Biofuels from Trees:
Renewable Energy Research Branches Out

On sites ranging from the Pacific Northwest to the Mississippi delta, Jud Isebrands envisions the architecture of a future solar-energy installation: Sprawling across a thousand acres, it bristles with a million solar collection towers, each stretching 50 feet sunward. Each tower bears thousands of thin, maintenance-free photochemical panels. ❧ By day, these panels look to the light of the sun, converting solar radiation into stored chemical energy that will fuel vehicles or illuminate homes; by night, the panels double as exhaust vents, releasing the installation's airborne emissons: oxygen and water vapor. ❧ And every autumn, Isebrands knows, the panels will turn golden-brown and flutter to the ground.

The architectural elements Isebrands envisions, in other words, are stems, branches, and leaves, and his solar towers are trees—hardy, fast-growing, air-cleansing hybrid poplars, planted on surplus farmland and cultivated for the energy they can yield.

Isebrand's vision is closer to being realized than you might think. At research sites across the nation, a major research program of the U.S. Department of Energy (DOE) is exploring and expanding the potential of trees to provide clean, sustainable fuels. The program, sponsored by DOE's Office of Energy Efficiency and Renewable Energy, is called the Bioenergy Feedstock Development Program. Managed by Oak Ridge National Laboratory (ORNL), it's tapping the expertise of Isebrands, a plant physiologist with the U.S. Forest Service—along with dozens of other federal, university, and timber-industry scientists—to increase the growth rates and hardiness of trees grown as energy crops, or *biomass*.

Advanced techniques, including gene-mapping and cloning, allows researchers to select and reproduce large numbers of hardy, fast-growing trees.

Planted in rows and cultivated as energy crops, hybrid poplars show particular promise for high yields under a wide range of growing conditions.

As one of the nation's leading centers of energy research, ORNL has decades of experience with efficient, advanced energy systems. They've found one of the best systems to be the tree, says Gerald Tuskan, an ORNL geneticist. Transfered into *ethanol* (a form of alcohol), biomass can fuel cars and trucks. After high-temperature *gasification*, biomass can yield an array of products, including methanol and diesel fuel and a wide variety of chemical feedstocks for industry. Mixed with coal and burned in a conventional power plant, biomass can extend conventional fuels for producing electricity and, at the same time, reduce pollution from carbon dioxide, sulfur, and nitrogen oxides.

High-tech trees

For biofuels to become mainstream fuels, they must become economically competitive with petroleum, the liquid that quenches most vehicles' thirst fairly inexpensively. Farmers, therefore, must start with extremely hardy trees remarkably resistant to drought, insects, and diseases that can produce high yields on many kinds of cropland. That combination of attributes isn't normally found in nature, so researchers must find ways to nurture it in the laboratory.

It's a job for cutting-edge science. Using the same *gene-mapping* tools developed to unlock the secrets of human DNA, plant geneticists in Oak Ridge and at the University of Washington are probing the genes of fast-growing poplars. By finding the genes responsible for traits such as height, drought tolerance, and pest resistance, researchers can identify individual trees with particular promise, cross them with other trees that excel in other traits, and then produce genetically identical copies by the handful or by the hundred.

After screening dozens of species of trees for growth rates, adaptability, drought tolerance, and disease resistance, researchers have found particular promise in the members of the genus *Populus*—which includes poplars and cottonwoods—and in the poplar's cousin, the willow.

And Isebrands' interest in the architecture of trees is more than just aesthetic, too. The shape of a tree's crown—the geometry of branches, the size and spacing of leaves—determines its efficiency as a solar array. And one of the best solar arrays in the plant kingdom, Isebrands has found, is the crown of the hybrid poplar.

In the Pacific Northwest, by crossing the eastern cottonwood with the region's indigenous black cottonwood, scientists have attained yields as high as 10 tons of dry biomass per acre, per year. That's about 5 to 10 times more than trees produce in the wild. Now, taking the best individual hybrids and crossing them with other superior specimens, they're seeking trees with even faster growth rates, as well as greater drought tolerance and insect resistance.

