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Renewable Fuel Standard (RFS): Overview and Issues

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Summary

Federal policy has played a key role in the emergence of the U.S. biofuels industry. Policy measures include minimum renewable fuel usage requirements, blending and production tax credits, an import tariff, loans and loan guarantees, and research grants. This report focuses on the mandated minimum usage requirements—referred to as the Renewable Fuel Standard (RFS)—whereby a minimum volume of biofuels is to be used in the national transportation fuel supply each year. It describes the general nature of the RFS mandate and its implementation, and outlines some emerging issues related to the sustainability of the continued growth in U.S. biofuels production needed to fulfill the expanding RFS mandate, as well as the emergence of potential unintended consequences of this rapid expansion.

Congress first established an RFS with the enactment of the Energy Policy Act of 2005 (EPAct, P.L. 109-58). This initial RFS (referred to as RFS1) mandated that a minimum of 4 billion gallons be used in 2006, and that this minimum usage volume rise to 7.5 billion gallons by 2012. Two years later, the Energy Independence and Security Act of 2007 (EISA, P.L. 110-140) superseded and greatly expanded the biofuels blending mandate. The expanded RFS (referred to as RFS2) required the annual use of 9 billion gallons of biofuels in 2008 and expanded the mandate to 36 billion gallons annually in 2022, of which no more than 15 billion gallons can be ethanol from corn starch, and no less than 16 billion must be from cellulosic biofuels. In addition, EISA carved out specific requirements for "other advanced biofuels" and biomass-based biodiesel.

The Environmental Protection Agency (EPA) is responsible for establishing and implementing regulations to ensure that the nation's transportation fuel supply contains the mandated biofuels volumes. EPA's initial regulations for administering RFS1 (issued in April 2007) established detailed compliance standards for fuel suppliers, a tracking system based on renewable identification numbers (RINs) with credit verification and trading, special treatment of small refineries, and general waiver provisions. EPA rules for administering RFS2 (issued in February 2010) built upon the earlier RFS1 regulations; however, there are four major distinctions. First, mandated volumes are greatly expanded and the time frame over which the volumes ramp up is extended through at least 2022. Second, the total renewable fuel requirement is divided into four separate, but nested categories—total renewable fuels, advanced biofuels, biomass-based diesel, and cellulosic ethanol—each with its own volume requirement. Third, biofuels qualifying under each category must achieve certain minimum thresholds of lifecycle greenhouse gas (GHG) emission reductions, with certain exceptions applicable to existing facilities. Fourth, all renewable fuel must be made from feedstocks that meet a new definition of renewable biomass, including certain land use restrictions.

In the long term, the expanded RFS is likely to play a dominant role in the development of the U.S. biofuels sector, but with considerable uncertainty regarding potential spillover effects in other markets and on other important policy goals. Emerging resource constraints related to the rapid expansion of U.S. corn ethanol production have provoked questions about its long-run sustainability and the possibility of unintended consequences in other markets as well as on the environment. Questions also exist about the ability of the U.S. biofuels industry to meet the expanding mandate for biofuels from non-corn sources such as cellulosic biomass materials, whose production capacity has been slow to develop, or biomass-based biodiesel, which remains expensive to produce owing to the relatively high prices of its feedstocks. Finally, considerable uncertainty remains regarding the development of the infrastructure capacity (e.g., trucks, pipelines, pumps, etc.) needed to deliver the expanding biofuels mandate to consumers.

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Introduction

Increasing dependence on foreign sources of crude oil, concerns over global climate change, and the desire to promote domestic rural economies have raised interest in renewable biofuels as an alternative to petroleum in the U.S. transportation sector. In response to this interest, U.S. policymakers have enacted an increasing variety of policies, at both the state and federal levels, to directly support U.S. biofuels production and use.[1] Policy measures have included blending and production tax credits to lower the cost of biofuels to end users, an import tariff to protect domestic ethanol from cheaper foreign-produced ethanol, research grants to stimulate the development of new biofuels technologies, loans and loan guarantees to facilitate the development of biofuels production and distribution infrastructure, and, perhaps most important, minimum usage requirements to guarantee a market for biofuels irrespective of their cost.[2] As a result of expanding policy support, biofuels (primarily corn-based ethanol and biodiesel) production has grown significantly in the past few years. However, despite the rapid growth, U.S. biofuels consumption remains small as a component of U.S. motor fuels, comprising about 5.9% of total transportation fuel consumption (on a gasoline-equivalent basis) in 2011.[3]

Initially, the most significant federal programs for supporting biofuels were tax credits for the production or blending of ethanol and biodiesel into the nation's fuel supply. However, under the Renewable Fuel Standard (RFS)—first established in 2005, then greatly expanded in 2007 (as described below)—Congress mandated biofuels use. In the long term, the expanded RFS usage mandate is likely to prove more significant than tax incentives in promoting the use of these fuels.

This report focuses specifically on the RFS. It describes the general nature of the biofuels RFS and its implementation, and outlines some of the emerging issues related to the sustainability of the continued growth in U.S. biofuels production needed to fulfill the expanding RFS mandate, as well as the emergence of potential unintended consequences of this rapid expansion. This report does not address the broader public policy issue of how best to support U.S. energy policy.

The Renewable Fuel Standard (RFS)

Congress first established a Renewable Fuel Standard (RFS)—a mandatory minimum volume of biofuels to be used in the national transportation fuel supply—in 2005 with the enactment of the Energy Policy Act of 2005 (EPAct, P.L. 109-58). The initial RFS (sometimes referred to as RFS1) mandated that a minimum of 4 billion gallons of renewable fuel be used in the nation's gasoline supply in 2006, and that this minimum usage volume rise to 7.5 billion gallons by 2012 (**Table 1**).

Two years later, the Energy Independence and Security Act of 2007 (EISA, P.L. 110-140) superseded and greatly expanded the biofuels blending mandate to 36 billion gallons by 2022. This expanded RFS is sometimes referred to as RFS2. In addition to gasoline, RFS2 applies to all

[1] For more information, see CRS Report R41282, *Agriculture-Based Biofuels: Overview and Emerging Issues*.

[2] For more information on incentives (both tax and non-tax) for ethanol, see CRS Report R40110, *Biofuels Incentives: A Summary of Federal Programs*.

[3] In gasoline-equivalent shares with 7% for ethanol and 2% for biodiesel. CRS estimates based on extrapolating from EIA/DOE, "Table C1. Estimated Consumption of Vehicle Fuels in the United States, by Fuel Type, 2003-2008," with recent data for 2009 through 2011.

transportation fuel used in the United States—including diesel fuel intended for use in highway motor vehicles, non-road, locomotive, and marine diesel (MVNRLM).[4]

EPA Administration of the RFS

The RFS is administered by the Environmental Protection Agency (EPA).[5] As with RFS1, the expanded RFS (or RFS2) directly supports U.S. biofuels production by providing a mandatory market for qualifying biofuels—fuel blenders must incorporate minimum volumes of biofuels in their annual transportation fuel sales irrespective of market prices. By guaranteeing a market for biofuels, RFS2 substantially reduces the risk associated with biofuels production, thus providing an indirect subsidy for capital investment in the construction of biofuels plants. As such, the expanding RFS is expected to continue to stimulate growth of the biofuels industry.

EPA issued its final rule for administering RFS1 in April 2007.[6] This rule established detailed compliance standards for fuel suppliers, a tracking system based on renewable identification numbers (RINs) with credit verification and trading, provisions for treatment of small refineries, and general waiver provisions.

EISA was passed on December 19, 2007, and EPA issued its final rule to implement and administer the RFS2 on February 3, 2010.[7] The new rule builds upon the earlier rule for RFS1. However, there are four major distinctions between the rules for administering RFS1 and RFS2:

- First and foremost, RFS2 increases the mandated usage volumes and extends the time frame over which the volumes ramp up through at least 2022 (**Table 1**).
- Second, RFS2 subdivides the total renewable fuel requirement into four separate but nested categories—total renewable fuels, advanced biofuels, biomass-based diesel, and cellulosic ethanol—each with its own volume requirement or standard (described below).
- Third, biofuels qualifying under each nested category must achieve certain minimum thresholds of lifecycle greenhouse gas (GHG) emission performance, with certain exceptions applicable to existing facilities (**Table 2**).[8]
- Fourth, under RFS2 all renewable fuel must be made from feedstocks that meet the new definition of renewable biomass, including certain land use restrictions.[9]

[4] Heating oil, jet fuel, and fuels for ocean-going vessels are excluded from RFS2's national transportation fuel supply; however, renewable fuels used for these purposes may count towards the RFS2 mandates. EPA, 40 C.F.R. Part 80, "Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program, Final Rule," Feb. 3, 2010.

[5] EPA's official "Renewable Fuel Standard (RFS)" website, with links to all official documents, is available at http://www.epa.gov/otaq/fuels/renewablefuels/.

[6] "Renewable Fuels: Regulations & Standards," EPA's online chronicle of RFS rulemaking , available at http://www.epa.gov/otaq/renewablefuels/regulations.htm.

[7] Ibid.

[8] CRS Report R40460, *Calculation of Lifecycle Greenhouse Gas Emissions for the Renewable Fuel Standard (RFS)*.

[9] CRS Report R40529, *Biomass: Comparison of Definitions in Legislation Through the 111th Congress*.

