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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 have included minimum renewable fuel usage requirements, blending and production tax credits, an import tariff, loans and loan guarantees, and research grants. One of the more prominent forms of federal policy support is the Renewable Fuel Standard (RFS)—whereby a minimum volume of biofuels is to be used in the national transportation fuel supply each year. This report describes the general nature of the RFS mandate and its implementation, and outlines some emerging issues related to the continued growth of U.S. biofuels production needed to fulfill the expanding RFS mandate, the potential inability of the domestic market to absorb ethanol above a 10% share of domestic gasoline fuels (a problem known as the "blend wall"), and the emergence of potential unintended consequences of this rapid expansion.

Congress first established the 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, rising to 7.5 billion gallons by 2012. Two years later, the Energy Independence and Security Act of 2007 (EISA, P.L. 110-140) greatly expanded the biofuel mandate volumes and extended the ramp-up through 2022. The expanded RFS (referred to as RFS2) required the annual use of 9 billion gallons of biofuels in 2008, rising to 36 billion gallons in 2022, with at least 16 billion gallons from cellulosic biofuels, and a cap of 15 billion gallons for corn-starch ethanol.

In addition to the expanded volumes and extended date, RFS2 has three important distinctions from RFS1. First, the total renewable fuel requirement is divided into four separate, but nested categories—total renewable fuels, advanced biofuels, biomass-based diesel, and cellulosic biofuels—each with its own volume requirement. Second, biofuels qualifying under each category must achieve certain minimum thresholds of lifecycle greenhouse gas (GHG) emission reductions, with certain exceptions applicable to existing facilities. Third, all renewable fuel must be made from feedstocks that meet an amended definition of renewable biomass, including certain land use restrictions.

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 and include specific deadlines for announcing annual standards, as well as greater specificity on potential waiver requests and RIN oversight.

Over the long term, the RFS is likely to play a dominant role in the development of the U.S. biofuels sector. However, 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, retail pumps, etc.) needed to deliver the expanding biofuels mandate to consumers.

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Introduction

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 a variety of policies, at both the state and federal levels, to directly support U.S. biofuels production and use (although some of these policies have expired).[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 (up over 600%) since the early 2000s. However, despite the rapid growth, U.S. biofuels consumption remains small as a component of U.S. motor fuels, comprising about 5.7% of total transportation fuel consumption (on a gasoline-equivalent basis) in 2012.[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 (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 mandate to 36 billion gallons by 2022. In addition to gasoline, the expanded RFS (referred to as RFS2) applies to most transportation fuel used in the United

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[1] For more information, see CRS Report R41282, *Agriculture-Based Biofuels: Overview and Emerging Issues* and CRS Report R41985, *Renewable Energy Programs and the Farm Bill: Status and Issues*.

[2] For more information on incentives (both tax and non-tax) for biofuels, see CRS Report R42566, *Alternative Fuel and Advanced Vehicle Technology Incentives: A Summary of Federal Programs*.

[3] In gasoline-equivalent shares with 7.3% for ethanol and 2.1% for biodiesel. CRS estimates based on data from Energy Information Agency (EIA), Department of Energy (DOE).

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

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, particularly for the advanced and cellulosic biofuels categories that are potentially in short supply relative to their growing RFS mandates.

EISA was passed on December 19, 2007, and EPA issued its final rule to implement and administer the RFS2 on February 3, 2010.[5] The new rule builds upon the earlier rule for RFS1. However, there are four major distinctions between 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 biofuels—each with its own volume requirement or standard (described below).
- Third, biofuels qualifying under each nested RFS2 category must achieve certain minimum thresholds of lifecycle greenhouse gas (GHG) emission performance, with exceptions applicable to facilities existing or under construction when EISA was enacted (**Table 2**).[6]
- Fourth, under RFS2 all renewable fuel must be made from feedstocks that meet a revised definition of renewable biomass, including certain land use restrictions.[7]

The RFS is administered by the Environmental Protection Agency (EPA).[8] EPA issued its final rule for administering RFS1 in April 2007.[9] 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. EPA rules for administering RFS2 (issued in February 2010) built upon the earlier RFS1 regulations and include specific deadlines for announcing annual standards, as well as greater specificity on potential waiver requests and RIN oversight.

[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] Ibid.

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

[7] CRS Report R40529, *Biomass: Comparison of Definitions in Legislation Through the 112th Congress*.

[8] For more information, see the section "Implementation of the RFS" later in this report.

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

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 advanced[h]	Cellulosic	Biomass-based diesel
2006	4.0	—	—	—	—	—
2007	4.7	—	—	—	—	—
2008	5.4	9.00	9.0	0.00	0.00	0.00
2009	6.1	11.10	10.5	0.60	0.00	0.00
2010	6.8	12.95	12.0	0.95	0.0065[a]	1.15[b]
2011	7.4	13.95	12.6	1.35	0.006 (0.00)[c]	0.80
2012	7.5	15.20	13.2	2.00	0.00[d]	1.00
2013	7.6 (est.)	16.55	13.8	2.75	0.006[e]	1.28[e]
2014	7.7 (est.)	18.15 (15.21)[i]	14.4 (13.0)[h]	3.75 (2.20)[h]	1.75 (0.017)[h]	1.28[h]
2015	7.8 (est.)	20.50	15.0	5.50	3.00	[f]
2016	7.9 (est.)	22.25	15.0	7.25	4.25	[f]
2017	8.1 (est.)	24.00	15.0	9.00	5.50	[f]
2018	8.2 (est.)	26.00	15.0	11.00	7.00	[f]
2019	8.3 (est.)	28.00	15.0	13.00	8.50	[f]
2020	8.4 (est.)	30.00	15.0	15.00	10.50	[f]
2021	8.5 (est.)	33.00	15.0	18.00	13.50	[f]
2022	8.6 (est.)	36.00	15.0	21.00	16.00	[f]
2023	—	[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. It should be noted that the definition of "cellulosic biofuel" was changed between the RFS1 and RFS2 and that some qualifying fuel produced in the first phase of the program no longer qualifies as cellulosic biofuel.

b. The biomass-based diesel mandate for 2010 combines the original EISA mandate of 0.65 billion gallons (bgals) with the 2009 mandate of 0.5 bgals.

c. The initial RFS for cellulosic biofuels for 2011 was 250 million gallons. In November 2010 EPA revised this mandate downward to 6.0 million ethanol-equivalent gallons. In its preliminary proposal for 2014, EPA proposed rescinding the 2011 standard to reflect a lack of supply in 2011 and to respond to the issues raised in the appeals court ruling of January 2013 (see next table note).

d. The initial RFS for cellulosic biofuels for 2012 was 500 million gallons. In December 2011 EPA revised this mandate downward to 10.45 million ethanol-equivalent gallons. In January 2013, the U.S. Court of Appeals for D.C. vacated EPA's initial cellulosic mandate for 2012 and remanded EPA to replace it with a revised mandate. On February 28, 2013, EPA dropped the 2012 RFS for cellulosic biofuels to zero.

e. The initial 2013 cellulosic RFS was 1 bgals. In January 2013, EPA preliminarily revised this mandate to 14 million ethanol-equivalent gals.; then in August 2013, finalized it at 6 million ethanol-equivalent gals. The 2013 biodiesel mandate was revised upwards from 1 bgals to 1.28 bgals actual volume.

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.

h. Advanced biofuels explicitly excludes corn-starch ethanol from inclusion. The preliminary 2014 RFS proposed by EPA (released on November 15, 2013) is in parentheses. Once the proposal is published in the *Federal Register*, it will be open to a 60-day comment period.

i. Total non-corn-starch or advanced biofuels includes both cellulosic and biomass-based diesel biofuels as well as other qualifying biofuels such as imported sugar-cane-based ethanol.

Four Biofuel Categories

RFS2 includes four biofuel 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). Each is also subject to biomass feedstock criteria.

- **Total renewable fuels**. The scheduled mandate grows from nearly 13 billion gallons (bgals) in 2010 to 36 bgals in 2022. Biofuels from new facilities must reduce lifecycle GHG emissions by at least 20% relative to conventional fuels 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 in the RFS is capped at 13.8 bgals in 2013, but 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 at least 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. The total advanced biofuel mandate for 2013 is 2.75 bgals (ethanol equivalent).
- **Cellulosic and agricultural waste-based biofuel**. The mandate grows from 100 million gallons in 2010 to 16 bgals in 2022 (subsequently, RFS mandates were lowered for 2010, 2011, 2012, and 2013—see discussion under "Waivers to Annual Biofuel Standards"). 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.

[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). EISA defines "advanced biofuels" as biofuels other than ethanol derived from corn starch (kernels) having 50% lower lifecycle greenhouse gas emissions relative to gasoline. In some 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" includes ethanol from sugar cane, despite the fact that Brazilian sugar growers have been producing fuel ethanol for decades.

