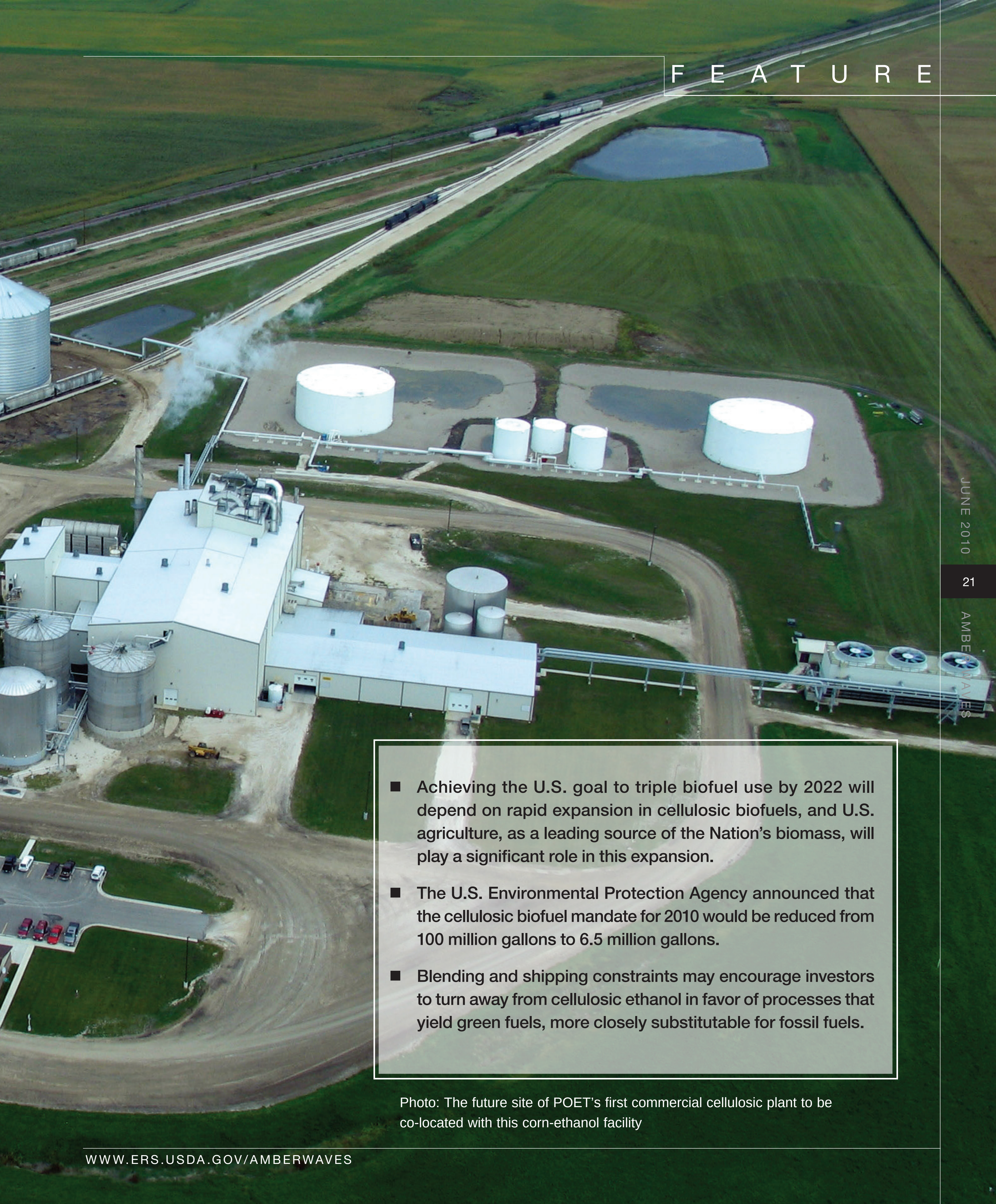
FEATURE

Next-Generation Biofuels

Near-Term Challenges and Implications for Agriculture

William Coyle
wcoyle@ers.usda.gov

Photo courtesy of Poet



- Achieving the U.S. goal to triple biofuel use by 2022 will depend on rapid expansion in cellulosic biofuels, and U.S. agriculture, as a leading source of the Nation's biomass, will play a significant role in this expansion.
- The U.S. Environmental Protection Agency announced that the cellulosic biofuel mandate for 2010 would be reduced from 100 million gallons to 6.5 million gallons.
- Blending and shipping constraints may encourage investors to turn away from cellulosic ethanol in favor of processes that yield green fuels, more closely substitutable for fossil fuels.

