Meeting the Renewable Fuel Standard (RFS) Mandate for Cellulosic Biofuels: Questions and Answers

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Summary

The Renewable Fuel Standard (RFS) was expanded under the Energy Independence and Security Act of 2007 (EISA; P.L. 110-140) in an effort to reduce dependence on foreign oil, promote biofuel use, and stabilize transportation fuel prices, among other goals. Over a 15-year period, the RFS seeks to establish a market for biofuels in the transportation sector by requiring that increasing amounts of biofuels—36 billion gallons by 2022—be blended into transportation fuel. The mandate is to be accomplished with an assortment of advanced biofuels, including cellulosic biofuels—fuels produced from cellulosic materials including grasses, trees, and agricultural and municipal wastes. The cellulosic biofuel allotment in the mandate, as established by Congress in EISA, was 100 million gallons due in 2010, increasing to 16 billion gallons by 2022. However, on March 26, 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.

Recent analysis has suggested that the United States might not have sufficient cellulosic biofuel production capacity to meet the 2010 RFS mandate of 100 million gallons instituted by Congress in EISA. The cellulosic biofuel community may fare better at achieving the new mandate set by EPA if certain obstacles are overcome. No commercial-scale cellulosic biofuel plants are currently operating. Roadblocks include unknown levels of feedstock supply, expensive conversion technology that has not yet been applied commercially, and insufficient financial support from private investors and the federal government.

Some financial support from the Departments of Energy and Agriculture is available to expedite cellulosic biofuel production. For example, the Biomass Crop Assistance Program (BCAP), created under the Food, Conservation, and Energy Act of 2008 (2008 farm bill; P.L. 110-246), is to support establishment and production of crops for conversion to bioenergy. Financial support available thus far via BCAP is for collection, harvest, storage, and transportation of eligible material. BCAP support for the establishment and production of eligible crops for the conversion to bioenergy is anticipated to begin in 2010. Also, the Department of Energy's Loan Guarantee Program, created under the Energy Policy Act of 2005 (EPAct05, P.L. 109-58), distributes loan guarantees to eligible commercial-scale renewable energy systems, including cellulosic biofuel plants, although criticisms have been raised that the program has been slow to get started.

Many questions regarding cellulosic biofuels and the RFS may arise as Congress engages in energy legislation debates. Can and will the 2010 and future RFS mandates for cellulosic biofuels be met? What impact will significantly lowering the 2010 cellulosic ethanol mandate have on investment in celluosic ethanol production? What are the next steps Congress could take to expedite cellulosic biofuel production? Proposed legislation (H.R. 2454, S. 1462, H.R. 2283, and S. 943), if enacted, may influence cellulosic biofuel production by providing additional financial, infrastructure, and environmental support. This report, in a question and answer format, discusses some of the concerns facing the cellulosic biofuel community, including feedstock supply estimates, an expected time frame for the first commercial cellulosic biofuel projects, and potential legislative options to address cellulosic biofuel production uncertainty for the RFS.

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Introduction

The Renewable Fuel Standard (RFS) was enacted to ensure that domestic transportation fuel contains a specified volume of biofuels, including advanced biofuel, cellulosic biofuel, and biomass-based diesel.[1] The RFS requires that increasing amounts of biofuels be blended into U.S. transportation fuel over a 15-year period, with the goal of using 36 billion gallons of biofuels annually by 2022. The mandate is to be accomplished in large part with cellulosic biofuels. The cellulosic biofuel allotment in the mandate established by Congress began with 100 million gallons due in 2010, increasing to 16 billion gallons by 2022. However, on March 26, 2010, the U.S. Environmental Protection Agency (EPA) issued a final rule for the RFS lowering the 2010 cellulosic biofuel mandate to 6.5 million gallons.[2]

A concern for Congress is whether enough cellulosic biofuel can be produced to satisfy the RFS mandate in future years. Cellulosic feedstock supply, financial assistance, and technology advancement are considered among the most pressing issues that could thwart cellulosic biofuel production. More than two years after EISA was enacted, progress towards meeting the cellulosic biofuels mandate has been delayed on multiple fronts (e.g., financial, administrative, and technical), despite government financial incentives, estimates of feedstocks available, and technological developments. If the revised 2010 RFS cellulosic biofuel mandate is not met, Congress may reconsider the configuration of the RFS, determine whether additional resources are necessary for cellulosic biofuel production, and assess the success rate of this effort compared to other renewable energy efforts.

What Are Cellulosic Biofuels?

Cellulosic biofuels are liquid, solid, or gaseous fuels made from cellulose material. Cellulose—a complex carbohydrate—is the organic matter found in plant walls that, along with hemicellulose and lignin, helps to give a plant its rigid structure. Cellulose feedstock includes agricultural residues (e.g., corn stover), forestry residues (e.g., wood chips), energy crops (e.g., switchgrass), tree crops (e.g., hybrid poplar), and urban sources of waste (e.g., municipal solid waste).

The most widely discussed cellulosic biofuel is cellulosic ethanol for transportation.[3] Cellulosic ethanol differs from the corn ethanol currently blended into transportation fuel; it is made from feedstock with no food value, potentially results in fewer greenhouse gas emissions, and has a higher energy balance.[4] Converting cellulosic feedstock to ethanol, however, is more expensive and difficult than converting corn to ethanol. The conversion of cellulose to ethanol generally happens in three phases—pretreatment, hydrolysis, and fermentation to ethanol. Pretreatment weakens the plant wall structure so that the cellulose is easier to obtain during hydrolysis.

[1] The RFS was expanded under the Energy Independence and Security Act of 2007 (EISA; P.L. 110-140). For more information on the expanded RFS, see CRS Report R40155, *Renewable Fuel Standard (RFS): Overview and Issues*, by Randy Schnepf and Brent D. Yacobucci

[2] 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.

