The Business of Biomass

Solving the science is only part of the challenge.

Al Womac spends a lot of time chopping switchgrass. The stuff sits in bags, boxes and bales scattered throughout his garage-style laboratory. The lab boasts an array of dicing, mashing, pounding machines—a hammermill, a diskmill, a knifemill and the up-and-coming knife grid that slices up plant matter with the help of a hydraulic ram—along with measuring tools, sifting tools and a conveyor. A researcher at the University of Tennessee, Womac and his colleagues, both from UT and Oak Ridge National Laboratory, are seeking the most energy-efficient means to prepare biomass for conversion into ethanol in a form most conducive to bioprocessing.

As one segment of researchers examines the molecular and genetic questions surrounding bioenergy production, others like Womac are working to resolve issues of how to build a new agri-based industry from scratch. Although more than two decades of research at ORNL and other institutions have laid the foundation for a new bioenergy industry, many "ifs" remain, from growing the crops to transporting and storing the harvested plant matter to preparation of the feedstock for processing.

Researchers at the University of Tennessee are exploring a variety of ways to chop and otherwise prepare switchgrass and corn stover for potential use as a source of biofuel.

No existing commercial plants yet make ethanol from lignocellulosic feedstocks—the tough, fibrous content of plant stalks, leaves and stems. The cost is still prohibitive, approximately $2.26 per gallon versus $2.11 for corn-based ethanol, according to the latest government figures. Part of the cost conundrum can be answered by science. "But then by the same token I realistically have to be able to grow, transport and store feed-stocks economically, environmentally and sustainably," says Mark Downing, agricultural economist at ORNL.

At UT and ORNL, researchers are paying particular attention to issues surrounding switchgrass, which has been identified as an easy, alternative crop for local farmers. The grass, still currently used as a forage grass crop, was identified in the late 1970s as a potential "model species" for any herbaceous crop. Switchgrass once carpeted large portions of the American prairie where buffalo herds roamed. The hearty plant grows at least eight feet tall in any climatic variation, from the Gulf Coast into Canada.

Despite the apparent ease of growing switchgrass, Downing ticks off a laundry list of concerns: How can a biofeedstock supply be created before cellulose-based ethanol refineries are built? Which are the best switchgrass varieties? How often should a farmer plant and harvest? What are the environmental consequences of a so-called "monoculture crop" that could span vast acreage across the nation? Can a low-value commodity with, essentially, the low-bulk density of toilet paper be transported economically? What is the best method of preparing biomass for processing? How and where would the grass and trees be stored after harvest?

A number of Department of Energy-funded projects involving Oak Ridge National Laboratory and other institutions are examining these and other questions that accompany the creation of a major new industry.

Supply or demand

At Iowa State University, for instance, a project launched more than 15 years ago to market grass crops in the southern part of the state has evolved into research on commercial production of switchgrass. In this case the grass is fed to a nearby power plant, but the production has obvious implications for the bioenergy industry, says Downing, who has been working with the university. Farmers there have planted more than 6,000 acres of switchgrass on both Conservation Reserve Program land and some less productive corn-producing acreage.

Through the years researchers have evaluated a variety of issues, from how best to harvest the grass to the impacts of planting and harvesting on local bird populations. "We've got farmers out there in the back shop with welders going to town developing machinery to harvest and manage crops," Downing says. "Environmental issues are very big. Some environmental advocates are uncomfortable with monoculture production or cutting trees along streambeds, so we are examining which techniques offer farmers the best advantage to the environment as well as economic benefits to farmers. A number of similar tradeoffs affect the economics. We are at a very fledgling stage in understanding how we should manage crops for fuel."

A key to the growth of the biomass industry is the potential genetic modification of crops such as switchgrass and poplar trees for higher production, drought tolerance and resistance to disease. The research brings with it concern that such genetic modification could affect native communities and prove detrimental to surrounding ecosystems.

"We do not fully understand the effect of genetically modified crops on native populations," says Neal Stewart, who holds the Racheff Chair of Excellence in UT's Department of Plant Sciences. Such crops not surprisingly undergo a high degree of government regulation, a hurdle that farmers and biorefineries must overcome.

These issues can be addressed, Stewart is quick to add. "I think bioenergy will create an agricultural revolution," he says.

