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Renewable Fuel Standard (RFS): Overview and Issues

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Summary

Federal policy has played a key role in the emergence of the U.S. biofuels industry. Policy measures include minimum renewable fuel usage requirements, blending and production tax credits, an import tariff, loans and loan guarantees, and research grants. 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, as well as 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 date 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, but with considerable uncertainty regarding potential spillover effects in other markets and on other important policy goals. Emerging resource constraints related to the rapid expansion of U.S. corn ethanol production have provoked questions about its long-run sustainability and the possibility of unintended consequences in other markets as well as on the environment. Questions also exist about the ability of the U.S. biofuels industry to meet the expanding mandate for biofuels from non-corn sources such as cellulosic biomass materials, whose production capacity has been slow to develop, or biomass-based biodiesel, which remains expensive to produce owing to the relatively high prices of its feedstocks. Finally, considerable uncertainty remains regarding the development of the infrastructure capacity (e.g., trucks, pipelines, pumps, etc.) needed to deliver the expanding biofuels mandate to consumers.

Contents

Figures

Tables

Contacts

Introduction

Increasing dependence on foreign sources of crude oil, concerns over global climate change, and the desire to promote domestic rural economies have raised interest in renewable biofuels as an alternative to petroleum in the U.S. transportation sector. In response to this interest, U.S. policymakers have enacted an increasing variety of policies, at both the state and federal levels, to directly support U.S. biofuels production and use (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*.

[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.

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.

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[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 non-corn starch	Cellulosic	Biomass-based diesel	Other[a]
2006	4.0	—	—	—	—	—	—
2007	4.7	—	—	—	—	—	—
2008	5.4	9.00	9.0	0.00	0.00	0.00	0.00
2009	6.1	11.10	10.5	0.60	0.00	0.00	0.10
2010	6.8	12.95	12.0	0.95	0.0065[b]	1.15[c]	0.29
2011	7.4	13.95	12.6	1.35	0.006[d]	0.80	0.54
2012	7.5	15.20	13.2	2.00	0.00[e]	1.00	1.00
2013	7.6 (est.)	16.55	13.8	2.75	0.014[f]	1.28[f]	1.46
2014	7.7 (est.)	18.15	14.4	3.75	1.75	[g]	1.00
2015	7.8 (est.)	20.50	15.0	5.50	3.00	[g]	1.50
2016	7.9 (est.)	22.25	15.0	7.25	4.25	[g]	2.00
2017	8.1 (est.)	24.00	15.0	9.00	5.50	[g]	2.50
2018	8.2 (est.)	26.00	15.0	11.00	7.00	[g]	3.00
2019	8.3 (est.)	28.00	15.0	13.00	8.50	[g]	3.50
2020	8.4 (est.)	30.00	15.0	15.00	10.50	[g]	3.50
2021	8.5 (est.)	33.00	15.0	18.00	13.50	[g]	3.50
2022	8.6 (est.)	36.00	15.0	21.00	16.00	[g]	4.00
2023	—	[h]	[h]	[h]	[h]	[h]	[h]

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

a. "Other" advanced biofuels is a residual category left over after the ethanol-equivalent gallons of cellulosic and biodiesel biofuels are subtracted from the "Total" advanced biofuels mandate.

b. 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.

c. 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.

d. 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.

e. 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.

f. The initial 2013 cellulosic RFS was 1 bgals. In January 2013, EPA revised this mandate to 14 million ethanol-equivalent gals. The 2013 biodiesel mandate was revised upwards from 1 bgals to 1.28 bgals actual volume.

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

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

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 subject to biomass feedstock criteria.

- **Total renewable fuels**. The mandate grows from nearly 13 billion gallons (bgals) in 2010 to 36 bgals in 2022. Biofuels must reduce lifecycle GHG emissions by at least 20% 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 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, and 2012, and are proposed to be lowered in 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.
- **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).

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[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" potentially includes ethanol from sugar cane, despite the fact that Brazilian sugar growers have been producing fuel ethanol for decades.