[3] For more information on cellulosic biofuels, see CRS Report RL34738, *Cellulosic Biofuels: Analysis of Policy Issues for Congress*, by Kelsi Bracmort et al.

[4] For more information on ethanol, see CRS Report RL33290, *Fuel Ethanol: Background and Public Policy Issues*, by Brent D. Yacobucci.

Hydrolysis—acid or enzymatic—separates the cellulose into sugars. Fermentation converts the sugars into ethanol. Cellulose can also be converted to liquid fuels through processes other than fermentation (e.g., thermochemical processes).[5]

Analysis suggests that increased use of cellulosic biofuels for transportation could potentially help to reduce U.S. dependence on foreign oil, stabilize energy prices, strengthen rural infrastructure, and improve the environment. In addition, cellulosic feedstocks may fare better in the food-energy debate, since crop residue, and not the crop itself, is used for cellulosic biofuel production. Some contend, however, that cellulosic biofuels require a substantial feedstock supply that has yet to be verified, may cause environmental degradation (e.g., by removing residues that furnish nutrients and stability to the soil),[6] and may hinder efforts to promote energy efficiency.

What Is the Relationship Between Cellulosic Biofuels and the Renewable Fuel Standard?

The RFS established in Section 202 of EISA called for 100 million gallons of cellulosic biofuels to be blended in the national transportation fuel supply in 2010, and the mandate increases to 16 billion gallons by 2022.[7] Data and analysis presented during the RFS debate and ultimate passage of EISA in 2007 supported these levels of cellulosic biofuel production capacity. Some reasoned that plentiful feedstock was available[8] and that the conversion technology was on the brink of being certified as commercially viable. Moreover, some presumed that the federal government would provide substantial financial support and enhance the infrastructure needed to spur a commercial cellulosic biofuels market.[9] Others were leery about the time frame provided to meet the RFS cellulosic biofuel mandate given capacity restrictions, weather impacts, and uncertainty about technology advancements.[10]

EPA has the authority to waive completely or in part the 100 million gallons per year (mgy) 2010 mandate established in EISA, given certain circumstances.[11] For instance, the Administrator may

[5] Cellulose feedstocks can also be used to provide heat or generate electricity via gasification, combustion, anaerobic digestion, and other conversion processes. For more information on anaerobic digestion, see CRS Report R40667, *Anaerobic Digestion: Greenhouse Gas Emission Reduction and Energy Generation*, by Kelsi Bracmort.

[6] R. M. Cruse and C .G. Herndl, "Balancing Corn Stover Harvest for Biofuels with Soil and Water Conservation," *Journal of Soil and Water Conservation*, vol. 64, no. 4 (July/August 2009), pp. 286-291.

[7] For more information on the RFS, see CRS Report R40155, *Renewable Fuel Standard (RFS): Overview and Issues*, by Randy Schnepf and Brent D. Yacobucci.

[8] U.S. Dept. of Energy, U.S. Dept. of Agriculture, *Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply*, April 2005, http://www1.eere.energy.gov/biomass/pdfs/final_billionton_vision_report2.pdf.

[9] Diane Greer, "Creating Cellulosic Ethanol: Spinning Straw into Fuel," *BioCycle*, April 2005; Biotechnology Industry Organization, *Achieving Sustainable Production of Agricultural Biomass for Biorefinery Feedstock*, Washington, DC, 2006, http://www.bio.org/ind/biofuel/SustainableBiomassReport.pdf; and Biotechnology Industry Organization, "Energy Bill Biofuels Mandates Will Be Achievable with Biotechnology Advances," press release, November 18, 2007, http://bio.org/news/pressreleases/newsitem.asp?id=2007_1218_01&p=yes.

[10] Ian Talley, "Renewed Energy: US Biofuel Mandate Calls for Big Production Boost," *Dow Jones International News*, December 18, 2007, at http://www.factiva.com/.

[11] For more information on EPA's waiver authority, see CRS Report RS22870, *Waiver Authority Under the Renewable Fuel Standard (RFS)*, by Brent D. Yacobucci.

waive the cellulosic biofuel requirement if the Administrator determines, after public notice and opportunity for comment, that there is an inadequate domestic supply.[12] On March 26, 2010, EPA lowered the 2010 cellulosic biofuel mandate set forth in EISA by roughly 93% with the issuance of a waiver that expires after one year:

> EISA requires the Administrator to evaluate and make an appropriate market determination for setting the cellulosic standard each year. Based on an updated market analysis considering detailed information from pilot and demonstration scale plants, an Energy Information Administration analysis, and other publically and privately available market information, we are setting the 2010 cellulosic biofuel standard at 6.5 million ethanol-equivalent gallons. While this volume is significantly less than that set forth in EISA for 2010, a number of companies and projects appear to be poised to expand production over the next several years.[13]

The 2011 renewable fuel standard for cellulosic biofuels was 250 millions gallons. However, EPA announced on July 9, 2010, that it would lower this mandate to a range of 5-17.1 million gallons.[14] For the final rule, EPA intends to pick a single value from within this range.

What Challenges Are Associated with Cellulosic Biofuels Production?

Over the two years since the RFS was expanded,[15] obstacles have stalled U.S. cellulosic biofuel production capacity. Impediments to meeting the cellulosic biofuel mandate include technology setbacks, escalating prices for certain feedstocks, lack of feedstock availability, and delayed financial support. Limited access to capital has been indicated as one of the primary reasons that timely completion of many cellulosic biofuel plants has stalled. Commercial cellulosic biofuel facilities are estimated to cost hundreds of millions of dollars (see **Table 1**), roughly three times as much as a corn ethanol plant. (In comparison, a 40 mgy corn ethanol plant costs approximately $80 million to construct.[16]) Some lenders find it extremely risky, perhaps even cost-prohibitive, to provide financial backing to cellulosic biofuel plants, mainly because the conversion technology has not been applied or proven on a large scale.

[12] 42 U.S.C. 7545(o)(7).