In a research plot at Oregon State University (OSU), a cloned hybrid poplar—a product of genetic engineering—matures and begins to flower. Then, on the verge of reproduction, something unusual happens: the tree's flowers begins to shrivel, then die. A failed experiment? The work of insects or disease? No: A genetically engineered safety measure. Geneticist Steve Strauss and a team of other OSU researchers are working to implant the tree's reproductive system with a self-destruct mechanism that lets them test sterilized genetically engineered trees in the field.

University and government research plots allow initial screening and development of promising hybrids, but it's the big leagues—giant plantings like James River Corp.'s 10,000 acres in Oregon and Washington—where the lab work can be put to the ultimate test. Brian Stanton, a James River geneticist, draws on the research tools and insights of DOE's research program to complement his company's tree-breeding program. In the company's stands, hybrid

Biofuels researchers have found that a tree's "crown geometry" plays a key role in efficiently converting sunlight into cellulose.

Trees destined for conversion to biofuels can be harvested with the same equipment as trees grown for timber, pulp, or fiber.

In just six growing seasons, hybrid poplars can reach sixty feet or more in height.

Besides offering a promising and renewable energy source, trees also lessen the greenhouse effect by removing carbon dioxide from the air.

poplars are reaching heights of 70 feet, with trunks nearly a foot in diameter ... after just six short years. By working together, the public and private sectors divide the cost of research—but double its value.

Think farming, not logging

One surprising beneficiary of biomass energy could be America's forests. Energy researchers hope to protect natural forests by developing a new source of wood—tree crops. The crops could be grown on biomass farms, sited on land that's too erosion-prone for row crops, soil that's been worked too hard for too long, acreage that crop surpluses have rendered unprofitable for agriculture.

By displacing idle farmland, biomass crops could help revitalize America's farm economy. By stabilizing soil, reducing erosion and runoff, and restoring organic matter to depleted land, these crops could restore the land's vigor. And by providing shelter for birds and other wildlife, they could boost the environmental diversity of the farm belt.

And no matter where it's grown or how it's used, biomass offers tremendous environmental advantages compared with coal, petroleum, and natural gas: It's renewable, and as it grows, biomass removes carbon dioxide from the air, thus helping slow the buildup of "greenhouse gases" that threaten to warm the globe and alter Earth's climate forever.

Stakeholders in the future

In a former pasture in upstate New York, a graduate student shoves a pencil-sized twig into soil softened by spring rains. Four years from now, that twig could yield the light by which a first-grader learns to read, or the heat that browns a family's Thanksgiving turkey.

That small twig is part of a big demonstration of the energy-producing potential of biomass. Planted in a research plot at State University of New York (SUNY), the twig—like thousands of others around it—is a live cutting from a willow that will root and grow, then help fire utility boilers. The demonstration program, involving researchers, farmers, and several power companies, aims to reduce the state's fossil-fuel consumption, cut emissions of carbon dioxide and other pollutants, and promote renewable energy sources.

According to Ed White, SUNY's dean of research, the willow cuttings will grow for a single season, then be lopped off near the ground. The following spring, three or four new stalks will emerge from each set of roots. In just three more years, White says, each of the thousands of stalks will measure up to three inches thick and 20 feet tall.

Then, come autumn, they'll be harvested, chipped, and burned in an electric utility boiler, mixed with coal. The mixture—10% biomass, 90% coal—will reduce emissions of nitrogen oxides and sulfur by about 10%, White figures. In addition, the willows will have begun to recycle carbon, removing several tons of carbon dioxide from the air to feed their photosynthetic growth.

By the end of the decade, White hopes to see 2,000 acres planted in boiler-bound willow. As it burns, say White and other researchers who believe in the promise of biomass, it will light the way to a cleaner, greener energy future for America.

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