- **Biomass-based biodiesel (BBD)**. The mandate grows from 0.5 bgals in 2009 to 1 bgals in 2012.[11] Any diesel fuel made from biomass feedstocks (including algae) qualifies, including biodiesel (mono-alkyl esters) and non-ester renewable diesel (e.g., cellulosic diesel).[12] The lifecycle GHG emissions reduction threshold is 50%. EPA established the 2013 mandate at 1.28 bgals (actual volume). EPA is proposing the same 1.28 bgals (actual volume) for 2014. BBD produced from cellulosic feedstocks could potentially be used to simultaneously meet the cellulosic and BBD standards.

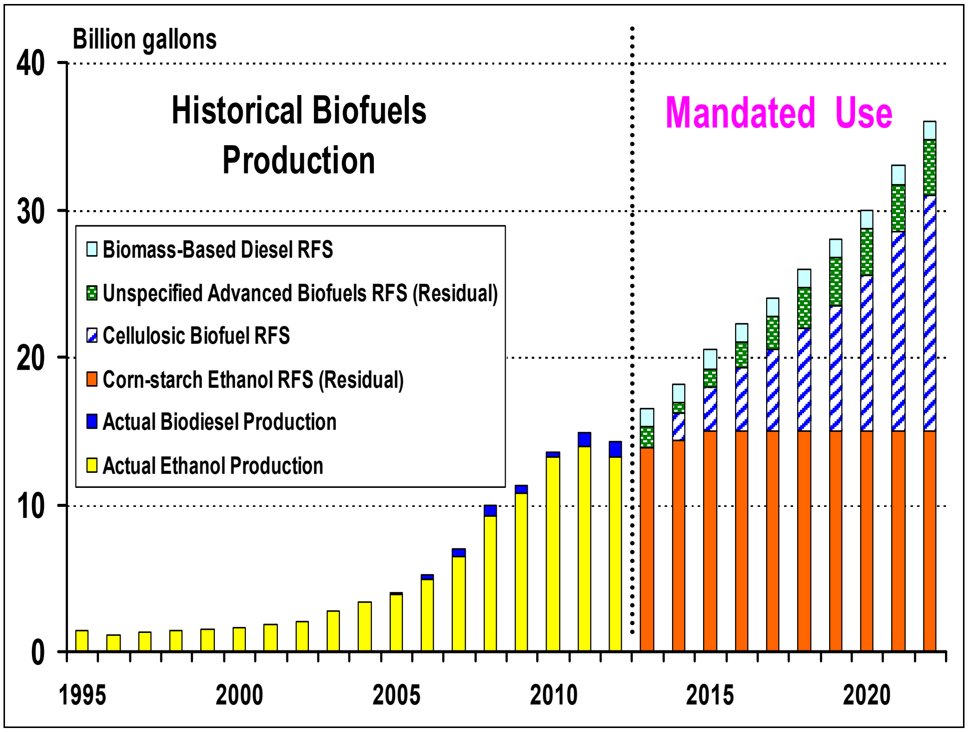
Usage Volume Requirements

RFS2 is essentially a biofuels mandate with limits on corn-starch ethanol inclusion and carve-outs for higher-performing biofuels (**Figure 1**)—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. As a result, corn-starch ethanol blended in excess of its annual cap is not credited toward the annual total RFS.

[11] As part of its February 3, 2010, final rule, EPA announced a revision in the BBD 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 BBD standard. As a result, it was integrated into the 2010 standard. Qualifying RINs accumulated during 2009 were acceptable in compliance.

[12] A diesel fuel product produced from cellulosic feedstocks that meets the 60% GHG threshold can qualify as either cellulosic biofuel or BBD.

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



Source: Actual ethanol and biodiesel production data for 1995-2012 are from the U.S. Energy Information Administration (EIA), Department of Energy; the RFS2 mandates by category for 2013-2022 are from EISA (P.L. 110-140).

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 (BBD) is also valid for meeting the advanced biofuels requirement. Thus, if any combination of cellulosic biofuels or BBD 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 (which grows to 21 bgals by 2022).[13]

Similarly, any renewable fuel that meets the requirement for advanced biofuels is also valid for meeting the overall total renewable fuel requirement (which grows to 36 bgals by 2022). As a result, any combination of cellulosic biofuels, BBD, 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.

[13] In addition, certain advanced biofuels have ethanol equivalency values greater than one. See the note on equivalency values later in this report. As a result, there is additional incentive to produce higher nested biofuels in meeting advanced and total biofuels RFS mandates.

Required Reduction in Lifecycle Greenhouse Gas 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% criterion applies to renewable fuel from facilities that commenced construction after December 19, 2007, the date EISA was signed into law. EISA further exempted facilities that operate on natural gas through 2009. Plants that existed or commenced construction prior to these dates are grandfathered in, and are not subject to any GHG emissions requirement.

Fuel Pathways (including ILUC) Meeting Lifecycle GHG Thresholds

Under EISA, EPA is required to evaluate the lifecycle emissions of all biofuel pathways registered in the RFS2. A key point of contention was the inclusion in the statute of a requirement that EPA 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 grow a biofuels feedstock crop might result (due to market price effects) in that same acre 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. EPA's initial assessment of biofuel lifecycle GHG emissions in its proposed RFS2 was met with criticism from many stakeholders.

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. As a result, EPA reconsidered all of the evidence (including ILUC) and

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

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

made relevant adjustments to its analytical tools. The resultant changes were announced as part of its final RFS2 rule of February 3, 2010.[16]

In addition, EPA has pointed out that other pathways are likely to be similar enough to existing qualifying pathways (**Table 3**) that they can be extended the same GHG reduction compliance determinations.[17] However, EPA stated that, although the announced determinations for the qualifying fuel pathways (**Table 3**) 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.[18] For example, in a February 2013 rule that qualified several new fuel pathways for cellulosic biofuel production, EPA stated that it hoped to provide opportunities to increase the volume of advanced, low-GHG renewable fuels.[19] For other biofuel pathways not yet modeled, EPA encourages parties to use a petition process to request EPA to examine additional pathways.

Table 3. Qualifying Fuel Pathways for Lifecycle GHG Emissions by Biofuel Category

Renewable Fuel—20% GHG Reduction
• Biofuel from the capacity of plants or production facilities that commenced construction after December 19, 2007, unless subject to more stringent criteria as listed below.[a] • Ethanol produced from corn starch at a new natural gas-fired facility (or expanded capacity from an existing facility) using advanced efficient technologies. • Biobutanol from corn starch. • Ethanol made from barley or grain sorghum at dry mill facilities that use natural gas for process energy. • **Note:** Biodiesel and renewable diesel produced from palm oil *do not* meet the minimum 20% lifecycle GHG reduction threshold needed to qualify as renewable fuel under the RFS program.
Advanced biofuels—50% GHG Reduction
• Ethanol produced from sugarcane (as in Brazil). • Naphtha and liquefied petroleum gas (LPG) from camelina oil. • Ethanol made from barley or grain sorghum at dry mill facilities that use specified forms of biogas for both process energy and most electricity production.

[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] For information on adding a potential new biofuel feedstock or production process pathway, see EPA, "Guidance on New Fuel Pathway Approval Process" at http://www.epa.gov/otaq/fuels/renewablefuels/compliancehelp/rfs2-lca-pathways.htm.

[19] EPA, "EPA Issues Final Rule Additional Qualifying Renewable Fuel Pathways Under the Final RFS2 Program," EPA-420-F-13-014, February 2013.

Renewable Fuel—20% GHG Reduction

Biomass-based diesel (including jet fuel and heating oil)—50% GHG Reduction

- Biodiesel and non-ester renewable diesel from soy oil, non-food grade corn oil, camelina oil, algal oils, waste oils, fats, and greases.
- Biodiesel produced using esterification (a new process method) from soybean oil, oil from annual cover crops, algal oil, biogenic waste oils, fats, and greases, non-food grade corn oil, Canola or rapeseed oil, and camelina oil.
- Non-ester renewable diesel based on electricity or natural gas for process energy and feedstocks of soybean oil, oil from annual cover crops, algal oil, biogenic waste oils, fats, and greases, or the non-cellulosic portions of food wastes (i.e., non-food grade corn oil, and camelina oil).
- Biodiesel produced using a glycerolysis production process element combined with the traditional transesterification process from free fatty acids (FFA).

Cellulosic biofuels (either cellulosic ethanol or cellulosic diesel)—60% GHG Reduction

- Cellulosic biofuels based on perennial grasses including switchgrass, miscanthus, energy cane, giant reed, and napier grass.
- Cellulosic biofuels produced from crop residue (e.g., corn stover, wheat straw, rice straw, and citrus residue), forest material (including slash, pre-commercial thinnings, and solid tree residue remaining from forest product production), secondary annual cover crops planted on existing crop land (e.g., winter cover crops), cellulosic components of separated food and yard waste (including biogenic waste from food processing), and separated municipal solid waste using certain processes identified below.
- *The following processes*—all utilizing natural gas, biogas, and/or biomass as the only process energy sources—*qualify as cellulosic biofuel*: thermochemical pyrolysis; thermochemical gasification; biochemical direct fermentation; biochemical fermentation with catalytic upgrading; and any other process that uses biogas and/or biomass as the only process energy sources.