[13] EPA, "Changes to Renewable Fuel Standard; Final Rule," p. 14.

[14] U.S. Environmental Protection Agency, "Regulation of Fuels and Fuel Additives: 2011 Renewable Fuel Standards; Proposed Rule," 75 *Federal Register* 42242, July 20, 2010.

[15] The original RFS established by § 1501 of EPAct05 required 4.0 billion gallons of renewable fuel for 2006, ascending to 7.5 billion gallons by 2012. The original RFS would have required that 250 million gallons of the renewable fuel be derived from cellulosic biomass starting in 2013. The current RFS, established under EISA, had required 250 million gallons of cellulosic biofuel starting in 2011. However, as discussed above, the EPA recently announced it would lower the 2011 mandate to somewhere between 5 and 17.1 million gallons.

[16] Clean Fuels Development Corporation, Nebraska Ethanol Board, and U.S. Dept. of Agriculture, *A Guide for Evaluating the Requirements of Ethanol Plants*, 2006, http://www.ethanol.org/pdf/contentmgmt/guide_for_evaluating_the_requirements_of_ethanol_plants.pdf.

Table 1. Selected Examples of Cellulosic Ethanol Plant Cost Estimates

Company	Production Capacity (mgy)	Feedstock Required	Capital (millions)
BlueFire (California Plant)[a]	3.9	190 wet tons/day of post-sorted municipal solid waste	$120
BlueFire (Mississippi Plant)[a]	19	550 tons/day of wood waste (mostly forest residues)	$250
Enerkem (Mississippi Plant)[b]	10	300 dry tons/day of post-sorted municipal solid waste	$118
POET (Iowa Plant)[c]	25	770 dry tons/day (mostly corncobs with some corn residue)	$200
ZeaChem Inc. (Oregon Plant)[d]	0.25	10 dry tons/day of hybrid polar trees	$73

Source: Compiled by CRS.

a. Conversation with Arnold Klann from BlueFire Ethanol Inc., February 2, 2010.

b. E-mail from Marie-Helene Labrie of Enerkem, February 3, 2010.

c. Conversation with Jim Sturdevant from POET, February 2, 2010.

d. Conversation with Carrie Atiyeh from ZeaChem Inc., February 2, 2010.

The government provides financing through two programs to encourage investment in cellulosic biofuel production technologies. In addition, the 2008 farm bill offers a production credit of $1.01 per gallon for biofuels produced from qualifying cellulosic feedstocks.[17] To increase investment, the government established the Department of Energy (DOE) Loan Guarantee Program (LGP).[18] Loans may not exceed 80% of total project costs. Over 90% of the projects that have received funding to date are pilot- or demonstration-scale projects that are seen as likely to become a commercial technology.[19] Biomass renewable energy technologies accounted for approximately 24% of applications for the LGP in 2008. DOE received $18.5 billion toward the LGP for energy-efficiency and renewable energy projects—including cellulosic biofuel projects—in the 2009 Omnibus Appropriations Act (P.L. 111-8).[20] An additional $60 billion in loan guarantees was provided under the American Recovery and Reinvestment Act of 2009 (ARRA, P.L. 111-5), partly for renewable energy projects.[21] Some are concerned that the LGP is not being carried out

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[17] For more information on the blender tax credit, see CRS Report RL34130, *Renewable Energy Programs in the 2008 Farm Bill*, by Megan Stubbs

[18] A loan guarantee is defined as a "pledge with respect to the payment of all or a part of the principal or interest on any debt obligation of a non-federal borrower to a non-federal lender." The LGP was first authorized under Title XVII of EPAct05 and then amended under the American Recovery and Reinvestment Act of 2009 (P.L. 111-5). DOE may issue loan guarantees to eligible projects that "avoid, reduce, or sequester air pollutants or anthropogenic emissions of greenhouse gases" and "employ new or significantly improved technologies as compared to technologies in service in the United States at the time the guarantee is issued." Eligible projects include commercial-scale renewable energy systems. EISA authorized the DOE to issue loan guarantees in part to support renewable energy projects.

[19] DOE considers a project commercial-scale if it converts, at a minimum, 700 tons of biomass per day to energy. Dan Tobin, "Biomass Summit," *The DOE Loan Guarantee Program: A Status Report,* Washington, DC, October 20, 2009.

[20] For more information on appropriations for the LGP, see CRS Report R40669, *Energy and Water Development: FY2010 Appropriations*, coordinated by Carl E. Behrens.

[21] The funding amount listed in ARRA is $6 billion to cover certain costs, but this amount was recently reduced to $4 billion, as $2 billion was transferred to the "cash for clunkers" automobile trade-in program. For more information on appropriations for DOE loan guarantees and direct loans, see CRS Report R40669, *Energy and Water Development: FY2010 Appropriations*, coordinated by Carl E. Behrens; and CRS Report RL30346, *Federal Credit Reform: Implementation of the Changed Budgetary Treatment of Direct Loans and Loan Guarantees*, by James M. Bickley.

at a pace responsive to market momentum for cellulosic biofuels.[22] Recently, DOE distributed roughly $564 million to 19 advanced biorefinery projects, including cellulosic ethanol plants.[23]

The second government program is the U.S. Department of Agriculture's (USDA's) Biomass Crop Assistance Program (BCAP).[24] BCAP is to assist "agricultural and forest land owners and operators with matching payments for the amount paid for the collection, harvest, storage and transportation (CHST) of eligible material by a qualified Biomass Conversion Facility (BCF)" and to support "establishing and producing eligible crops for the conversion to bioenergy through project areas and on contract acreage up to 5 years for annual and non-woody perennial crops or up to 15 years for woody perennial crops." The CHST portion of the program began in June 2009. USDA's Farm Services Agency (FSA) anticipates implementing the bioenergy crops portion of the program in FY2010. Some question the intent of BCAP and whether it is effective at assisting the groups Congress originally intended.[25]

In addition to financing issues, other challenges to cellulosic biofuel production include the definitions of biomass in various laws. The renewable biomass definition for the RFS under EISA does not allow biomass removal from federal lands, and the law excludes crops from forested lands.[26] Some argue that opening up federal lands for biomass removal could provide an inexpensive supply of cellulosic feedstock that would be immediately available to biorefineries for cellulosic biofuel production. Others contend that biomass removal from federal lands is a short-term response to the cellulosic feedstock source problem and might not be carried out in a sustainable manner, leading to deterioration of the nation's parks and recreation areas. The definition of biomass under EISA excludes most municipal solid waste (MSW), which some view as a potential source for conversion to biofuels.