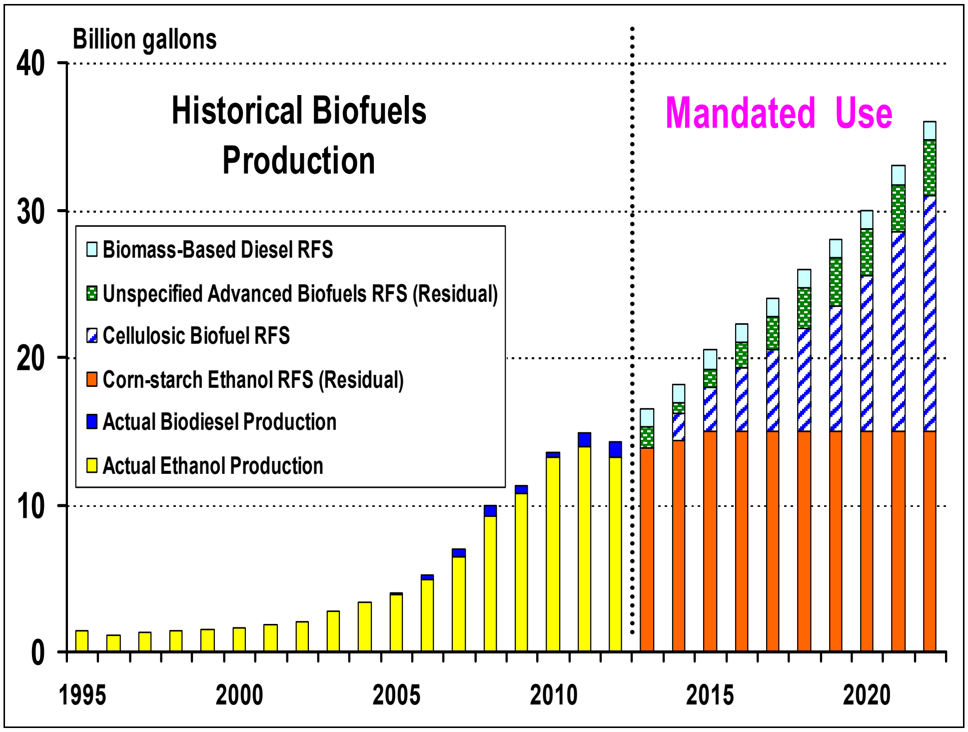
[11] As part of its February 3, 2010, final rule, EPA announced a revision in the BBD standard for 2010 to 1.15 bgals. This revision represents a summation of the 2009 standard of 0.5 bgals with the 2010 standard of 0.65 bgals. The RFS1 regulatory system, which was in effect during 2009 and which was 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.

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.

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 Energy Information Agency (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).

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.

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.[13] EISA established lifecycle GHG emission thresholds for each of the RFS2 biofuels categories (**Table 2**). With respect to the GHG emissions assessments, EISA specifically directed EPA to evaluate the aggregate quantity of GHG emissions (including direct emissions and significant indirect emissions, such as significant emissions from land use changes) related to the full lifecycle, including all stages of fuel and feedstock production, distribution, and use by the ultimate consumer.

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

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

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

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

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

Fuel Pathways (including ILUC) Meeting Lifecycle GHG Thresholds

EPA's initial measurement of lifecycle GHG reductions for various biofuels pathways under RFS1 was viewed as contentious by some due to the explicit requirement to incorporate so-called "indirect land use changes" (ILUC) in the GHG emissions assessment.[14] 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.

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 made relevant adjustments to its analytical tools. The resultant changes were announced as part of its final RFS2 rule of February 3, 2010.[15]

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

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

[15] 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)*.

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 either existed or commenced construction prior to December 19, 2007.
- 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 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 grain sorghum at dry mill facilities that use specified forms of biogas for both process energy and most electricity production.

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.

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.[16] 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.[17] 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.[18] For other biofuel pathways not yet modeled, EPA encourages parties to use a petition process to request EPA to examine additional pathways.

Grandfathered Plants

Fuel from the capacity of facilities that either existed or commenced construction prior to December 19, 2007 (the date of enactment of EISA), 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."[19] 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.

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[16] 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.

[17] 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.

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

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

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:[20]

- 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.[21] 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.

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 transportation fuel that is expected to be used in the United States during the upcoming year. EPA relies on projections from the Department of Energy's Energy Information Agency (EIA) for this estimate.[22] The 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 Energy Information Agency (EIA) of the Department of Energy (DOE). 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,

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

[21] 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/.

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

and on a final basis by November 30 of the preceding year.[23] 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. Proposed RFS Standards for 2013

RFS Category	Percentage Ratio (%)	Volume of Renewable Fuel (billion gallons)
Cellulosic biofuels	0.008%	0.014
Biomass-based diesel	1.12%	1.28
Advanced biofuels	1.60%	2.75
Total renewable fuel	9.63%	16.55

Source: EPA, "Regulation of Fuels and Fuel Additives: 2013 Renewable Fuel Standards; Proposed Rule," *Federal Register,* vol. 78, no. 26, February 7, 2013, pp. 9282-9306.

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

Determining an Individual Company's Obligation

The RFS mandates (by biofuel category) are ultimately enforced on retail fuel blenders and exporters (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.[24]

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.

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[23] EPA, 40 C.F.R. Part 80, Final Rule, Feb. 3, 2010, p. 14675.

[24] U.S. Code, "Regulation of fuels," 42 USC 7545.

