Cellulosic Biofuels: Analysis of Policy Issues for Congress

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Summary

Cellulosic biofuels are produced from cellulose (fibrous material) derived from renewable biomass. They are thought by many to hold the key to increased benefits from renewable biofuels because they are made from potentially low-cost, diverse, non-food feedstocks. Cellulosic biofuels could also potentially decrease the fossil energy required to produce ethanol, resulting in lower greenhouse gas emissions.

Cellulosic biofuels are produced on a very small scale at this time—significant hurdles must be overcome before commercial-scale production can occur. The renewable fuels standard (RFS), a major federal incentive, mandates a dramatic increase in the use of renewable fuels in transportation, including the use of cellulosic biofuels—100 million and 250 million gallons per year (mgpy) for 2010 and 2011, respectively. After 2015, most of the increase in the RFS is intended to come from cellulosic biofuels, and by 2022, the mandate for cellulosic biofuels will be 16 billion gallons. Whether these targets can be met is uncertain. In March 2010, the Environmental Protection Agency issued a final rule that lowered the 2010 cellulosic biofuel mandate to 6.5 million gallons. In December 2010, EPA lowered the 2011 mandate to 6.6 million gallons. Research is ongoing, and the cellulosic biofuels industry may be on the verge of rapid expansion and technical breakthroughs. There are no large-scale commercial cellulosic biofuel plants in operation in the United States. A few small-scale plants came online in 2010.

The federal government, recognizing the risk inherent in commercializing this new technology, has provided loan guarantees, grants, and tax credits in an effort to make the industry competitive by 2012. In particular, the Food, Conservation, and Energy Act of 2008 (the 2008 farm bill, P.L. 110-246) supports the nascent cellulosic industry through authorized research programs, grants, and loans exceeding $1 billion. The enacted farm bill also contains a production tax credit of up to $1.01 per gallon for fuels produced from cellulosic feedstocks. Private investment, in many cases by oil companies, also plays a major role in cellulosic biofuels research and development.

Three challenges must be overcome if the RFS is to be met. First, cellulosic feedstocks must be available in large volumes when needed by refineries. Second, the cost of converting cellulose to ethanol or other biofuels must be reduced to a level to make it competitive with gasoline and corn-starch ethanol. Third, the marketing, distribution, and vehicle infrastructure must absorb the increasing volumes of renewable fuel, including cellulosic fuel mandated by the RFS.

Congress will likely continue to face questions about the appropriate level of intervention in the cellulosic industry as it debates both the risks in trying to pick the winning technology and the benefits of providing start-up incentives. The current tax credit for cellulosic biofuels is set to expire in 2012, but its extension may be considered during the 112th Congress. Congress may continue to debate the role of biofuels in food price inflation and whether cellulosic biofuels can alleviate its impacts. Recent congressional action on cellulosic biofuels has focused on the definition of renewable biomass eligible for the RFS, which is considered by some to be overly restrictive. To this end, legislation was introduced in the 111th Congress to expand the definition of renewable biomass eligible under the RFS.

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Introduction

Cellulosic biofuels are produced from cellulose[1] derived from renewable biomass feedstocks such as corn stover (plant matter generally left in the field after harvest), switchgrass, wood chips, and other plant or waste matter. Current production consists of a few small-scale pilot projects—and significant hurdles must be overcome before industrial-scale production can occur.

Ethanol produced from corn starch and biodiesel produced from vegetable oil (primarily soybean oil) are currently the primary U.S. biofuels.[2] High oil and gasoline prices, environmental concerns, rural development, and national energy security have driven interest in domestic biofuels for many years. However, the volume of fuel that can be produced using traditional row crops such as corn and soybeans without causing major market disruptions is limited; to fulfill stated goals, biofuels must also come from other sources that do not compete for the same land used by major food crops. Proponents see cellulosic biofuels as a potential solution to these challenges and support government incentives and private investment to hasten efforts toward commercial production. Some federal incentives—grants, loans, tax credits, and direct government research—attempt to push cellulosic biofuels technology to the marketplace. Demand-pull mechanisms such as the renewable fuel standard (RFS) mandate the use of biofuels, creating an incentive for the development of a new technology to enter the marketplace.

In contrast, petroleum industry critics of biofuel incentives argue that technological advances such as seismography, drilling, and extraction continue to expand the fossil-fuel resource base, which has traditionally been cheaper and more accessible than biofuel supplies. Other critics argue that current biofuel production strategies can only be economically competitive with existing fossil fuels in the absence of subsidies if significant improvements are made to existing technologies or new technologies are developed. Until such technological breakthroughs are achieved, critics contend that the subsidies distort energy markets and divert research funds from the development of other renewable energy sources not dependent on internal combustion technology, such as wind, solar, or geothermal, which offer potentially cleaner, more bountiful alternatives. Still others debate the rationale behind policies that promote biofuels for energy security, questioning whether the United States could ever produce and manage sufficient feedstocks of starches, sugars, vegetable oils, or even cellulose to permit biofuel production to meaningfully offset petroleum imports. Finally, there are those who argue that the focus on development of alternative energy sources undermines efforts to score energy savings through lower consumption.

The Renewable Fuel Standard: A Mandatory Usage Mandate

Principal among the cellulosic biofuels goals to be met is a biofuels usage mandate—the renewable fuel standard (RFS) as expanded by the Energy Independence and Security Act of 2007 (EISA, P.L. 110-140, Section 202)—that includes a specific carve-out for cellulosic biofuels.[3] The RFS is a demand-pull mechanism that requires a minimum usage of biofuels in the nation's fuel supply. This mandate can be met using a wide array of technologies and fuels.

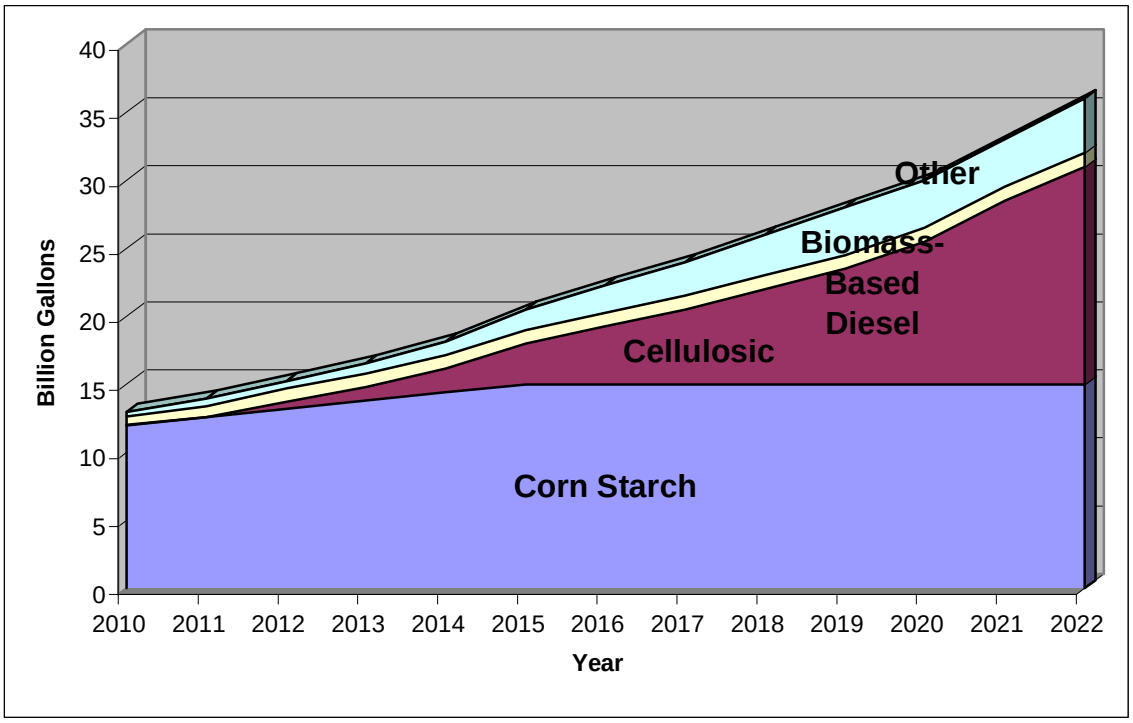
[1] Cellulose is the structural component of the primary cell wall of green plants.

[2] For more information on ethanol, see CRS Report R40488, *Ethanol: Economic and Policy Issues*, by (name redacted).

[3] For more information on the RFS, see CRS Report R40155, *Renewable Fuel Standard (RFS): Overview and Issues*, by (name redacted) and (name redacted).