Table 1. EISA 2007 Expansion of the Renewable Fuel Standard

(in billions of gallons)

Year	RFS1 biofuel mandate in EPAct of 2005	RFS2 biofuel mandate					
		Total renewable fuels	Cap on corn starch-derived ethanol	Portion to be from advanced biofuels			
				Total non-corn starch	Cellulosic	Biodiesel	Other
2006	4.0	—	—	—	—	—	—
2007	4.7	—	—	—	—	—	—
2008	5.4	9.00	9.0	0.00	0.00	0.00	0.00
2009	6.1	11.10	10.5	0.60	0.00	0.00	0.10
2010	6.8	12.95	12.0	0.95	0.0065[a]	1.15[b]	0.20
2011	7.4	13.95	12.6	1.35	0.0066[c]	0.80	0.30
2012	7.5	15.20	13.2	2.00	0.00865[d]	1.00	0.50
2013	7.6 (est.)	16.55	13.8	2.75	1.00	1.28[e]	0.75
2014	7.7 (est.)	18.15	14.4	3.75	1.75	[f]	1.00
2015	7.8 (est.)	20.50	15.0	5.50	3.00	[f]	1.50
2016	7.9 (est.)	22.25	15.0	7.25	4.25	[f]	2.00
2017	8.1 (est.)	24.00	15.0	9.00	5.50	[f]	2.50
2018	8.2 (est.)	26.00	15.0	11.00	7.00	[f]	3.00
2019	8.3 (est.)	28.00	15.0	13.00	8.50	[f]	3.50
2020	8.4 (est.)	30.00	15.0	15.00	10.50	[f]	3.50
2021	8.5 (est.)	33.00	15.0	18.00	13.50	[f]	3.50
2022	8.6 (est.)	36.00	15.0	21.00	16.00	[f]	4.00
2023	—	[g]	[g]	[g]	[g]	[g]	[g]

Source: RFS1 is from EPAct (P.L. 109-58), Section 1501; RFS2 is from EISA (P.L. 110-140), Section 202.

a. The initial EISA cellulosic biofuels mandate for 2010 was for 100 million gallons. On February 3, 2010, EPA revised this mandate downward to 6.5 million ethanol-equivalent gallons.

b. The biodiesel mandate for 2010 combines the original EISA mandate of 0.65 billion gallons (bgal) with the 2009 mandate of 0.5 bgal.

c. The initial RFS for cellulosic biofuels for 2011 was 250 million gallons. In November 2010 EPA revised this mandate downward to 6.6 million gallons.

d. The initial RFS for cellulosic biofuels for 2012 was 500 million gallons. In December 2011 EPA revised this mandate downward to 8.65 million gallons.

e. EPA announced, in December 2011, a provisional volume of 1.28 billion gallons. A final rule is expected in early 2012.

f. To be determined by EPA through a future rulemaking, but no less than 1.0 billion gallons.

g. To be determined by EPA through a future rulemaking.

Four Biofuel Categories

The expansion of the renewable fuels mandate under RFS2 includes four new biofuels categories, each with a specific volume mandate and lifecycle GHG emission reduction threshold (as compared to the lifecycle GHG emissions of the 2005 baseline average gasoline or diesel fuel that it replaces), and each subject to strict biomass feedstock criteria.

- **Total renewable fuels**. The mandate grows from nearly 13 billion gallons (bgals) in 2010 to 36 bgals in 2022. Biofuels must reduce lifecycle GHG emissions by at least 20% to qualify as a renewable fuel. Most biofuels, including corn-starch ethanol from new facilities, qualify for this mandate. However, the volume of corn-starch ethanol included under the RFS is capped at 13.2 bgals in 2012. The cap grows to 15 bgals by 2015 and is fixed thereafter.
- **Advanced biofuels**.[10] The mandate grows from nearly 1 bgals in 2010 to 21 bgals in 2022. Advanced biofuels must reduce lifecycle GHG emissions by 50% to qualify. A subcomponent of the total renewable fuels mandate, this category includes biofuels produced from non-corn feedstocks—corn-starch ethanol is expressly excluded from this category. Potential feedstock sources include grains such as sorghum and wheat. Imported Brazilian sugarcane ethanol, as well as biomass-based biodiesel and biofuels from cellulosic materials (including non-starch parts of the corn plant such as the stalk and cob) also qualify.
- **Cellulosic and agricultural waste-based biofuel**. The mandate grows from 100 million gallons in 2010 (subsequently, RFS mandates were revised downward for 2010, 2011, and 2012) to 16 bgals in 2022.[11] Cellulosic biofuels must reduce lifecycle GHG emissions by at least 60% to qualify. Cellulosic biofuels are renewable fuels derived from cellulose, hemicellulose, or lignin. This includes cellulosic biomass ethanol as well as any biomass-to-liquid fuel such as cellulosic gasoline or diesel.
- **Biomass-based biodiesel (BBD)**. The mandate grows from 0.5 bgals in 2009 to 1 bgals in 2012.[12] Any diesel fuel made from biomass feedstocks qualifies, including biodiesel (mono-alkyl esters) and non-ester renewable diesel (e.g., cellulosic diesel).[13] The lifecycle GHG emissions reduction threshold is 50%.

[10] The term "advanced biofuels" comes from legislation in the 110th Congress, and is defined in Section 201 of the Energy Independence and Security Act of 2007 (EISA). In many cases, the definition of "advanced biofuels" includes mature technologies and fuels that are currently produced in large amounts. For example, the EISA definition of "advanced biofuels" potentially includes ethanol from sugar cane, despite the fact that Brazilian sugar growers have been producing fuel ethanol for decades. EISA defines "advanced biofuels" as biofuels other than ethanol derived from corn starch (kernels) having 50% lower lifecycle greenhouse gas emissions relative to gasoline.

[11] As part of its February 3, 2010, final rule, EPA announced a revision in the cellulosic biofuel standard for 2010 to 6.5 million ethanol-equivalent gallons based on an assessment of U.S. production capacity in place or under construction. Similarly, EPA lowered the 2011 cellulosic biofuels RFS from 250 million gallons to 6.6 million gallons (December 9, 2010), and the 2012 cellulosic biofuels RFS from 500 million gallons to 8.65 million gallons (December 2011).

[12] As part of its February 3, 2010, final rule, EPA announced a revision in the biomass-based biodiesel standard for 2010 to 1.15 bgals. This revision represents a summation of the 2009 standard of 0.5 bgals with the 2010 standard of 0.65 bgals. The RFS1 regulatory system, which was in effect during 2009 and which was based on national gasoline supply, did not provide any mechanism for implementing the 2009 biomass-based diesel standard. As a result, it was integrated into the 2010 standard. Qualifying RINs accumulated during 2009 are acceptable in compliance.

[13] A diesel fuel product produced from cellulosic feedstocks that meets the 60% GHG threshold can qualify as either cellulosic biofuel or biomass-based biodiesel.

Usage Volume Requirements

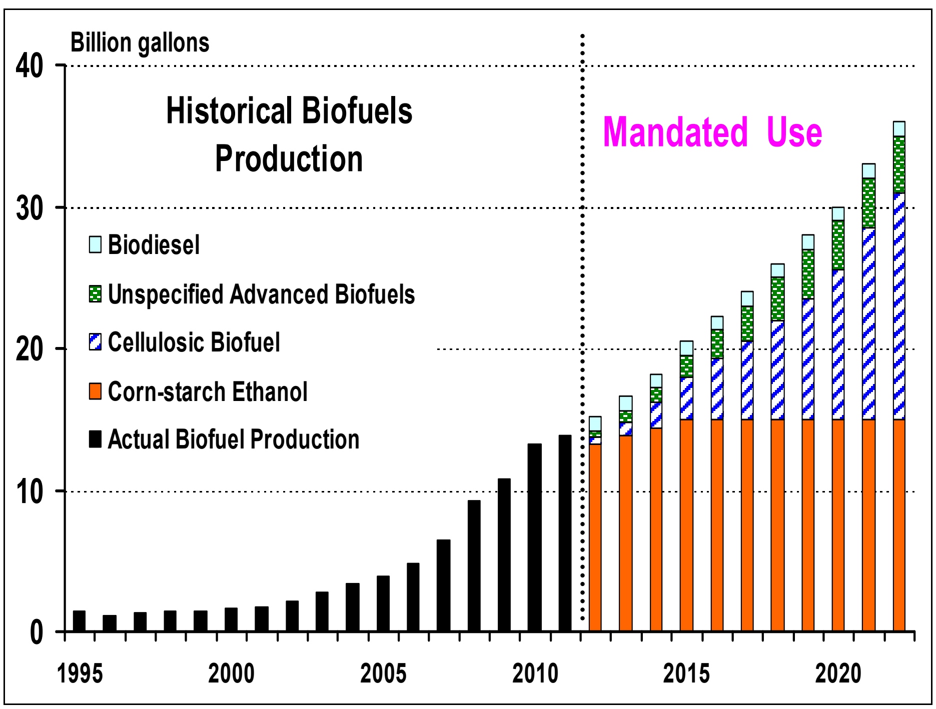
RFS2 is essentially a biofuels mandate with limits on corn-ethanol inclusion and carve-outs for higher-performing biofuels (as measured by reductions in lifecycle GHG emissions). The cap on the volume of ethanol derived from corn starch that can be counted under the RFS is intended to encourage the use of non-corn-based biofuels, not to limit the federal budget liability. As a result, corn-starch ethanol blended in excess of its annual cap is not credited toward the annual total renewable fuels mandate.

Nested Categories

Because of the nested nature of the biofuel categories, any renewable fuel that meets the requirement for cellulosic biofuels or biomass-based diesel is also valid for meeting the overall advanced biofuels requirement. Thus, if any combination of cellulosic biofuels or biomass-based biodiesel were to exceed their individual mandates, the surplus volume would count against the advanced biofuels mandate, thereby reducing the potential need for imported sugar-cane ethanol or other fuels to meet the unspecified portion of the advanced biofuels mandate.

Similarly, any renewable fuel that meets the requirement for advanced biofuels is also valid for meeting the total renewable fuel requirement. As a result, any combination of cellulosic biofuels, biomass-based biodiesel, or imported sugar-cane ethanol that exceeds the advanced biofuel mandate would reduce the potential need for corn-starch ethanol to meet the overall mandate.

Figure 1. Renewable Fuels Standard (RFS2) vs. U.S. Ethanol Production Since 1995



Source: Actual ethanol production data for 1995-2010 is from Renewable Fuels Association; the RFS2 by category is from EISA (P.L. 110-140).

Required Reduction in Lifecycle Greenhouse Gas (GHG) Emissions

In addition to volume mandates, EISA specified that the lifecycle GHG emissions of a qualifying renewable fuel must be less than the lifecycle GHG emissions of the 2005 baseline average gasoline or diesel fuel that it replaces.[14] EISA established lifecycle GHG emission thresholds for each of the RFS2 biofuels categories (**Table 2**).

With respect to the GHG emissions assessments, EISA specifically directed EPA to evaluate the aggregate quantity of GHG emissions (including direct emissions and significant indirect emissions, such as significant emissions from land use changes) related to the full lifecycle, including all stages of fuel and feedstock production, distribution, and use by the ultimate consumer.