Waivers to Annual Biofuel Standards

EISA requires that EPA evaluate and make an appropriate market determination for setting the cellulosic standard each year. As part of this process, EPA announced that it will issue a notice of proposed rulemaking by summer and a final rule by November 30 of each year to set the renewable fuel standard for each ensuing year.[25] Pursuant to this task, the EPA Administrator has the authority to waive the RFS requirements, in whole or in part, if, in her determination, there is inadequate domestic supply to meet the mandate, or if "implementation of the requirement would severely harm the economy or environment of a State, a region, or the United States."[26] Further, under certain conditions, the EPA administrator may waive (in whole or in part) the specific carve-outs for cellulosic biofuel and biomass-based diesel fuel.

For example, in each of the years 2010 through 2013 EPA has waived or proposed waiving most of the original RFS mandates for cellulosic biofuels, 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.[27]
- In November 2010, EPA lowered the 2011 RFS for cellulosic biofuels to 6 mgals (ethanol equivalent), down from its original 250 mgals.[28]
- In December 2011, EPA lowered the 2012 RFS for cellulosic biofuels to 8.65 mgals (ethanol equivalent), down from its original 500 mgals.[29]
- In January 2013, EPA proposed to lower the 2013 RFS for cellulosic biofuels to 14 mgals (ethanol equivalent), down from its original 1 billion gallons.[30]

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 biofuel RINs were registered in 2012 (20,069 gallons), while no commercial production was reported in 2010 and 2011.[31] The downward revisions for 2010 through 2013 suggest that the actual cellulosic biofuels standard for future years, although explicitly listed in **Table 1**, is uncertain.

In addition to waivers associated with the annual RFS review process, EPA may respond to waiver requests resulting from unusual circumstances. For example, in 2008 the governor of Texas requested a waiver of the RFS because of high grain prices; however, that waiver request

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[25] 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.

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

[27] 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.

[28] 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.

[29] 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.

[30] EPA Proposes the 2013 requirements in February 2013. EPA, "EPA Proposes 2013 Renewable Fuel Standards," EPA-420-F-13-007, January 2013.

[31] 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/.

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. In both cases, the petition was ultimately denied.[32]

Cellulosic Biofuel Waiver Credits

If EPA reduces the required volume of cellulosic biofuel according to the waiver provisions in EISA, EPA will 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. 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 a proposed $0.42 (or 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 2013.

Unachieved Cellulosic Biofuels Mandates

After three successive years (2010-2012) where, first, EPA lowered the cellulosic biofuels mandate and, then, cellulosic biofuels production failed to achieve the lowered mandates, the American Petroleum Institute (API), in 2012, challenged the obligation under the RFS to use cellulosic biofuels that do not exist in sufficient amounts in commercial markets or pay a fee. API petitioned the U.S. Court of Appeals, D.C., charging that EPA exceeded its authority by setting unachievable 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).[33] Then, on March 13, 2013, EPA also announced that it was voluntarily, retroactively lowering the 2011 RFS to zero.[34]

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.[35] Each

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[32] 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.

[33] EPA, "Update—2012 Cellulosic Biofuel Standard Mandate Issued," *EnviroFlash,* mailto:enviroflash@epa.govFebruary 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.

[34] Amanda Peterka, "EPA to File Motion Taking Back 2011 Cellulosic Decision," *Greenwire*, E&E Publishing, LLC, March 13, 2013.

[35] 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.

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**).

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).

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.

Any party that owns RINs at any point during the year (including domestic and foreign producers, refiners, exporters, and importers of renewable fuels) must register with the EPA and follow RIN record-keeping and reporting guidelines. RINs can only be generated if it can be established that the feedstock from which the fuel was made meets EISA's definitions of renewable biomass, including land restrictions. The feedstock affirmation and record-keeping requirements apply to RINs generated by both domestic renewable fuel producers and RIN-generating foreign renewable fuel producers or importers. After a RIN is created by a biofuel producer or importer, it must be reported to the EPA (usually on a quarterly basis). When biofuels change ownership (e.g., are sold by a producer to a blender), the RINs are also transferred. When a renewable fuel is blended for retail sale or at the port of embarkation for export, the RIN is separated from the fuel and maybe used for compliance or trade. The Code K status of the RIN is changed at separation.

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

In addition to compliance demonstration, RINs can be used for credit trading. When a fuel supplier has blended or sold a quantity of biofuel, the RINs are detached 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 supplier (who has failed to meet its mandate for that same biofuel standard) 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). 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 of biofuels. Because four separate biofuel mandates must be met, the RIN value may vary across the individual biofuel categories.[36] Since the RFS biofuels categories are nested, the price of RINs for