Although most of the RFS is expected to be met using corn ethanol initially, over time the share of advanced (non-corn-starch derived) biofuels in meeting the mandate increases. The RFS specifies three non-corn-starch carve-outs: cellulosic biofuels, biomass-based diesel fuel, and other (or unspecified), which could potentially be met by imports of sugarcane-based ethanol. The RFS mandate for cellulosic biofuels in the EISA begins at 100 million gallons per year in 2010 and rises to 16 billion gallons per year in 2022 (**Figure 1**).[4] This mandate represents a prodigious challenge to the biofuels industry in light of the fact that no large-scale commercial production of cellulosic biofuels yet exists in the United States. Indeed, in March 2010, the U.S. Environmental Protection Agency (EPA) issued a final rule for implementation of the RFS that sets a new, lower cellulosic biofuel mandate of 6.5 million gallons for 2010. In December 2010, EPA issued a final rule to lower the 2011 cellulosic biofuel mandate of 250 million gallons to 6.6 million gallons (actual volume).[5]

Figure 1. Renewable Fuel Standard Under EISA as of December 2010



Source: EISA, (P.L. 110-140, Section 202).

Notes: Corn-starch ethanol volume is a cap, whereas other categories are floors. Biodiesel includes any type of biomass-based diesel substitute.

The RFS also mandates maximum lifecycle greenhouse gas emissions for each type of biofuel. Lifecycle greenhouse gas emissions encompass emissions[6] at all levels of production, from the field to retail sale, including emissions resulting from land use changes (e.g., the clearing of

[4] U.S. Environmental Protection Agency, "Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program; Final Rule," 75 *Federal Register*, March 26, 2010.

[5] U.S. Environmental Protection Agency, "Regulation of Fuels and Fuel Additives: 2011 Renewable Fuel Standards; Final Rule," *Federal Register*, December 9, 2010.

[6] Greenhouse gases include carbon dioxide, methane, and nitrous oxide (CO_2, CH_4, and N_2O respectively).

forests for cropland due to increased energy crop production elsewhere). Under the law, GHG emissions for cellulosic biofuels qualifying for the RFS are limited to 60% of the GHG emissions from extracting, refining, distributing, and consuming gasoline.[7]

Challenges Facing the Industry

Cellulosic biofuels have potential, but there are significant hurdles to overcome before competitiveness is reached. In his 2007 State of the Union Address, President Bush announced the "Twenty in Ten" initiative, calling for the rapid expansion of renewable biofuels production as a major part of an effort to reduce U.S. gasoline use by 20% through biofuels and conservation. This goal was given substance in December 2007, when Congress passed EISA, mandating the RFS for the use of specific volumes of renewable biofuels through 2022 and setting a goal of commercial-scale cellulosic biofuels production by 2012.

This report provides background on the current effort to develop industrial-scale, competitive technology to produce biofuels from cellulosic feedstocks. It outlines the three major challenges faced in the context of the RFS: (1) feedstock supply, (2) extraction of fuel from cellulose, and (3) biofuel distribution and marketing issues. It then examines the current role of government (in cooperation with private industry) in developing that technology. Finally, the report reviews the role of Congress with respect to the emerging cellulosic biofuels industry, reviews recent congressional actions affecting the industry, and discusses key questions facing Congress.

Cellulosic Feedstock Supplies

Feedstocks used for cellulosic biofuels are potentially abundant and diverse. Initially it was thought that a major advantage of cellulosic biofuels over corn-starch ethanol was that they could be derived from potentially inexpensive feedstocks that could be produced on marginal land.[8] Corn, on the other hand, is a resource-intensive crop that requires significant use of chemicals, fertilizers, and water, and is generally grown on prime farmland. However, field research now suggests that establishment costs, as well as collection, storage, and transportation costs, associated with the production of bulky biomass crops are likely to be more challenging than originally thought.[9]

Cellulose, combined with hemicellulose and lignin, provides structural rigidity to plants and is also present in plant-derived products such as paper and cardboard. Feedstocks high in cellulose come from agricultural, forest, and even urban sources (see **Table 1**). Agricultural sources include crop residues and biomass crops such as switchgrass; forest sources include tree plantations, natural forests, and cuttings from forest management operations. Municipal solid waste, usually from landfills, is the primary urban source of renewable biomass.

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[7] For more information on the lifecycle analysis of greenhouse gas emissions under the RFS, see CRS Report R40460, *Calculation of Lifecycle Greenhouse Gas Emissions for the Renewable Fuel Standard (RFS)*, by (name redacted) and (name redacted).

[8] *Breaking the Link between Food and Biofuels*, Bruce A. Babcock, Briefing Paper 08-BP 53, July 2008.

[9] Preliminary draft of the feedstock and technology chapters from a Purdue University study on "Cellulosic Biofuels: Technology, Market, and Policy Assessment," September 7, 2009. This study is being conducted by Purdue University under contract with CRS and is supported by Joyce Foundation funding.

Cellulosic feedstocks may have some environmental drawbacks. Some crops suggested for biomass are invasive species when planted in non-native environments. Municipal solid wastes may likely require extensive sorting to segregate usable material and may also contain hazardous material that is expensive to remove. In general, calculation of the estimated cost of biofuels production does not reflect environmental or related impacts, but such impacts are relevant to overall consideration of biofuels issues.

Table 1. Potential Cellulosic Feedstock Sources

Source	Feedstock
Agricultural crop residues	Crop residues—stover, straw, etc.
Agricultural commercial crops	Perennial prairie grasses
Forest woody biomass	Logging residues from conventional harvest operations and forest management and land clearing operations
	Removal of excess biomass from timberlands and other forest lands
	Fuelwood from forest lands
	Perennial woody crops
Agricultural or forest processing by-products	Food/feed processing residues
	Pulping (black) liquor from paper mills
	Primary and secondary wood processing mill residues
Urban	Municipal solid waste
	Packaging wastes and construction debris

Source: CRS.

Biomass feedstocks are bulky and difficult to handle, presenting the industry with a major challenge. Whether feedstocks are obtained from agriculture or forests, specialized machinery would need to be developed to harvest and handle large volumes of bulky biomass. For instance, harvesting corn for both grain and stover would be more efficient with a one-pass machine capable of simultaneously segregating and processing both—a combination forage and grain harvester. Currently, machines such as these are being developed to handle biomass crops, but few are commercially available.[10] Storage facilities capable of keeping immense volumes of cellulosic material in optimal conditions may need to be developed, if an industry is to grow.

Crop Residues

Crop residues are by-products of production processes (such as producing grain), and so their production costs are minimal. Corn stover[11] and rice and wheat straw are abundant agricultural residues with biomass potential.[12] Among residues, corn stover has attracted the most attention for biofuels production. However, an important indirect cost associated with using crop residue as a biomass feedstock is a potential loss of soil fertility. When harvesting stover, sufficient crop residue must be left in place to prevent erosion and maintain soil fertility. Research suggests that,

[10] *Growing and Harvesting Switchgrass for Ethanol Production in Tennessee*, Clark D. Garland, Tennessee Biofuels Initiative, University of Tennessee Institute of Agriculture, UT Extension SP-701a.

[11] Corn stover consists of the cob, stalk, leaf, and husk left in the field after harvest.

[12] Bioenergy Feedstock Information Network, Biomass Resources, http://bioenergy.ornl.gov/main.aspx.

under the right soil conditions, up to 60% of some residuals can be removed without detrimental soil nutrition or erosion effects. Results from early trials suggest the potential ethanol yield from corn stover (not including the grain harvested, which could be used for feed or fuel) is approximately 180 gallons of ethanol per acre. This compares with roughly 425 gallons of corn-starch ethanol[13] (from grain) and 662 gallons per acre of sugar cane (in Brazil), when grown as dedicated energy crops.[14]

Prairie Grasses

Perennial prairie grasses include native species, which were common before the spread of agriculture, and non-indigenous species, some of which are now quite common. Switchgrass is a native perennial grass that once covered American prairies and is a potential source of biomass. Its high density and native immunity to diseases and pests have caused many to focus on its use as a cellulosic feedstock. According to research at the University of Tennessee, the 10-foot tall grass, if harvested after frost, will produce for 10 to 20 years. However, like other perennials, switchgrass takes some time to establish—according to field trials, in the first year of production, yields are estimated at 30% (two tons per acre) of the full yield potential. In the second year, yield is about 70% (five tons per acre), and in the third year yields reach full potential at seven tons per acre,[15] the equivalent of 500[16] to 1,000 gallons of ethanol.[17]

Miscanthus is another fast-growing perennial grass. Originally from Asia, it is now common in the United States. Miscanthus produces green leaves early in the planting season and retains them through early fall, maximizing the production of biomass.[18] Like switchgrass, it grows on marginal lands with minimal inputs. Research in Illinois shows miscanthus can produce 2½ times the volume of ethanol (about 1,100 gallons) per acre as corn—under proper conditions.[19]

At South Dakota State University, field trials with mixtures of native grasses produced biomass yields slightly lower than switchgrass monocultures, but suggest that such mixtures result in better soil health, improved water quality, and better wildlife habitat.[20] Similar research at the University of Minnesota with mixtures of 18 native prairie species resulted in biomass yields three times greater than switchgrass.[21]

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[13] USDA Economic Research Service, *Ethanol Reshapes the Corn Market*, Amber Waves, April 2006, http://www.ers.usda.gov/AmberWaves/April06/Features/Ethanol.htm.