Researchers and farmers are still learning the basics of growing crops for bioenergy. In another project, managed by the University of Tennessee, researchers are experimenting with various ways to grow switchgrass using several plant varieties and varying levels of fertilization. The experimental plots are situated on 32 acres at UT's Research and Education Center at Milan in West Tennessee.

"We chose four distinctly different soil and landscape positions that represent the different soil and area compositions for this part of the state," says Don Tyler, UT soil management researcher. "On each position we have two experiments, one looking at different seeding rates and one at different nitrogen rates for switchgrass production." Another experiment compares traditional native switchgrass with three "synthetic" cultivars, bred for improvements in production and early seedling vigor.

Through another UT project, funded by the Department of Energy, the university has set up contracts with five farmers in two Tennessee counties to grow 92 acres of switchgrass. The project aims to uncover the challenges and economic viability of raising the bioenergy crop, says Kelly Tiller, agricultural economist at UT.

"The goal is to make this a competitive option for the farmer," Tiller says. "One of the nice things about this crop is that switchgrass is a perennial. Once the plant is established, the cost of production is minimal. With switchgrass, farmers do not need to see the same level of market returns as with corn or soybeans because they do not have as much invested in the crop." In addition, she says, "switchgrass can be grown on much more marginal cropland."

The project is experimenting with some different types of contracts, including yield-based payment, fixed payment and a combination of the two, allowing farmers to determine which concept works best and to document production on their land.

Farmers have been more than willing to sign up for the program, but launching full-fledged switchgrass production for biofuel production reveals "a classic chicken-and-egg problem," Tiller says. "If farmers grow switchgrass today, there is no market. On the other side, if companies want to build processing plants, they need a supply of switchgrass. One side has to move first—probably the demand side. If the demand is there, I think that agricultural production could ramp up pretty quickly."

After growing the biomass crops, farmers and bioprocessing companies must then determine how best to transport biomass to the biorefinery as well as how to store the harvest in the meantime. Some farmers are baling switchgrass; others are simply leaving the harvested and chopped switchgrass in piles on the field, where Downing says the grass naturally forms a lattice configuration that protects the crop from the elements. There are also issues related to "the whole process of detwining, de-baling, chopping and blowing the switchgrass as the biomass is fed into a biorefinery," Downing says. "You would think it would be easy but it's not."

Slicing and dicing

That brings us back to Womac—the UT researcher who is, as Downing says, "chopping the daylights out of switchgrass."

Womac's research group, funded through the U.S. Department of Agriculture–DOE Joint Biomass Research and Development Initiative, has practiced a variety of methods in cutting switchgrass and corn stover in search of the perfect combination of maximum surface area—for easiest breakdown of the plant into cellulose—and energy efficiency. To that end, the researchers are collecting measurements using sensors planted inside the various chopping, knifing and clubbing machines to determine variables such as the point at which a plant breaks most easily, the kilowatt hours per ton required to chop the material and the feed rate into the chopping machines.

One project involves running samples through sieves. In another exercise, a graduate student, aided by a computer scanner and software package, counts the fragments of a particular sample in order to classify by size the particles that shoot out the other end of the chopping equipment. The information is necessary to determine ideal particle size for bioprocessing and to address environmental considerations in designing and operating a biorefinery, Womac says. "Fugitive dust emissions create a whole new set of issues," he says.

UT, through collaboration with ORNL, is also working with industry to receive feedback on the research and, eventually, integrate the data into commercial processes. Each step of the way, bioenergy companies and researchers must be guided by whether the energy cost of creating biofuel exceeds the payback. In that context the model for biofuel production appears to be very localized in nature, Downing says. Because ethanol's corrosive properties prevent the fuel from being transported via pipeline, and because the costs of transportation and storage are often prohibitive, ethanol production will likely be housed in facilities that serve local regions within a state, or even a county.

With this in mind, DOE has funded an initiative to "begin assigning a matrix of costs and a projection of expectations for the handling, management and qualitative aspects of crops generated for biofuel" on a region-by-region basis. Known as Regional Feedstock Partnerships, the effort has motivated many government agencies—federal, state and local—to begin the process of planning for a future in which fuel flows not from oil fields but from nearby fields of switchgrass, corn and trees.

"Let me tell you, when we get these challenges worked out, everybody is going to want a piece of the action," Downing says. "The results will open up wonderful opportunities for lots of sectors in the U.S. economy."—*Larisa Brass*