Photo: The future site of POET's first commercial cellulosic plant to be co-located with this corn-ethanol facility

The Energy Independence and Security Act (EISA) of 2007 mandates a tripling in U.S. biofuel use to 36 billion gallons by 2022. Achieving this goal will depend on rapid expansion in *next-generation biofuels*, primarily from cellulose. The EISA mandates expanded use of cellulosic biofuel to 16 billion gallons in 2022, on a trajectory to surpass corn ethanol use under the Renewable Fuel Standard.

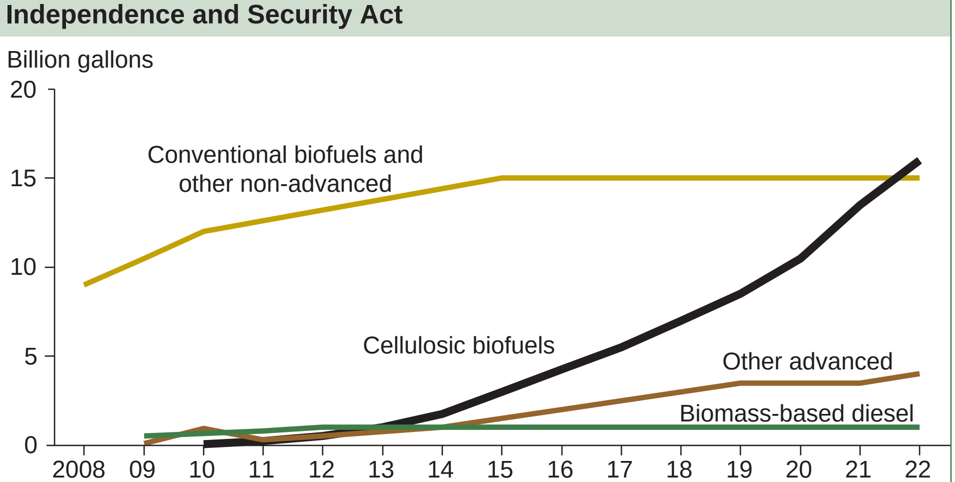
Advanced conversion technologies will be used to create next-generation biofuels from widely available, largely nonfood biomass, including wood waste; crop residues; dedicated energy crops such as switchgrass, energy cane, and biomass sorghum; municipal solid waste; and algae. While some next-generation processes that yield biobutanol or petroleum-equivalent fuels will use corn and other first-generation feedstocks, overall next-generation biofuels likely will have less direct impact on food crops than first-generation biofuels.

ERS estimates that production capacity may be somewhat higher for cellulosic biofuel, about 10 million gallons, with capacity expanding to over 200 million gallons by 2012.

Little Production of Next-Generation Biofuel Expected in Short Term

There are more than 30 U.S. companies developing biochemical, thermochemical, and other approaches to produce next-generation fuels. Most of these firms are currently engaged in small-scale production, experimenting with a variety of feedstocks. Most are also focusing on cellulosic ethanol, a fuel identical to corn ethanol—now commonly used as a gasoline additive. Because ethanol provides only two-thirds of the energy of gasoline and faces blending and transportation constraints, some companies are developing products like green gasoline, green diesel, and biobutanol, which are closer substitutes for fossil fuels.

Rapid rise in use of cellulosic biofuel mandated by Energy Independence and Security Act



Note: The primary mandate for next-generation biofuels under the Energy Independence and Security Act is for cellulosic biofuel. Some types of next-generation biofuels fit under other categories. For example, green diesel made from animal fat is classified as "biobased diesel."

Source: USDA, Economic Research Service using information from the 2007 Energy Independence and Security Act and the U.S. Environmental Protection Agency.

