



# Power Plants

Tomorrow's energy crops are germinating in laboratories today **BY JENNIFER WEEKS**

"MUST BE FAST-GROWING, resist disease, have a small canopy, and a high cellulose-to-lignin ratio." It might sound like a science-fiction personal ad, but these characteristics describe a different kind of ideal plant: one engineered for making biofuel. Today, 3 percent of U.S. automotive fuel comes from corn-based ethanol, and many critics argue that it's a pale-green choice at best, because manufacturing it consumes nearly as much fossil fuel as gasoline and generates significant amounts of greenhouse gases. But biofuels made from cellulose—the tough, woody plant material found in the cell walls of plants—require less energy to make and emit less greenhouse gas. They will enter production in the next several years, and have the potential to replace one third of our current oil consumption by 2030.

Corn ethanol, or grain alcohol, is produced by grinding up corn, adding enzymes that con-

vert the starch to sugar, mixing in yeast to ferment the sugars, and distilling the product to separate alcohol from water. Corn ethanol currently dominates the biofuel market because corn starches break apart easily into sugars for fermentation. Cellulosic ethanol, on the other hand, requires an extra step, called "pretreatment," to break down cellulose chains found in plants, such as switchgrass and poplar, into sugars. It's a complex and expensive process right now, but researchers backed by private and federal dollars are developing new processing methods and more efficient enzymes that could make cellulosic ethanol production significantly cheaper in the future.

Energy experts view cellulosic biomass as an attractive commodity because it contains more energy than corn and is cheaper to grow. "An ideal energy crop is drought-resistant, grows with minimal fertilizer and pesticides, and can

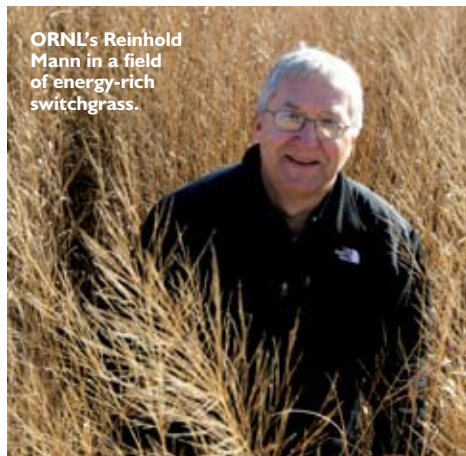
be harvested without special equipment," says Reinhold Mann, associate director at Oak Ridge National Laboratory (ORNL). The most promising of the so-called energy crops, which could be grown on a large scale for fuel, include switchgrass, willows, and poplars. What's more, they can be raised on marginal lands that are unsuitable for food crops, and they improve the habitat where they grow.

These species are naturally energy rich, but researchers are taking steps to improve nature. One acre can currently yield four to six tons of switchgrass, but Mann estimates that selective breeding could produce up to ten tons per acre. Biotech is another tool: In September 2006, after four years of work, an international team published the poplar's complete genetic sequence. "We're zeroing in on genes that enable trees to grow close together in a plantation and regulate features like stem thickness,

so we can maximize biomass production,” says Mann. Scientists are also developing specialized enzymes to break cellulose apart efficiently. Ottawa-based Iogen Corporation, which operates North America’s only cellulosic-ethanol plant, created and patented an enzyme cocktail that separates wheat straw into sugars. And Virginia-based Edenspace is engineering crops with genes for cellulases. These enzymes speed the breakdown of cellulose, lowering the cost of converting plants into ethanol.

Unlike corn, which grows mainly in the Midwest, cellulosic crops flourish nationwide. But so far, they’re growing mainly on modestly scaled research plots. The State University of New York’s College of Environmental Science and Forestry (SUNY-ESF) in Syracuse has planted more than 500 acres of shrub willows, some of which will feed a nearby pilot biorefinery, to be built in 2008 or 2009. “There’s lots of interest in growing willow for commercial uses,” says Tim Volk, the project’s director. “I expect thousands of acres will be planted in the next five years in New York alone.” Other researchers are testing willow strains developed by SUNY-ESF researchers at various locations between Maryland and Canada.

But farmers who grow subsidized commodities, like corn and soybeans, will need incentives to convert to switchgrass and willows. Iogen’s factory produces only about one million gallons per year, reflecting the low demand for feedstocks. But that may soon change. “Markets are the biggest challenge right now,” says Volk. “It’s a chicken-and-egg situation: If people grow it, will somebody buy it?” Congress may offer energy-crop incentives in the 2007 farm bill, the major agricultural legislation that is rewritten every five years. Under the federal Conservation Reserve Program, farmers can receive rental payments for taking environmental-



ORNL’s Reinhold Mann in a field of energy-rich switchgrass.

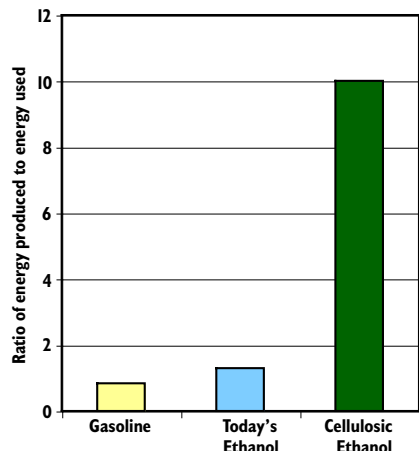
**“I’m already getting e-mails from farmers asking about growing switchgrass for cellulosic ethanol.”**

ly sensitive land out of cultivation for 10 to 15 years. Most of this land is planted with grasses or trees, so some advocates (including the USDA) support using part of it for energy crops.

But according to Scott Faber, director of Environmental Defense’s farm policy campaign, this approach could mean paying farmers to grow crops far from where they’re used. “Refinery developers contract with nearby farmers for feedstocks. If energy crops are grown more than 50 or 60 miles away, it’s too costly to ship them to the factories,” he says. Environmentalists also warn that frequent harvesting on conservation lands would disturb wildlife.

Despite these growing pains, cellulosic ethanol is attracting investments from major corporations, including Dupont and Chevron, and from prominent venture capitalists like Richard Branson and Vinod Khosla. In February, the Department of Energy invested \$385 million in six plants that together will be able to produce more than 130 million gallons of cellulosic ethanol per year. As factories are built, the market for energy crops will expand. “I’m already getting e-mails from farmers asking about growing switchgrass for cellulosic ethanol,” says Mann. If Dustin Hoffman were to revisit his role in *The Graduate* today, the key to future success that’s whispered in his ear might well be *cel-lulose*. ©

## BANG FOR YOUR BUCK



Compared to oil and corn ethanol, the environmental and economic benefits of cellulosic ethanol are clear. This chart compares the ratio of energy produced to fossil-fuel energy used for the production of gasoline, today’s ethanol, and cellulosic ethanol.

(Source: Allen E. Farrell, et al, Science 311, 506-8; 2006)

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