Table 2. EISA-Mandated Reductions in Lifecycle GHG Emissions by Biofuel Category

(percent reduction from 2005 baseline for gasoline or diesel fuel)

Biofuels category	Threshold reduction
Renewable fuel[a]	20%
Advanced biofuels	50%
Biomass-based diesel	50%
Cellulosic biofuel	60%

Source: "Regulatory Announcement: EPA Finalizes Regulations for the National Renewable Fuel Standard Program for 2010," EPA-420-F-10-007, Office of Transportation and Air Quality, EPA, February 3, 2010.

a. The 20% criteria applies to renewable fuel from facilities that commenced construction after December 19, 2007, the date EISA was signed into law.

Fuel Pathways (including ILUC) Meeting Lifecycle GHG Thresholds

Prior to EPA's release of its final rule on RFS2 (on February 3, 2010), EPA measurement of lifecycle GHG reductions for various biofuels pathways had become somewhat contentious due to the explicit requirement to incorporate so-called "indirect land use changes" (ILUC) in the GHG emissions assessment.[15] ILUC refers to the idea that diversion of an acre of traditional field cropland in the United States to production of a biofuels feedstock crop might result (due to market price effects) in that same acre of field crop production reappearing at another location and potentially on virgin soils, such as the Amazon rainforest. Such a transfer—when included in the lifecycle GHG calculation of a particular biofuel—could result in an estimated net increase in GHG emissions.

Several environmental and academic groups argued that, as a result of ILUC costs, corn ethanol should not be permissible under the RFS2. Biofuels proponents argued that ILUC was too vague a concept to be measurable in a meaningful way, and that it alone should not determine the fate of the U.S. biofuels industry. After considering all of the evidence (including ILUC) and making

[14] CRS Report R40460, *Calculation of Lifecycle Greenhouse Gas Emissions for the Renewable Fuel Standard (RFS)*.

[15] EISA (P.L. 110-140), Title II, Sec. 201 Definitions, "(H) Lifecycle Greenhouse Gas Emissions."

relevant adjustments to its analytical tools, EPA determined (as part of its final RFS rule of February 3, 2010) that[16]

- ethanol produced from corn starch at a new natural gas-fired facility (or expanded capacity from an existing facility) using advanced efficient technologies complies with the 20% GHG emission reduction threshold;
- biobutanol from corn starch complies with the 20% GHG threshold;
- ethanol produced from sugarcane (as in Brazil) complies with the 50% GHG reduction threshold for the advanced fuel category;
- biodiesel from soy oil and renewable diesel from waste oils, fats, and greases comply with the 50% GHG threshold for the biomass-based diesel category;
- diesel produced from algal oils complies with the 50% GHG threshold for the biomass-based diesel category; and
- cellulosic ethanol and cellulosic diesel (based on currently modeled pathways) comply with the 60% GHG reduction threshold applicable to cellulosic biofuels.

In addition, EPA pointed out that other pathways are likely to be similar enough to the above-listed items that they can be extended the same GHG reduction compliance determinations.[17] However, EPA also pointed out that, although the announced determinations for the fuel pathways listed above are final for the time being, its lifecycle methodology remains subject to new developments in the state of scientific knowledge, and that future reassessments may alter the current status of these fuel pathways.

EPA says that it will be able to make determinations on several other potential biomass crops and their fuel pathways in the future. For example, in July 2010, EPA made a final determination that biodiesel from canola oil meets the 50% emissions reduction requirement.[18] Similarly, in November 2011, EPA determined that[19]

- biodiesel and renewable diesel (including jet fuel and heating oil) from camelina oil qualify as biomass-based diesel and advanced biofuel;
- naphtha and liquefied petroleum gas (LPG) from camelina oil qualify as advanced biofuel;
- biofuels from energy cane, giant reed, and napiergrass qualify as cellulosic biofuel;
- renewable gasoline (and blendstock) produced from crop residue, slash, pre-commercial thinnings, tree residue, annual cover crops, and cellulosic components of separated yard waste, separated food waste, and separated

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[16] For more information on EPA's determination of lifecycle GHG emissions see CRS Report R40460, *Calculation of Lifecycle Greenhouse Gas Emissions for the Renewable Fuel Standard (RFS)*.

[17] See "Section V. Lifecycle Analysis of Greenhouse Gas Emissions," Preamble, EPA RFS2 Final Rule, February 3, 2010, at http://epa.gov/otaq/renewablefuels/rfs2-preamble.pdf.

[18] EPA, "Supplemental Determination for Renewable Fuels Produced Under the Final RFS2 Program From Canola Oil; Final Rule," 75 *Federal Register* 59622-59634, September 28, 2010.

[19] EPA, "EPA Issues Direct Final Rule for Additional Qualifying Renewable Fuel Pathways Under the RFS2 Program," EPA-420-F-11-043, November 2011.

municipal solid waste using certain processes (see footnote 19) qualify as cellulosic biofuel; and

- biodiesel produced using esterification (a new process method) from soybean oil, oil from annual cover crops, algal oil, biogenic waste oils/fats/greases, non-food grade corn oil, Canola/rapeseed oil, and camelina oil qualify as biomass-based diesel and advanced biofuel.

For other biofuel pathways not yet modeled, EPA encourages parties to use a petition process to request EPA to examine additional pathways.

Grandfathered Plants

Fuel from the capacity of facilities that either existed or commenced construction prior to December 19, 2007 (the date of enactment of EISA), are exempt from the 20% lifecycle GHG threshold requirement. The exemption is extended to ethanol facilities that commenced construction on or before December 31, 2009, provided that those facilities use natural gas, biofuels, or a combination thereof as processing fuel. Any new expansion of production capacity at existing facilities must be designed to achieve the 20% GHG reduction threshold if the facility wants to generate RINs for that volume.

Feedstock Requirements

EISA changed the definition of renewable fuel to require that it be made from feedstocks that qualify as "renewable biomass."[20] As such, EISA limits not only the types of feedstocks that can be used to make renewable fuel, but also the land that these renewable fuel feedstocks may come from. Specifically excluded under the EISA definition are virgin agricultural land cleared or cultivated after December 19, 2007, as well as tree crops, tree residues, and other biomass materials obtained from federal lands. These restrictions are applicable to both domestic and foreign feedstock and biofuels producers.

Existing agricultural land includes three land categories—cropland, pastureland, and Conservation Reserve Program (CRP) land. Rangeland is excluded. Fallow land is defined as idled cropland and is therefore included within the definition of agricultural land.

EPA determined that fuels produced from five categories of feedstocks (primarily targeted for cellulosic biofuels) were expected to have less or no indirect land use change and thereby qualify as renewable biomass:

- crop residues such as corn stover, wheat straw, rice straw, citrus residue;
- forest material including eligible forest thinnings and solid residue remaining from forest product production;
- secondary annual crops planted on existing cropland, such as winter cover crops;
- separated food and yard waste, including biogenic waste from food processing; and
- perennial grasses, including switchgrass and miscanthus.

[20] CRS Report R40529, *Biomass: Comparison of Definitions in Legislation Through the 111th Congress*.

Implementation of the RFS

The EPA is responsible for revising and implementing regulations to ensure that the national transportation fuel supply sold in the United States during a given year contains the mandated volume of renewable fuel in accordance with the four nested volume mandates of the RFS2.[21] To accomplish this task, EPA first calculates annual blending standards for the four biofuel categories of RFS2. The blending standards apply to refiners, blenders, and importers of gasoline and diesel fuels and are used to determine each individual company's renewable volume obligation (RVO). To facilitate meeting the blending requirements, while taking into consideration regional differences in biofuels production and availability, EPA established a system of tradable RINs. Blending standards, RVOs, and RINs are described in this section.

Determining Annual Blending Standards

In order to ensure that the requisite volumes of biofuels are used each year, EPA first estimates the total volume of transportation fuel that is expected to be used in the United States during the upcoming year. EPA relies on projections from the Department of Energy's Energy Information Agency (EIA) for this estimate.[22] The blending percentage obligation (or standard) is computed as the total amount of renewable fuels mandated to be used in a given year expressed as a percentage of expected total U.S. transportation fuel use (**Table 3**). This ratio is adjusted to account for the small refinery exemptions. A separate ratio is calculated for each of the four biofuel categories.

The biofuels standards for each upcoming year are announced on a preliminary basis in the spring of the preceding year, when EPA issues a notice of proposed rulemaking, and on a final basis by November 30 of the preceding year, when EPA issues a final rule.

Table 3. RFS Standards for 2012

RFS Category	Blending Ratio (%)	Volume of Renewable Fuel (billion gallons)
Cellulosic biofuels	0.006	0.00865
Biomass-based diesel	0.91	1.0
Advanced biofuels	1.21	2.0
Total renewable fuel	9.23	15.2

Source: "EPA Finalizes 2012 Renewable Fuel Standards," EPA-420-F-11-044, Office of Transportation and Air Quality, EPA, December 2011.

Waivers to Annual Blending Standards

EISA requires that EPA evaluate and make an appropriate market determination for setting the cellulosic standard each year. As part of this process, EPA announced that it will issue a notice of

[21] For more information, see the EPA website for "Renewable Fuel Standard Program," at http://www.epa.gov/otaq/renewablefuels/index.htm#regulations.

[22] The data are taken from EIA's October issue of its monthly Short-Term Energy Outlook Report, "Table 4a. U.S. Crude Oil and Liquid Fuels Supply, Consumption, and Inventories," and "Table 8. U.S. Renewable Energy Supply and Consumption," available at http://www.eia.doe.gov/emeu/steo/pub/contents.html.

proposed rulemaking each spring and a final rule by November 30 of each year to set the renewable fuel standard for each ensuing year. Pursuant to this task, the EPA Administrator has the authority to waive the RFS requirements, in whole or in part, if, in her determination, there is inadequate domestic supply to meet the mandate, or if "implementation of the requirement would severely harm the economy or environment of a State, a region, or the United States."[23] Further, under certain conditions, the EPA administrator may waive (in whole or in part) the specific carve-outs for cellulosic biofuel and biomass-based diesel fuel.

For example, in February 2010 EPA waived most of the 2010 cellulosic biofuel carve-out—EISA had set the mandate at 100 million gallons but EPA lowered the requirement to 6.5 million gallons, more than 90% less than scheduled by EISA.[24] In November 2010, EPA lowered the 2011 RFS for cellulosic biofuels to 6.6 million gallons.[25] In December 2011, EPA lowered the 2012 RFS for cellulosic biofuels to 8.65 million gallons.[26] EPA cited a lack of current and expected production capacity, driven largely by a lack of investment in commercial-scale refineries. The 2010, 2011, and 2012 downward revisions suggests that the actual cellulosic biofuels standard, although explicitly listed in **Table 1**, is uncertain.