The U.S. Environmental Protection Agency (EPA) announced in early 2010 that the cellulosic biofuel mandate for 2010 would be reduced from 100 million gallons to 6.5 million gallons. There were no changes to mandated levels for subsequent years. ERS estimates that production capacity may be somewhat higher for cellulosic biofuel, about 10 million gallons, with capacity expanding to over 200 million gallons by 2012. Production is likely less than capacity, particularly with the short-term prevalence of pilot and demonstration facilities that are not operated on a continuous basis. Total production capacity for next-generation biofuels, including cellulosic biofuel, biobutanol, and biobased petroleum equivalents, is expected to be about 88 million gallons per year (primarily one company) by the end of 2010, less than the average capacity of a single new corn ethanol plant. Total sector capacity is expected to surpass 350 million gallons by 2012.

Range Fuels and Dynamic Fuels are expected to complete the first commercial next-generation biofuel plants in 2010. Range's plant in Soperton, GA, will use pine tree waste as the feedstock. According to the EPA, the plant's initial capacity has been reduced from 10 million to 4 million gallons per year and initial output will be methanol. The company's ethanol production is expected to commence at a later stage of development.

Dynamic Fuel's plant in Geismar, LA, is expected to start commercial opera-

Selected U.S. companies developing next-generation biofuels shows range of plant capacity, fuel type, and biomass used

Company	Plant location	Plant type	Biofuel	2009	2010	2011	2012	Biomass
				Million gallons per year[1]				
Abengoa Bioenergy	Hugoton, KS	Commercial	Cellulosic ethanol				11.6	Ag residue/ energy crops
Amyris[2]	Emeryville, CA	Pilot	Petroleum equivalents	2	2	2	2	Crops
BlueFire Ethanol	Lancaster, CA	Commercial	Cellulosic ethanol			3.9	3.9	Municipal solid waste
Coskata	Madison, PA	Demo	Cellulosic ethanol	0.04	0.04	0.04	0.04	Multiple[3]
DuPont Danisco	Vonore, TN	Pilot	Cellulosic ethanol	0.25	0.25	0.25	0.25	Ag residue/ energy crops
Dynamic Fuels	Geismar, LA	Commercial	Petroleum equivalents		75	75	75	Animal fat, veg., and other oils
Enerkem	Pontotoc, MS	Commercial	Cellulosic ethanol				10	Multiple
Fulcrum Bioenergy	Storey County, NV	Demo	Cellulosic ethanol				10.5	Municipal solid waste
Gevo	Various locations	Commercial	Biobutanol			50	50	Crops
Frontier Renewable Resources (Mascoma)	Kinross, MI	Commercial	Cellulosic ethanol				20	Wood waste
POET	Emmetsburg, IA	Commercial	Cellulosic ethanol				25	Ag residue
Range Fuels	Soperton, GA	Commercial	Methanol, cellulosic ethanol		4	4	30	Wood waste
Rentech	Rialto, CA	Demo	Petroleum equivalents				9.2	Multiple
Terrabon	Bryan, TX	Pilot	Petroleum equivalents	0.11	0.11	0.11	0.11	Multiple
Verenium	Highlands County, FL	Commercial	Cellulosic ethanol				36	Energy crops
ZeaChem	Boardman, OR	Demo	Cellulosic ethanol		0.25	0.25	0.25	Poplars

	2009	2010	2011	2012
	Million gallons per year			
(1) Cellulosic biofuel	3.9	10.1	29.0	223.1
Mandate for cellulosic biofuels (2007 EISA)		6.5[4]	250.0	500.0
(2) Biobutanol	1.0	1.0	52.5	52.5
(3) Petroleum equivalents	2.3	77.3	77.3	86.5
Total next-generation (1) + (2) + (3)	7.1	88.4	158.9	362.2

Totals are volumetric, not adjusted for energy density, and are for a larger sample of companies. Thus, the totals for the companies listed in this table are less than the totals at the bottom.

For a complete list of companies, see *Next-Generation Biofuels: Near-Term Challenges and Implications for Agriculture,* by William Coyle, BIO-01-01, USDA, Economic Research Service, available at: www.ers.usda.gov/publications/bio0101/

[1]The numbers in this table represent "production capacity," not "production." Actual production is likely to be less because pilot and demonstration plants are not operated on a continuous basis.

[2]Company has joint venture with Brazilian companies; output from various Brazilian plants could be as much as 200 million gallons per year after 2012.