Source: EPA announcements of various rules and determinations as posted at "Renewable Fuels: Regulations and Standards," at http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm.

Notes: This table is not an official, inclusive listing of EPA certified biofuel pathways. For information on potential new biofuel feedstock or production process pathways currently under review, as well as completed pathways, see EPA, "Guidance on New Fuel Pathway Approval Process" at http://www.epa.gov/otaq/fuels/renewablefuels/compliancehelp/rfs2-lca-pathways.htm.

a. Biofuels from plants that existed or commenced construction prior to this date are grandfathered in, and are not subject to any GHG emissions requirement. Further, the grandfathering provisions extend through 2009 for plants that use natural gas.

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), is 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. However, 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 under an amended definition of "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:[21]

- 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.

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.[22] To accomplish this task, EPA first calculates annual percentage standards for the four biofuel categories of RFS2. The percentage 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 requirements, while taking into consideration regional differences in biofuels production and availability, EPA established a system of tradable RINs. Percentage standards, RVOs, and RINs are described in this section.

[20] CRS Report R40529, *Biomass: Comparison of Definitions in Legislation Through the 112th Congress*.

[21] From various EPA announcements on "Renewable Fuels Regulations and Standards," at http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm.

[22] EPA, 40 C.F.R. Part 80, "Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program, Final Rule," Feb. 3, 2010. EPA's official "Renewable Fuel Standard (RFS)" website, with links to all official documents, is available at http://www.epa.gov/otaq/fuels/renewablefuels/.

Determining Annual Percentage Standards

In order to ensure that the requisite volumes of biofuels are used each year, EPA first estimates the total volume of gasoline and diesel 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.[23] The 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 4**). This ratio is adjusted to account for the small refinery exemptions. A separate ratio is calculated for each of the four biofuel categories.

Under EISA, EPA is required to set the biofuel standards on a final basis by November 30 for the following year, based in part on information provided by the EIA. In order to accommodate this deadline, EPA announced that it intended to issue a notice of proposed rulemaking (NPRM) by summer of the preceding year, and on a final basis by November 30 of the preceding year.[24] These announcements are to include the cellulosic biofuel waiver credit price (see section on "Cellulosic Biofuel Waiver Credits") and the status of the aggregate compliance approach to land-use restrictions under the definition of renewable biomass for both the United States and Canada.

Table 4. RFS Standards: 2013 Final versus 2014 Proposed

RFS Category	Percentage Ratio (%)		Volume of Renewable Fuel (billion gallons)		
	2013 Final	2014 Proposed	2013 Final	2014 Proposed	2014 (EISA)[a]
Cellulosic biofuels	0.004%	0.010%	0.006	0.017	1.75
Biomass-based diesel	1.13%	1.16%	1.28	1.28	1.28[b]
Advanced biofuels	1.62%	1.33%	2.75	2.20	3.75
Total renewable fuel	9.74%	9.20%	16.55	15.21	18.15
Implied corn ethanol cap[c]	—	—	13.8	13.01	14.40

Source: EPA Fact Sheet, "EPA Finalizes 2013 Renewable Fuel Standards," *EPA-420-F-13-042,* August 2013; and "EPA Proposes 2014 Renewable Fuel Standards, 2015 Biomass-Based Diesel Volumes," *EPA-420-F-13-048*, November 2013.

Notes: All volumes are given in ethanol-equivalent gallons except for biomass-based diesel, which is given in terms of physical volume.

a. Original RFS as scheduled in EISA (P.L. 110-140).

b. See foonote h in **Table 1**.

[23] 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 Consumption," available at http://www.eia.gov/forecasts/steo/.

[24] EPA, 40 C.F.R. Part 80, Final Rule, Feb. 3, 2010, p. 14675. However, EPA was unable to meet the required timetable in announcing the 2013 Renewable Fuel Standards. Instead of November 2012, the final 2013 RFS was announced on August 6, 2013. Further, the proposed rule for 2014 was signed by EPA Administrator Gina McCarthy on November 15, 2013. The comment period runs for 60 days after the proposed rule is published in the Federal Register. However, the proposal had not been published as of November 22, 2013, so a final rule for 2014 is not expected until at least late January 2014. EPA Fact Sheet, "EPA Finalizes 2013 Renewable Fuel Standards," *EPA-420-F-13-042,* August 2013; and "EPA Proposes 2014 Renewable Fuel Standards, 2015 Biomass-Based Diesel Volumes," *EPA-420-F-13-048*, November 2013.

c. The implied corn ethanol cap under the RFS is the difference between the total and the advanced categories.

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 biofuel was granted a 2.5-to-1 credit.

In general, these equivalence values were continued in the RFS2, with one key exception. For purposes of meeting the biomass-based biodiesel standard, each gallon of BBD will count as 1.0; however, for purposes of meeting the advanced biofuel standard, cellulosic standard and/or the total renewable biofuel standard, each gallon of BBD will count as 1.5 or 1.7 (depending on the type of fuel) in order to reflect its higher energy content. Under the RFS2, the 2.5-to-1 bonus for cellulosic biofuel was eliminated.

Determining an Individual Company's Obligation

The RFS mandates (by biofuel category) are ultimately enforced on gasoline and diesel fuel refiners, blenders, and/or importers (not on biofuels producers or importers). Companies that supply 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 supplier must have enough RINs to show that it has met its share of each of the four mandated standards. Failure to acquire sufficient RINs to meet a party's RVO (see section "Renewable Identification Numbers (RINs)" for details) is subject to civil penalties of up to $32,500 per day, plus the amount of any economic benefit or savings resulting from the violation.[25]

Since the RFS program is intended to require a specific volume of renewable fuel to be consumed in the U.S. domestic transportation fuel market, RINs associated with exports of renewable fuel are not valid for RFS compliance purposes. To ensure that renewable fuels exported from the U.S. cannot be used by an obligated party for RFS compliance purposes, the RINs associated with any exported renewable fuel must be removed from circulation. To achieve this under the RIN-based program, exporters of renewable fuel are assigned an RVO that is equal to the annual volume of renewable fuel that they export.

Waivers to Annual Biofuel Standards

EISA requires that EPA evaluate and make an appropriate market determination for setting the RFS standards each year. As part of this process, EPA announced that it will issue a notice of proposed rulemaking by summer and a final rule by November 30 of each year to set the renewable fuel standard for each ensuing year.[26] 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

[25] U.S. Code, "Regulation of fuels," 42 U.S.C. 7545.

[26] However, EPA has missed this statutory deadline in multiple years. For 2013, EPA did not even propose a standard until February 2013, with a public comment period running through late March.

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."[27]

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. A similar waiver was requested in 2012 by the governors of Arkansas and North Carolina and several other states.[28] In both cases, the petition was ultimately denied.[29]

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. Because these categories are nested, EPA may pass the waiver along to the higher, aggregate totals for advanced and total renewable biofuels. However, through 2013 EPA has elected to limit the waiver to the cellulosic category. For example, in each of the years 2010 through 2013 EPA has waived the original RFS mandates for cellulosic biofuels, but left both the advanced and total renewable mandates unchanged as follows:

- In February 2010, EPA lowered the 2010 RFS for cellulosic biofuels to 6.5 million gallons (mgals), on an ethanol-equivalent basis, down from its original 100 mgals scheduled by EISA.[30]
- In November 2010, EPA lowered the 2011 RFS for cellulosic biofuels to 6 mgals (ethanol equivalent), down from its original 250 mgals.[31]
- In December 2011, EPA lowered the 2012 RFS for cellulosic biofuels to 8.65 mgals (ethanol equivalent), down from its original 500 mgals.[32]
- In August 2013, EPA lowered the 2013 RFS for cellulosic biofuels to 6 mgals (ethanol equivalent), down from its original 1 billion gallons.[33]

EPA cited a lack of current and expected production capacity, driven largely by a lack of investment in commercial-scale refineries—for example, only a limited number of cellulosic

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

[28] New Mexico, Georgia, Texas, Virginia, Maryland, Delaware, Utah, and Wyoming. The governor of Florida wrote EPA in support of the waiver requests. 77 *Federal Register* 70754.

[29] See, "EPA Decision on Texas Request for Waiver of Portion of Renewable Fuel Standard (RFS)," EPA 420-F-08-029, August 2008; at http://www.epa.gov/otaq/renewablefuels/420f08029.htm.

[30] 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. It should be noted that under the RFS1, fuels produced from feedstocks other than cellulose, but produced at facilities that used biomass for process energy, were treated as "cellulosic biofuels" for compliance purposes. These fuels were excluded from the definition of cellulosic biofuels in the EISA amendments to the RFS.