[14] Cellulosic Ethanol: A Greener Alternative, by Charles Stillman, June 2006, http://www.cleanhouston.org/energy/features/ethanol2.htm.

[15] *Growing and Harvesting Switchgrass for Ethanol Production in Tennessee*, Clark D. Garland, Tennessee Biofuels Initiative, University of Tennessee Institute of Agriculture, UT Extension SP-701a.

[16] Ibid.

[17] "DuPont Danisco and University of Tennessee Partner to Build Innovative Cellulosic Ethanol Pilot Facility," press release, Nashville, TN, July 23, 2008.

[18] Science News, "Giant Grass Miscanthus Can Meet US Biofuels Goal Using Less Land Than Corn Or Switchgrass," *Science Daily*, August 4, 2008, http://www.sciencedaily.com/releases/2008/07/080730155344.htm.

[19] Ibid.

[20] *Perennial Bioenergy Feedstocks Report to Chairman Collin Peterson*—House Agriculture Committee, April 5, 2007, North Central Bio-economy Consortium.

[21] *Carbon-Negative Biofuels from Low-Input High-Diversity Grassland Biomass*, by David Tilman, Jason Hill, and Clarence Lehman, Science, December 8, 2006: vol. 314, p. 1598.

Forest Sources of Biomass

Forest resources for biomass include naturally occurring trees, residues from logging and other removals, and residue from fire prevention treatments. Extracting and processing forest biomass can be expensive because of poor accessibility, transportation, and labor availability. More efficient and specialized equipment than currently exists is needed for forest residual recovery to become cost effective.[22]

Commercial tree plantations (perennial woody crops) are another source of woody biomass. Compared to prairie grasses, perennial woody crops such as hybrid poplar, willow, and eucalyptus trees, are relatively slow to mature and require harvesting at long intervals (2-4 year intervals for willow or 8-15 years for poplar). Using specialized equipment, harvesting usually occurs in the winter, when trees are converted to chips on site and then transported to the refinery for processing. Some trees, such as willow, re-sprout after cutting and can be harvested again after a few years.[23] An acre of woody biomass (i.e., hybrid poplar) yields an estimated 700 gallons of biofuel on an annual basis.[24]

Secondary and Tertiary Feedstocks

Secondary and tertiary feedstocks are derived from manufacturing (secondary) or consumer (tertiary) sources. In many cases their use as feedstocks recovers value from low- or negative-value materials. Food and feed processing residues such as citrus skins are major agricultural residues often suitable as renewable biomass. Residues from wood processing industries such as paper mills or from feed processing are major secondary sources. Tertiary sources include urban wood residues such as construction debris, urban tree trimmings, packaging waste, and municipal solid waste. One ton of dry woody biomass produces approximately 70 gallons of biofuels.[25]

Feedstock Issues

Volumes Required

Ethanol plants are intended to operate 24/7, that is, year-round with only a brief temporary stoppage for maintenance. As a result, accumulating and storing enough feedstock to supply a commercial-scale refinery producing 10-20 million gallons per year (mgpy) would require as much as 700 tons of feedstock a day—nearly the volume of 900 large round bales of grass or hay—or about 240,000 tons annually.[26] In contrast, a (much larger) 100 mgpy corn ethanol plant requires about 2,500 tons of corn per day, but corn is much denser and easier to handle than most

[22] *Biomass as a Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply*, Environmental Sciences Division, Oak Ridge National Laboratory, 2005, http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf, p36.

[23] IAE Bioenergy, *Sustainable Production of Woody Biomass for Energy*, March 2002, http://www.energycommission.org/files/finalReport/IV.4.c%20-%20Cellulosic%20Ethanol%20Fact%20Sheet.pdf.

[24] "Fast-Growing Trees Could Take Root as Future Energy Source," press release of Purdue University Study funded by DOE, http://www.purdue.edu/UNS/html4ever/2006/060823.Chapple.poplar.html.

[25] *Producing Ethanol from Wood*, presentation by Alan Rudie, USDA Forest Service Forest Products Laboratory, Madison, WI, http://www.csrees.usda.gov/nea/plants/pdfs/rudie.pdf.

[26] DOE refinery feedstock estimates and CRS calculations into large round bales.

renewable biomass sources.[27] The U.S. Department of Energy (DOE) is currently focusing research efforts on harvest and collection, preprocessing, storage and queuing, handling, and transportation of feedstocks.[28] These are major challenges facing an emerging biofuels industry due to the sheer bulk of the biomass and divergent growth cycles of different biomass crops. Pelletizing and other methods for compressing feedstocks reduce transportation costs but increase processing costs. According to a Purdue University study, the total per ton costs for transporting biomass 30 miles range from $39 to $46 for corn stover and $57 to $63 for switchgrass—compared with roughly $10 for corn.[29] The USDA-DOE goal is to reduce the total feedstock cost at the plant (production, harvest, transport, and storage) from $60 per ton (the 2007 level) to $46 per ton in 2012.[30]

A 2005 USDA-DOE study undertaken by the Oak Ridge National Laboratory estimates that just over 1.3 billion tons of biomass (**Figure 2**) could be available annually in the United States for all forms of bioenergy production (including electricity and power from biomass, and fuels from cellulose) and bioproducts.[31] If processed into biofuel, this 1.3 billion tons of biomass could replace 30% of U.S. transportation fuel consumption at 2004 levels, according to USDA. However, this estimate has been heavily criticized for several reasons, including the claim that it ignores the costs and difficulties likely to be associated with harvesting or collecting woody biomass and urban waste, as well as that it uses optimistic yield growth assumptions to achieve its biomass tonnages. The USDA estimate also predates the definition of renewable biomass eligible for the RFS. Current provisions restrict the use of woody biomass to trees grown in plantations or pre-commercial thinnings from non-federal lands, while USDA's study included woody biomass from federal and private forests as well as commercial forests. As a result, the potential volume of biomass available for conversion may be substantially less than the USDA-DOE estimate of 1.3 billion tons.

[27] *Analysis of the Efficiency of the U.S. Ethanol Industry 2007*, by May Wu, Center for Transportation Research Argonne National Laboratory Delivered to Renewable Fuels Association on March 27, 2008.

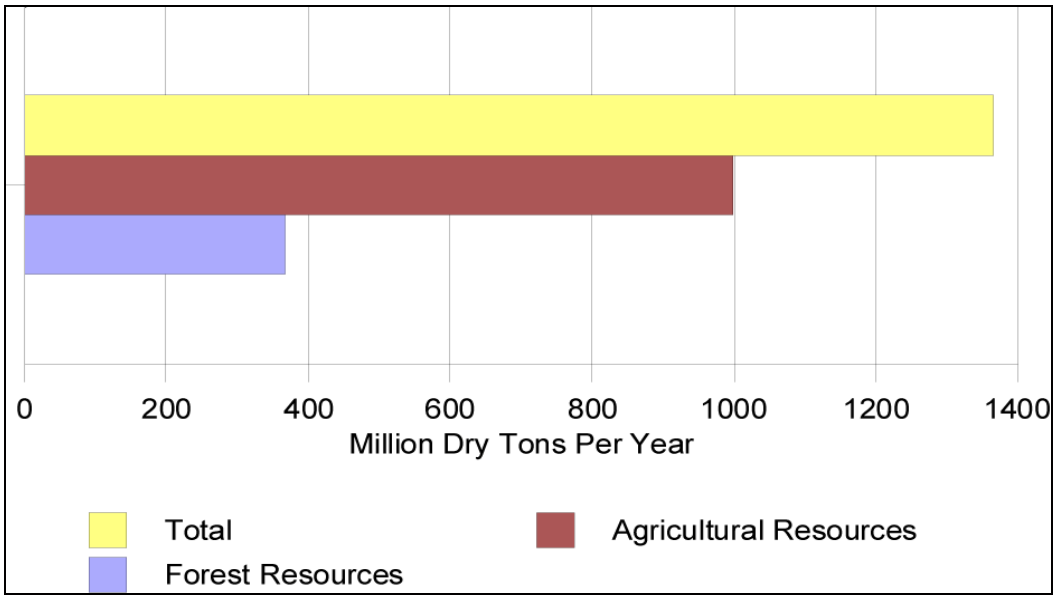
[28] *From Biomass to Biofuels*, National Renewable Energy Laboratory; NREL/BR-510-39436, August 2006, http://www.nrel.gov/biomass/.

[29] *The Economics of Biomass Collection, Transportation, and Supply to Indiana Cellulosic and Electric Utility Facilities*, Working Paper #08-03, by Sarah Brechbill and Wallace Tyner Purdue University, April 25, 2008.