[3]Multiple = At least two biomass categories.

[4]Mandate for cellulosic biofuel reduced by EPA in February 2010 from 100 million gallons per year for 2010 (originally specified in 2007 EISA) to 6.5 million gallons.

Source: USDA, Economic Research Service using data from the U.S. Environmental Protection Agency, company websites, and other sources.

tions in late 2010, using animal fat as the feedstock and producing a biobased diesel fuel. POET, which has a pilot plant operational in Scotland, SD, may have the first commercial plant to produce cellulosic ethanol. The facility will be co-located with one of POET's existing corn ethanol plants in Emmetsburg, IA, and is scheduled to be operational in late 2011 or early 2012, using corn cobs as the feedstock. Most other companies have pilot or demonstration plants, with average estimated production capacity of less than 1 million gallons in 2010, but future plans to expand.

In the short term, production of next-generation biofuels will be limited and thus will have a minor impact on feedstock demand. Furthermore, some companies will exploit already existing streams of forestry waste and municipal solid waste while supply arrangements for agricultural biomass (crop residues and energy crops) are developed. But if production of next-generation biofuels gets on an expansionary path, agriculture could eventually play a large role. Biomass inventory and other analyses by the U.S. Department of Energy (DOE), USDA, and EPA conclude that of all potential sources of biomass, U.S. agricultural sources (crop residues and energy crops) are the most significant.

High Costs Are a Challenge for Next-Generation Biofuels

If next-generation biofuels are to play a key role in America's energy future, a number of challenges must be overcome, foremost of which are reducing costs. High production and initial construction costs for untested technologies and processes on a large scale increase investment risk and affect the willingness of investors to underwrite projects.

In 2007, USDA estimated cellulosic ethanol production costs at $2.65 per gallon, compared with $1.65 for corn-based ethanol.

Capital investment costs for cellulosic ethanol plants are estimated at three to four times those for first-generation biofuel plants. These are the costs incurred in the purchase of land, buildings, construction, and equipment and represent the total cost to bring a project to a commercially operable status. According to 2004 estimates of the DOE's Energy Information Administration, capital investment costs for biomass-to-liquid facilities ranged from $650 million to $900 million for a 100-million gallon capacity plant, compared with $130 million to $230 million for a similar-sized corn ethanol plant. Other more recent studies estimate lower capital investment costs to $320 million to $340 million for cellulosic ethanol plants, suggesting that these costs could be trending downward despite significant increases since 2003 in material and energy costs.

In 2007, USDA estimated cellulosic ethanol production costs at $2.65 per gallon, compared with $1.65 for corn-based ethanol. Capital and conversion costs are expected to decline as companies increase production and have greater access to low-cost biomass.

According to a 2008 report by the Biomass Research and Development Board, farmers would need to receive $40 to $60 per dry ton to produce sufficient feedstocks for 12 billion to 20 billion gallons of cellulosic ethanol from agricultural biomass—agricultural residues and energy crops. These prices are consistent with the $40 to $60 per ton that POET plans to pay suppliers of corn cobs for delivery at its commercial cellulosic ethanol plant when it opens in 2011.

For farmers to shift to production of dedicated energy crops such as switchgrass, however, farm prices would need to compete with the lowest value crops such as hay, whose price has exceeded $100 per ton since 2007. The new Biomass Crop Assistance Program in the Food, Conservation, and Energy Act of 2008 (Farm Act) will help to boost farmer incentives and lower feedstock costs for biorefineries. This program provides assistance up to $45 per dry ton to producers of eligible biomass. The assistance is directed at the establishment and production of new feedstocks for biofuels. The subsidy significantly increases incentives to produce, harvest, collect, and deliver bulky low-value biomass products to biorefineries and other conversion facilities. This, in turn, will help to lower feedstock costs and facilitate timely availability of supply to biorefineries.