In addition to waivers associated with the annual RFS review process, EPA may respond to waiver requests resulting from unusual circumstances. For example, in 2008 the governor of Texas requested a waiver of the RFS because of high grain prices; however, that waiver request was denied because EPA determined that the RFS requirements alone did not "severely harm the economy ... of a State, a region, or the United States," a standard required by the statute.

Determining an Individual Company's Obligation

Companies that blend gasoline or diesel transportation fuel for the retail market are obligated to include a quantity of biofuels equal to a percentage of their total annual fuel sales—referred to as a renewable volume obligation (RVO). The RVO is obtained by applying the EPA-announced standards for each of the four biofuel categories to the firm's annual fuel sales to compute the mandated biofuels volume. At the end of the year, each blender must have enough RINs to show that it has met its share of each of the four mandated standards.

Equivalence Values

The equivalence value (EV) of a renewable fuel represents the number of gallons that can be claimed for compliance purposes for every physical gallon of renewable fuel. Under RFS1, the EV was based on the energy content of each renewable fuel relative to ethanol. As a result, the EV for ethanol was 1.0; butanol was 1.3; biodiesel (mono-alkyl ester) was 1.5, and non-ester renewable diesel was 1.7. Cellulosic ethanol was granted a 2.5-to-1 credit.

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[23] For more information, see CRS Report RS22870, *Waiver Authority Under the Renewable Fuel Standard (RFS)*.

[24] The 2010 RFS was revised as part of a final rulemaking implementing the RFS as expanded by EISA, available at http://www.epa.gov/otaq/renewablefuels/420f10007.pdf.

[25] EPA finalized the 2011 requirements in November 2010. EPA, "Regulation of Fuels and Fuel Additives: 2011 Renewable Fuel Standards; Final Rule," 75 *Federal Register* 76790-76830, Dec. 9, 2010.

[26] EPA finalized the 2012 requirements in December 2011. EPA, "Regulation of Fuels and Fuel Additives: 2012 Renewable Fuel Standards; Final Rule," 77 *Federal Register* 1320-1358, Jan. 9, 2012.

Under RFS2, each biofuel category has its own volume requirements. As a result, there is no longer any need to incentivize different biofuels based on their energy content. Thus, under RFS2 each RIN represents one gallon of renewable fuel in the context of demonstrating compliance with the renewable volume obligation. The exception occurs when a renewable biofuel with a higher energy content than ethanol is used in excess of its RFS standard—in such situations an equivalence value reflecting the higher energy content should be used. For example, for purposes of meeting the biomass-based biodiesel standard, each gallon of biodiesel will count as 1.0; however, for purposes of meeting the advanced biofuel standard or the total renewable biofuel standard, each gallon of biodiesel will count as 1.5 in order to reflect its higher energy content.

Renewable Identification Numbers (RINs)

A RIN is a unique 38-character number that is issued (in accordance with EPA guidelines) by the biofuel producer or importer at the point of biofuel production or the port of importation.[27] Each qualifying gallon of renewable fuel has its own unique RIN. RINs are generally assigned by batches of renewable fuel production as follows:

RIN = KYYYYCCCCFFFFFBBBBBRRDSSSSSSSSEEEEEEEE

Where

K	= code distinguishing RINs still assigned to a gallon from RINs already detached
YYYY	= the calendar year of production or import
CCCC	= the company ID
FFFFF	= the company plant or facility ID
BBBBB	= the batch number
RR	= the biofuel equivalence value (described below)
D	= the renewable fuel category
SSSSSSSS	= the start number for this batch of biofuel
EEEEEEEE	= the end number for this batch of biofuel

Under the RFS2 RIN formulation, Code D has been redefined to identify which of the four RFS categories—total, advanced, cellulosic, or biodiesel—the biofuel satisfies. Together, SSSSSSSS and EEEEEEEE identify the RIN block which demarcates the number of gallons of renewable fuel that the batch represents in the context of compliance with the RFS—that is, RIN gallons.

[27] The more discussion on RINs see Robert Wisner, "Renewable Identification Numbers (RINs) and Government Biofuels Blending Mandates," *AgMRC Renewable Energy Newsletter*, Agricultural Marketing Research Center, Iowa State University, April 2009, available at http://www.agmrc.org/renewable_energy/agmrc_renewable_energy_newsletter.cfm; or Wyatt Thompson, Seth Meyer, and Pat Westhoff, "Renewable Identification Numbers are the Tracking Instrument and Bellwether of U.S. Biofuel Mandates," *EuroChoices* 8(3), 2009, pp. 43-50.

The RIN-gallon total equals the product of the liquid volume of renewable fuel times its equivalence value. For example, since biodiesel has an equivalence value of 1.5 when being used as an advanced biofuel, 1,000 gallons of biodiesel would equal 1,500 RIN gallons of advanced biofuels. If the RIN block start for that batch was 1 (i.e., SSSSSSSS = 00000001), then the end value (EEEEEEEE) would be 00001500, and the RR code would be RR = 15).

Any party that owns RINs at any point during the year (including domestic and foreign producers, refiners, exporters, and importers of renewable fuels) must register with the EPA and follow RIN record-keeping and reporting guidelines. RINs can only be generated if it can be established that the feedstock from which the fuel was made meets EISA's definitions of renewable biomass, including land restrictions. The feedstock affirmation and record-keeping requirements apply to RINs generated by both domestic renewable fuel producers and RIN-generating foreign renewable fuel producers or importers. After a RIN is created by a biofuel producer or importer, it must be reported to the EPA (usually on a quarterly basis). When biofuels change ownership (e.g., are sold by a producer to a blender), the RINs are also transferred. When a renewable fuel is blended for retail sale or at the port of embarkation for export, the RIN is separated from the fuel and maybe used for compliance or trade. The Code K status of the RIN is changed at separation. The RFS mandates (by biofuel category) are ultimately enforced on retail fuel blenders and exporters (not on biofuels producers or importers).

Small Refinery Exemption

Any parties who produce or import less than 10,000 gallons of renewable fuel in a year are not required to generate RINs for that volume, and are not required to register with the EPA if they do not take ownership of RINs generated by other parties. Under EISA, this exemption is temporarily extended (for up to three years) to renewable fuel producers who produce less than 125,000 gallons per year from new production facilities. This exemption is intended to allow pilot and demonstration plants to focus on developing the technology and obtaining financing during their early stages rather than complying with RFS2 regulations.

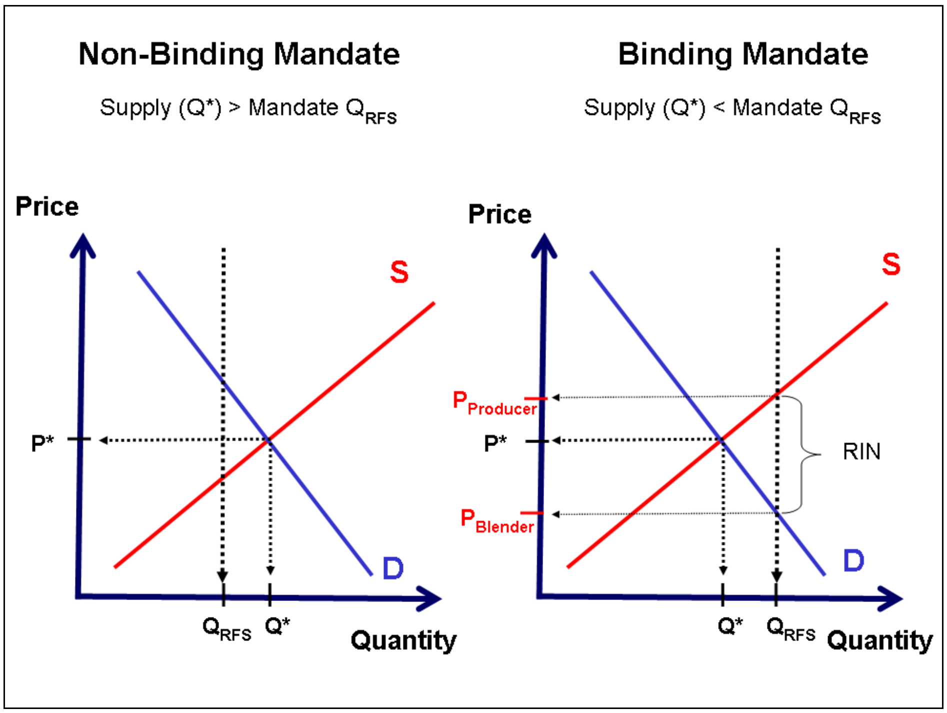
Flexibility in Administering the RIN Requirements

RINs generated during the current year may be used to satisfy either the current year's or the following year's RVO. A RIN would not be viable for any year's RVO beyond the immediately successive year; thus giving it essentially up to a two-year lifespan. For any individual company, up to 20% of the current year's RVO may be met by RINs from the previous calendar year.

In addition to compliance demonstration, RINs can be used for credit trading. When a blender has blended a quantity of biofuel, the RINs are detached from the biofuels. If a blender has already met its mandated share and has blended surplus biofuels for a particular biofuel category, it can sell the extra RINs to another blender (who has failed to meet its blending mandate for that same biofuel standard) or it can hold onto the RINs for future use (either to satisfy the succeeding year's blending requirement or for sale in the succeeding year). Since biofuels supply and demand can vary over time and across regions, a market has developed for RINs.

The marketability of RINs allows blenders who have not bought enough biofuels to fulfill their RFS requirement for each of the four RFS categories by purchasing the biofuels-specific RINs instead. As a result, RINs have value as a replacement for the actual purchase of biofuels. Because four separate biofuel mandates must be met, the RIN value may vary across the individual biofuel categories.[28] Since the RFS biofuels categories are nested, the price of RINs for specific sub-mandates (e.g., cellulosic biofuels or biodiesel) must be equal to or greater than the price of RINs for advanced biofuels which, in turn is equal to or greater than the RIN value for total renewable biofuels. Thus, RIN values may vary across RFS categories as well as geographically with variations in specific biofuels supply and demand conditions. Differences in RIN values also reflect the degree to which the mandate associated with a specific RIN biofuel category is binding on the market equilibrium.[29] For example, if the supply of a specific biofuel—including both domestically produced as well as imported—available to the market exceeds the RFS mandate (see left-hand side of **Figure 2**), then the RIN's "core" value (i.e., its price minus transaction costs and speculative component) would be zero at the mandated level (Q_{RFS}).