Also challenging for cellulosic biofuel production are the time periods of feedstock contracts. Agricultural and forestry producers may not agree to a contract that requires a lengthy time commitment. For example, it generally takes three years for switchgrass crops to reach maturity.[27] A producer may have to commit his land to one particular cellulosic feedstock crop for a number of years, thus limiting the producer's choice to grow certain crops on an annual basis depending upon market demand.

[22] Renewable Fuels Association, "2010 State of the Industry Address," 2010 National Ethanol Conference, Orlando, FL, February 16, 2010, http://www.ethanolrfa.org/objects/documents/2772/2010_state_of_the_industry.pdf?utm_medium=email&utm_source=Emailmarketingsoftware&utm_content=313532555&utm_campaign=2010SOTI+_+osdik&utm_term=StateoftheIndustryaddress.

[23] U.S. Dept. of Energy, "Secretaries Chu and Vilsack Announce More Than $600 Million Investment in Advanced Biorefinery Projects," press release, December 4, 2009, http://www1.eere.energy.gov/biomass/news_detail.html?news_id=15660.

[24] BCAP receives its authorization from Title IX of the Farm Security and Rural Investment Act of 2002 (P.L. 107-171) and was amended by Title IX of the Food, Conservation, and Energy Act of 2008 (P.L. 110-246). For more information on BCAP, see CRS Report R41296, *Biomass Crop Assistance Program (BCAP): Status and Issues*, by Megan Stubbs, or visit http://www.fsa.usda.gov/FSA/webapp?area=home&subject=ener&topic=bcap.

[25] Juliet Eilperin, "The Unintended Ripples from the Biomass Subsidy Program," *Washington Post*, January 10, 2010, p. A3; and Nathanael Greene, Natural Resources Defense Council Switchboard, "USDA Sets BCAP on Horrid Path," blog post, January 26, 2010, http://switchboard.nrdc.org/blogs/ngreene/usda_sets_bcap_on_horrid_path.html.

[26] For more information on biomass definitions, see CRS Report R40529, *Biomass: Comparison of Definitions in Legislation*, by Kelsi Bracmort and Ross W. Gorte

[27] University of Tennessee, *Growing and Harvesting Switchgrass for Ethanol Production in Tennessee*, SP701-A, http://www.utextension.utk.edu/publications/spfiles/SP701-A.pdf.

Will the Revised 2010 RFS Mandate for Cellulosic Biofuels Be Met?

Even before enactment of EISA, reported production data indicated that overcoming any or all of the hurdles to increase cellulosic biofuel production to meet the original 2010 RFS mandate of 100 million gallons set by Congress was unlikely. The new 2010 cellulosic biofuel mandate of 6.5 million gallons announced by EPA may be attainable with a relatively small number of pilot- or demonstration-scale projects. EPA acknowledges that the pilot or demonstration facilities tasked with producing the majority of the cellulosic biofuel mandate seldom operate continuously or at full "nameplate" capacity. Thus, some argue, it is difficult to state with certainty how much cellulosic biofuel will be produced and over what time frame. EPA anticipates that more than one-third of the mandate will be met with cellulosic ethanol production from the Range Fuels plant located in Georgia.[28]

According to data provided by the Renewable Fuels Association, two of the 20 U.S. cellulosic ethanol projects currently under construction or development that could produce more than 1 mgy are expected to come online in 2010.[29] Combined, these two facilities are expected to produce roughly 18 mgy of cellulosic ethanol in their first stage of operation. Cellulosic ethanol production capacity of 100 million gallons may not be reached until 2012 or later.[30]

What Impact Will Significantly Lowering the 2010 RFS Mandate Have on Investment in Cellulosic Biofuel Production?

As noted above, EPA has the authority to waive the cellulosic biofuel mandate on a yearly basis. Indeed, EPA issued a waiver to substantially lower the 2010 cellulosic biofuel mandate and proposes to do the same for 2011. EPA's waiver authority creates uncertainty for investors in cellulosic biofuel ventures. Investors may fear that the cellulosic biofuel mandate will never be required by EPA. Some lenders may deny financing due to lack of confidence in federal support for cellulosic biofuels.[31] If the cellulosic biofuel community is unable to produce 10% of the cellulosic biofuel mandate, as established in EISA, for its first year of inclusion in the RFS, some

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[28] The plant is scheduled to come online in mid-2010 with an expected utilization rate of 50%. U.S. Environmental Protection Agency, *Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis*, EPA-420-R-10-006, Washington, DC, February 2010, p. 175, http://www.epa.gov/oms/renewablefuels/420r10006.pdf.

[29] Renewable Fuels Association, *U.S. Cellulosic Ethanol Projects Under Development and Construction*, February 25, 2010, http://www.ethanolrfa.org/resource/cellulosic/documents/CurrentAdvancedCelluloseBiofuelsProjects2-25-10.pdf. Projects were selected based on operation dates and production capacity for first stage of operation provided. Projects identified as small-scale or pilot-scale were not included in the tally.

[30] Based on information provided for 20 U.S. cellulosic ethanol projects under development and construction by the Renewable Fuels Association, http://www.ethanolrfa.org/resource/cellulosic/documents/CurrentAdvancedCelluloseBiofuelsProjects2-25-10.pdf.