Companies Pursue a Variety of Strategies To Secure Financial Support for Development

Next-generation biofuel companies are using a variety of strategies to overcome high initial capital costs and to remain financially viable during precommercial development, including venture capital, government grants and loan guarantees, and alliances with large corporations. Venture capital has been a crucial source of capital for next-generation

Photo courtesy of Ken Goddard, University of Tennessee Extension

U.S. Policies and Programs Support Next-Generation Biofuels

In addition to Federal programs that provide direct support to bioenergy companies, a number of U.S. policies are designed to provide broad support for next-generation biofuel producers. The most significant of the broad market policies is the Renewable Fuel Standard (RFS2) enacted in the 2007 Energy Independence and Security Act (EISA). RFS2 mandates expanded use of conventional (ethanol primarily from corn starch) and advanced biofuels (from cellulosic, bio-based diesel, and other sources) through 2022.

The 2008 Farm Act provides funding for research on and development of conversion technologies and biomass; a tax credit of $1.01 per gallon for cellulosic ethanol for 2009-12, more than double the $0.45 per gallon for corn ethanol; and assistance to producers for eligible second-generation feedstocks. Cellulosic ethanol benefits from the same border protection as for first-generation ethanol: a 2.5-percent ad valorem surcharge and a $0.54-per-gallon surcharge (which are waived for imports from Caribbean Basin Initiative countries that meet certain conditions regarding local content).

The Biomass Crop Assistance Program provides assistance up to $45 per dry ton for eligible biomass. The assistance is directed at the establishment and production of biomass for heat, power, biobased products or advanced biofuels. The subsidy boosts incentives to produce, harvest, collect, and deliver bulky low-value biomass products to biorefineries and other conversion facilities. This, in turn, will help to lower feedstock costs and facilitate timely and sustainable supplies to biorefineries.

USDA and the U.S. Department of Energy (DOE) are committed to basic and applied research through their national networks of labs and experiment stations. USDA provides loan guarantees to support development of innovative conversion technologies for next-generation biofuels. It is also proposing a program to encourage biorefineries to use renewable biomass energy instead of fossil fuels and a payment system to support production. EISA provides a 50-percent depreciation deduction for eligible cellulosic biofuel plants in the first year of operation through 2012.

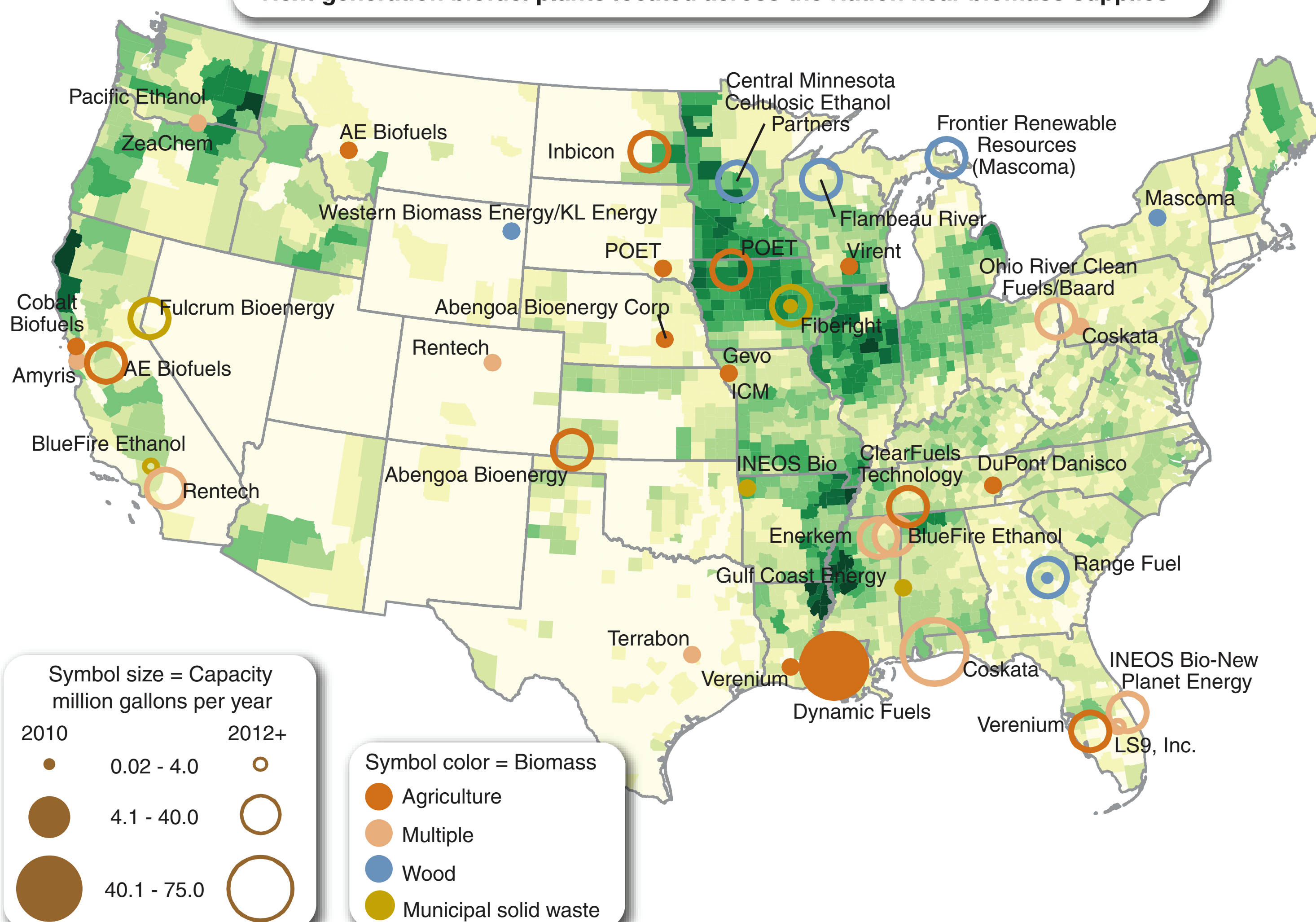
DOE also has funneled significant resources in the creation of three Bioenergy Research Centers at DOE's Oak Ridge National Laboratory in Oak Ridge, TN; at the University of Wisconsin in Madison, WI; and at DOE's Lawrence Berkeley National Laboratory, Berkeley, CA. Significant resources are allocated through DOE labs, including the National Renewable Energy Lab in Colorado. Public research funds target efforts to lower the costs of production of next-generation biofuels through increasing biomass yields (tons per acre), conversion yields (gallons per ton), and speed of conversion; finding new uses for co-products; improving the understanding of optimal removal rates for agricultural residues; and addressing economic and environmental issues.