Figure 2. How a Mandate May or May Not Affect RIN Values



Source: "Renewable Identification Numbers are the Tracking Instrument and Bellwether of U.S. Biofuel Mandates," by Wyatt Thompson, Seth Meyer, and Pat Westhoff, *EuroChoices* 8(3), 2009.

Note: Supply equals domestic production and imports; demand equals both blenders and exporters demand.

In contrast, if the mandated biofuel usage level exceeds what is offered by the market (see right-hand side of **Figure 2**), the biofuels mandate is binding because it forces biofuels producers to

[28] This was the case in late 2010. The biodiesel production tax credit of $1.00 per gallon had expired at the end of 2009 and subsequent biodiesel production dropped in 2010, potentially below that needed to meet the combined 2009/2010 mandate. As a result, biomass-based diesel RINs were trading at dramatically higher levels than one year previously. By the second week in December 2010, biomass-based diesel RINs were trading at $0.85 to $0.90 as compared to $0.01 to $0.02 the same week in 2009. However, with the enactment of an extension of the tax credit, biomass-based diesel RIN prices dropped by more than 30% in one week. "RIN Quotes," *The Ethanol Monitor*, vol. 6, no. 48 (December 20, 2010), p. 12.

[29] This discussion is based on "Renewable Identification Numbers are the Tracking Instrument and Bellwether of U.S. Biofuel Mandates," by Wyatt Thompson, Seth Meyer, and Pat Westhoff, *EuroChoices* 8(3), 2009.

supply a greater quantity and blenders to use more biofuels than either would without the mandate. The price of the biofuel has to rise to $P_{producer}$ to solicit the extra production from the biofuels producers, while the biofuels price must fall to $P_{blender}$ to encourage greater blender purchases. The RIN's core value would be equal to the gap between these two prices, $P_{producer}$ minus $P_{blender}$. However, the blender must pay the full price of $P_{producer}$, which includes both $P_{blender}$ plus the RIN's core value, to acquire the mandated Q_{RFS}.

A RIN may have speculative value, even when in surplus, if an investor were to anticipate a shortage in the near future (i.e., within the period for which a RIN is valid) and seek to acquire RINs cheaply in advance of the shortage. To date, the biofuels mandates have not been binding and until recently RIN values generally have been small. It is expected that, once the RFS becomes binding, blenders will pass the added cost of biofuels acquisition (i.e., the RIN value), on to motor fuel consumers in the form of higher fuel prices.[30]

EPA Analysis of RFS Impacts

As part of its final rule determination, EPA included an analysis of the market and environmental impact of the increased use of renewable fuels under the RFS2 standards.[31] The analytical results are by and large positive and include the following.

- **Reduced dependence on foreign sources of crude oil.** By 2022, the mandated 36 bgals of renewable fuel will displace about 13.6 bgals of petroleum-based gasoline and diesel fuel, representing about 7% of expected annual U.S. transportation fuel consumption.
- **Reduced price of domestic transportation fuels.** By 2022, the increased use of renewable fuels is expected to decrease gasoline costs by $0.024 per gallon and diesel costs by $0.121 per gallon, producing a combined annual savings of nearly $12 billion.
- **Reduced GHG emissions.** When fully implemented in 2022, the expanded use of biofuels under the RFS is expected to reduce annual GHG emissions by 138 million metric tons—equivalent to taking about 27 million vehicles off the road.
- **Increased U.S. farm income.** By 2022, the expanded market for agricultural products such as corn and soybeans resulting from biofuels production is expected to increase annual net farm income by $13 billion.
- **Decreased corn and soybean exports.** The expanded use of corn starch and soybean oil for biofuels is expected to reduce corn exports by 8% and soybean exports by 14% by 2022.
- **Increased cost of food in the United States.** The increased demand for U.S. agricultural products is expected to raise the overall commodity price structure, leading to an annual increase in the cost of food per capita of about $10 by 2022, or over $3 billion.

[30] Ibid., p. 46.

[31] EPA, "Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis," Assessment and Standards Division, Office of Transportation and Air Quality, EPA-420-R-10-006, February 2010.

- **Increased emissions of certain air contaminants, but decreased emissions of others.** Contaminants expected to increase include hydrocarbons, nitrogen oxides (NOx), acetaldehyde, and ethanol; those expected to decrease include carbon monoxide (CO) and benzene. The effects are expected to vary widely across regions, but in the net, increases in population-weighted annual average ambient PM and ozone concentrations are anticipated to lead to up to 245 cases of adult premature mortality.

RFS as Public Policy

Proponents' Viewpoint

Supporters of an RFS claim it serves several public policy interests in that it:

- reduces the risk of investing in renewable biofuels by guaranteeing biofuels demand for a projected period (such risk would otherwise keep significant investment capital on the sidelines);
- enhances U.S. energy security via the production of liquid fuel from a renewable domestic source resulting in decreased reliance on imported fossil fuels (the U.S. currently imports over half of its petroleum, two-thirds of which is consumed by the transportation sector);
- provides an additional source of demand—renewable biofuels—for U.S. agricultural output that has significant agricultural and rural economic benefits via increased farm and rural incomes and substantial rural employment opportunities;[32]
- underwrites the environmental benefits of renewable biofuels over fossil fuels (most biofuels are non-toxic, biodegradable, and produced from renewable feedstocks), and
- responds to climate change concerns because agricultural-based biofuels emit substantially lower volumes of direct greenhouse gases (GHGs) than fossil fuels when produced, harvested, and processed under the right circumstances.

Critics' Viewpoints

Critics of an RFS, particularly of the EISA expansion of the original RFS, have taken issue with many specific aspects of biofuels production and use, including the following:

- By picking the "winner," policymakers may exclude or retard the development of other, potentially preferable alternative energy sources.[33] Critics contend that biofuels are given an advantage via billions of dollars of annual subsidies that distort investment markets by redirecting venture capital and other investment

[32] For example, see John M. Urbanchuk (Director, LECG LLC), *Contribution of the Ethanol Industry to the Economy of the United States*, white paper prepared for National Corn Growers Assoc., February 21, 2006.

[33] For example, see Bruce A. Babcock, "High Crop Prices, Ethanol Mandates, and the Public Good: Do They Coexist?" *Iowa Ag Review*, Vol. 13, No. 2, Spring 2007; and Robert Hahn and Caroline Cecot, "The Benefits and Costs of Ethanol," Working Paper 07-17, AEI-Brookings Joint Center for Regulatory Studies, November 2007.

dollars away from competing alternative energy sources. Instead, these critics have argued for a more "technology-neutral" policy such as a carbon tax, a cap-and-trade system of carbon credits, or a floor price on imported petroleum.

- Continued large federal incentives for ethanol production are no longer necessary since the sector is no longer in its "economic infancy" and would have been profitable during much of 2006 and 2007 without federal subsidies.[34]
- The expanded mandate could have substantial unintended consequences in other areas of policy importance, including energy/petroleum security, pollutant and greenhouse gas emissions, agricultural commodity and food markets, land use patterns, soil and water quality, conservation, the ability of the gasoline-marketing infrastructure and auto fleet to accommodate higher ethanol concentrations in gasoline, the likelihood of modifications in engine design, and other considerations.
- Taxpayers are being asked to finance ever-increasing biofuels subsidies that have the potential to affect future federal budgetary choices.

The Increasing Cost of Biofuels Policy

A 2007 survey of federal and state government subsidies in support of ethanol production reported that total annual federal support fell somewhere in the range of $5.4 to $6.6 billion per year—nearly $1 per gallon.[35] In 2011, federal subsidies alone were estimated at over $7.8 billion, including nearly $7.5 billion in tax credits.[36] Historically, the major direct federal costs associated with the implementation of the RFS have been the federal tax credits available to the various biofuels that are blended to meet the RFS mandate.[37] However, most of these tax credits expired at the end of 2011 and have not been renewed. The principal remaining tax credit is the $1.01 per gallon credit for cellulosic biofuels.

Potential Issues with the Expanded RFS

Most U.S. biofuels production is ethanol produced from corn starch. As a result, as the U.S. ethanol industry has grown over the years, so too has its usage share of the annual corn crop. In 2001, national ethanol production was using about 7% of the U.S. corn crop; by 2011 it was using about 40%.[38] Under the expanded RFS, the 2015 corn ethanol cap of 15 billion gallons could place a call on over 40% of the volume of U.S. corn production depending on yield and area developments.[39] Such a shift towards greater corn use for biofuels has meant higher prices for other corn users, including both the livestock and export sectors (**Figure 3**).

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[34] Chris Hurt, Wally Tyner, and Otto Doering, Department of Agricultural Economics, Purdue University, *Economics of Ethanol*, December 2006, West Lafayette, IN.

[35] Ronald Steenblik, *Biofuels—At What Cost? Government Support for Ethanol and Biodiesel in the United States*, Global Subsidies Initiative of the International Institute for Sustainable Development, Geneva, Switzerland, September 2007, p. 37; available at http://www.globalsubsidies.org.

[36] CRS projection based on available data.