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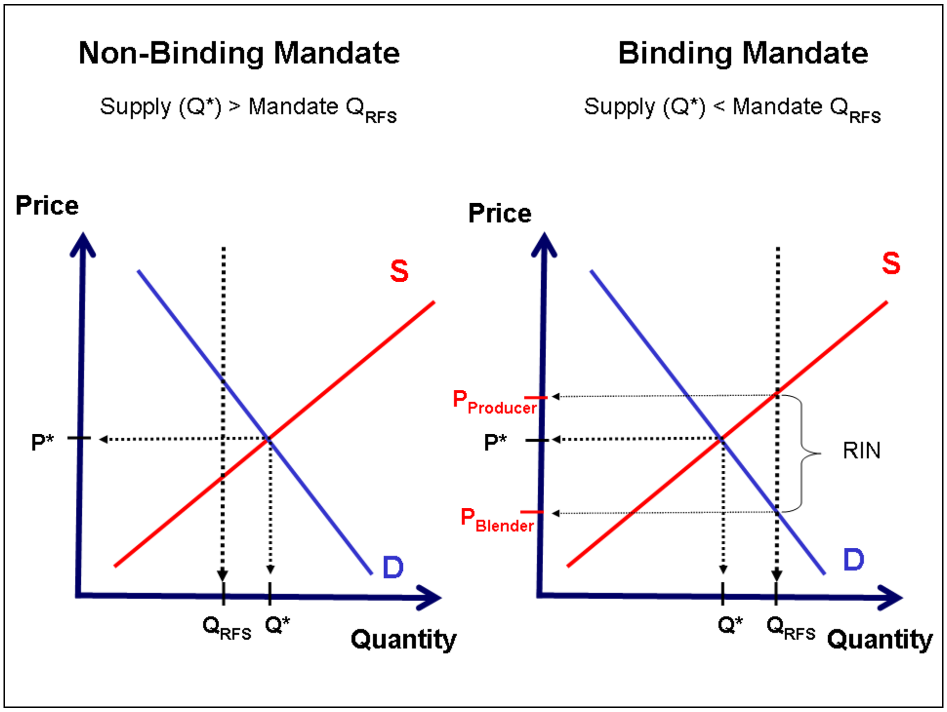
[36] For example, this was the case in late 2010. The biodiesel production tax credit of $1.00 per gallon had expired at the end of 2009 and subsequent biodiesel production dropped in 2010, potentially below that needed to meet the combined 2009/2010 mandate. As a result, biomass-based diesel RINs were 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 (continued...)

specific sub-mandates (e.g., cellulosic biofuels or biodiesel) must be equal to or greater than the price of RINs for advanced biofuels which, in turn is equal to or greater than the RIN value for total renewable biofuels. Thus, RIN values may vary across RFS categories as well as geographically with variations in specific biofuels supply and demand conditions.

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.

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.[37] 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}).

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 biofuels blenders 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

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(...continued)

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.

[37] 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.

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. To date, the overall biofuels mandates have not been binding and until recently general renewable fuel RIN values generally have been small. It is expected that, if the RFS becomes binding, fuel suppliers will pass the added cost of biofuels acquisition (i.e., the RIN value), on to motor fuel consumers in the form of higher fuel prices.[38]

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.[39]

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.[40] 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.

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[38] Ibid., p. 46.

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

[40] 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 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.
- **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[41] 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,[42] 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;[43]
- 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:

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

[42] 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.

[43] 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.

- By picking the "winner," policymakers may exclude or retard the development of other, potentially preferable alternative energy sources.[44] Critics contend that biofuels are given an advantage via billions of dollars of annual subsidies that distort investment markets by redirecting venture capital and other investment dollars away from competing alternative energy sources. Instead, these critics have argued for a more "technology-neutral" policy such as a carbon tax, a cap-and-trade system of carbon credits, or a floor price on imported petroleum.
- Continued large federal incentives for 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.[45]
- 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.

The Increasing Cost of Biofuels Policy

A 2007 survey of federal and state government subsidies in support of ethanol production reported that total annual federal support fell somewhere in the range of \$5.4 billion to \$6.6 billion per year—nearly \$1 per gallon of biofuel produced in the United States.[46] In 2011 (prior to the expiration of various tax credits on December 31, 2011), federal subsidies were estimated at over \$7.8 billion, including nearly \$7.5 billion in tax credits.[47] In 2012, following the expiration of the corn ethanol tax credit, a preliminary estimate of federal biofuel subsidies (including Title IX farm bill energy programs)[48] is approximately \$1.3 billion, of which slightly more than \$1 billion is attributable to the biodiesel tax credit of \$1.00 per gallon.

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.[49] Most of these tax credits expired at the end of 2011, while the cellulosic biofuels

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

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

[46] 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.

[47] CRS projection based on available data various USDA and DOE sources.

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

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

production tax credit expired at the end of 2012. On January 2, 2013, 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.

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 40%.[50]

Under the expanded RFS, the 2015 corn ethanol cap of 15 billion gallons—coupled with the existing U.S. ethanol production capacity of nearly 14 billion gallons—suggests that corn ethanol will continue to use about 40% of the volume of U.S. corn production for several years to come, depending on yield and area developments.[51] This significant shift towards greater corn use for biofuels has 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.