[31] Dan Chapman, "Bio Energy Backers Stay Upbeat Despite Setbacks," *Atlanta Journal-Constitution* , January 13, 2010.

may wonder about the viability of this advanced biofuel type over the long term.[32] Others contend the cellulosic biofuel community hit a stumbling block mainly due to a bad economy, and that production will drastically increase over the coming years.[33]

How Much Cellulosic Feedstock Exists for Conversion to Biofuels?

A significant criterion in evaluating whether a commercial cellulosic biofuel production plant will be a favorable investment is whether a steady feedstock supply exists at a location suitable to the biorefinery.[34] However, determining actual availability of feedstock is difficult. Quantifying feedstock available for conversion to biofuels requires information about feedstock sources, production rates, accessibility, and location restrictions (e.g., public versus private lands if the feedstock is to be used for certain energy purposes). Investors must make feedstock predictions based on data from weather patterns and land use change, as well as handling, storage, and transportation costs, among other things. This is a particularly important problem where a growth season of four to five months must provide biomass feedstock for 12 months of plant operation. To make the supply available throughout the year, special equipment may be required for feedstock harvest, handling, collection, storage, or transport, as cellulosic feedstock is often too bulky for average farming equipment to handle.

The amount of cellulosic feedstock necessary for conversion to a biofuel depends on the feedstock type, the conversion process, and the desired biofuel (see **Table 2**). Biofuel conversion yield is measured in gallons per ton. Feedstock, or crop, yield is measured in tons per acre. Total yield, measured in gallons per acre, depends on both the feedstock yield and the conversion yield. Some argue that current estimated cellulosic feedstock yields will need to increase markedly over the next decade to meet the RFS mandate of 16 billion gallons of cellulosic biofuel production per year by 2022. Others contend that a significant growth of cellulosic feedstock is not essential, as advances in conversion technologies will afford the opportunity to produce more cellulosic biofuel with less feedstock.

If cellulosic feedstock yields do increase, the traditional geographic areas for feedstock cultivation may be subject to additional energy, environmental, and agricultural policy scrutiny (see **Figure 1**).

Few studies have estimated the current or long-term cellulosic feedstock supply available for conversion to biofuels on a national basis. Estimates of the amount of cellulosic feedstock available in recent years (2003-2007) range from 5,000 to 300,000 tons per year (**Figure 2** and **Figure 3**). Assuming a yield of 100 gallons per ton, this would equate to between 0.5 and 30 mgy of potential fuel production from that feedstock. This is well below the 100 million gallons needed to meet the 2010 mandate originally set by Congress, but is within range of the 6.5 million gallons production volume set by EPA for 2010.

[32] Russel Gold and Siobhan Hughes, "Biofuel Production Fall Far Short of Targets," *Wall Street Journal*, February 4, 2010.

[33] Renewable Fuels Association, "Obama Administration on Right Track with Biofuels," press release, February 3, 2010, http://renewablefuelsassociation.cmail1.com/T/ViewEmail/y/9C2814171DC11FF6/F83B91963160BD91C5EC08CADFFC107B.

[34] A biorefinery is a facility that processes biomass into biofuels.

Long-term cellulosic feedstock supply projections—for varying time periods beginning in 2020 and continuing to 2050—range from roughly 500 million to more than 1 billion tons per year capable of producing biofuels, well beyond the 16 billion gallons needed to meet the 2022 mandate (**Table 3**).[35]

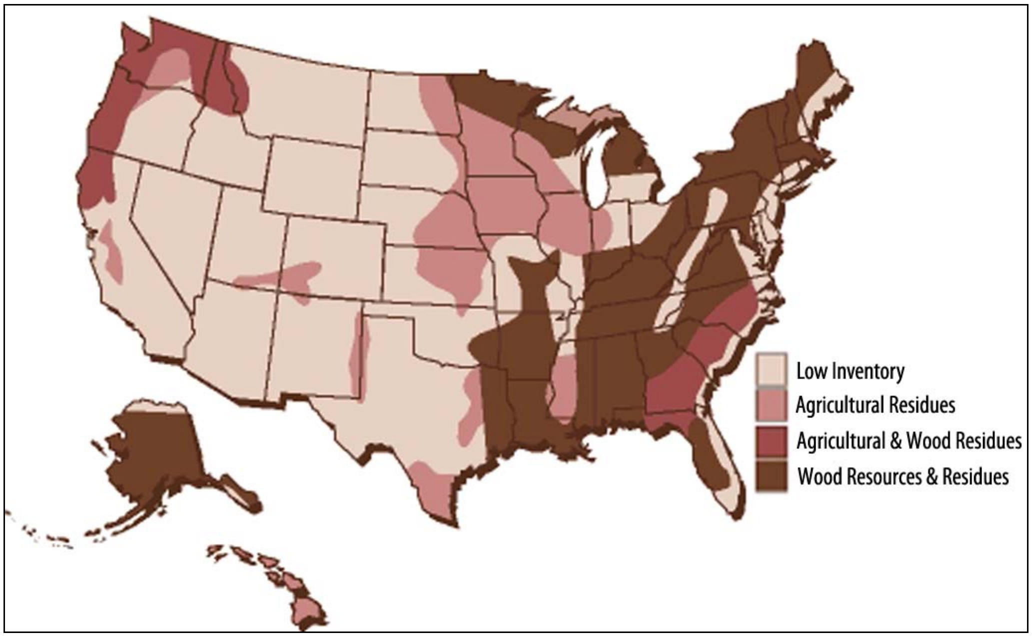
Table 2. Theoretical Ethanol Production Yields for Selected Feedstocks

Feedstock	Ethanol (gallons per dry ton of feedstock)
Corn Grain	124.4
Corn Stover	113.0
Rice Straw	109.9
Cotton Gin Trash	56.8
Forest Thinnings	81.5
Hardwood Sawdust	100.8
Bagasse	111.5
Mixed Paper	116.2

Source: U.S. Dept. of Energy, Biomass Program, http://www1.eere.energy.gov/biomass/ethanol_yield_calculator.html.

