Improving Hybrid Poplars as a Renewable Source of Ethanol Fuel

Challenge

The National Biofuels Initiative aims to replace 30% of fossil fuel used for light duty vehicle transportation in the United States by 2030. Cellulosic biomass—including wastes (agricultural, forestry, municipal, industrial/food processing) and energy crops (fast-growing grasses and trees)—is expected to be an important source for ethanol production. In addition, it can be burned to produce steam and electricity.

Most ethanol from biomass now comes from starch-based biomass, such as corn, which easily breaks down into sugars for fermentation. Starch-based ethanol production is a well-developed, relatively mature technology, but lacks a low-cost, large-volume alternative to corn for feedstock. Cellulose and hemicellulose make up the bulk of all trees, grasses, and other plant matter—a supply large enough to compete with oil fields—and researchers are developing processes to produce ethanol from those renewable resources.

Innovating Solutions

GreenWood Resources saw potential in growing poplar trees—remarkable for their sheer biomass productivity—to make ethanol. GreenWood's objective was to develop fast-growing and disease-resistant hybrid poplars that offer maximum levels of cellulose and/or hemicellulose, optimizing the growing cycle and economics of farming poplars as an energy feedstock.

With DOE EERE SBIR Phase I funding, GreenWood was able to conduct a study that established the feasibility of hybridizing poplar trees for biomass feedstock. This study identified the primary traits needing improvement in order to make poplars a better fuel source for biochemical (fermentation) conversion to ethanol, including wood-specific gravity, lignin content, ratio of syringyl-to-guaicyl (S/G) lignin forms, and glucose and xylose content. With a follow-on DOE SBIR Phase II award, GreenWood began a hybridization program with an inheritance study to examine how selective breeding can improve the biofuels properties of the world's most productive hybrid poplar pedigree: *Populus x generosa*. GreenWood built on an existing relationship with Washington State University in conducting this program and in developing a rapid assessment technique for efficiently determining critical energy characteristics of trees in the field.

The DOE SBIR Phase II project also involved field trials of a range of elite hybrid varieties in demonstration plots established at 12 locations throughout the western U.S. to test the range of genetic adaptability. To explore the benefits possible through tree farm management, GreenWood closely integrated their research and development efforts with their operational tree farms and with local energy developers.

The inheritance study was the foundation for continuing work in selective breeding of poplars for high energy value. The rapid assessment technique, which uses near-infrared spectroscopy to characterize the calorific value, chemical composition, and specific gravity of a feedstock tree, enables staff to determine the essential energy properties of trees during regular in-field measurements, avoiding expensive and time-consuming lab tests.

Poplars have a wide range of uses beyond energy conversion, as well—including chips for pulping and logs for veneers and sawn wood products. The demonstration plots showed the economic feasibility of growing poplars solely for energy production and for a combination of saw logs and residual ethanol feedstock. On one plot located near an ethanol production facility in Boardman, Oregon, poplar is being grown as a dedicated energy crop to supply feedstock for

DOE Small Business Innovation Research (SBIR) support enabled GreenWood Resources to advance scientific understanding of the ways chemical traits are inherited in hybrid poplars and the extent of variations in characteristics such as lignin content and forms of lignin—enabling the best traits to be developed and significantly advancing the potential of hybrid poplars to provide a substantial, renewable source of ethanol fuel.

GreenWood Resources (Portland, Oregon) is an integrated forest products company involved in research, plantation management, and product marketing. Established in 1998, GreenWood's staff has extensive experience in poplar research and the company is a leading developer of commercial poplar breeding stock. Initially, GreenWood's specialty in developing high-yield hybrid poplar varieties as well as tree farm management and product sales and trading was primarily aimed at the pulp and paper and solid wood industries. A downturn in those businesses prompted GreenWood to seek other opportunities, leading the company to pursue the great potential of hybrid poplars as cellulosic biomass to make biofuels.