[30] *Biomass Multi-Year Plan*, DOE Office of the Biomass Program, March 2006. http://www1.eere.energy.gov/biomass/pdfs/biomass_program_mypp.pdf.

[31] *Biomass as a Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply*, Environmental Sciences Division, Oak Ridge National Laboratory, 2005, http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf.

Figure 2. Annual Biomass Resource Potential According to USDA



Source: Oak Ridge National Laboratory, 2005.
Note: Total is roughly equivalent to 42 billion gallons of gasoline.

Impacts on Food Supplies

Compared with corn, cellulosic feedstocks are thought to have smaller impacts on food supplies.[32] By refining corn into ethanol, food markets are indirectly affected via cattle and dairy feed markets. In contrast, cellulosic feedstocks are non-food commodities and thus do not reduce food output unless they displace food crops on cropland.[33] However, many cellulosic feedstocks do not need prime farmland. Waste streams such as municipal solid waste, most crop residues, wood pulp residues, and forest residues are potential sources of biomass that have no impact on food crop acreage.[34] Corn stover, removed in appropriate quantities, could also be refined into ethanol without affecting food supplies. Feedstocks such as switchgrass and fast-growing trees appear to do well in marginal conditions and would likely have a minimal impact on food supplies, particularly in the case of woody biomass feedstocks from forested areas not suitable for crops.[35]

Establishment Costs and Contracting Arrangements

In the United States, crops are traditionally grown on an annual basis. Thus, contracts, loans, and other arrangements are generally established for a single growing year. Arrangements for producing perennial crops would necessarily reflect their multi-year cycles. Producers, whether they own or rent land, can expect reduced returns while the crop becomes established. Producers renting land would need long-term agreements suitable for multi-year crops. Some suggest a legal

[32] *Breaking the Link between Food and Biofuels*, Bruce A. Babcock, Briefing Paper 08-BP 53, July 2008, Center for Agricultural and Rural Development, Iowa State University, http://www.card.iastate.edu.

[33] *Ibid.*

[34] *Ibid.*

[35] For more information on biofuels and food supplies see CRS Report RL34474, *High Agricultural Commodity Prices: What Are the Issues?*, by (name redacted).

framework would have to be developed for multi-year harvests. For example, the University of Tennessee has entered into three-year contracts with producers to ensure switchgrass availability for a pilot refinery scheduled to have started ethanol production in 2009.[36]

Extracting Fuel from Cellulose: Conversion

Breaking down cellulose and converting it into fuel requires complex chemical processing—technology that is now rudimentary and expensive (see **Table 2**). Starches (such as corn) and sugars (such as cane sugars) are easily fermented into alcohol, but cellulose must first be separated from hemicellulose and lignin and then broken down into sugars or starches through enzymatic processes.[37] Alternatively, biomass can be thermochemically converted into synthesis gas (syngas),[38] which can then be used to produce a variety of fuels. Regardless of the pathway, as discussed below, at the present time processing cellulose into fuels is expensive relative to other conventional and alternative fuel options.

Table 2. Basic Steps Required to Produce Ethanol

Product	Feedstock	Refining Required after Milling			Cost (per gal.)
Sugar ethanol	Sugar cane	Fermentation into ethanol			$0.30
Corn-starch ethanol	Corn starch	Hydrolysis makes fermentable sugars	Fermentation into ethanol		$0.53
Cellulosic ethanol (biochemical process)	Switchgrass, corn stover, woody biomass, municipal solid waste	Pre-treatment makes cellulose accessible	Hydrolysis makes fermentable sugars	Fermentation into ethanol	$1.59
Cellulosic ethanol (therm-chemical process)	Switchgrass, corn stover, woody biomass, municipal solid waste	Pre-treatment makes cellulose accessible	Syngas production through therm-chemical processes	Conversion of syngas to products including ethanol	$1.21

Source: National Renewable Energy Laboratory (NREL), Research Advances in Cellulosic Ethanol, costs from the *Economic Feasibility of Ethanol Production From Sugar in the United States*, Hosein Shapouri, USDA, and Michael Salassi, Nelson Fairbanks, LSU Agricultural Center, March 2005.

Production Processes

Three basic methods can be used to convert cellulose into ethanol: (1) acid hydrolysis (dilute or concentrated), (2) enzymatic hydrolysis, and (3) thermochemical gasification and pyrolysis. There are many different variations on these, depending on the enzymes and processes used.

[36] "DuPont Danisco and University of Tennessee Partner to Build Innovative Cellulosic Ethanol Pilot Facility," TN, July 23, 2008, http://www.utbioenergy.org/NR/rdonlyres/7D4527E3-00F7-....-92B1-E6749851AA41/1262/072308FINALUTDDCEPressReleaseDDCELetteralllogos.pdf.

[37] *Biofuels Energy Program 2007*, DOE http://www1.eere.energy.gov/biomass/publications.html#vision.

[38] A mixture of hydrogen and carbon monoxide.

Currently all these methods are limited to pilot or demonstration plants, and all comprise the "pre-treatment" phase of ethanol production.

Acid Hydrolysis

Dilute and concentrated acid hydrolysis pre-treatments use sulphuric acid to separate cellulose from lignin and hemicellulose. Dilute acid hydrolysis breaks down cellulose using acid at high temperature and pressure. Only about 50% of the sugar is recovered because harsh conditions and further reactions degrade a portion of the sugar. In addition, the combination of acid, high temperature, and pressure increase the need for more expensive equipment.

On the other hand, concentrated acid hydrolysis occurs at low temperature and pressure and requires less expensive equipment. Although sugar recovery of over 90% is possible, the process is not economical, due to extended processing times and the need to recover large volumes of acid.[39]

Enzymatic Hydrolysis

DOE suggests that enzymatic hydrolysis, a biochemical process that converts cellulose into sugar using cellulase enzymes, offers both processing advantages as well as the greatest potential for cost reductions.[40] However, the cost of cellulase enzymes remains a significant barrier to the conversion of lignocellulosic biomass to fuels and chemicals. Enzyme cost primarily depends on the direct cost of enzyme preparation ($/kg enzyme protein) and the enzyme loading required to achieve the target level of cellulose hydrolysis (gram enzyme protein/gram cellulose). According to DOE, the near-term goal is to reduce the cost of cellulase enzymes from $0.50 to $0.60 per gallon of ethanol to approximately $0.10 per gallon.[41] The National Renewable Energy Laboratory (NREL) of DOE is conducting research to lower enzyme costs by allowing cellulase yeasts and fermenting yeasts to work simultaneously—with significant savings.

The total conversion cost (excluding feedstock cost) for biochemical conversion of corn stover to ethanol is estimated to be about $1.59 per gallon[42]—compared with the USDA-DOE goal of $0.82 per gallon in 2012.[43]

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[39] J. D. Wright and C. G. d'Agincourt, "Evaluation of Sulfuric Acid Hydrolysis Processes for Alcohol Fuel Production," *Biotechnology and Bioengineering Symposium*, no. 14, (New York: John Wiley and Sons, 1984), pp 105-123, http://qibioenergy.wordpress.com/¬2008/03/08/acid-hydrolysis/; P. C. Badger, "Ethanol From Cellulose: A General Review," in J. Janick and A. Whipkey, eds., *Trends in New Crops and New Uses* (ASHS Press, 2002).

[40] DOE, EERE, Biomass Program, "Cellulase Enzyme Research," at http://www1.eere.energy.gov/biomass/biomass_feedstocks.html.

[41] *Development of New Sugar Hydrolysis Enzymes: DOE, Novozymes Biotech, Inc.* http://search.nrel.gov/cs.html?url=http%3A//www1.eere.energy.gov/biomass/fy04/new_sugar_hydrolysis_enzymes.pdf&charset=utf-8&qt=cellulase+enzymes&col=eren&n=2&la=en.

[42] *Biomass Multi-Year Plan*, DOE Office of the Biomass Program, March 2006. http://www1.eere.energy.gov/biomass/pdfs/biomass_program_mypp.pdf.

[43] *Biomass Multi-Year Plan*, DOE Office of the Biomass Program, March 2006. http://www1.eere.energy.gov/biomass/pdfs/biomass_program_mypp.pdf.

Thermochemical Gasification and Pyrolysis

Thermochemical processes such as gasification and pyrolysis convert lignocellulosic biomass into a gas or liquid intermediate (syngas) suitable for further refining to a wide range of products including ethanol, diesel, methane, or butanol.[44] Recovery rates of up to 50% of the potentially available ethanol have been obtained using synthesis gas-to-ethanol processes. Two-stage processes producing methanol as an intermediate product have reached efficiencies of 80%. However, developing a cost-effective thermochemical process has been difficult.[45] The Fischer-Tropsch (FT) process uses gasification to produce syngas that is then converted into biofuels such as diesel, methane, or butanol. It is possible to produce diesel and other fuels using syngas from coal or natural gas, but biomass-derived syngas is technically challenging because of impurities that must be removed during processing.

