sources. This differs from the 2007 DOE grant program, which stressed commercial production of domestic fuels to enhance energy security.



Sandia National Laboratories

FUTURE FUEL Sandia Labs' researchers have studied how innovations in converting cellulose to ethanol could bring down costs.

THE GREENHOUSE GAS savings to be realized from cellulosic ethanol are uncertain but are likely to be high compared with other sources of biofuels, according to a report by the U.K.'s Renewable Fuels Agency. The so-called Gallagher Report estimates that cellulosic ethanol from agriculture or forestry residues would save 80 to 90% of greenhouse gas emissions compared with fossil fuels. Ethanol from corn has a more mixed impact, generating between 30% more and 35% less emissions than fossil fuels, depending on how it is grown.

Even if a cellulosic ethanol project qualifies for loan guarantees, Alexander is skeptical that loan offers will be announced before late this year or even early next year. "In the quest for financing, you end up pushing plant construction back, which makes quite a bit of impact" on the overall value of the project, he points out.

To attract financing, Alexander says, all the major cellulosic players, regardless of technology, are aiming to produce ethanol for a price of $2.00 per gal. At that price, he says, cellulosic ethanol can compete with ethanol derived from corn. But perhaps more important to cellulosic ethanol's near-term viability is the likely price that fuel blenders—companies that mix ethanol and gasoline for service stations—will be forced to pay for ethanol under the federal renewable fuel standard starting in 2010.

The renewable fuel standard is part of the Energy Independence & Security Act of 2007. It mandates increasing the amounts of renewable transportation fuels, starting in 2008 with 9 billion gal of conventional corn ethanol. The first year that cellulosic ethanol will be included in the standard is 2010, when fuel blenders will be required to take in 100 million gal of the new fuel. By 2022, the requirement grows to 36 billion gal of renewable fuels, including 16 billion gal of ethanol from cellulose.

David Woodburn, a green technology analyst at ThinkEquity, an investment adviser, has added up all the cellulosic biofuel production planned in

2010, including small-scale demonstration plants. He came up with the paltry sum of 28.5 million gal, well short of the mandated 100 million gal. The largest share, 10 million gal, will come from Range Fuels. For 2011, Woodburn's most optimistic measure jumps to 246.7 million gal, just shy of the renewable fuel standard requirement of 250 million gal.

Fuel blenders will be caught in the middle of this shortfall. To make up the gap in 2010 and 2011, blenders that cannot get enough cellulosic ethanol will have to purchase a biofuels credit from EPA that values ethanol at around $2.00 per gal. This scenario gives early movers like Range a two-year window of guaranteed price and demand, Alexander says.

THIS YEAR, low demand for fuel combined with the 11 billion-gal renewable fuels mandate means blenders need corn ethanol or credits for more than 10% of their gasoline production. But today's gasoline contains a maximum of 10% ethanol. Woodburn points out that the renewable fuel standard and the ethanol/gasoline blend wall are two policies that have come into conflict.

Starting next year, the fuel blenders will have to take on even more ethanol. "In 2010 and beyond, the credits will become much more valuable. That could help push up the price of ethanol per gallon, even if we are stuck at a 10% blend," Woodburn says.

Ethanol makers are hoping for a near-term resolution of the blend-wall conundrum. DOE is studying the impact of higher proportions of ethanol on emissions and wear and tear on engines. It has published preliminary results suggesting that increasing ethanol content to 15 to 20% would not have significant negative effects.

Another route to absorbing more ethanol in the fuel supply is to increase the number of vehicles that can run on E85, a fuel containing 85% ethanol. In 2007, according to DOE, only 1% of automobiles in the U.S. had this flex-fuel capability. Given the recent drop in sales of all vehicles, Woodburn observes, that small market share is not likely to change soon.

"When you have to haul biomass, it's more economical to haul a load of cobs than a load of leaves, husks, and stalks."

Meanwhile, the slow development timeline of cellulosic ethanol projects means that corn-derived ethanol will remain dominant for the foreseeable future. Meaningful amounts of cellulosic ethanol—say, 2 to 3% of gasoline consumption—won't be produced before 2013, Woodburn says.

Reaching the levels of cellulosic ethanol production envisioned by the Energy Independence & Security Act will require dramatic, but not impossible, advances in both technology and policy, say researchers at Sandia National Laboratories. They designed a computer model to study all of the components of production from the field to the fuel station. One important guideline of the study was an assumption that cellulosic ethanol would eventually have to compete in price with regular gasoline.

The study, which was funded by General Motors, examined the full cost of producing ethanol. It assumed an ethanol yield of 95 gal per dry ton of biomass. Current estimates of large-scale yield are around 65 gal per dry ton, according to Sandia.

The study concluded that ethanol would be undercut by gasoline whenever gasoline is sold at the pump for $2.65 per gal or less. "The basic issue is that it's difficult for cellulosic ethanol to compete with gasoline if oil is less than $90 per barrel," Sandia's lead researcher, Todd West, says. "The question is, 'How do you deal with times when the price of oil is less than that?' "

More daunting yet, the summary report says that even with efficient ethanol production, the industry will be dependent on government policies for significant scale-up through at least 2022. It suggests implementing a "multidecade energy policy that values stable fuel prices that are high enough to enable energy diversity in light of oil price volatility and periodic economic dislocations." The report also says the U.S. could pursue additional market incentives and carbon pricing to minimize investment risks.

Despite the obstacles aligned against cellulosic ethanol, ThinkEquity's Woodburn says companies will be able to get investors for their projects. "They are still getting funding from venture capitalists and strategic investors, although not at the high valuations of last year." Overall, Woodburn anticipates growth among the players in the industry. "They are employing a lot of chemists, biologists, and engineers as they scale up the technology," he says. "And state legislatures are mesmerized by clean energy projects," he notes, adding that savvy players ought to be able to attract tax and other incentives.

Range Fuels' Aldous expects to be part of that growth, although he would like a little more clarity on policies supporting cellulosic ethanol after the next three years. "If mandates and renewable biofuel credits end in 2012 when more plants will come on-line, I will need a strong risk-return profile or a vision that something like carbon cap-and-trade or a carbon credit will add value to our products," he says.

Aldous points out that scaling up cellulosic ethanol has parallels to other industrial processes. "As you look at any new technology, like industrial-scale refining or corn ethanol, the plants cost more at the inexperience part of the learning curve." The experience that industry will gain during the next few years will help close the price gap with fossil fuels, Aldous says. But, he warns, "if the incentives aren't there, it will take much longer to make the advancements that will drive down costs."

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