[31] 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.

[32] 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. EPA has proposed further revising this requirement to zero in response to the decision in API v. EPA vacating the 2012 standard (next page).

[33] EPA finalized the 2013 requirements in August 2013. EPA, "EPA Finalizes 2013 Renewable Fuel Standards," EPA-420-F-13-042, August 2013.

biofuel RINs were registered in 2012 (20,069 gallons), while no commercial production was reported in 2010 and 2011.[34] The downward revisions for 2010 through 2013 suggest that the actual cellulosic biofuels standard for future years, although explicitly scheduled in statute, is uncertain.

In contrast to these previous waivers, which were limited to the cellulosic biofuels mandate, on November 15, 2013, EPA released its proposed 2014 RFS mandates and included a waiver of cellulosic, advanced, and total renewable biofuels. EPA is proposing to use both its cellulosic waiver authority and its general authority to lower the total 2014 RFS below the 2013 levels. EPA has determined that the current "blend wall" limitation of 10% ethanol in gasoline[35] would lead to inadequate supply of RINs to comply with the mandate.[36] Therefore, EPA is proposing lowering the advanced biofuel mandate by 1.55 billion gallons,[37] and the overall RFS by 2.94 billion gallons,[38] from the amounts scheduled for 2014 in the statute. Under the proposal, the corn-ethanol cap would be roughly 1.4 billion gallons below the level scheduled in the statute for 2014, and roughly 800 million below the 2013 cap. Some ethanol proponents argue that EPA has exceeded its legislative waiver authority and that this action will likely result in litigation.[39]

Cellulosic Biofuel Waiver Credits

If EPA reduces the required volume of cellulosic biofuel according to the waiver provisions in EISA, EPA must offer a number of credits to obligated parties no greater than the reduced cellulosic biofuel standard. These waiver credits are not allowed to be traded or banked for future use, and are only allowed to be used to meet the cellulosic biofuel standard for the year that they are offered. The formula for determining the value of the credits is set in statute. Since the cellulosic standard was lowered for each year from 2010 through 2013, cellulosic waiver credits were made available to obligated parties at announced prices per gallon—$1.56 in 2010; $1.13 in 2011; $0.78 in 2012; and $0.42 in 2013. The value of the credits is equal to the amount by which $3.00 per gallon—adjusted for inflation—exceeds the average wholesale price of a gallon of gasoline in the United States in the preceding year.

Unachieved Cellulosic Biofuels Mandates

In 2012 the American Petroleum Institute (API) challenged the obligation under the RFS to use cellulosic biofuels that do not exist in sufficient amounts in commercial markets or pay a fee. After three successive years (2010-2012) where, first, EPA lowered the cellulosic biofuels mandate, cellulosic biofuels production failed to achieve the lowered mandates. API petitioned the U.S. Court of Appeals, D.C., charging that EPA exceeded its authority by setting unachievable

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[34] This is the number of cellulosic RINs generated under the RFS2 program in 2012 as reported by EPA (as of March 1, 2013) on its "RFS2 EMTS Informational Data" online reporting system at http://www.epa.gov/otaq/fuels/rfsdata/.

[35] See "The Blend Wall and Higher-Level Ethanol Blends."

[36] EPA, *2014 Standards for the Renewable Fuel Standard Program; Proposed Rule (Prepublication Version)*, EPA-HQ-OAR-2013-0479, Washington, DC, November 15, 2013, p. 90, http://www.epa.gov/otaq/fuels/renewablefuels/documents/420f13048.pdf.

[37] 3.75 billion gallons – 2.20 billion gallons = 1.55 billion gallons.

[38] 18.15 billion gallons – 15.21 billion gallons = 2.94 billion gallons.

[39] "EPA Authority to Reduce the RFS", *farmdocdaily.com*, November 6, 2013, available at http://farmdocdaily.illinois.edu/pdf/fdd061113.pdf.

standards in an effort to promote cellulosic biofuel development. On January 25, 2013, the appeals court agreed with API's charge, ruling that the EPA's cellulosic biofuels mandate for 2012 was vacated and that EPA must replace it with a revised mandate. On February 27, 2013, EPA announced that the 2012 cellulosic biofuel standard was vacated (dropped to zero).[40] Then, in November, 2013, EPA proposed retroactively lowering the 2011 RFS to zero.[41]

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.[42] 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 (**Table 5**).

[40] EPA, "Update—2012 Cellulosic Biofuel Standard Mandate Issued," *EnviroFlash,* February 27, 2013. As part of the news release, EPA announced that since the 2012 mandate was zero, no compliance was necessary and any parties who had already submitted payment for 2012 cellulosic biofuel waiver credits would be issued refunds.

[41] EPA, *2014 Standards for the Renewable Fuel Standard Program; Proposed Rule (Prepublication Version)*, EPA-HQ-OAR-2013-0479, Washington, DC, November 15, 2013, p. 24, http://www.epa.gov/otaq/fuels/renewablefuels/documents/420f13048.pdf.

[42] See CRS Report R42824, *Analysis of Renewable Identification Numbers (RINs) in the Renewable Fuel Standard (RFS)*. Other sources include Robert Wisner, "Renewable Identification Numbers (RINs) and Government Biofuels Blending Mandates," *AgMRC Renewable Energy Newsletter*, Agricultural Marketing Research Center, Iowa State University, April 2009; 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.

Table 5. RFS D Code Definitions

D value	RFS1	RFS2
1	Cellulosic biomass ethanol	na
2	Any other renewable fuel	na
3	na	Cellulosic biofuel
4	na	Biomass-based diesel
5	na	Advanced biofuel
6	na	Renewable fuel
7	na	Cellulosic diesel

Source: EPA, 40 C.F.R. Part 80, "Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program, Final Rule," Feb. 3, 2010.

Notes: na = not applicable.

Together, SSSSSSSS and EEEEEEEE identify the RIN block that demarcates the number of gallons of renewable fuel the batch represents in the context of compliance with the RFS—that is, RIN gallons. 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. 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 or supplied 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.

Small Refinery Exemption

A permanent exemption is available to any parties who produce or import less than 10,000 gallons of renewable fuel in a year—they 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 beginning with the calendar year in which the refinery produces its first gallon of renewable fuel) 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 is not 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 fuel supplier has blended or sold a quantity of biofuel, the RINs are separated from the biofuels. If a supplier has already met its mandated share and has supplied surplus biofuels for a particular biofuel category, it can sell the extra RINs to another entity or it can hold onto the RINs for future use (either to satisfy the succeeding year's requirement or for sale in the succeeding year). An obligated party who faces a RIN deficit can purchase excess RINs. Since biofuels supply and demand can vary over time and across regions, a market has developed for RINs.

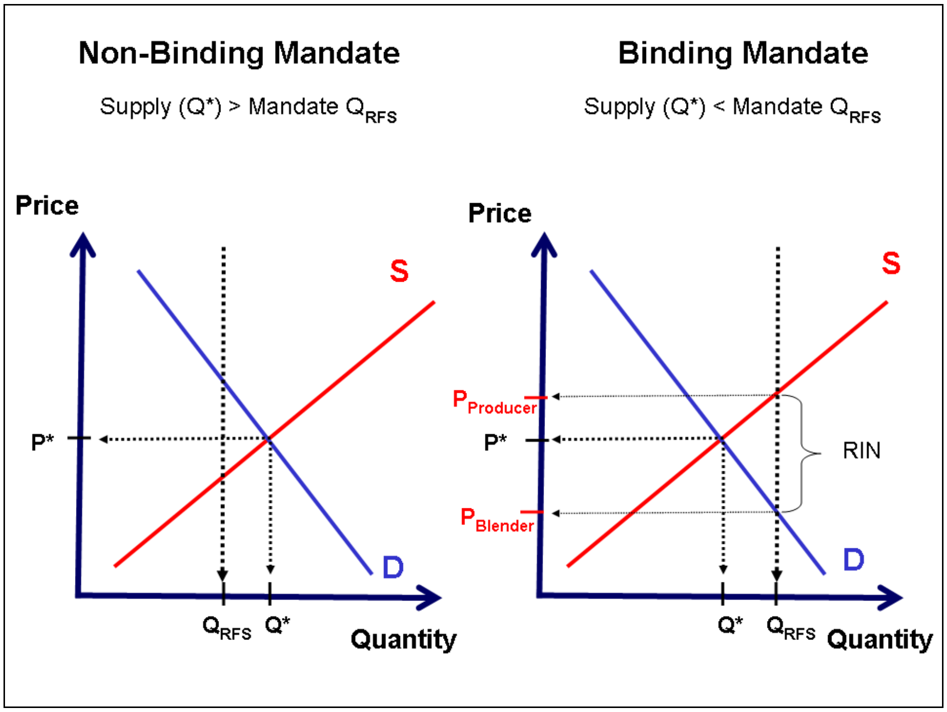
The marketability of RINs allows fuel suppliers who have not bought enough biofuels to fulfill their RFS requirement for each of the four RFS categories by purchasing the biofuels-specific RINs instead. As a result, RINs have value as a replacement for the actual purchase and supply of biofuels. Because four separate biofuel mandates must be met, the RIN value may vary across the individual biofuel categories.[43] Since the RFS biofuels categories are nested, the price of biodiesel RINs is generally equal to or greater than the price of RINs for advanced biofuels which, in turn is generally 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.[44] 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** where $Q^* > Q_{RFS}$), 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}).