Notes: Actual yield commonly ranges from 60% to 90% of theoretical yields.

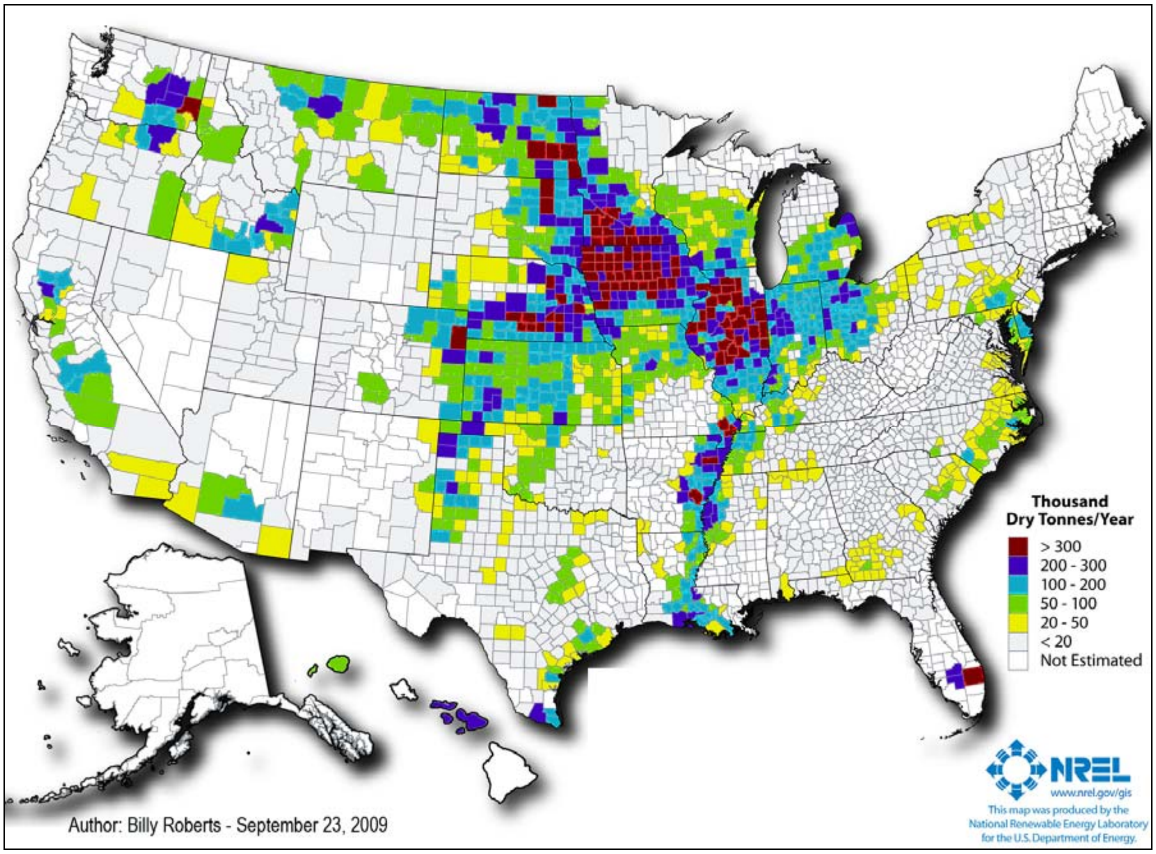
Figure 1. Geographical Areas with Biomass Resources



Source: U.S. Department of Energy, http://www.energysavers.gov/images/biomass_map.gif.

[35] The estimates provided in **Table 3** are based on numerous assumptions and modeling techniques unique to each study. While general categories may appear similar in name (e.g., agricultural lands), one should refer to the table footnotes for clarification on the category makeup.

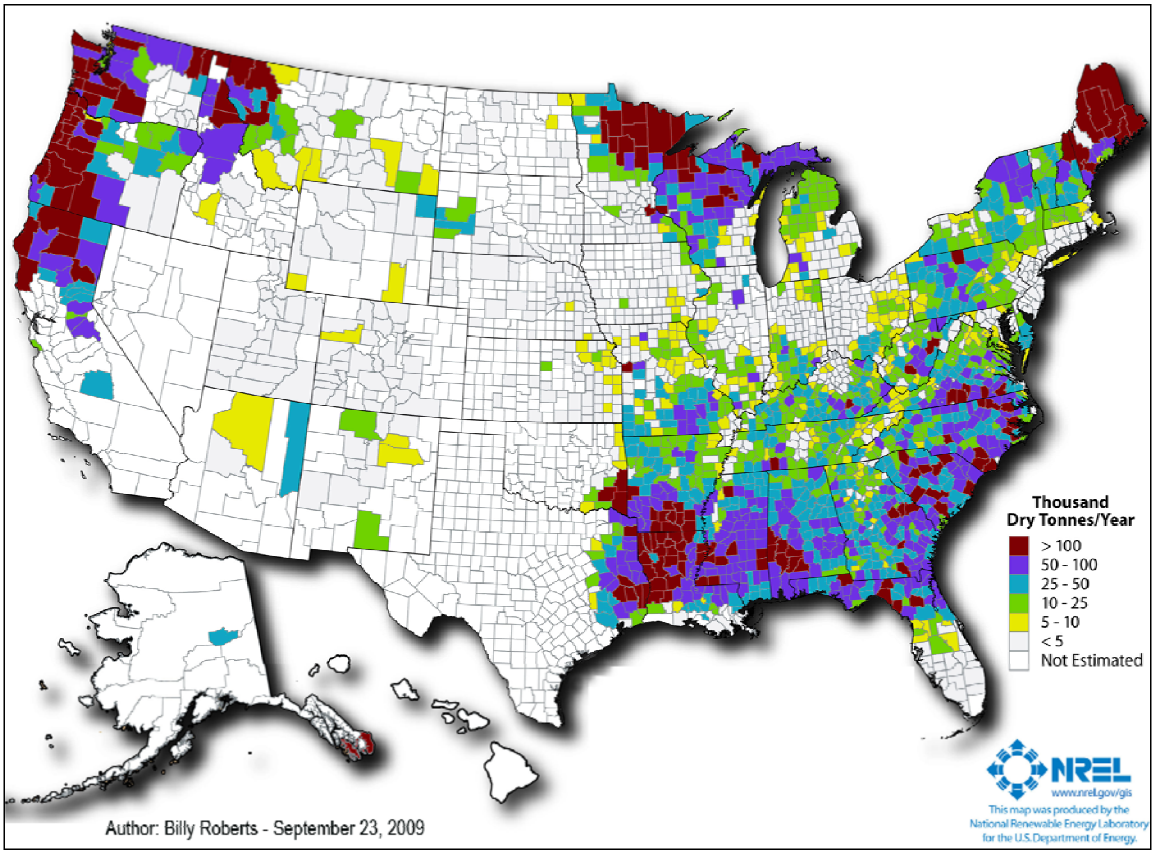
Figure 2. Cellulosic Feedstock Available from Crop Residues in the United States