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A case study from the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy SBIR program, providing competitive grants for scientific excellence and technological innovation to advance critical American priorities and build a strong national economy – one small business at a time.

either liquid fuel conversion or combined heat and power production. At a second demonstration plot in Clatskanie, Oregon, poplars are being grown to produce two products: mature, 12-year-old trees will be used for saw logs, and the sawmill waste and trees thinned after 5 years can be used as energy feedstock.

By studying these demonstration plots, GreenWood gained valuable data on the economics of managing plantations for energy feedstock under a diversity of management scenarios. GreenWood's SBIR demonstration plots and varietal-site trials have already helped the company commercialize the use of hybrid poplars for biofuels. Data from test plots in a wide range of climates and drought conditions in the western U.S. show that specially-bred varieties can grow 10 feet in height annually, producing up to 10 tons of dry biomass per acre each year. Unlike many other trees, poplars can be easily hybridized with related species and readily reproduced by clonal propagation from hardwood cuttings. Both are features that accelerate the rate of genetic improvement. As other energy facilities are built in this region, GreenWood will have the data needed to show which varieties are best suited for specific areas, and will be well positioned to supply those facilities with poplar feedstock based on data developed in the varietal site trials.

SBIR Impacts

Projected Benefits of Hybrid Poplar- vs. Corn-based Ethanol Biofuel: 2009 to 2020[1]

Energy	Increased ethanol output	200 gallons ethanol/acre/year
	Reduced energy required for producing the feedstock	15,600 Btu/gallon of ethanol
Environmental	Reduced fertilizer, herbicide, and insecticide use	470 lb/acre
	Reduced CO_2 emissions	160 tons of CO_2 equivalent/acre

Innovation

Poplar has many advantages as an ethanol feedstock.

- As a perennial, poplars require only 1/6 of the fossil energy needed to produce traditional feedstock, such as corn.
- The reduced petroleum requirement results in reduced CO_2 emissions. Poplar plantations are also a large carbon sink.
- High-yield, short-rotation tree farms need less fertilizer and chemical input to produce than many other cellulosic biomass crops, resulting in less water pollution from field run-off. In addition, poplars can be grown on land that is unsuitable for other uses.
- They have a relatively rapid growth cycle of 6 to 12 years, depending on climate, which is longer than annual crops but creates a more stable wildlife habitat because it is not disturbed by annual harvests.
- They can be harvested any time of the year and, unlike other energy crops, do not require the extended storage after harvesting that exposes other biomass crops to degradation from microbial activity.

Company Success

GreenWood credits the SBIR program with opening many doors in the areas of renewable energy and carbon sequestration, adding a vital new component to the company's hybridization program and enabling it to make rapid progress in this area. Previously focused on agronomic qualities such as growth rate, stem form, pest resistance, etc., GreenWood is now able to look at chemical content and lignin form and exploit those traits for energy production.

GreenWood has grown from a staff of 25 to a staff of about 60, and is now a global company with offices in Beijing, China, and Los Angeles, Chile, as well as their Portland, Oregon headquarters.

GreenWood today has a vision based on managing short- and medium-rotation tree farms for multiple markets in timber, energy, CO_2 sequestration, and other environmental applications. They are already breeding poplar for liquid fuels production and entered into a long-term agreement with ZeaChem to provide poplar feedstock for an initial 1.5 million gallon per year cellulosic bio-refinery located near their Boardman, Oregon, tree farm. They are also building on the SBIR contacts they made with companies, universities, and government agencies for future research, partnerships, and collaboration—such as working with USDA's National Agroforestry Center to develop methods of treating industrial and municipal waste in poplar plantations, thereby recycling nutrients as fertilizer.

[1] All benefits are hypothetical using data and conversion factors from the U.S. Department of Energy, GreenWood Resources, and the U.S. Department of Agriculture (USDA). Poplars as a feedstock is a recent option for Greenwood Resources plantations so long term process data is not available.

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