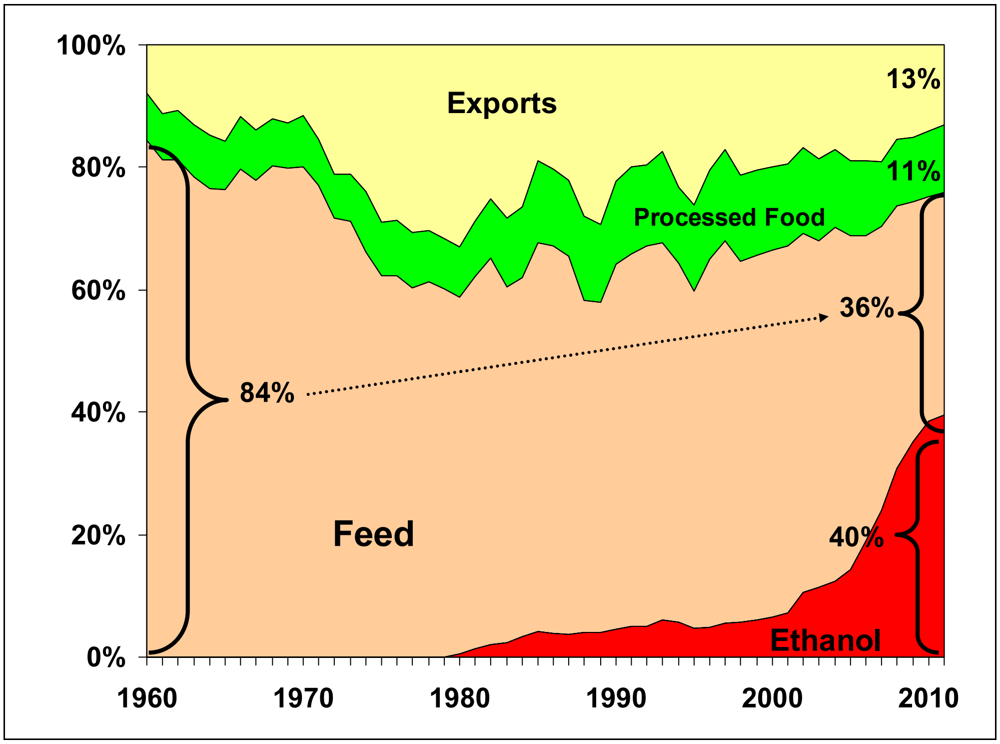
[37] See CRS Report R40110, *Biofuels Incentives: A Summary of Federal Programs*.

[38] See CRS Report R41282, *Agriculture-Based Biofuels: Overview and Emerging Issues*.

[39] CRS projection based on the *FAPRI March 2010 Baseline Briefing Book*, FAPRI-MU Report #01-10, March 2010.

Figure 3. Ethanol Uses an Increasing Share of U.S. Corn Production, Particularly Since 2005, While Feed Use Has Fallen Sharply

(annual U.S. corn disappearance, as a percent of total use, excluding ending stocks)



Source: USDA, PSD database January 12, 2012.

Note: Does not account for use of ethanol by-products as animal feed; about 30% (by weight) of corn used for biofuels is left over from the production process and is useful as a relatively high-protein animal feed.

An RFS-driven expansion in biofuels feedstocks (especially corn for grain and stover) is likely to heighten competition for available cropland between biofuels feedstocks and other field crops, as well as to engender an intensification of agricultural activity on U.S. cropland to meet growing demand for food, feed, and fuel resources. This could have consequences for several important agricultural markets, including

- grains—because corn would compete with other grains for land;
- livestock—because animal feed costs will likely increase with the price of corn;
- agricultural inputs—because corn is more input-intensive (in terms of fertilizers and pesticides) than other major field crops; and
- land—because the value of cropland, as well as total harvested acreage, would both likely increase.

In addition to agricultural effects, an increase in corn-based ethanol production would likely have other market effects, including effects on:

- energy markets—because natural gas is a key input in both corn and ethanol production (and should production of biofuels exceed the mandate, then they will compete with traditional petroleum fuels for transportation fuel demand);

- water quality—because expanding corn-based ethanol production likely involves heavier use of farm chemicals with increased potential for run-off or leaching;
- water resource availability—because water plays a crucial role in all stages of biofuels production, from cultivation of feedstocks through their conversion into biofuels, yet there remain many uncertainties about national and regional effects of increased biofuels production on water resources;[40]
- soil fertility—because several potential biofuels activities (including intensive year-over-year corn production, diversion of corn stover to cellulosic biofuels production and away from field retention as a soil amendment under low-till cultivation, and the expansion of biofuels feedstock cultivation on marginal land) could result in diminished soil fertility and/or increased erosion;
- wildlife habitat—because expanding biofuels feedstock production on marginal lands traditionally left fallow under a conserving practice could compete with wildlife and fowl habitat; and
- federal budget exposure—because applying the federal cellulosic biofuels production tax credit of $1.01 per gallon to the RFS requirements produces an annual budget liability of $16 billion by 2022 (assuming that the tax credit is extended and that the cellulosic mandate is met).

Overview of Long-Run Corn Ethanol Supply Issues

The ability of the U.S. corn industry to continue to expand production and satisfy the steady growth in demand depends, first and foremost, on continued productivity gains. U.S. corn yields have shown strong, steady growth since the late 1940s, with some acceleration occurring since the mid-1990s as bio-engineered advances in seed technology have heightened drought and pest resistance in corn plants (**Figure 4**).

Corn Prices

Expanding U.S. corn production has only partially offset the rapid growth in demand following the rapid expansion of the U.S. ethanol industry that has occurred since 2005. As a result, corn prices have trended steadily upward in direct relation to the added growth in demand from the ethanol sector (**Figure 5**). Both USDA and the Food and Agricultural Policy Research Institute (FAPRI) project corn prices to remain in the $4 to $5 per bushel range through 2020, compared with an average farm price of $2.15 per bushel during the 10-year period from 1997 to 2006.[41]

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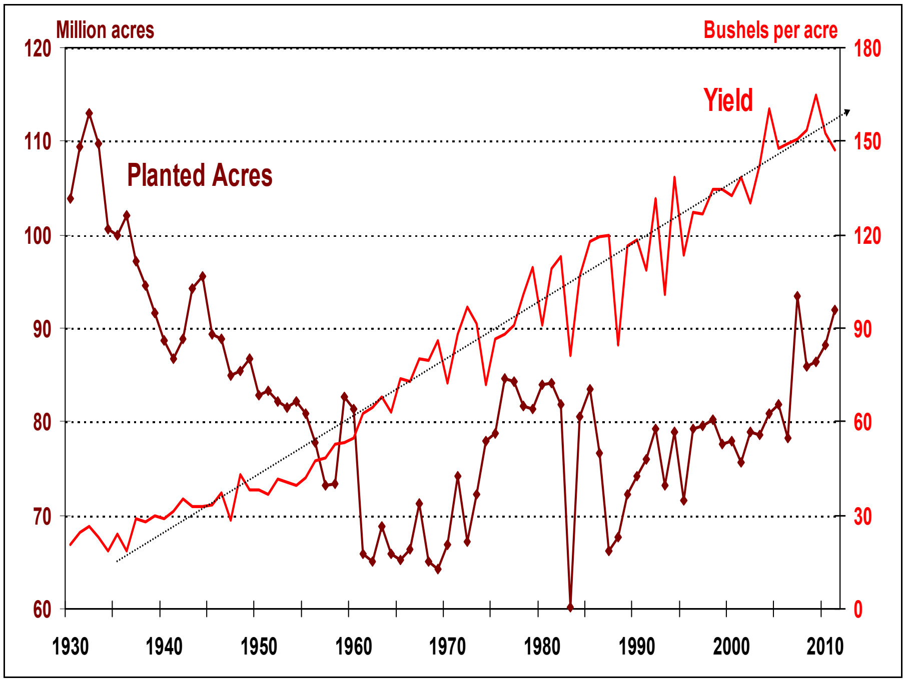
[40] "Many Uncertainties Remain about National and Regional Effects of Increased Biofuel Production on Water Resources," GAO-10-116, U.S. Government Accountability Office, November 2009.

[41] *USDA Agricultural Projections to 2020*, Long-Term Projections Report, OCE-2011-1, Office of the Chief Economist, February 2011; and *FAPRI March 2011 Baseline Briefing Book* , FAPRI-MU Report #02-11, March 2011.

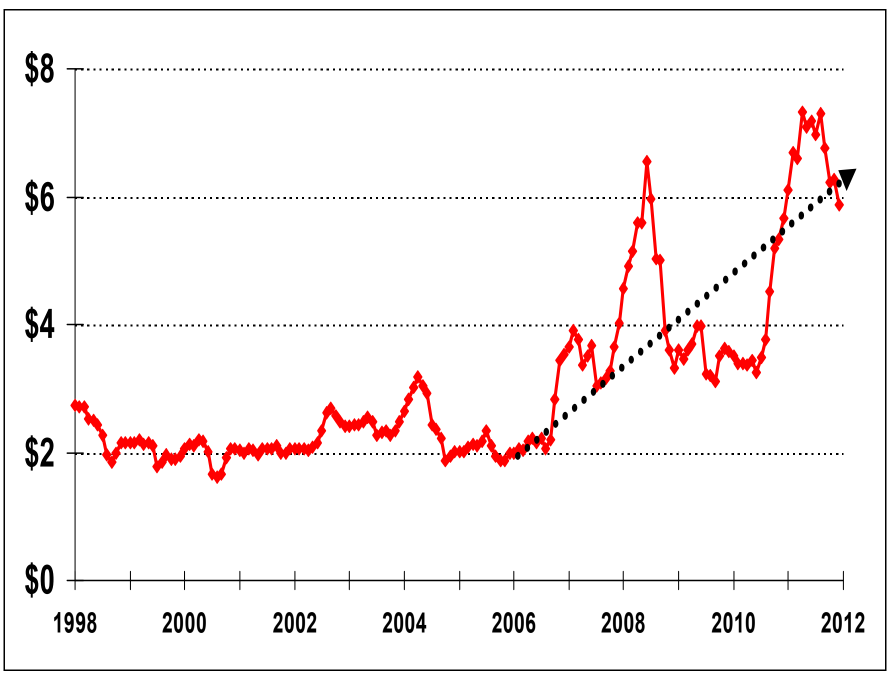
Figure 4. U.S. Annual Corn Planted Acres and Yield



Source: USDA, PSD database, as of January 12, 2012.

Figure 5. Monthly U.S. Corn Prices Have Trended Upward Since Late 2005

(Central Illinois cash price for no. 2, yellow corn)



Source: USDA, ERS, Feed Grains Database, at http://www.ers.usda.gov/Data/feedgrains/; as of January 23, 2012.