[43] For example, 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.

[44] 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.

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** where $Q_{RFS} > Q^*$), the biofuels mandate is binding because it forces obligated parties ("blenders" for this discussion)[45] to use more biofuels than they would without the mandate. The price of the biofuel purchased by the blender 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 also 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. Prior to 2013, the overall biofuels mandates had not been binding and renewable fuel RIN values were small (usually less than $0.05/gallon). However, based on EIA data for U.S. gasoline consumption, it is expected that the RFS as scheduled in the statute will become binding sometime during 2013 or 2014 (see discussion later in this report). As a result, RIN prices escalated sharply in 2013 to prices well in excess of $1.00/gallon, before dropping dramatically in the second half of the year. Economists suggest that market conditions—supply, demand, and asymmetries in market power—will determine how any added cost of biofuels acquisition (i.e., the RIN value) would be distributed along the supply

[45] There is no explicit requirement in the RFS statute or regulations to blend biofuels into conventional fuels. However, the vast majority of compliance with the RFS mandates is the use of ethanol blended into motor gasoline.

chain—that is, partially absorbed by biofuel producers and blenders or passed on to motor fuel consumers in the form of higher fuel prices.[46]

Because RINs have value, they are not immune to fraudulent activity. In late 2011 and early 2012, EPA issued notices of violations (NOVs) to three companies (Clean Green Fuels, LLC, Absolute Fuels, LLC, and Green Diesel, LLC) that the agency alleges fraudulently generated a combined 140 million biodiesel RINs in 2010 and 2011. Subsequently, individuals representing two of these companies have also faced criminal prosecution.[47]

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.[48] The analytical results 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.

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[46] For a series of articles discussing the RFS mandate, RIN prices, and the blend wall, readers are referred to the policy articles authored by Nick Paulson, Scott Irwin, and Darrel Good (Dept. of Agriculture and Consumer Economics, Univ. of Illinois Urbana-Champaign) at http://farmdocdaily.illinois.edu/areas/policy/; Bruce Babcock and colleagues (Center for Agricultural and Rural Development, Iowa State Univ.) at http://www.card.iastate.edu/; or Pat Westhoff, Wyatt Thompson, and colleagues at the Food and Agricultural Policy Research Institute, Univ. of Missouri at http://www.fapri.missouri.edu/.

[47] For more information, see CRS Report R42824, *Analysis of Renewable Identification Numbers (RINs) in the Renewable Fuel Standard (RFS)*.

[48] 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[49] 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 United States currently imports over half of its petroleum,[50] 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;[51]
- 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 certain 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.[52] Critics contend that

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[49] See Renewable Fuels Assoc. (RFA), *Position Papers* at http://www.ethanolrfa.org/pages/position-papers.

[50] DOE, EIA, *Annual Energy Review 2013*, Table A1, "Total Energy Supply and Disposition Summary," Washington, December 5, 2012, at http://www.eia.gov/forecasts/aeo/er/pdf/tbla1.pdf.

[51] For example, see John M. Urbanchuk (Technical Director, Environmental Economics), *Contribution of the Ethanol Industry to the Economy of the United States*, white paper prepared for Renewable Fuels Assoc., January 31, 2013.

[52] 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 (continued...)

biofuels are given an advantage via billions of dollars of annual subsidies that distort investment markets by redirecting venture capital and other investment 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 direct and indirect federal incentives for corn-starch ethanol production are no longer necessary since the sector is no longer in its "economic infancy" and would have been profitable in most months since 2006 without federal subsidies.[53]
- 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 continued biofuels subsidies in support of existing and future biofuels infrastructure that have the potential to affect future federal budgetary choices.

Cost Estimates of Biofuels Policy

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.[54] Most of these tax credits expired at the end of 2011, while the cellulosic biofuels production tax credit is scheduled to expire at the end of 2013.

Prior to their expiration, the combination of biofuels tax credits with other federal and state government subsidies in support of ethanol production were estimated to be in the range of $5.4 billion to $6.6 billion per year—averaging nearly $1 per gallon of biofuel produced in the United States.[55] In 2011 (the last year in which the full suite of biofuels tax credits was in effect), federal subsidies were estimated at over $7.8 billion, including nearly $7.5 billion in tax credits.[56]

With the expiration of the ethanol tax credit, estimates of federal support have fallen sharply. In 2012, following the expiration of the corn ethanol tax credit, a preliminary estimate of federal

(...continued)

Ethanol," Working Paper 07-17, AEI-Brookings Joint Center for Regulatory Studies, November 2007.

53 AgMRC (agricultural marketing resource cneter), "Renewable Energy & Climate Change," Ethanol Profitability Spreadsheet, Iowa State University Extension and Outreach, November 6, 2013 .

54 See CRS Report R42566, *Alternative Fuel and Advanced Vehicle Technology Incentives: A Summary of Federal Programs*.

55 Based on a 2007 survey of federal and state biofuel subsidies as reported in 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.

56 CRS projection based on available data various USDA and DOE sources.

biofuel subsidies (including Title IX farm bill energy programs)[57] was approximately $1.3 billion, of which slightly more than $1 billion was attributable to the biodiesel tax credit of $1.00 per gallon.

Both the cellulosic biofuels production tax credit of $1.01 per gallon and the biodiesel and renewable diesel fuel mixtures tax credit of $1.00 per gallon were extended through 2013 by the American Taxpayers Relief Act of 2012 (ATRA: P.L. 112-240). ATRA also retroactively applied the extension to biodiesel and renewable diesel fuel mixtures produced in 2012.

Proposed RFS-Related Legislation

There is currently no proposed legislation in the 113th Congress to renew or extend either of these biofuel tax credits. However, several bills propose to alter RFS mandates and EPA's waiver of E15 blending ratios.

Table 6. Selected Biofuels-Related Bills in the 113th Congress

Bill Number	Bill Name	Sponsor	Action
H.R. 550 S. 251	Phantom Fuel Reform Act of 2013	Rep. Gregg Harper Sen. Flake	To amend the RFS to require the cellulosic biofuel requirement to be based on actual production for the Jan.-Oct. period of the preceding year, pro-rated to an annual basis.
H.R. 596	Public Lands Renewable Energy Development Act of 2013	Rep. Paul Gosar	To promote the development of renewable energy on public lands.
H.R. 796	Amendment to the Clean Air Act	Rep. Sensenbrenner	To limit the cellulosic RFS mandate to be not more than 5% or 1 million gallons (whichever is greater) more than the total volume of cellulosic biofuel that was commercially available for the most recent calendar year.
H.R. 875	untitled	Rep. Sensenbrenner	To provide for a comprehensive assessment of the scientific and technical research on the implications of the use of mid-level ethanol blends (e.g., E15).
H.R. 979	Forest Products Fairness Act of 2013	Rep. Thompson	To modify the definition of the term "biobased product" to more broadly include forest products.
H.R. 1214	Domestic Fuels Protection Act of 2013	Rep. Shimkus	To provide liability protection for claims based on the design, manufacture, sale, offer for sale, introduction into commerce, or use of certain fuels and fuel additives (e.g., E15).
H.R. 1273	Rural Energy Improvement Act	Rep. Welch	To reauthorize and improve the Rural Energy for America Program (REAP).
H.R. 1461	RFS Elimination Act	Rep. Goodlatte	To repeal the RFS program of the EPA.
H.R. 1462 S. 344	RFS Reform Act of 2013	Rep. Goodlatte Sen. Wicker	To prohibit the EPA from approving the introduction into commerce of gasoline that contains greater than 10%-volume ethanol

[57] See CRS Report R41985, *Renewable Energy Programs and the Farm Bill: Status and Issues*.

Bill Number	Bill Name	Sponsor	Action
H.R. 1469	Leave Ethanol Volumes at Existing Levels (LEVEL) Act	Rep. Burgess	To limit expansion of RFS biofuel mandates, to prohibit authorization of ethanol blends greater than 10%.
H.R. 1482	RFS Amendments Act	Rep. Womak	To eliminate corn ethanol requirements under the RFS program
S. 389	Freedom Fuels Act of 2013	Sen. Baucus	To authorize long-term contracts for the procurement of certain liquid transportation fuels for the Dept. of Defense

Source: Legislative Information System of the U.S. Congress.