The cost of gasification conversion (excluding the cost of feedstock) in 2005 was estimated at $1.21 per gallon (2007 dollars).[46] The USDA-DOE goal for 2012 is $0.82 cents per gallon.

Distribution and Absorption Constraints

Distribution and absorption constraints may hinder the use of cellulosic biofuels even if they are ultimately produced on an industrial scale. In the coming years, greater volumes of advanced biofuels (i.e., cellulosic or non-corn-starch ethanol, biodiesel, or imported sugar ethanol) would need to be blended into motor fuel to fulfill the rising advanced biofuel mandate.

Distribution Bottlenecks

Distribution issues may hinder the efficient delivery of ethanol to retail outlets. Ethanol, mostly produced in the Midwest, would need to be transported to more populated areas for sale. It cannot currently be shipped in pipelines designed for gasoline because it tends to attract water in gasoline pipelines.

In addition, ethanol must be stored in unique storage tanks and blended prior to delivery to the retail outlet, because it tends to separate if allowed to sit for an extended period after blending. This would require further infrastructure investments.

The current ethanol distribution system is dependent on rail cars, tanker trucks, and barges. Because of competition, options (especially rail cars) are often limited. As non-corn biofuels play a larger role, some infrastructure concerns may be alleviated as production is more widely dispersed across the nation. If biomass-based diesel substitutes are produced in much larger quantities, some of these infrastructure issues may be mitigated.

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[44] J. D. Wright, "Evaluation of Sulfuric Acid Hydrolysis Processes for Alcohol Fuel Production," in *Biotechnology and Bioengineering Symposium*, no. 14, (New York: John Wiley and Sons, 1984), pp 103-123.

[45] P. C. Badger, "Ethanol From Cellulose: A General Review," in J. Janick and A. Whipkey, eds., *Trends in New Crops and New Uses* (ASHS Press, 2002).

[46] *Biomass Multi-Year Plan*, DOE Office of the Biomass Program, March 2006. http://www1.eere.energy.gov/biomass/pdfs/biomass_program_mypp.pdf.

The Blend Wall[47]

The blend wall refers to the volume of ethanol required if all gasoline used in the United States contained 10% ethanol (E-10)[48]—or roughly 14 billion gallons. However, because of infrastructure issues associated with transporting and storing midwestern ethanol in coastal markets, the effective blend wall is probably about 12 billion to 13 billion gallons per year. U.S. ethanol production is rapidly approaching this level. Once the blend wall is reached, the market will likely have difficulty absorbing further production increases, even if they are mandated by the RFS. Although greater use of E-85 could absorb additional volume, it is limited by the lack of E-85 infrastructure (including the considerable expense of installing or upgrading tanks and pumps) and the size of the flex-fuel fleet. These concerns could be sidestepped if additional non-ethanol biofuels are introduced into the market, especially "drop-in" fuels that are chemically similar to petroleum fuels and could be blended directly with those fuels.[49]

EPA considered proposals to raise the ethanol blend level for conventional vehicles from E-10 to E-15 or E-20 after a petition was submitted by Growth Energy in 2009. In October 2010, EPA issued a waiver for fuel to contain up to 15% ethanol (E15) for model year 2007 and newer light-duty vehicles.[50] A decision on the use of E15 in model year 2001-2006 vehicles will be made after EPA receives the results of additional DOE testing. However, no waiver is being granted for E15 use in model year 2000 and older cars and light trucks—or in any motorcycles, heavy-duty vehicles, or non-road engines—because currently there is not sufficient testing data to support such a waiver. In addition to the EPA waiver announcement, numerous other changes have to occur before gas stations will begin selling E15, including many approvals by states and significant infrastructure changes (pumps, storage tanks, etc.). As a result, the vehicle limitation to newer models, coupled with infrastructure issues, is likely to limit rapid expansion of blending rates. Along with the waiver, EPA issued a notice of proposed rulemaking (NPRM) to promote the successful introduction of E15 into commerce by ensuring that E15 is used in approved motor vehicles and reducing the potential for the misfueling of E15 into vehicles and engines for which it is not approved.

Economic and Environmental Issues

Economic Efficiency

Cellulosic biofuels are generally thought to have favorable economic efficiency potential over corn-starch ethanol primarily because of the low costs of production for feedstocks. However, current NREL estimates of the total cost of producing cellulosic ethanol, including feedstock

[47] For more information on the blend wall, see CRS Report R40445, *Intermediate-Level Blends of Ethanol in Gasoline, and the Ethanol "Blend Wall"*, by (name redacted).

[48] E-10 refers to a fuel blend of 10% ethanol and 90% gasoline. Likewise, E-15 is a blend of 15% ethanol, 85% gasoline; E-20 is 20% ethanol, 80% gasoline; and E-85 is 85% ethanol, 15% gasoline.

[49] Potential drop-in fuels include synthetic gasoline or diesel fuel produced from biomass, as well as butanol or other chemicals that may not have some of the blending limitations faced by ethanol.

[50] Environmental Protection Agency, "EPA Grants E15 Waiver for Newer Vehicles/A New Label for E15 Is Being Proposed to Help Ensure Consumers Use the Correct Fuel," press release, October 13, 2010, http://yosemite.epa.gov/opa/admpress.nsf/0/BF822DDBEC29C0DC852577BB005BAC0F.

production, marketing, and conversion, are $2.40 per gallon, more than twice the cost of producing corn ethanol.

A major impediment to the development of a cellulose-based ethanol industry is the state of cellulosic conversion technology (i.e., the process of gasifying cellulose-based feedstocks or converting them into fermentable sugars).[51] DOE's goal of competitiveness in 2012 assumes $1.30 (2007 dollars) per gallon costs for corn stover ethanol based on a feedstock price of $13 per ton. This compares with USDA's estimated cost of producing corn-based ethanol in 2002 of $0.958 per gallon (about $1.07 per gallon in 2007 dollars).[52] In addition, the cost of harvesting, transporting, and storing bulky cellulosic biomass is not well understood and consequently is often undervalued. As a result, even though cellulosic biofuels benefit from a production tax credit of up to $1.01 (discussed below), which is $0.56 per gallon higher than the blender's tax credit of $0.45 per gallon for corn ethanol, it remains at a substantial cost disadvantage compared with corn-starch ethanol.

Energy Balance

The net energy balance (NEB) is a comparison of the ratio of the per-unit energy produced versus the fossil energy used in a biofuel's production process. The use of cellulosic biomass in the production of biofuels yields an improvement in NEB compared with corn ethanol. Corn ethanol's NEB was estimated at 67% by USDA in 2004—67% more energy was available in the ethanol than was contained in the fossil fuel used to produce it. This is at the upper range of estimates for corn ethanol's energy balance. By contrast, estimates of the NEB for cellulosic biomass range from 300%[53] to 900%.[54] As with corn-based ethanol, the NEB varies based on the production process used to grow, harvest, and process feedstocks.

Another factor that favors cellulosic ethanol's energy balance over corn-based ethanol relates to byproducts. Corn-based ethanol's co-products are valued as animal feeds, whereas cellulosic ethanol's co-products, especially lignin, are expected to serve directly as a processing fuel at the plant, substantially increasing energy efficiencies.

Additionally, switchgrass uses less fertilizer than corn, by a factor of two or three,[55] and its perennial growth cycle reduces field passes for planting. Some suggest that ethanol from switchgrass has at least 700% more energy output per gallon than fossil energy input.[56] The same is largely true of woody biomass that, even in plantations, requires minimal fertilizer and infrequent planting operations.

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[51] *Research Advances in Cellulosic Ethanol*, DOE-NREL, at http://www.nrel.gov/biomass/pdfs/40742.pdf/NOEL/BR-510-40742, March 2007.

[52] *The Energy Balance of Corn Ethanol: An Update*, Shapouri, Hosein; James A. Duffield, and Michael Wang. USDA, Office of the Chief Economist, Office of Energy Policy and New Uses, Agricultural Economic Report (AER) No. 813, July 2002; available at http://www.usda.gov/oce/reports/energy/index.htm.

[53] *Cellulosic Ethanol Fact Sheet*, by Lee R. Lynd, presented at the National Commission on Energy Policy Forum: The Future of Biomass and Transportation Fuels, June 13, 2003.

[54] Worldwatch Institute, *Biofuels for Transportation, Global Potential and Implications for Sustainable Agriculture and Energy in the 21st Century*. Table 10-1, p. 127, June 2006.

[55] *Ethanol From Biomass: Can It Substitute for Gasoline?* Michael B. McElroy, book chapter draft.

[56] *Net Energy of Cellulosic Ethanol from Switchgrass*, M.R. Schimer, K.P. Vogel, R.B. Mitchell, and R.B. Perrin, PNAS January 15, 2008, vol. 105, no. 2, available at http://www.pnas.org/cgi/doi/10.1073/pnas.0704767105.