Corn Yields

It is likely that upward-trending farm prices (**Figure 5**) will encourage continued research investments to move corn yields steadily higher in the future. However, even slight differences in the long-run growth rate portend large impacts in the price outlook. Some economists think that yield increases will slow in coming decades because of land degradation and the impact of climate change. Others suggest that dramatic developments in bio-engineering and seed technology will push corn yields sharply higher. A prime example of the differences in U.S. corn yield outlooks is the contrast between USDA, whose economists project U.S. corn yields to reach about 240 bushels per acre by 2050, and the scientists of the biotech seed company Monsanto, who predict that corn yields will be much higher—as much as 300 bushels per acre—by 2030.[42] According to USDA, achieving "300-bushel corn" by 2030 would require an extraordinary deviation (a tripling) from both projected and accelerated corn yield trends, and would be historically unprecedented.[43]

Corn Area

U.S. cropland planted to corn has increased in recent years from the 1983 low of 60.3 million acres to as high as 93.5 million acres in 2007. Prospects for further expansion in crop area are far less certain, as corn is an energy-intensive crop that prefers deep, fertile soils and timely precipitation. Within the prime corn-growing regions of the Corn Belt, per-acre returns for corn easily dwarf other field crops that vie for the same acreage. Recent seed developments have allowed corn production to expand dramatically into the central and northern Plains states. However, the risk of investing up front in high operating costs to be offset at harvest by strong returns increases as production moves into less traditional regions, such as the northern Plains, the Delta, and the Southeast.

Corn-Soybean Rotation

The most likely source of new corn acreage will come from shifts in crop rotation from soybeans to corn.[44] However, crop intensification also has its limits. Corn (of the grass family) is traditionally planted in an annual rotation with soybeans (a broad-leaf legume) that offers important agronomic benefits including pest and disease control, as well as enhanced soil fertility.[45] When farmers shift away from this rotation, corn yields tend to suffer. Planting corn-on-corn in two consecutive years usually results in a 10% to 20% yield decline in the second year. As a result, the corn-to-soybean price ratio would have to tilt fairly strongly in favor of corn for corn-on-corn production to be profitable. Given the limitations on corn area expansion and rotational intensification, it is likely that the sustainable long-run corn planted area is probably in the range of 90 to 95 million acres. If this is the case, then it would mean that future growth in U.S. corn production will be increasingly dependent on yield growth.

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[42] Philip Brasher, "2050 Corn Harvest Will Affect Food, Fuel Policies," *Des Moines Register*, November 15, 2009.

[43] Paul W. Heisey, "Science, Technology, and Prospects for Growth in U.S. Corn Yields," *Amber Waves*, vol. 7, no. 4, Economic Research Service, USDA, December 2009.

[44] Chad E. Hart, "Feeding the Ethanol Boom: Where Will the Corn Come From?" *Iowa Ag Review*, vol. 12, no. 4 (Fall 2006), pp. 4-5.

[45] Bruce A. Babcock and David A. Hennessy, "Getting More Corn Acres from the Corn Belt," *Iowa Ag Review*, vol. 12, no. 4 (Fall 2006), pp. 6-7.

Overview of Non-Corn-Starch-Ethanol RFS Issues

EISA defines "advanced biofuels" very broadly as biofuels other than corn-starch ethanol. As such, advanced biofuels would include imported Brazilian sugar-cane ethanol, as well as home-grown biodiesel. However, the principal focus of advanced biofuels is on biofuels based on cellulosic biomass. Under the RFS2, advanced biofuels use is mandated to reach a minimum of 21 billion gallons by 2022, of which at least 16 billion gallons must be some type of cellulosic biofuel. However, many obstacles must first be overcome before commercially competitive cellulosic biofuels production occurs.[46]

In the near term, it is likely that corn stover[47] will be the primary biomass of choice for cellulosic biofuels production. This is because many ethanol plants already exist in corn production zones and an extension of those plants to include cellulosic biofuels production from stover would offer some scale economies. However, stover-to-biofuel conversion has its own set of potential environmental trade-offs, paramount of which is the dilemma of sacrificing soil fertility gains by harvesting the stover rather than returning it to the soil under no- or minimum-tillage practices.

Cellulosic Biofuels Production Uncertainties

There are substantial uncertainties regarding both the costs of producing cellulosic feedstocks and the costs of producing biofuels from those feedstocks. Dedicated perennial crops are often slow to establish, and it can take several years before a marketable crop is produced. Crops heavy in cellulose tend to be bulky and represent significant problems in terms of harvesting, transporting, and storing. New harvesting machinery would need to be developed to guarantee an economic supply of cellulosic feedstocks.[48] Seasonality issues involving the operation of a biofuels plant year-round based on a four- or five-month harvest period of biomass suggest that storage is likely to matter a great deal. In addition, most marginal lands (i.e., the low-cost biomass production zones) are located far from major urban markets, making it difficult to reconcile plant location with the cost of fuel distribution.

Under current technologies, the cost of the conversion process for cellulosic biofuel (including physical, chemical, enzymatic, and microbial treatment and conversion of the biomass feedstocks into motor fuel) remains significantly higher than for corn ethanol or other alternative fuels. Many scientists still suggest that commercialization of cellulosic ethanol is several years down the road.[49]

These uncertainties, plus the financial crisis of 2008 and the ensuing recession and credit crunch, have severely curtailed new investment in the biofuels sector.[50] Some initial investments have

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[46] For more information, see CRS Report R41460, *Cellulosic Ethanol: Feedstocks, Conversion Technologies, Economics, and Policy Options*, by Randy Schnepf, and CRS Report RL34738, *Cellulosic Biofuels: Analysis of Policy Issues for Congress*, by Kelsi Bracmort et al.

[47] Stover is the above-soil part of the corn plant excluding the kernels.

[48] To economically supply field residues to biofuels producers, farm equipment manufacturers likely would need to develop one-pass harvesters that could collect and separate crops and crop residues at the same time.

[49] For example, the Department of Energy's goal is to make cellulosic biofuels cost-competitive with corn ethanol by 2012. Other groups are less optimistic.

[50] Robert Wisner, "Cellulosic Ethanol: Will the Mandates be Met?" *AgMRC Renewable Energy Newsletter*, Agricultural Marketing Research Center, Iowa State University, September 2009.

been made in small-scale (generally less than 5 million gallons per year) cellulosic ethanol plants, but as of early 2012 no commercial-scale cellulosic biofuel plant was yet online in the United States. An unofficial CRS estimate of operational U.S. cellulosic plant capacity falls far short of the RFS mandate.[51] As a result, the EPA has been compelled to sharply lower the cellulosic mandate for each of the first three years—2010, 2011, and 2012.[52]

Unintended Policy Outcomes of the "Advanced Biofuels" Mandate

Because the advanced biofuels mandate in the RFS is a fixed mandate, irrespective of prices, the above uncertainties about the production of cellulosic ethanol could have significant implications for fuel supply and fuel prices. If cellulosic ethanol production is unable to advance rapidly enough to meet the RFS mandate for non-corn-starch ethanol, then other unexpected biofuels sources may be forced to step in and fill the void:

- production of domestic sorghum-starch ethanol may expand across the prairie states and in other regions less suitable for corn production;
- costly domestic sugar-beet ethanol or biodiesel production may be undertaken to fill the mandate; or
- imports of Brazilian sugar-cane ethanol could expand.

Energy Supply Issues

Biofuels are not primary energy sources. Energy is first stored in biological material (through photosynthesis), and then must be converted into a more useful, portable fuel. This conversion requires energy. The amount and types of energy used to produce biofuels (e.g., coal versus natural gas), and the feedstocks for biofuels production (e.g., corn versus cellulosic biomass), are critical in determining a biofuels net energy balance and the environmental benefits of a biofuel.

Energy Balance

To analyze the net energy consumption of ethanol, the entire fuel cycle must be considered. The fuel cycle consists of all inputs and processes involved in the development, delivery and final use of the fuel. For corn-based ethanol, these inputs include the energy needed to produce fertilizers, operate farm equipment, transport corn, convert corn to ethanol, and distribute the final product.

USDA estimated an energy output/input ratio of 2.3 based on a 2005 survey of corn growers and 2008 data for ethanol plants (and assuming the then-most-advanced technology for corn and ethanol production)—in other words, the energy contained in a gallon of corn ethanol was 130% higher than the amount of energy needed to produce and distribute it.[53] Ethanol industry sources argue that technological innovation will continue to improve corn ethanol's energy balance. However, other analyses have resulted in a significantly lower output/input ratio.

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[51] Based on various news media reports as of January 23, 2012.

[52] Discussed earlier in this report in the section entitled "Waivers to Annual Blending Standards."

[53] H. Shapouri, Paul W. Gallagher, Ward Nefstead, Rosalie Schwartz, Stacey Noe, and Roger Conway, *2008 Energy Balance for the Corn-Ethanol Industry*, AER No. 846, Office of the Chief Economist, USDA, June 2010; hereinafter referred to as Shapouri et al. (2010).

If feedstocks other than corn are used to produce biofuels, it is expected that lower nitrogen fertilizer use would greatly improve the energy balance. Further, if biomass were used to provide process energy at the biofuels refinery (rather than coal or natural gas), the energy savings would be even greater.[54] Some estimates are that cellulosic ethanol could have an energy balance of 8.0 or more.[55] Similarly high energy balances have been calculated for sugar-cane ethanol and certain types of biodiesel.

Natural Gas Demand

As biofuels production increases, the total energy needed to process biomass into liquid fuel can be expected to increase. The resultant increase in energy demand will likely support higher energy prices. The two principal processing fuels used in the United States are natural gas and coal. Other fuels include electricity and biomass.

The United States has been a net importer of natural gas since the early 1980s. However, recent technological breakthroughs in accessing gas shale have the potential to alter long-run U.S. natural gas supplies.[56] As a result, processing energy has diminished as an issue for biofuels production.

Energy Security[57]

Despite the fact that ethanol displaces gasoline, the benefits to energy security from ethanol remain relatively small. While roughly 40% of the U.S. corn crop was used for ethanol in 2011, the resultant ethanol only accounts for about 7% of gasoline consumption on an energy-equivalent basis.[58] Expanding corn-based ethanol production to levels needed to significantly promote U.S. energy security is likely to be infeasible. If the entire 2011 U.S. corn crop of 12.4 billion bushels were used as ethanol feedstock, the resultant 35 billion gallons of ethanol (24 billion gasoline-equivalent gallons, or GEG) would represent about 17% of estimated national gasoline use of approximately 138 billion gallons.[59] In contrast, the import share of U.S. liquid fuel consumption (crude oil and other petroleum products) was estimated at 69% in 2010.[60]

An expanded RFS would certainly displace petroleum consumption, but the overall effect on life-cycle fossil fuel consumption is questionable, especially if there is a large reliance on corn-based ethanol. Under the EISA RFS mandate, by 2022 biofuels will still represent less than 14% of gasoline energy demand.