Source: U.S. Department of Energy, National Renewable Energy Laboratory, http://www.nrel.gov/gis/images/map_biomass_crop_residues.jpg. Feedstock estimate based on five-year average for 2003 to 2007 from the U.S. Department of Agriculture, National Agricultural Statistics Service.

Note: The following crops were included in this analysis: corn, wheat, soybeans, cotton, sorghum, barley, oats, rice, rye, canola, dry edible beans, dry edible peas, peanuts, potatoes, safflower, sunflower, sugarcane, and flaxseed. The quantities of crop residues that can be available in each county are estimated using total grain production, crop to residue ratio, and moisture content, taking into consideration the amount of residue left on the field for soil protection, grazing, and other agricultural activities. USDA, National Agricultural Statistics Service, five-year average, 2003-2007 data.

Figure 3. Cellulosic Feedstock Available from Forest Residues in the United States



Source: U.S. Department of Energy, National Renewable Energy Laboratory, http://www.nrel.gov/gis/images/map_biomass_forest_residues.jpg. Feedstock estimate based on U.S. Forest Service Timber Product Output database for 2007.

Note: Forest residues include logging residues and other removable material left after carrying out silvicultural operations and site conversions. Logging residue comprises unused portions of trees cut or killed by logging and left in the woods. Other removable materials are the unutilized volumes of trees cut or killed during logging operations. USDA, Forest Service's Timber Product Output database, 2007.

Table 3. Cellulosic Feedstock Supply Estimates of Availability and Need

Source	Feedstock Quantity (Tons)	Comments
	Estimates of Availability	
USDA / DOE Billion-Ton Study (2005)[a]	1.366 billion available on a yearly basis roughly around the mid-21st century • 368 million from forest lands (27% of estimated total) • 621 million from agricultural lands[b] (45% of estimated total) • 377 million for dedicated energy crops[c] (28% of estimated total)	The agricultural land component of the estimated total includes grains (corn and soybean) used for ethanol and biodiesel which are not cellulosic feedstock. The study included biomass available for bioenergy in general (e.g., wood for electricty). The Billion-Ton Study may have overestimated the amount of feedstock that can be economically harvested because it did not calculate costs associated with harvesting potential feedstocks using existing technology. The study also included woody biomass from federal forest lands, but EISA subsequently excluded such biomass from qualifying under the RFS. An updated study is expected to be published later this year.[d]
National Academy of Sciences (2009)[e]	548 million available in 2020 • 124 million from forest lands (23% of estimated total) • 160 million from agricultural lands[f] (29% of estimated total) • 164 million from dedicated energy crops (30% of estimated total)	The study estimates that the cellulosic feedstock can be available sustainably for conversion to liquid fuel in 2020.
	Estimates of Need	
Sandia National Laboratories / General Motors' R&D Center (2009)[g]	775 million • 126 million tons from forest lands (16% of estimated total) • 182 million from agricultural lands (23% of estimated total) • 467 million from dedicated energy crops (60% of estimated total)	The study estimates that 775 million tons of biomass are required to produce 70 billion gallons/year (BGY) of cellulosic ethanol by 2030

Source	Feedstock Quantity (Tons)	Comments
Biomass Research and Development Initiative (2008)[h]	240 million • 153 million from agricultural lands[i] (64% of estimated total) • 85 million from dedicated energy crops (35% of estimated total)	The study estimates, for one scenario out of the three provided, that 240 million tons of biomass are required to produce 36 BGY of cellulosic ethanol by 2022. Assumptions for the scenario include meeting the 36 BGY of cellulosic ethanol with corn-based ethanol of 15 BGY, soybean diesel of 1 BGY, 20 BGY from cropland biomass, 0 BGY from forestland biomass, and 0 BGY from imports.

Source: Compiled by CRS.

a. DOE, USDA, *Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply*, April 2005, http://www1.eere.energy.gov/biomass/pdfs/final_billionton_vision_report2.pdf.

b. Agricultural lands include crop residues, grains, and animal manure.

c. Perennial crops (e.g., grasses) are generally considered dedicated energy crops.

d. U.S. Government Accountability Office, *Biofuels: Potential Effects and Challenges of Required Increases in Production and Use*, GAO-09-446, August 2009, http://www.gao.gov/new.items/d09446.pdf.

e. National Academy of Sciences, National Academy of Engineering, National Research Council, *Liquid Transportation Fuels from Coal and Biomass: Technological Status, Costs, and Environmental Impacts*, Washington, DC, 2009, http://www.nap.edu/catalog.php?record_id=12620.

f. Agricultural lands include corn stover, wheat and grass straw, hay, and animal manure.

g. Sandia National Laboratories, *90-Billion Gallon Biofuel Deployment Study*, February 2009, http://hitectransportation.org/news/2009/Exec_Summary02-2009.pdf. E-mail from Todd West of Sandia National Laboratory, February 10, 2010. Estimates vary based on the assumptions made for conversion yields, feedstock availability and relative cost, and more.

h. Biomass Research and Development Initiative, *Increasing Feedstock Production for Biofuels Economic Drivers, Environmental Implications, and the Role of Research*, December 2008, http://www.brdisolutions.com.

i. Agricultural lands include corn stover and straw.