Environment

Ethanol and biodiesel produced from cellulosic feedstocks, such as prairie grasses and fast-growing trees, have the potential to improve the energy and environmental effects of U.S. biofuels. As previously stated, a key potential benefit of cellulosic feedstocks is that they can be grown without the need for chemicals. Reducing or eliminating the need for chemical fertilizers could address one of the largest energy inputs for corn-based ethanol production. Fast-growing trees and woody crops could offer additional environmental benefits of improved soil and water quality, reduced CO_2 emissions, and enhanced biodiversity.[57]

Despite potential environmental benefits, additional concerns about cellulosic feedstocks exist, including concerns that required increases in per-acre yields to obtain economic feasibility could require the use of fertilizers or water resources, and that availability of sufficient feedstock supply is limited and expansion could generate additional land use pressures for expanded production (see "Greenhouse Gas Emissions" discussion, below). In addition to these concerns, some groups say that other potential environmental drawbacks associated with cellulosic fuels should be addressed, such as the potential for soil erosion, increased runoff, the spread of invasive species, and disruption of wildlife habitat.

Greenhouse Gas Emissions

Greenhouse gas emissions differ among types of ethanol because of a number of factors, including the feedstock crop converted into ethanol, the fuel used to power the refinery (fossil or renewable), and the original state of the land on which the feedstock was produced. For instance, if virgin forest land were cleared and planted with switchgrass, higher greenhouse gas emissions would result than if switchgrass were grown on previously cleared cropland, mainly because GHG emissions associated with clearing and plowing the virgin soil would have to be included as part of the production process. Likewise, a cellulosic refinery powered by coal or natural gas would have higher greenhouse gas emissions than one powered by recovered feedstock co-products.

Multi-year harvesting of perennial crops decreases greenhouse gas emissions by minimizing field passes. Prairie grasses and woody crops require reduced inputs compared with corn—and have lower greenhouse gas emissions. Also, because cellulosic feedstocks require less fertilizer for their production, the energy balance benefit of cellulosic ethanol could be significant. A study by the Argonne National Laboratory concluded that with advances in technology, the use of herbaceous[58]-feedstock cellulose-based E-10 could reduce fossil energy consumption per mile by 8%, while herbaceous-feedstock cellulose-based E-85 could reduce fossil energy consumption by roughly 70%.[59]

According to the EPA's Office of Transportation and Air Quality, for every unit of energy measured in British thermal units (BTU) of gasoline replaced by cellulosic ethanol, the total

[57] Timothy A. Volk, Theo Verwijst, and Pradeep J. Tharakan et al., "Growing Fuel: A Sustainability Assessment of Willow Biomass Crops," *Frontiers in Ecology & Environment Journal*, vol. 2, no. 8 (2004), pp. 411-418.

[58] A herbaceous plant is a plant that has leaves and stems that die down at the end of the growing season to the soil level.

[59] Wang, et al., table 7.

lifecycle greenhouse gas emissions (including carbon dioxide, methane, and nitrous oxide) would be reduced by an average of about 90%. In comparison, the reduction from corn ethanol averages 22%.[60]

Private Investment

Private investment is viewed by many to be critical to the development of the cellulosic biofuels industry. However, the aggregate value of required private investment is difficult to determine. Anecdotal evidence suggests the main sources of capital are venture capitalists and petroleum companies—commercial banks have a minor role. Venture capitalists generally have an extended (10-year) perspective, which fits well with nascent technologies and is insulated from shorter-term financial volatility. Petroleum companies, faced with mandatory blending of biofuels with gasoline, have been eager to invest in the cellulosic industry. Numerous partnerships have been formed: British Petroleum (BP) and Verenium announced a partnership in August 2008 to accelerate the commercialization of cellulosic ethanol, with BP investing $90 million in the deal.[61] In another collaboration, Royal Dutch Shell has teamed up with Imogen Corporation to develop cellulosic ethanol processes.[62] Mascoma, a major ethanol producer, raised $30 million to support its investment in cellulosic feedstock conversion with technical support from General Motors and Marathon Oil.[63] A collaboration between Monsanto and Mendel Biotechnology Inc. will focus on the breeding and development of crops for production of cellulosic biofuels.[64]

Federal Cellulosic Biofuels Policies

USDA and DOE are currently engaged in a variety of activities to encourage development and demonstration of cellulosic biofuels technologies. The Energy Independence and Security Act of 2007 (EISA, P.L. 110-140), the Food, Conservation, and Energy Act of 2008 (the 2008 farm bill, P.L. 110-246), and other legislation support research and development of a broad range of cellulosic technologies through USDA and DOE programs. Many of these programs extend the goals of the Energy Policy Act of 2005 (EPAct, P.L. 109-58) and President Bush's *20 in 10* initiative.[65] The Biomass Research and Development Initiative (BRDI) coordinates federal interagency *technology-push* efforts, such as R&D, loans, and grants, under the guidance of the Biomass Research and Development Board. The board was authorized in the Biomass Research

[60] *Greenhouse Gas Impacts of Expanded Renewable and Alternative Fuels Use*, EPA Office of Transportation and Air Quality, EPA-420-F-07-035, April 2007.

[61] *BP and Verenium Partner To Commercialize Cellulosic Ethanol*, RenewableEnergy-World.com, August 11, 2008, http://www.renewableenergyworld.com/rea/news/story?id=53280.

[62] *Shell Boosts Second Generation Biofuels*, by Ed Crooks, Financial Times, July 16, 2008, http://www.ft.com/cms/s/7f9f1ee8-52d0-11dd-9ba7-....77b07658.html.

[63] *U.P. Biofuel Plant Lands $50m in State, Fed Aid*, by Gary Heinlein and David Shepardson, The Detroit News, October 8, 2008, http://www.detnews.com/apps/pbcs.dll/article?AID=/20081008/BIZ/810080393.

[64] *Monsanto Company and Mendel Biotechnology, Inc. Announce Cellulosic Biofuels Collaboration*, BioSpace.com, April 28, 2008, http://www.biospace.com/news_story.aspx?NewsEntityId=94113.

[65] "2007 State of the Union Address" 20 in 10: *Strengthening America's Energy Security*, http://www.whitehouse.gov/stateoftheunion/2007/initiatives/energy.html.

and Development Act of 2000 and is co-chaired by USDA and DOE. BRDI plays a major role in R&D for the cellulosic biofuels industry.[66]

In October 2008, then-USDA Secretary Ed Schafer and DOE Secretary Samuel W. Bodman released the National Biofuels Action Plan (NBAP), which provided an outline of the major challenges facing the cellulosic biofuels industry: feedstock production and logistics; conversion science and technology; distribution infrastructure and blending. The plan reflects current federal and industry efforts to develop the cellulosic biofuels industry.[67]

Direct Federal Spending on R&D

Recognizing that cellulosic biofuels can contribute to improving national energy security, reducing greenhouse gas emissions, and boosting rural economic development, discretionary DOE spending on bioenergy R&D (including a major cellulosic component) under the Biomass and Biorefinery Systems Program (Energy Efficiency and Renewable Energy Programs) was $196 million in FY2007.[68] DOE appropriations for this purpose totaled $198 million in FY2008, of which 33% was spent on conversion R&D, 7% on feedstock infrastructure, and 52% on biorefinery development.[69] DOE appropriations for 2009 amounted to $217 million, of which $215 million was directed toward cellulosic biofuels, plus an FY2009 stimulus of $786 million. DOE appropriations for FY2010 were $220 million and the FY2011 request was $220 million.[70] Approximately $3 million in congressionally directed spending for FY2010 was directed toward cellulosic biofuel initiatives.[71]

USDA discretionary outlays for cellulosic biofuels were approximately $100 million in FY2009, with commercialization of thermochemical conversion technologies accounting for an estimated $80 million.[72] These totals are modest in comparison to the $5 to $8 billion in annual federal support for corn ethanol. Over time, as the corn ethanol industry matures, the focus of USDA efforts is likely to increasingly shift to cellulosic biofuels.

Federal-Private Partnerships

Private sector investment received a substantial federal policy boost on February 28, 2007, when the DOE announced the awarding of up to $385 million in mandatory cost-share funding for the construction of six cellulosic ethanol plant projects over a four-year period under Section 932 of the EPAct of 2005 as expanded by EISA of 2007. When fully operational, the six plants combined were expected to produce up to 100 mgpy of cellulosic ethanol. These demonstration-scale

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[66] For more information on federal biofuels incentives see CRS Report R40110, *Biofuels Incentives: A Summary of Federal Programs*, by (name redacted).

[67] The National Biofuels Action Plan is available at http://www.eere.energy.gov/biomass/pdfs/nbap.pdf.

[68] FY2009 DOE Budget Request to Congress, available at http://www.cfo.doe.gov/budget/09budget/start.htm#Detailed%20Budget%20Justifications.