Notes: This is not meant to serve as a comprehensive list of all energy-related bills, but instead represents a selection of bills deemed (by CRS) most relevant to federal biofuels programs and policies.

Potential Issues with the Expanded RFS

Most U.S. biofuel 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 2000, national ethanol production was using about 6% of U.S. corn supplies; by 2012 it was expected to use about 31%.[58] The principal co-product from ethanol production—Distiller's Dried Grains or DDG—is useful as a relatively high-protein animal feed. About 30% (by weight) of corn used for biofuels is left over from the production process in the form of DDGs. The supply of DDGs has become more abundant in direct correlation with the expansion of the ethanol industry, and the U.S. livestock sector has learned how to incorporate this new feedstuff into animal and poultry rations, thus increasing both DDG value and average returns to ethanol production.

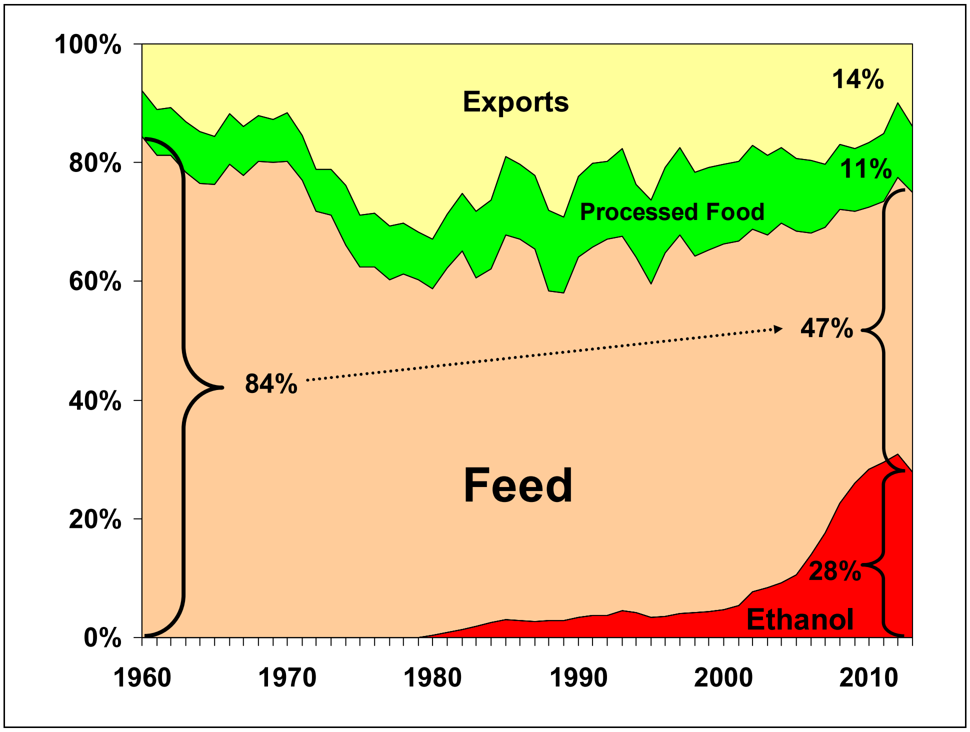
Corn use for ethanol peaked at 5,019 million bushels in 2010, then declined sharply to 4,648 million bushels during the severe drought of 2012. USDA currently estimates 2013 corn use for ethanol at 4,900 million bushels.[59] Under the expanded RFS, the 2015 corn ethanol cap of 15 billion gallons, coupled with the existing U.S. ethanol production capacity of nearly 15 billion gallons, suggests that ethanol will likely use a declining share—perhaps in the 25% to 30% range—of the volume of U.S. corn production (adjusted for DDGs) in the future, depending on yield and area developments, and petroleum market conditions.

[58] The percentage is 42% prior to adjusting for the share of Distiller's Dried Grains or DDG contained in the corn used for ethanol that is diverted to animal feed. World Agricultural Outlook Board (WAOB), USDA, *World Agr. Supply and Demand Estimates (WASDE)*, Nov. 8, 2013.

[59] Ibid.

Figure 3. Ethanol Use Grew Rapidly as Share of U.S. Corn Supply from 2005 to 2012

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



Source: USDA, Production, Supply, and Demand (PSD) database, November 8, 2013.

Note: Data are adjusted to 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 which is both used domestically and exported.

The shift towards greater corn use for biofuels that occurred from 2006 to 2010 meant higher prices for other corn users, including both the livestock and export sectors (**Figure 3**). The biofuels-driven expansion in feedstocks production (especially corn for grain and stover) has heightened competition for available cropland between biofuels feedstocks and other field crops, and has resulted in more intense agricultural activity on U.S. cropland to meet growing demand for food, feed, and fuel resources. This has consequences for several important agricultural markets, including

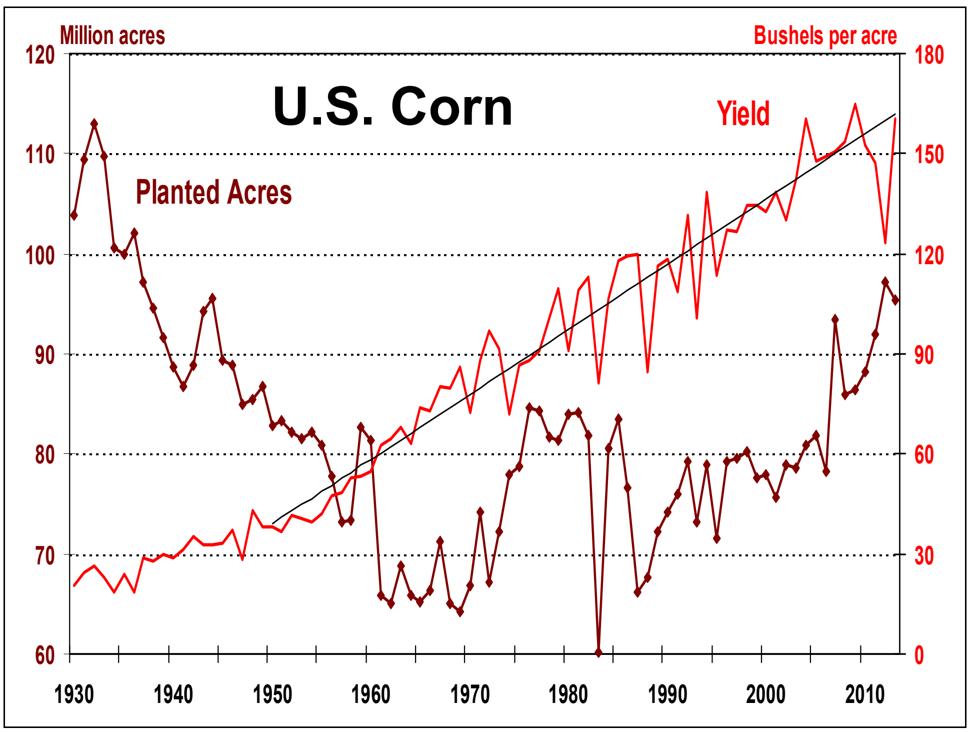
- grains—because corn competes with other grains for land;
- livestock—because animal feed costs increase with the price of corn;
- agricultural inputs—because corn is more input-intensive (in terms of fertilizers and pesticides) than other major field crops; and
- land—because the value of cropland, as well as total harvested acreage, increases with commodity prices and returns per acre.

As recently as 2004, over 60% of U.S. corn production was used as feed. The feed share of corn declined to 40% in 2011, but is expected to rebound slightly to 47% with the outlook for a record corn crop in 2013.[60]

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**). Weather-related problems, including the severe drought of 2012, pulled corn yields well below trend; however, yields are estimated to return to trend in 2013. A return to normal growing conditions is expected to replenish corn supplies, lower prices, and return the supply and demand situation to a more traditional balance.

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



Source: USDA, PSD database, as of November 8, 2013. Yield trend line calculated by CRS.