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

- energy markets—because natural gas is a key input in both corn and ethanol production (although the recent growth in U.S. production of natural gas under new fracking methods has largely diminished this aspect);
- water quality—because expanding corn-based ethanol production likely involves heavier use of farm chemicals with increased potential for run-off or leaching;
- water resource availability—because water plays a crucial role in all stages of biofuels production, from cultivation of feedstocks through their conversion into

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[50] World Agr. Outlook Board (WAOB), USDA, *World Agr. Supply and Demand Estimates (WASDE)*, Feb. 8, 2013.

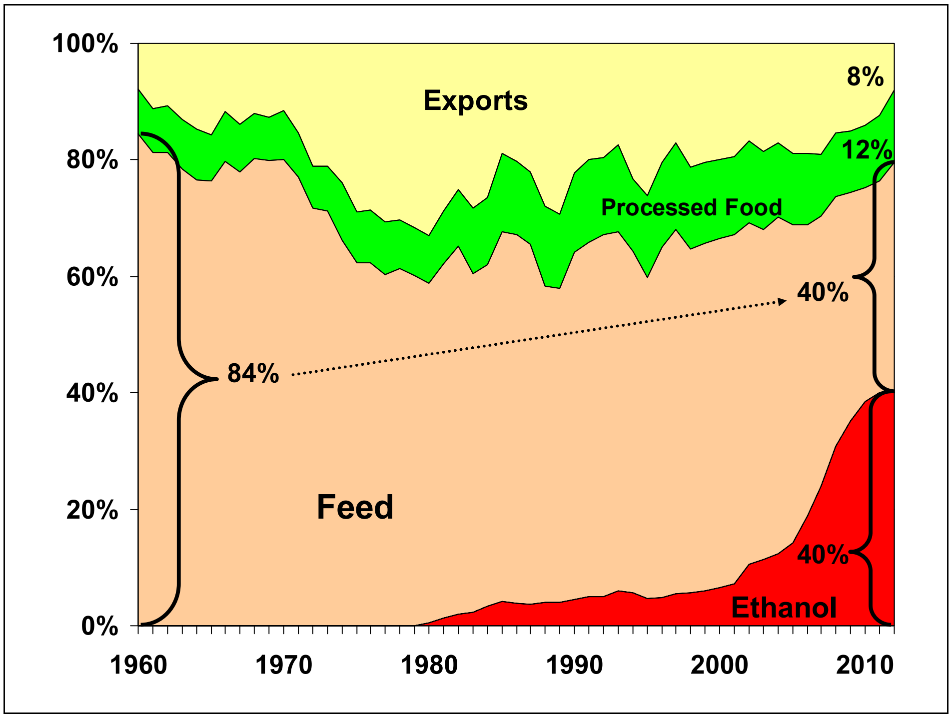
[51] *USDA Agricultural Projections to 2022*, OCE-2013-1, Office of the Chief Economist, February 2013.

biofuels, yet there remain many uncertainties about national and regional effects of increased biofuels production on water resources;[52]

- soil fertility—because several potential biofuels activities (including intensive year-over-year corn production, diversion of corn stover to cellulosic biofuels production and away from field retention as a soil amendment under low-till cultivation, and the expansion of biofuels feedstock cultivation on marginal land) could result in diminished soil fertility and/or increased erosion;
- wildlife habitat—because expanding biofuels feedstock production on marginal lands traditionally left fallow under a conserving practice could compete with wildlife and fowl habitat; and
- federal budget exposure—because applying the federal cellulosic biofuels production tax credit of $1.01 per gallon to the RFS requirements produces an annual budget liability of $16 billion by 2022 (assuming that the tax credit is extended and that the cellulosic mandate is met).

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

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



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

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

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

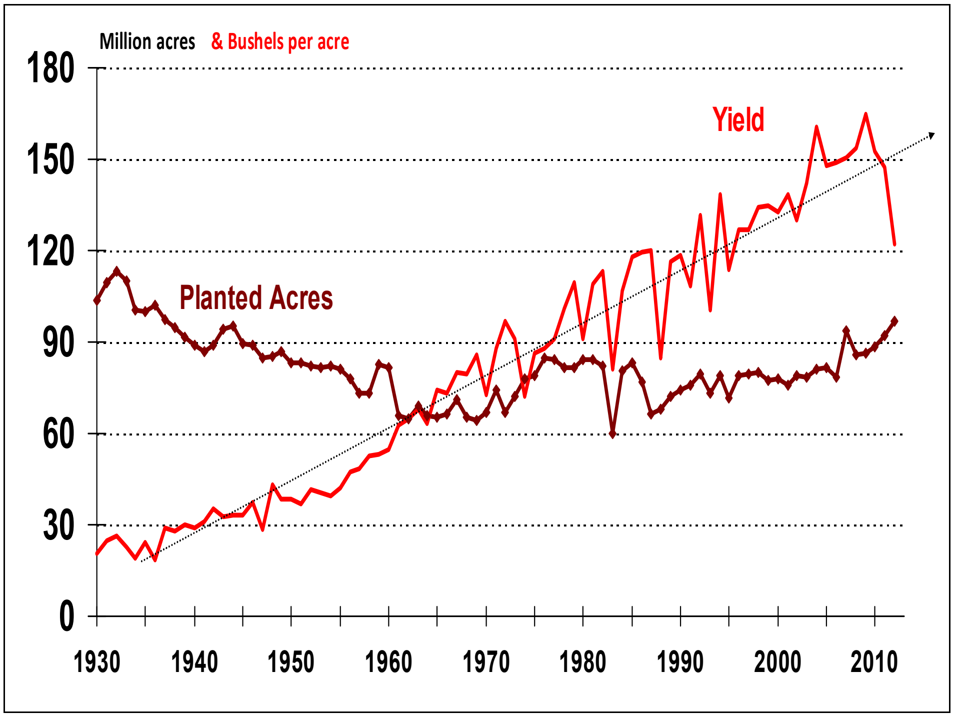
Overview of Long-Run Corn Ethanol Supply Issues