How Many Commercial Cellulosic Biofuel Plants Exist?

As of mid-2010, no large-scale commercial cellulosic biofuel plants are in operation in the United States. Several small-scale plants may come online this year (see **Table 4**). Proposed cellulosic ethanol plants span an array of production capacities—ranging from 20,000 gallons per year to 100 mgy.[36] Development and construction for some commercial cellulosic ethanol plants began in 2008. Industry sources anticipate that many of the plants will be fully operational by 2012. More than two dozen demonstration- or pilot-scale cellulosic ethanol plants are reported to exist currently in the United States.

[36] Renewable Fuels Association, *U.S. Cellulosic Ethanol Projects Under Development and Construction,* February 25, 2010, http://www.ethanolrfa.org/resource/cellulosic/documents/CurrentAdvancedCelluloseBiofuelsProjects2-25-10.pdf.

Table 4. Estimated National Cellulosic Ethanol Plant Tally

Source	Total Number of Commercial Plants / Combined Production Capacity	Total Number of Pilot or Demonstration Plants / Combined Production Capacity	Total Number of Proposed, Planned, or Under Construction Plants / Combined Production Capacity	Comments
Purdue University[a]	0	25 / 3.5 mgy	30 / 1bgy	
GAO[b]	0		25 / 376 mgy	Data for the GAO study was obtained from the Renewable Fuels Association.
Renewable Fuels Association[c]	0	not provided	20 / 242 mgy	Two of the plants may come online in 2010. Total planned production capacity is based on estimates provided for initial stages of operation.
EPA[d]	0	23 / 4.1mgy	17 / 265 mgy	

Source: Compiled by CRS.

Notes: mgy = million gallons per year. bgy = billion gallons per year.

a. Wallace E. Tyner and Sarah Brechbill, "Cellulosic Biofuels: Feedstocks, Conversion Technologies, Economics, and Policy Issues," CRS Workshop on the Development of the U.S. Cellulosic Biofuels Industry, Washington, DC, October 6, 2009; and conversation with Wallace Tyner from Purdue University, February 2, 2010.

b. GAO, *Biofuels: Potential Effects and Challenges of Required Increases in Production and Use*, p. 118.

c. Renewable Fuels Association, *U.S. Cellulosic Ethanol Projects Under Development and Construction*, February 25, 2010, http://www.ethanolrfa.org/resource/cellulosic/documents/CurrentAdvancedCelluloseBiofuelsProjects2-25-10.pdf.

d. EPA, *Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis*, EPA-420-R-10-006, Washington, DC, February 2010, pp. 171 and 186, http://www.epa.gov/oms/renewablefuels/420r10006.pdf.

What Policy Options Are Available to Expedite Cellulosic Biofuel Production?

Congress is considering legislation that will affect cellulosic biofuel production if enacted. Section 129 of the American Clean Energy and Security Act of 2009 (H.R. 2454, also known as Waxman-Markey) would amend the Loan Guarantee Program to incorporate renewable fuel pipeline construction.[37] Title I of the American Clean Energy Leadership Act of 2009 (ACELA, S. 1462) would amend the Loan Guarantee Program and create a Clean Energy Deployment

[37] For more information on expansion of the Loan Guarantee Program, see CRS Report R40643, *Greenhouse Gas Legislation: Summary and Analysis of H.R. 2454 as Passed by the House of Representatives* , coordinated by Mark Holt and Gene Whitney

Administration, under DOE, to advance lending and implementation of commercial clean energy technologies.[38] H.R. 2283 and S. 943 would waive the lifecycle greenhouse gas emission reduction requirements for renewable fuel production.

Congress may decide to take additional legislative action to address the limited cellulosic biofuel production capacity for the RFS. Some options available to Congress are lowering the cellulosic biofuel mandate, delaying the start year for cellulosic biofuel production requirements, modifying the DOE Loan Guarantee Program, implementing new financial support mechanisms, or making federal lands available for biomass removal. Cellulosic biofuels advocates may find it beneficial for Congress to make the cellulosic biofuel mandate more attainable in the near term (e.g., two to five years). Opponents may view any additional congressional action to assist the cellulosic biofuel community as harmful to the entire renewable energy market in the long run.

Congress may also choose to monitor EPA's facilitation of the RFS. EPA is responsible for implementing the RFS and revising the RFS when necessary. In May 2009, EPA announced a notice of proposed rulemaking for the RFS seeking public comment for a number of issues related to the RFS, including the cellulosic biofuel production volume, the definition of cellulosic biofuel, and the lifecycle emissions analysis.[39] On March 26, 2010, EPA published its final rule for the RFS.[40] The final rule was effective as of July 1, 2010. As discussed above, the most significant change pertaining to cellulosic biofuels was issuance of a waiver that lowered the 2010 cellulosic biofuel mandate to 6.5 million gallons. Some suggest the waiver was issued partly due to the economic hardships faced by the industry.[41]

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[38] For more information on measures that may improve cellulosic ethanol production contained within S. 1462, see CRS Report R40837, *Summary and Analysis of S. 1462: American Clean Energy Leadership Act of 2009, As Reported*, coordinated by Mark Holt and Gene Whitney.

[39] U.S. Environmental Protection Agency, "Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program," 74 *Fed. Reg.* 24904-25143, May 26, 2009.

[40] 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.

[41] Renewable Fuels Association, January 2010, personal consultation.