Corn Prices

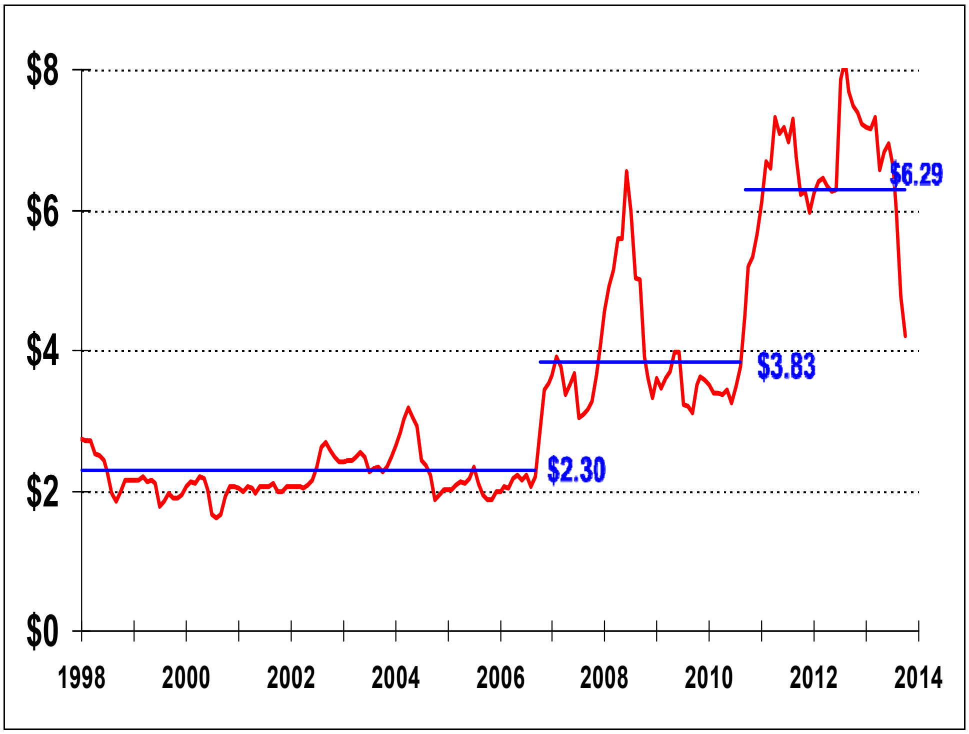
From 1998 through early 2006, the U.S. farm price of corn averaged $2.09 per bushel. However, average corn prices jumped to $3.83 per bushel during the 2006-2010 period, when the rapid expansion of the U.S. ethanol industry exceeded the growth in U.S. corn production. Unfavorable weather reduced corn yields slightly below trend in both 2010 and 2011, but the severe drought of

[60] WAOB, USDA, *WASDE*, Aug. 12, 2013.

2012 (**Figure 4**) dropped yields 23% below trend. The combination of these successive below-trend yield outcomes, in the face of continued strong demand for corn, pushed prices temporarily to a $6.29-per-bushel average during 2011 through early 2013 (**Figure 5**). The outlook for a return to trend yields and a record harvest of 14 billion bushels of corn in 2013 has since pressured prices back towards the $4.00 per bushel level. USDA projects corn prices to remain in the $4.00 to $5.00 per bushel range through 2020.[61]

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 Nov. 22, 2013.

Corn Yield and Area

It is likely that upward-trending farm prices (**Figure 5**) will encourage continued research investments to move corn yields steadily higher in the future. U.S. cropland planted to corn has increased in recent years from the 1983 low of 60.3 million acres to an estimated high of 97.2 million acres in 2012—the highest since 1936. 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.

[61] *USDA Agricultural Projections to 2022*, OCE-2013-1, Office of the Chief Economist, February 2013.

The most likely source of new corn acreage will come from shifts in crop rotation from soybeans to corn.[62] 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.[63] When farmers shift away from this rotation, corn yields tend to suffer. Planting successive corn crops—referred to as corn-on-corn cultivation—rather than in rotation with soybeans, wheat, or fallow generally produces a yield drag on successive corn crops that can lower yields anywhere from 5% to 15%, depending on soil, climate, and cultivation practices.[64] 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 million 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.

Overview of Non-Corn-Starch-Ethanol RFS Issues

EISA defines "advanced biofuels" very broadly as biofuels other than corn-starch ethanol that achieve a 50% reduction in greenhouse gas emissions relative to gasoline. 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.[65]

In the near term, it is likely that corn stover[66] will be a 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. Other potential near-term supplies include other agricultural and municipal wastes.

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[62] 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.

[63] 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.

[64] Michael Duffy and David Correll, "The Economics of Corn on Corn," *Integrated Crop Management*, IC-498 (1), February 12, 2007.

[65] See CRS Report R41106, *Meeting the Renewable Fuel Standard (RFS) Mandate for Cellulosic Biofuels: Questions and Answers*, and CRS Report R41460, *Cellulosic Ethanol: Feedstocks, Conversion Technologies, Economics, and Policy Options*.

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

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.[67] 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.

Following the EPA's substantial revisions to the first four years of cellulosic biofuels mandates (2010-2013), there has been considerable uncertainty surrounding current cellulosic biofuel conversion technologies and the cost of the conversion process (including physical, chemical, enzymatic, and microbial treatment and conversion of the biomass feedstocks into motor fuel). These uncertainties, plus the financial crisis of 2008 and the ensuing recession and credit crunch, severely curtailed new investment in the biofuels sector.[68]

However, it appears that 2013 may experience the first substantial commercial production levels of cellulosic biofuels. EPA finalized a cellulosic biofuels RFS of 6 million gallons under the expectation that two plants would begin commercial production during 2013, with possibly one more plant expected to follow by the fourth quarter of 2013.[69] However, while production from at least one of the plants has started, through October 2013 fewer than 0.6 million cellulosic RINs were registered in EPA's system[70] – significantly more than in previous years, but still well below the 2013 mandate level.

However, cellulosic fuel supply may be poised to grow rapidly, at least in relative terms. Industry reports suggest that new cellulosic biofuels plants are either in the planning stages or under construction in as many as 20 states and Canadian provinces.[71]

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

[67] 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.

[68] CRS Report R41106, *Meeting the Renewable Fuel Standard (RFS) Mandate for Cellulosic Biofuels: Questions and Answers*.

[69] EPA, "Regulation of Fuels and Fuel Additives: 2013 Renewable Fuel Standards; Final Rule," August 6, 2013, at http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm.

[70] EPA, *2013 RFS2 Data*, http://www.epa.gov/otaq/fuels/rfsdata/2013emts.htm.

[71] For example see, Advanced Ethanol Council (AEC), "Cellulosic Plants: Industry Progress Report 2012/13," December 19, 2012; and "Visible Progress in Commercialization of Advanced Biofuels, Biobased Products and Renewable Chemicals," Biotechnology Industry Organization (BIO), June 15, 2012.

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 biofuel's 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.

There are a wide range of estimates of the net energy output/input ratio for corn-starch ethanol production, although many of these are now dated. The most recent study by 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).[72] A 2.3 ratio implies that the energy contained in a gallon of corn ethanol was 130% higher than the amount of energy needed to produce and distribute it. 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.

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.[73] Some estimates are that cellulosic ethanol could have an energy balance of 8.0 or more.[74] Similarly high energy balances have been calculated for sugar-cane ethanol and certain types of biodiesel.

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[72] 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).

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

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

Energy Security[75]

Ethanol displaces gasoline, and the benefits to energy security from ethanol, while relatively small, are still potentially important. However, biofuels' potential to play a larger role in energy security is questionable. Roughly 40% of the U.S. corn crop was used for ethanol in 2012, and the resultant ethanol accounted for about 7% of gasoline consumption on an energy-equivalent basis.[76] There is considerable uncertainty regarding how quickly or how much U.S. corn production can expand. If the entire 2012 U.S. corn crop of 10.8 billion bushels were used as ethanol feedstock, the resultant 30 billion gallons of ethanol (20.6 billion gasoline-equivalent gallons, or GEG) would represent about 16% of estimated national gasoline use of approximately 132 billion gallons.[77]

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 about 20% of gasoline energy transportation fuel demand and 2.4% of diesel transportation fuel demand.[78]

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 may also provide an incentive for imports of biodiesel and other renewable diesel substitutes from tropical countries, although EPA has determined that biodiesel from palm oil does not meet the necessary greenhouse gas reductions. The supplies 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 thought to be so high for some biofuels, especially cellulosic biofuels and biodiesel from algae, that significant technological advances—or significant increases in petroleum prices—would be necessary to make them competitive with gasoline.[79]

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[75] 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.

[76] By volume, ethanol accounted for nearly 10% of gasoline consumption in the United States in 2012, but a gallon of ethanol yields only about 68% of the energy of a gallon of gasoline.

[77] This estimate is based on DOE, EIA, *Annual Energy Review 2013*, Table A1, "Total Energy Supply and Disposition Summary," Washington, December 5, 2012,, and USDA's February 8, 2013, *WASDE Report*, using comparable conversion rates.

[78] Calculated by CRS based on EIA's 2013 Energy Outlook and the assumption that the BBD RFS remains fixed at 1.28 bgals through 2022.

[79] Plant-level cost-of-production (COP) data is proprietary and not readily available to the general public. News reports vary widely in their estimates of per-gallon COP for cellulosic biofuels. Furthermore, since commercial production of (continued...)

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 bio-butanol 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

Unlike petroleum products, ethanol and ethanol-blended gasoline cannot be shipped in existing U.S. pipeline infrastructure. Ethanol-blended gasoline tends to separate in pipelines due to the presence of water in the lines.[80] Further, ethanol is corrosive and may damage existing pipelines and storage tanks. Also, 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 coasts 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 on a large scale.[81]

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.