biofuel companies. In 2009, however, the global recession slowed growth in venture capital for biofuels. This slowdown was partially offset by a major infusion of public-sector support.

In December 2009, DOE Secretary Steven Chu and USDA Secretary Tom Vilsack announced the selection of 19 integrated biorefinery projects to receive $564 million from the American Recovery and Reinvestment Act to accelerate the construction and operation of pilot, demonstration, and commercial-scale facilities. USDA also extended two major loan guarantees totaling $134.5 million in 2009 (Sapphire and Range Fuels) through the Biorefinery Assistance Program, authorized in the 2008 Farm Act. The program promotes the development of new and emerging technologies for production of fuels from starch biomass other than corn. The program provides loan guarantees to develop, construct, and retrofit viable commercial-scale biorefineries producing advanced biofuels.

The Federal Government has committed a total of more than $2 billion (this includes the $564 million announced in December 2009) to next-generation biofuels in 2007-09 in direct private-sector support and to university research and development, including biomass projects.

Next-generation biofuel plants located across the Nation near biomass supplies



Note: The darker the green, the greater the density (tons per county) of cropland and forestland biomass.

Source: *Next-Generation Biofuels: Near-Term Challenges and Implications for Agriculture*, by William Coyle, BIO-01-01, USDA, Economic Research Service, available at: www.ers.usda.gov/publications/bio0101/

States have also provided significant support for projects in their jurisdictions.

Some biofuel companies have partnered with large fuel corporations, such as BP, Exxon Mobil, Chevron, Conoco Phillips, Shell, and Valero. Other corporations, including General Motors, Weyerhaeuser, Novozymes, Honeywell, Dow Chemical, and DuPont, also collaborate on next-generation biofuel projects. These arrangements can augment a small company's financial resources and provide opportunities to gain access to engineering and conversion technologies and marketing expertise. For the large companies, these arrangements provide an opportunity to vertically integrate or diversify their businesses or gain access to new technologies.