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**). However, since achieving a record 164.7 bushels/acre in 2009, U.S. corn yields have experienced three consecutive years of decline (related to unfavorable precipitation and temperature conditions at critical points in the growing season), to the point where the 2012 national corn yield estimate of 122.3 bushels/acre is the lowest yield since 1995.

Corn Prices

Expanding U.S. corn production has only partially offset the rapid growth in demand following the rapid expansion of the U.S. ethanol industry that has occurred since 2005. As a result, corn prices have trended steadily upward in direct relation to the added growth in demand from the ethanol sector (**Figure 5**). USDA projects corn prices to remain in the $4 to $5 per bushel range through 2020, compared with an average farm price of $2.15 per bushel during the 10-year period from 1997 to 2006.[53]

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



Source: USDA, PSD database, as of February 8, 2013.

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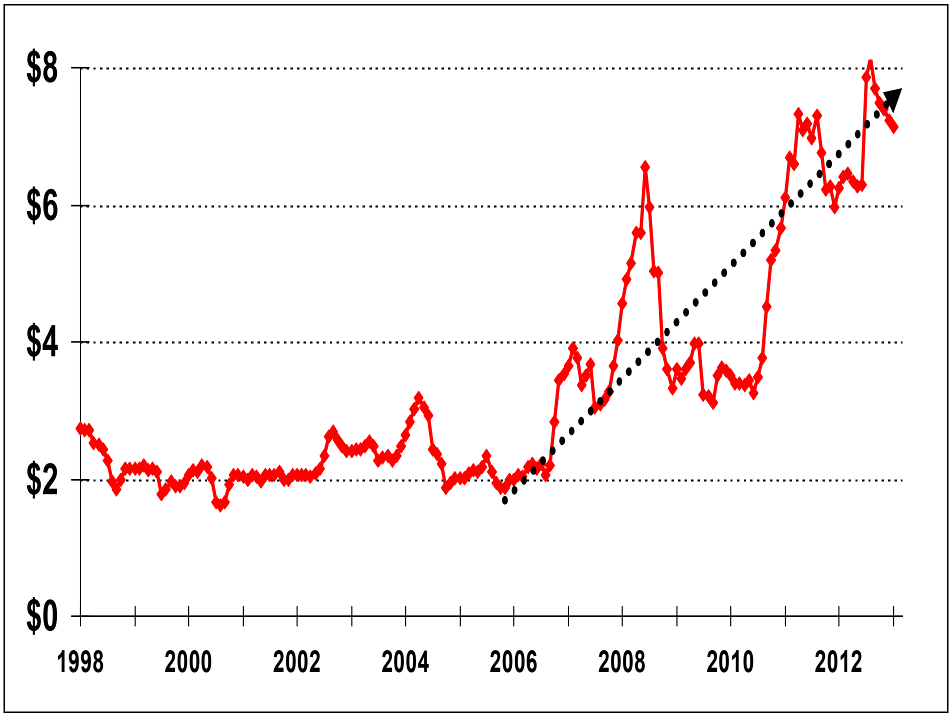
[53] *USDA Agricultural Projections to 2022*, OCE-2013-1, Office of the Chief Economist, February 2013.

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 Feb. 26, 2013.

Corn Yields

It is likely that upward-trending farm prices (**Figure 5**) will encourage continued research investments to move corn yields steadily higher in the future. However, even slight differences in the long-run growth rate portend large impacts in the price outlook. Some economists think that yield increases will slow in coming decades because of land degradation and the impact of climate change. Others suggest that dramatic developments in bio-engineering and seed technology will push corn yields sharply higher. A prime example of the differences in U.S. corn yield outlooks is the contrast between USDA, whose economists project U.S. corn yields to reach about 240 bushels per acre by 2050, and the scientists of the biotech seed company Monsanto, who predict that corn yields will be much higher—as much as 300 bushels per acre—by 2030.[54] According to USDA, achieving "300-bushel corn" by 2030 would require an extraordinary deviation (a tripling) from both projected and accelerated corn yield trends, and would be historically unprecedented.[55]

Corn Area

U.S. cropland planted to corn has increased in recent years from the 1983 low of 60.3 million acres to as high as 97.2 million acres in 2012. Prospects for further expansion in crop area are far

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

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

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. In addition, 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.