(...continued)

cellulosic biofuels is as yet minimal, most COP estimates are based on laboratory data which may not be representative of commercial scale costs.

[80] John Whims, "Pipeline Considerations for Ethanol," AgMRC, Sparks Companies, Inc., August 2002.

[81] For a DOE study of the economic feasibility of a hypothetical ethanol pipeline linking large East Coast demand centers with a stable supply from the Midwest, see "Report to Congress: Dedicated Ethanol Pipeline Feasibility Study," March 2010, at http://www1.eere.energy.gov/biomass/pdfs/report_to_congress_ethanol_pipeline.pdf.

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.

The Blend Wall and Higher-Level Ethanol Blends

It is now estimated that almost all gasoline sold in the United States contains some ethanol (mostly blended at the 10% level). 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 warrant 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.[82] If most or all gasoline in the country contained 10% ethanol, this would allow only for roughly 13 billion gallons, far less than the RFS mandates for 2013 onward—13.8 billion gallons in 2013; 14.4 billion in 2014; and 15 billion in 2015.

For ethanol consumption to exceed the so-called "blend wall" and meet the RFS mandates, increased consumption at higher blending ratios is likely 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.[83] According to the Renewable Fuel Association (RFA), the approval of E15 use in model year 2001 and newer passenger vehicles covered 62% of passenger vehicles on U.S. roads at the end of 2010.[84]

However, the EPA waiver for E15 is not sufficient, in and of itself, to ensure higher blending ratios. Fuel producers must also register new fuel blends and submit health effects testing to EPA. Further, numerous other changes have to occur before large numbers of gasoline 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, is likely to limit rapid expansion of blending rates. EPA acknowledged this infrastructure limitation when it stated,[85]

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

[83] For details, see EPA online information site, "E15 (a blend of gasoline and ethanol)," at http://www.epa.gov/otaq/regs/fuels/additive/e15/.

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

[85] EPA, "EPA Finalizes 2013 Renewable Fuel Standards," EPA-420-F-13-042, August 2013.

> EPA recognizes that ethanol will likely continue to predominate the renewable fuel pool in the near future, and that for 2014 the ability of the market to consume ethanol in higher blends such as E85 is highly constrained as a result of infrastructure- and market-related factors. EPA does not currently foresee a scenario in which the market could consume enough ethanol sold in blends greater than E10, and/or produce sufficient volumes of non-ethanol biofuels to meet the volumes of total renewable fuel and advanced biofuel as required by statute for 2014.

Moreover, a group of engine and equipment manufacturers 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 misfueling.[86] In response to these concerns, EPA requires E15 suppliers to submit to the agency misfueling mitigation plans (MMP).[87] Concerns over a preliminary MMP that required a four-gallon minimum purchase from some pumps supplying both E15 and E10 led to a new MMP that EPA approved in February 2013 that eliminates the four-gallon requirement as long as a fuel station has at least one dedicated E10 (or lower) pump to fuel older passenger cars and light trucks as well as non-road vehicles/engines.[88]

The blend wall problem is made more acute by substantial revisions in EIA's projections of U.S. transportation fuel consumption rates since the RFS was first passed into law in 2007 (**Figure 6**). At that time, EIA estimated that U.S. transportation consumers were using about 145 billion gallons of gasoline (including ethanol) per year, but that consumption would grow strongly to 176 billion gallons of gasoline by 2022—as a result, RFS mandated biofuels would represent about 19% of annual gasoline consumption. By 2013, EIA had substantially lowered its fuel consumption outlook—partly due to sustained high petroleum prices, the prolonged effects of the 2008 financial crises on consumer incomes, and significantly higher fuel economy standards on new vehicles. Instead of growth, EIA projects gasoline consumption to fall to about 120 billion gallons by 2022, thus causing the RFS mandate's share of the gasoline transportation fuel market (if left unchanged) to grow to nearly 20% of annual consumption (in gasoline-equivalent gallons).[89]

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

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[86] 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*. In August 2012 the D.C. Circuit held that the petitioners lacked standing because no engine or equipment owners had been injured *in fact* because little or no E15 had been introduced into commerce.

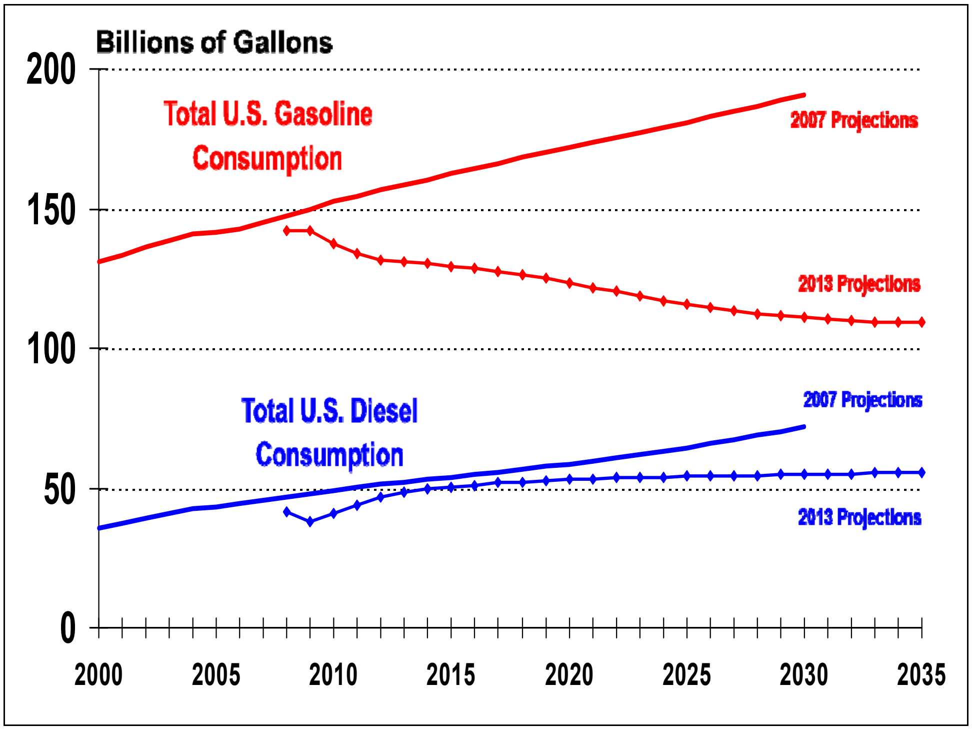
[87] See EPA online information site, "E15: Misfueling Mitigation Plans," at http://www.epa.gov/otaq/regs/fuels/additive/e15/e15-mmp.htm.

[88] Ibid.

[89] Data are from EIA/DOE's 2013 Annual Energy Outlook. EIA also projects the U.S. national biodiesel transportation fuel market to show slow but steady growth (at about 1% per year) from about 47 bgals in 2012 to nearly 54 bgals by 2022. As a result, RFS BBD's share of the biodiesel transportation fuel market is projected to remain steady at about 2.5% through 2022.

$200,000.[90] However, if existing equipment can be used with little modification, the cost could be less than $10,000.

Figure 6. EIA Long-Term Projections of U.S. National Transportation Fuel Use



Source: DOE, EIA, *Annual Energy Review 2007* and *Annual Energy Review 2013*.

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.[91] 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 has slowed during the recession, making it more difficult to integrate FFVs into the fleet.

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

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

Ethanol RINs and the Blend Wall

In the face of a looming blend wall, the status of available RIN stocks of renewable and advanced biofuels for use by obligated parties towards mandate compliance remains an important issue.[92] Current RIN stocks in mid-2013 are estimated at approximately 2.5 billion gallons, of which 2 billion gallons are D6 RINs which can only be used for compliance with the renewable portion of the RFS mandate. However, RIN stocks were expected to tighten substantially in 2014 as a large portion of existing RINs is used for current mandate compliance as well as a scheduled increase in the RFS mandates for all categories in 2014. As a result, the price of renewable fuel RINs increased dramatically in the first half of 2013. Spot prices for ethanol RINs averaged between $0.07 and $0.08 per gallon in the first weeks of January. However, in the first week of March 2013, ethanol RINs averaged roughly $0.76 per gallon—a nine-fold increase.[93] By July 2013, RIN prices have pushed past $1.00 per gallon. In the second half of the year RIN prices dropped steadily with the expectation that EPA might use its waiver authority to lower the 2014 mandates below the 2013 levels, as the agency ultimately proposed in November 2013.

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, particularly corn, and questions about the net energy and environmental benefits they might provide. Further, rapid expansion of biofuels production based on traditional field crops such as corn 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 (including biofuels from nontraditional feedstock sources) are widely seen as warranting consideration.

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[92] Nick Paulson, "RIN Update: Advanced and Renewable RIN Generation in 2013," http://farmdocdaily.com, July 31, 2013.

[93] "Ethanol & Gasoline Component Spot Market Prices," *OPIS Ethanol and Biodiesel Information Service*, various dates.

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