Companies Seek To Establish Reliable Supplies of Feedstock

When fully commercialized, cellulosic biofuel companies will require vast quantities of bulky material to be delivered and stored at their plants to help ensure a steady year-round supply of biomass. In some cases, companies are planning to exploit established streams of wood and municipal solid waste.

Other companies are working with local biomass producers to develop supplies for their pilot or demonstration plants and lay the groundwork for larger commercial operations. For example, The “blend wall” is a technical standard that adversely affects the outlook for both first- and next-generation biofuels.

—Poet is working with regional corn producers to supply cobs for its commercial combined-corn-and-cellulosic facility in Iowa scheduled for operation in 2011.

—ZeaChem is working with GreenWood Resources, Inc. to supply poplar trees for an initial output of 250,000 gallons of biofuel per year in 2010 at its plant in Boardman, OR.

—The Noble Foundation is partnering with the Oklahoma Bioenergy Center to develop 1,000 acres of switchgrass in anticipation of the 2011 opening of Abengoa's cellulosic plant in Kansas.

—The State of Tennessee is providing subsidies to more than 60 farmers to grow switchgrass to help meet feedstock demand at the DuPont Danisco pilot plant in Vonore, TN.

—The Verenium-BP joint venture signed a long-term lease for 20,000 nearby acres to grow energy cane and forage sorghum to help meet feedstock requirements at its future 36-million-gallon-per-year cellulosic ethanol plant in Highlands County, FL.

Overcoming Blend Wall Constraints

The “blend wall” is a technical standard that adversely affects the outlook for both corn- and cellulosic ethanol. Car manufacturers' warranties and extended warranties for non-flex-fuel vehicles cover only cars using gasoline with a maximum ethanol share of 10 percent because higher blends may damage the engine and other components.

Ethanol accounted for 7.9 percent of U.S. gasoline use, or 10.8 billion gallons in 2009. Under EISA, the maximum amount of corn ethanol use that can count toward the Renewable Fuel Standard in 2015-2022 is 15 billion gallons. If gasoline consumption remains constant at 138 billion gallons, as some industry analysts predict, corn ethanol's share could exceed 10 percent, providing only limited opportunity for next-generation cellulosic ethanol to compete with corn ethanol for the blended gasoline market.

Reaching the EISA target for cellulosic and corn-based ethanol by 2022 will require raising the 10-percent blend standard for regular vehicles and expanding use of the gasoline substitute, E85—a mixture of 85 percent ethanol and 15 percent gasoline (which now accounts for only 1 percent of ethanol use in the U.S.) (see “Full Throttle U.S. Ethanol Expansion Faces Challenges Down the Road” in the September 2009 issue of *Amber Waves*). In 2009, the EPA deferred until mid-2010 a decision to raise the 10-percent standard to 15 percent, at least for cars manufactured since 2000. Expanding the use of E85 will require development of an infrastructure to distribute and dispense E85 and expanded manufacture of vehicles capable of using it. Currently, 9 million of about 235 million cars and other light vehicles in the United States are E85-capable, and 2,200 of the Nation's 160,000 gas stations are set up to dispense E85.

Given the limited market for ethanol as a gasoline additive (due to the E10 blend wall) and as a gasoline substitute (because of the slow development of the E85 market), developers and investors may turn away from cellulosic ethanol in favor of production of green fuels. These green fuels are also called “drop-in” fuels because they are close substitutes for gasoline or diesel and can be used in current vehicles without limit and distributed in the existing transportation fuel infrastructure. There are a number of companies now developing drop-in fuels, including Amyris, LS9, and Rentech. Among the 19 bioenergy companies recently awarded DOE grants, half are developing biobased drop-in fuels.

This article is drawn from . . .

Next-Generation Biofuels: Near-Term Challenges and Implications for Agriculture, by William Coyle, BIO-01-01, USDA, Economic Research Service, May 2010, available at: www.ers.usda.gov/publications/bio0101/

“Full Throttle: U.S. Ethanol Expansion Faces Challenges Down the Road,” by Paul Westcott, in *Amber Waves,* Vol. 7, Issue 3, September 2009, USDA, Economic Research Service, available at: www.ers.usda.gov/amberwaves/september09/features/ethanolexpansion.htm

Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program: Final Rule, by U.S. Environmental Protection Agency, February 2010.