Corn-Soybean Rotation

The most likely source of new corn acreage will come from shifts in crop rotation from soybeans to corn.[56] 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.[57] When farmers shift away from this rotation, corn yields tend to suffer. Planting corn-on-corn in two consecutive years usually results in a 5% to 15% yield decline in the second year.[58] 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. 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.[59]

In the near term, it is likely that corn stover[60] 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

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[56] 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.

[57] 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.

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

[59] 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*.

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

some scale economies. However, stover-to-biofuel conversion has its own set of potential environmental trade-offs, paramount of which is the dilemma of sacrificing soil fertility gains by harvesting the stover rather than returning it to the soil under no- or minimum-tillage practices.

Cellulosic Biofuels Production Uncertainties

There are substantial uncertainties regarding both the costs of producing cellulosic feedstocks and the costs of producing biofuels from those feedstocks. Dedicated perennial crops are often slow to establish, and it can take several years before a marketable crop is produced. Crops heavy in cellulose tend to be bulky and represent significant problems in terms of harvesting, transporting, and storing. New harvesting machinery would need to be developed to guarantee an economic supply of cellulosic feedstocks.[61] 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 three years of cellulosic biofuels mandates (2010-2012) and a proposed revision for the fourth year (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.[62] However, it appears that 2013 will experience the first substantial commercial production levels of cellulosic biofuels. EPA has proposed a cellulosic biofuels RFS of 14 million gallons under the expectation that two plants will begin commercial production during the first quarter of 2013, with at least two more plants expected to follow by the fourth quarter of 2013.[63] In addition, 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.[64]

Unintended Policy Outcomes of the "Advanced Biofuels" Mandate

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

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[61] 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.

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

[63] EPA, "Regulation of Fuels and Fuel Additives: 2013 Renewable Fuel Standards; Proposed Rule," *Federal Register,* Vol. 78, No. 26, February 7, 2013, pp. 9282-9306.

[64] 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.

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

Energy Supply Issues

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

Energy Balance

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

Estimates of the net energy output/input ratio for corn-starch ethanol production are 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).[65] 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.[66] Some estimates are that cellulosic ethanol could have an energy balance of 8.0 or more.[67] Similarly high energy balances have been calculated for sugar-cane ethanol and certain types of biodiesel.

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[65] 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).

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

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

Natural Gas Demand

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

The United States has been a net importer of natural gas since the early 1980s, although the vast majority of this gas comes via pipeline from Canada. However, recent technological breakthroughs in accessing gas shale have the potential to alter long-run U.S. natural gas supplies. As a result, processing energy has diminished as an issue for biofuels production.

Energy Security[68]

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 only accounts for about 7% of gasoline consumption on an energy-equivalent basis.[69] 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.[70] In contrast, the import share of U.S. liquid fuel consumption (crude oil and other petroleum products) was estimated at 66% in 2011.[71]

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.[72]

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

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[68] 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.

[69] 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.

[70] 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.

[71] 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.

[72] 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.

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.[73] Without cost reductions, mandating large amounts of these fuels would likely raise fuel prices. If a price were placed on greenhouse gas emissions—perhaps through the enactment of a carbon tax—then the economics could shift in favor of these fuels despite their high production costs, as they have lower fuel-cycle and life-cycle greenhouse gas emissions (see below).

Ethanol Infrastructure and Distribution Issues

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

Distribution Issues

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.[74] 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 coast to other coastal cities and into the interior of the country. While some studies have concluded that shipping ethanol or ethanol-blended gasoline via pipeline could be feasible, no major U.S. pipeline has made the investments to allow such shipments.[75]

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

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

[75] 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.

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

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

The Blend Wall and Higher-Level Ethanol Blends

More than half of all U.S. gasoline contains some ethanol (mostly blended at the 10% level or lower). A key benefit of gasoline-ethanol blends up to 10% ethanol is that they are compatible with existing vehicles and infrastructure (fuel tanks, retail pumps, etc.). All automakers that produce cars and light trucks for the U.S. market warranty their vehicles to run on gasoline with up to 10% ethanol (E10). As a result, this 10% blend has represented an upper bound (sometimes referred to as the "blend wall") to the amount of ethanol that can be introduced into the gasoline pool.[76] 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.

For ethanol consumption to exceed the so-called "blend wall" and meet the RFS mandates, increased consumption at higher blending ratios is needed. For example, raising the blending limit from 10% to a higher ratio such as 15% or 20% would immediately expand the "blend wall" to somewhere in the range of 20 billion to 27 billion gallons. The U.S. ethanol industry is a strong proponent of raising the blending ratio.