[69] Presentation at Platts Cellulosic Ethanol Conference, by Valri Lightner, DOE Biomass Program, October 2008, http://www.autobloggreen.com/photos/platts-conference-doe-presentation/1099010/.

[70] CRS Report R41150, *Energy and Water Development: FY2011 Appropriations*, coordinated by (name redacted).

[71] U.S. Congress, House, *Energy and Water Development and Related Agencies Appropriations Act, 2010*, conference report to accompany H.R. 3183, 111th Cong., 1st sess., September 30, 2009, H.Rept. 111-278, pp. 282, 283, 290.

[72] The values are from personal correspondence with USDA's Office of Budget and Policy Analysis.

biorefinery projects focus on near-term commercial processes. The combined cost-share plus federal funding for the projects represents total planned investment of more than $1.2 billion.

The uncertainties of moving an industry from laboratory to commercial reality were highlighted when two recipients with total grant funding of $113 million dropped out of the program, one because of a substantially higher offer from the Canadian government,[73] and the other after determining that the risks involved outweighed any anticipated benefits.[74]

Renewable Energy Provisions in the 2008 Farm Bill (P.L. 110-246)

Renewable energy policy in the 2008 farm bill (Food, Conservation, and Energy Act of 2008, P.L. 110-246) builds on earlier programs originally authorized in the 2002 farm bill (P.L. 107-171) and the EPAct of 2005 (P.L. 109-58) but provides greater emphasis on cellulosic biofuels.[75] Title IX, the energy title, authorizes new programs and reauthorizes grants, loans, and loan guarantees to foster research on agriculture-based renewable energy, to share development risk, and to promote the adoption of renewable energy systems.[76] Implementation of the farm bill provisions continues, while congressional focus will likely be directed to reauthorization in 2012 (when most farm bill provisions expire). Funding for the cellulosic component of renewable energy programs is difficult to determine because most provide support to a wide range of biofuels. Title VII, the research title, contains provisions supporting R&D in cellulosic biofuels, and Title XV, the tax and trade title, contains tax incentives and tariffs. The following programs provide support to cellulosic biofuels research, demonstration, and production.

For information on additional related provisions in the 2008 farm bill, see CRS Report RL34130, *Renewable Energy Programs in the 2008 Farm Bill*, by (name redacted).

Tax Credit for Cellulosic Biofuels (Section 15321)

Tax and trade provisions in the 2008 farm bill benefit cellulosic biofuels. One significant incentive is a cellulosic biofuels production tax credit of $1.01 per gallon, more than twice the blenders' tax credit of 45 cents per gallon that applies to corn ethanol. In the case of cellulosic ethanol, the $1.01 credit amount is reduced by (1) the volumetric ethanol excise tax credit and (2) the small ethanol producer credit, making the total value of tax incentives for cellulosic ethanol equal to $0.46.[77] This tax credit is set to expire on December 31, 2012.

[73] "Iogen Suspends U.S. Cellulosic Ethanol Plant Plans," Earth2tech, http://earth2tech.com-/2008/06/04/iogen-suspends-us-cellulosic-ethanol-plant-plans/.

[74] "Alico to Discontinue Ethanol Efforts," June 2, 2008, press release, http://www.aliconinc.-com/june208.asp.

[75] CRS Report RL34130, *Renewable Energy Programs in the 2008 Farm Bill*, by (name redacted).

[76] Title IX cites are amendments to the 2002 farm bill (P.L. 107-171).

[77] For more information, see CRS Report R40110, *Biofuels Incentives: A Summary of Federal Programs*, by (name red acted).

Ethanol Tariff Extension (Section 15333)[78]

In addition to tax credits, an ethanol tariff benefits the U.S. industry by reducing the competitiveness of imported ethanol sold in this country. Domestic ethanol benefits from a 54-cent-per-gallon duty (and a smaller *ad valorem* tariff) on imported ethanol (except for limited imports under the Caribbean Basin Initiative).[79] The original intent of the tariff was to prevent imported ethanol from benefitting from the U.S. blender's tax credit. This tariff was extended through 2011.

Agricultural Bioenergy Feedstock and Energy Efficiency Research and Extension Initiative (Section 7207)

This new program awards competitive matching (up to 50%) grants for projects supporting on-farm biomass crop research and the dissemination of results to enhance the production of biomass energy crops and their integration with the production of bioenergy. It consists of elements of earlier initiatives that were moved to the research title (Title VII) in the 2008 farm bill. Discretionary funding of $50 million annually is authorized for FY2008 through FY2012, subject to appropriations. Funding has not been appropriated for this program in FY2008, FY2009, or FY2010.

Biorefinery Assistance (Section 9003)

This initiative provides loan guarantees for the development, construction, and retrofitting of commercial-scale biorefineries and provides grants to help pay for the development and construction costs of demonstration-scale biorefineries. Loan guarantees are limited to $250 million per project, subject to the availability of funds. The program received mandatory funding of $320 million ($75 million for FY2009 and $245 million for FY2010) for commercial-scale biorefinery loan guarantees, and discretionary funding, subject to appropriations, of $150 million annually for FY2009 through FY2012 for both demonstration and commercial-scale biorefineries. No discretionary funding has been appropriated; therefore, USDA continues to implement only the loan guarantee program under a notice of funds availability (NOFA).[80]

Repowering Assistance (Section 9004)

The Repowering Assistance program encourages existing biorefineries to replace fossil fuels used to produce heat or power at their facilities by making payments for installing new systems that use renewable biomass, or to produce new energy from renewable biomass. The 2008 farm bill provided mandatory funding of $35 million in FY2009 to remain available until expended. The program is also authorized to receive $15 million in discretionary funding for each of FY2009

[78] On December 17, 2010, the Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act of 2010 (P.L. 111-312) extended both the ethanol blender tax credit and the import tariff for ethanol. Both were set to expire at the end of 2010 under the 2008 farm bill. Section 708 of P.L. 111-312 extends both provisions at the current rate, including $0.54 per gallon for the ethanol import tariff until the end of 2011.

[79] For more information about ethanol imports under the CBI, see CRS Report RS21930, *Ethanol Imports and the Caribbean Basin Initiative (CBI)*, by (name redacted).

[80] Rural Business-Cooperative Service, "Notice of Funds Availability (NOFA) Inviting Applications for Biorefineries," 75 *Federal Register* 25076, May 6, 2010.

through FY2012, pending appropriations. There has been no appropriation of discretionary funding. USDA continues to implement the program using mandatory funding through a NOFA.[81]

Bioenergy Program for Advanced Biofuels (Section 9005)

The Bioenergy Program is the lead program under Title IX providing support for the development of conversion technologies for cellulosic biofuels. It was originally established by Executive Order in 1999 and provided Commodity Credit Corporation (CCC) incentive payments to ethanol and biodiesel producers on the basis of yearly increases in production. Eligibility is now limited to producers of advanced biofuels. Eligible producers entering into a contract with USDA are paid based on quantity and duration of advanced biofuel production and on net renewable energy content of the advanced biofuel. Under the 2002 farm bill (P.L. 107-171), the Bioenergy Program received total funding of $426 million during FY2003 to FY2006 but no appropriations for FY2007 or FY2008. The 2008 farm bill provides a total of $300 million in mandatory funding for FY2009 to FY2012 ($55 million annually in FY2009 and FY2010, $85 million in FY2011, and $105 million in 2012), and also authorizes $25 million annually, subject to appropriations, from FY2009 to FY2012. No discretionary funding has been appropriated; therefore, USDA implements the program using mandatory funding through a notice of contract proposal (NOCP).[82]

Biomass Research and Development Initiative (Section 9008)

This program was originally authorized in the 2002 farm bill (P.L. 107-171) and is administered jointly by USDA and DOE. It supports research on and development and demonstration of biofuels and biobased products, and the methods, practices, and technologies for their production. The 2008 farm bill provides mandatory funding of $118 million for FY2009 to FY2012 ($20 million for FY2009, $28 million for FY2010, $30 million for FY2011, and $40 million for FY2012). The farm bill also authorizes the appropriation of $35 million for each of FY2009 through FY2012. The program received funding between FY2002 and FY2006, totaling $160 million and funding 68 projects. In FY2009, USDA and DOE announced a funding opportunity of $25 million ($20 million of mandatory funding from the 2008 farm bill and $5 million from DOE).

Biomass Crop Assistance Program (Section 9011)

This is a new program intended to (1) help farmers establish and produce crops for conversion to bioenergy and (2) assist with the collection, harvest, storage, and transportation of eligible material for use in a biomass conversion facility that produces heat, power, biobased products, or advanced biofuels.[83] BCAP is intended to assist with the bioenergy industry's hurdle of continuous biomass availability. The program is implemented by the Farm Service Agency with support from other federal and local agencies and has mandatory CCC funding of such sums as

[81] Rural Business-Cooperative Service, "Notice of Funds Availability (NOFA) for Repowering Assistance Payments to Eligible Biorefineries," 75 *Federal Register* 24873, May 6, 2010.