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[54] "Ethanol Energy Balance," Alternative Fuels & Advanced Vehicles Data Center, Dept. of Energy, available at http://www.afdc.energy.gov/afdc/ethanol/balance.html.

[55] David Andress, *Ethanol Energy Balances*, November 2002.

[56] CRS Report R40894, *Unconventional Gas Shales: Development, Technology, and Policy Issues* .

[57] A key question in evaluating the energy security benefits or costs of an expanded RFS is "what is the definition of energy security." For many policymakers, "energy security" and "energy independence" (i.e., producing all energy within our borders) are synonymous. For others, "energy security" means guaranteeing that we have reliable supplies of energy regardless of their origin. For this section, the former definition is used.

[58] By volume, ethanol accounted for nearly 10% of gasoline consumption in the United States in 2011, but a gallon of ethanol yields only about 68% of the energy of a gallon of gasoline.

[59] This estimate is based on USDA's January 12, 2012, *World Agricultural Supply and Demand Estimates (WASDE) Report*, using comparable conversion rates.

[60] DOE, EIA, Annual Energy Review 2012, Table A1, "Total Energy Supply and Disposition Summary," Washington, January 23, 2012, at http://www.eia.gov/forecasts/aeo/er/pdf/tbla1.pdf.

The specific definition of "advanced biofuels" also affects the overall energy security picture for biofuels. For example an expanded RFS provides an incentive to increase imports of sugar-cane ethanol, especially from Brazil. The expanded RFS also provides an incentive for imports of biodiesel and other renewable diesel substitutes from tropical countries. This would represent a "diversification" of fuel sources, not the "domestication" that some claim is true energy security.

Energy Prices

The effects of the expanded RFS on energy prices are uncertain. If wholesale biofuels prices are higher than gasoline prices (after all economic incentives are taken into account), then mandating higher and higher levels of biofuels would likely lead to higher gasoline pump prices. However, if petroleum prices—and thus gasoline prices—are high, the use of some biofuels might help to mitigate high gasoline prices.

Current production costs are so high for some biofuels, especially cellulosic biofuels and biodiesel from algae, that significant technological advances—or significant increases in petroleum prices—are necessary to make them competitive with gasoline. Without cost reductions, mandating large amounts of these fuels would likely raise fuel prices. If a price were placed on greenhouse gas emissions—perhaps through the enactment of a carbon tax—then the economics could shift in favor of these fuels despite their high production costs, as they have lower fuel-cycle and life-cycle greenhouse gas emissions (see below).

Ethanol Infrastructure and Distribution Issues

In addition to the above concerns about feedstock supply for ethanol production, there also are issues involving ethanol distribution and infrastructure. Expanding ethanol production likely will strain the existing supply infrastructure. Further, expansion of ethanol use beyond the current 10% blend will require investment in entirely new infrastructure that would be necessary to handle an increasing percentage of ethanol in gasoline, or retrofitting and recertification of existing equipment. On the other hand, if drop-in fuels (i.e., petroleum-like biofuels such as biobutanol or biomass-based diesel substitutes) are produced in large quantities, some of these infrastructure issues may be mitigated, since these fuels can be used in existing infrastructure.

Distribution Issues

Ethanol-blended gasoline tends to separate in pipelines due to the presence of water in the lines. Further, ethanol is corrosive and may damage existing pipelines and storage tanks. Therefore, unlike petroleum products, ethanol and ethanol-blended gasoline cannot be shipped in existing U.S. pipeline infrastructure. Another issue with pipeline transportation is that corn ethanol must be moved from rural areas in the Midwest to more populated areas, which are often located along the coasts. This shipment is in the opposite direction of existing pipeline transportation, which moves gasoline from refiners along the coast to other coastal cities and into the interior of the country. While some studies have concluded that shipping ethanol or ethanol-blended gasoline via pipeline could be feasible, no major U.S. pipeline has made the investments to allow such shipments.[61]

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[61] Some small, proprietary ethanol pipelines do exist. American Petroleum Institute, *Shipping Ethanol Through*
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The current distribution system for ethanol is dependent on rail cars, tanker trucks, and barges. These deliver ethanol to fuel terminals where it is blended with gasoline before shipment via tanker truck to gasoline retailers. However, these transport modes lead to prices higher than for pipeline transport, and the supply of current shipping options (especially rail cars) is limited. Because of these distribution issues, some pipeline operators are seeking ways to make their systems compatible with ethanol or ethanol-blended gasoline. These modifications could include coating the interior of pipelines with epoxy or some other, corrosion-resistant material. Another potential strategy could be to replace all susceptible pipeline components with newer, hardier components. However, even if such modifications are technically possible, they likely will be expensive, and could further increase ethanol transportation costs.

As non-corn biofuels play a larger role, some of the supply infrastructure concerns may be alleviated. Cellulosic biofuels potentially can be produced from a variety of feedstocks that are more widely distributed throughout the country, unlike current dependency on a single crop (corn) from one region of the country. For example, municipal solid waste is ubiquitous across the United States, and could serve as a ready feedstock for biofuels production if the technology were developed to convert it economically to fuel. Further, increased imports of biofuels from other countries could allow for greater use of biofuels, especially along the coasts.

Higher-Level Ethanol Blends

More than half of all U.S. gasoline contains some ethanol (mostly blended at the 10% level or lower). A key benefit of gasoline-ethanol blends up to 10% ethanol is that they are compatible with existing vehicles and infrastructure (fuel tanks, retail pumps, etc.). All automakers that produce cars and light trucks for the U.S. market warranty their vehicles to run on gasoline with up to 10% ethanol (E10). As a result, this 10% blend has represented an upper bound (sometimes referred to as the "blend wall") to the amount of ethanol that can be introduced into the gasoline pool.[62] If most or all gasoline in the country contained 10% ethanol, this would allow only for roughly 14 billion gallons, far less than the RFS mandates. For ethanol consumption to exceed the so-called blend wall and meet the RFS mandates, increased consumption at higher blending ratios is needed. For example, raising the blending limit from 10% to a higher ratio such as 15% or 20% would immediately expand the "blend wall" to somewhere in the range of 20 billion to 27 billion gallons. The U.S. ethanol industry is a strong proponent of raising the blending ratio.

In response to industry concerns regarding the impending "blend wall," the EPA, after substantial vehicle testing, issued a partial waiver for gasoline that contains up to a 15% ethanol blend (E15) for use in model year 2001 or newer light-duty motor vehicles (i.e., passenger cars, light-duty trucks, and sport utility vehicles), but announced that no waiver would be granted for E15 use in model year 2000 and older light-duty motor vehicles, as well as in any motorcycles, heavy duty vehicles, or non-road engines.[63] According to the Renewable Fuel Association (RFA), the approval of E15 use in model year 2001 and newer passenger vehicles expands eligibility to 62% of vehicles on U.S. roads at the end of 2010.[64]

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Pipelines, available at http://www.api.org/aboutoilgas/sectors/pipeline/upload/pipelineethanolshipment-2.doc.

[62] See CRS Report R40445, *Intermediate-Level Blends of Ethanol in Gasoline, and the Ethanol "Blend Wall."*

[63] For details, see CRS Report R41282, *Agriculture-Based Biofuels: Overview and Emerging Issues*.

[64] "E15 Decision Opens Blend to 2 Out of 3 Vehicles; More Work Yet to be Done," RFA news release, Jan. 21, 2011.

In addition to the EPA waiver announcement, fuel producers will need to register the new fuel blends and submit health effects testing to EPA. Further, numerous other changes have to occur before gas stations will begin selling E15, including many approvals by states and potentially significant infrastructure changes (pumps, storage tanks, etc.). As a result, the vehicle limitation to newer models, coupled with infrastructure issues, are likely to limit rapid expansion of blending rates. Moreover, a group of engine and equipment manufacturers has challenged the partial waiver in court, arguing that EPA failed to estimate the likelihood of misfueling (using E15 in equipment denied a waiver), and the economic and environmental consequences of that mis-fueling.[65]

Two additional options to resolving this bottleneck exist but appear to be long-run alternatives. First, increased use of ethanol in flex-fuel vehicles (FFVs) at ethanol-to-gasoline blend ratios as high as 85% (referred to as E85) is a possibility. However, increased E85 use involves substantial infrastructure development, particularly in the number of designated storage tanks and E85 retail pumps, as well as a rapid expansion of the FFV fleet to absorb larger volumes of ethanol. Infrastructure expansion will require significant investments, especially at the retail level. Installation of a new E85 pump and underground tank can cost as much as $100,000 to $200,000.[66] However, if existing equipment can be used with little modification, the cost could be less than $10,000.

A second alternative is to expand use of processing technologies at the biofuel plant to produce biofuels in a “drop-in” form (e.g., butanol) that can be used by existing petroleum-based distribution and storage infrastructure and the current fleet of U.S. vehicles. However, more infrastructure-friendly biofuels generally require more processing than ethanol and are therefore more expensive to produce.

Vehicle Infrastructure Issues

As was stated above, if a large portion of any increased RFS is met using ethanol, then the United States likely does not have the vehicles to consume the fuel. The 10% blend wall on ethanol in gasoline for conventional vehicles still poses a significant barrier to expanding ethanol consumption beyond 14 billion gallons per year.[67] To allow more ethanol use, vehicles will need to be certified and warranted for higher-level ethanol blends, or the number of ethanol FFVs will need to increase. Turnover of the U.S. automobile fleet is likely to slow during the recession, making it more difficult to integrate FFVs into the fleet.

Conclusion

There is continuing interest in expanding the U.S. biofuels industry as a strategy for promoting energy security and achieving environmental goals. However, it is possible that increased biofuel production may place desired policy objectives in conflict with one another. There are limits to the amount of biofuels that can be produced from current feedstocks and questions about the net

[65] Outdoor Power Equipment Institute (OPEI), Fact Sheet: E-15 Partial Waiver Legal Challenge, December 17, 2010. The case is *Alliance of Automobile Manufacturers et. al v. Environmental Protection Agency*.

[66] David Sedgwick, *Automotive News*, January 29, 2007. p. 112.

[67] Note that 15 billion gallons is the corn starch ethanol limit for the expanded RFS in the EISA.

energy and environmental benefits they might provide. Further, rapid expansion of biofuels production may have many unintended and undesirable consequences for agricultural commodity costs, fossil energy use, and environmental degradation. Owing to these concerns, alternative strategies for energy conservation and alternative energy production are widely seen as warranting consideration.

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