[82] Rural Business-Cooperative Service, "Notice of Contract Proposal (NOCP) for Payment to Eligible Advanced Biofuel Producers," 75 *Federal Register* 24865, May 6, 2010.

[83] For more information, see CRS Report R41296, *Biomass Crop Assistance Program (BCAP): Status and Issues*, by (name redacted).

necessary. The program was originally authorized to receive mandatory funding at a "such sums as necessary" level until FY2012. Recent appropriations bills have reduced this level in FY2010 and FY2011.

USDA implemented one portion of BCAP—the Collection, Harvest, Storage, and Transportation (CHST) matching payment program—on June 11, 2009, through a Notice of Funds Availability.[84] The partial implementation created a possible unintended consequence of market competition for wood shavings, wood chips, sawdust, and other wood "scraps" between traditional purchasers—namely landscapers and particleboard manufactures—and facilities that convert biomass to energy. USDA issued a proposed rule on February 8, 2010,[85] suspending the CHST program enrollment and proposing rules for the remainder of the BCAP program. The final rule on October 27, 2010, implements both program components.[86]

Forest Biomass for Energy (Section 9012)

Under this new program, USDA's Forest Service is authorized to conduct a comprehensive research and development program to use forest biomass for energy. Other federal agencies, state and local governments, Indian tribes, land-grant colleges and universities, and private entities are eligible to compete for program funds. No mandatory funding is available, but discretionary appropriations of $15 million annually for FY2009 to FY2012 are authorized. This program has not yet been implemented or appropriated funding.

Energy Improvement and Extension Act of 2008 (P.L. 110-343)

The Emergency Economic Stabilization Act of 2008 (P.L. 110-343), which incorporates the Energy Improvement and Extension Act of 2008, contains tax and trade incentives for renewable energy production. Enacted on October 3, 2008, it expands federal benefits for renewable energy to fuels and processes that previously did not qualify and limits trade practices that benefit foreign producers but do not enhance U.S. energy independence.

Expansion of the Allowance for Cellulosic Ethanol Property (Division B, Section 201)

Previous federal tax law limited the eligibility for first-year bonus depreciation of cellulosic biofuels to facilities producing ethanol; those producing non-ethanol fuels from cellulosic feedstocks did not qualify for the allowance. P.L. 110-343 does not limit the allowance to any particular type of cellulosic fuel or production process. Taxpayers can immediately write off 50% of the cost of facilities that produce cellulosic biofuels if such facilities are placed in service before January 1, 2013.

[84] Commodity Credit Corporation, USDA, "Notice of Funds Availability for the Collection, Harvest, Storage, and Transportation of Eligible Material," 74 *Federal Register* 11, June 11, 2009.

[85] USDA, Commodity Credit Corporation, "Biomass Crop Assistance Program," 75 Federal Register 6264, February 8, 2010.

[86] USDA, Commodity Credit Corporation, "Biomass Crop Assistance Program," 75 Federal Register 66201, October 27, 2010.

Legislative Proposals

Congress has shown a strong interest in the development of biofuels in general and cellulosic biofuels in particular. Debate may continue on the appropriate level of incentives needed to jump start the industry. Perhaps the most critical emerging issue is the federal mandate for cellulosic biofuels under the RFS—and the industry's potential to meet that mandate. In the long term, Congress might also consider the ongoing level of government support that is appropriate for the cellulosic biofuels industry—considered by some to be essential, especially if the RFS is to be met. Others contend such support could distort market signals. The general level of support in the form of grants and loans has been determined in the 2008 farm bill but will likely be revisited as appropriations are considered. The cellulosic biofuels tax credit applies to fuel produced from 2009 through 2012 and extension of this credit could be the subject of debate during the 112th Congress. In addition, Congress has considered the definition of biofuels and biofuel feedstocks that qualify for federal incentives.

Legislative Changes in the RFS Volume

Citing the RFS and corn ethanol production as contributing to rising food prices and high input costs for livestock and poultry producers, some are calling for a reduction of the RFS. During the 110th Congress, S. 3031 was introduced in May 2008, to limit the corn-starch component of the RFS to 9 billion gallons compared with 15 billion under the current law. Opponents of the reduction claim it would set back efforts to reduce the nation's dependence on foreign oil and achieve environmental goals. Reducing the corn-starch component of the RFS would increase the importance of advanced fuels, primarily cellulosic biofuels, in meeting the mandate. Legislation to alter RFS volume requirements was not introduced in the 111th Congress.

Expanding Biomass Eligible under the RFS

The definition of forest-based renewable biomass under the RFS is considered by some to be too restrictive because it limits eligible woody biomass to privately planted trees and tree residue from actively managed tree plantations, and slash[87] and pre-commercial thinnings from non-federal forests.

The definition of renewable biomass specifically excludes biomass from federal forests. Some suggest that this exclusion eliminates much potential biomass and creates regional disparities. One-third of the 755 million acres of forest in the United States is owned by the federal government—and this acreage is concentrated in the western states. Likewise, the exclusion of private, naturally regenerated forests affects the northern and southeastern parts of the country where other feedstocks eligible under the RFS may not be as readily available. According to some, biomass extraction could become a powerful tool for improving federal land management.[88] Markets for small-diameter trees would enable a wider range of options for management of wildlife habitat, forest hydrology, hazardous fuels reduction, and pest

[87] The accumulation of limbs, tops, and miscellaneous residue left by forest management activities, such as thinning, pruning, and timber harvesting.

[88] *Federal Forests and the Renewable Fuel Standard Factsheet*, Environmental and Energy Study Institute, July 17, 2008.

infestations. These markets are not likely to appear if federal forests remain excluded from the RFS.

The House Committee on Agriculture Subcommittee on Conservation, Credit, Energy, and Research held hearings during July 2008 on producer eligibility under the RFS. The subcommittee heard from government officials, researchers, and producers who provided an update on the implementation of the RFS and shared concerns on barriers to eligibility for many agricultural producers. Subsequently, a Senate Energy and Natural Resources Committee field hearing on forest waste for biofuels was held in South Dakota on August 18, 2008.

During the 111th Congress, H.R. 2454, if enacted, would have allowed for modification of the non-federal lands portion of the definition of "renewable biomass." Low-value materials are frequently removed during fire or disease reduction efforts or ecosystem health supporting activities. Waste materials such as wood waste and wood residues from private forests are also included.

During the 110th Congress, the House passed the Comprehensive American Energy Security and Consumer Protection Act (H.R. 6899). It contained a sense of Congress provision recommending a broad definition of renewable biomass to "encourage cellulosic biofuels ... produced from a highly diverse array of feedstocks, allowing every region of the country to be a potential producer of this fuel." No Senate action was taken. No similar action was taken in the 111th Congress.

Time Frame for Cellulosic Biofuels Production

Estimates for commercial production of cellulosic biofuels vary widely. Some small-scale plants came online in 2010.[89] However, the pace of plant construction falls short of DOE's stated goal to make cellulosic ethanol competitive as a mature technology by 2012.[90] Some analysts have predicted a growth trend for the cellulosic ethanol industry similar to that for corn-starch ethanol. However, there is a major difference between the two: the basic process for making corn-starch ethanol (fermentation) is thousands of years old, whereas that for cellulosic is very new.

The USDA Office of Energy and New Uses projects that cellulosic biofuels are not expected to be commercially viable on a large scale until at least 2015.[91] However, the cellulosic biofuel portion of the RFS mandate is set at 3 billion gallons by 2015, a substantial amount. In its January 2009 baseline, the Food and Agricultural Policy Research Institute (FAPRI) of the University of Missouri assumes cellulosic biofuel production will fall behind the RFS and, as a consequence, the mandate will be waived by EPA.[92] In an August 2009 baseline update, FAPRI projects

[89] For more information, see CRS Report R41106, *Meeting the Renewable Fuel Standard (RFS) Mandate for Cellulosic Biofuels: Questions and Answers*, by (name redacted).

[90] *Biomass Multi-year Program Plan*, DOE, March 2008, http://www1.eere.energy.gov/biomass/publications.html#vision.

[91] *U.S. Biobased Products: Market Potential and Projections Through 2025*, Office of the Chief Economist, Office of Energy Policy and New Uses, USDA, the Center for Industrial Research and Service of Iowa State University, Informa Economics, Michigan Biotechnology Institute, and The Windmill Group. OCE-2008-1, http://www.oce.usda.gov.

[92] FAPRI, Iowa State University, and University of Missouri-Columbia, *FAPRI 2009: U.S. and World Agricultural Outlook*, Report 09-FSR 1, January 2009.

cellulosic ethanol production in 2013 at 245 mgpy, about one-third of the 1 billion gallons in the RFS for that year.[93]

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[93] *Baseline Update for Agricultural Markets*, FAPRI, FAPRI MU-Report #06-09, August 2009. http://www.fapri.missouri.edu.