In response to industry concerns regarding the impending blend wall, the EPA, after substantial vehicle testing, issued a partial waiver for gasoline that contains up to a 15% ethanol blend (E15) for use in model year 2001 or newer light-duty motor vehicles (i.e., passenger cars, light-duty trucks, and sport utility vehicles), but announced that no waiver would be granted for E15 use in model year 2000 and older light-duty motor vehicles, as well as in any motorcycles, heavy duty vehicles, or non-road engines.[77] According to the Renewable Fuel Association (RFA), the

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

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

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.[78]

In addition to the EPA waiver decision, fuel producers needed to register the 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, are likely to limit rapid expansion of blending rates. 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.[79] In response to these concerns, EPA requires E15 suppliers to submit to the agency misfueling mitigation plans (MMP).[80] 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.[81]

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 to grow to nearly 20% of annual consumption (in gasoline-equivalent gallons).[82]

As of March 2012, RFA listed only 13 stations in three states offering E15 for retail sale.[83] Thus concerns about a rapid expansion of E15 by its opponents may be overstated, at least as of the first quarter of 2013.

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

[79] 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.

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

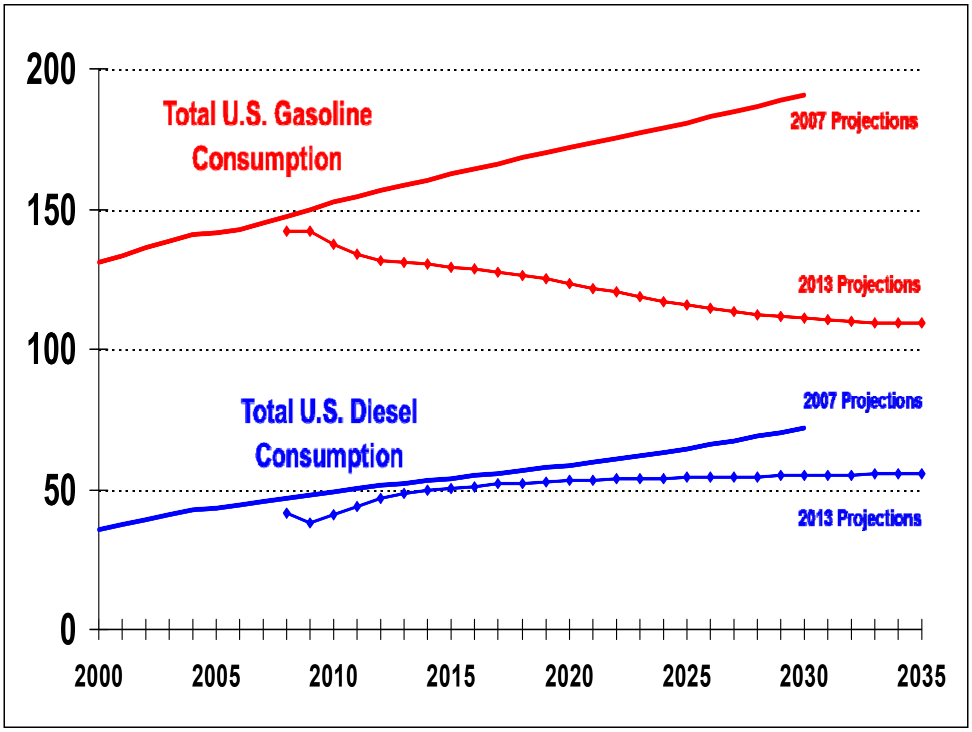
[81] Ibid.

[82] Data is 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.

[83] See http://www.chooseethanol.com/pages/e15-station-locations/. Accessed March 11, 2013.

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

Billion gallons



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

Two additional options to resolving this bottleneck exist but appear to be long-run alternatives. First, increased use of ethanol in flex-fuel vehicles (FFVs) at ethanol-to-gasoline blend ratios as high as 85% (referred to as E85) is a possibility. However, increased E85 use involves substantial infrastructure development, particularly in the number of designated storage tanks and E85 retail pumps, as well as a rapid expansion of the FFV fleet to absorb larger volumes of ethanol. Infrastructure expansion will require significant investments, especially at the retail level. Installation of a new E85 pump and underground tank can cost as much as $100,000 to $200,000.[84] However, if existing equipment can be used with little modification, the cost could be less than $10,000.

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

Vehicle Infrastructure Issues

As was stated above, if a large portion of any increased RFS is met using ethanol, then the United States likely does not have the vehicles to consume the fuel. The 10% blend wall on ethanol in gasoline for conventional vehicles still poses a significant barrier to expanding ethanol

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

consumption beyond 14 billion gallons per year.[85] 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.

Ethanol RINs and the Blend Wall

The price of renewable fuel RINs have increased dramatically in the first quarter 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.[86] It is unclear what is driving the increase, but concerns over the blend wall and a reduction in output from U.S. ethanol producers in the first quarter have increased concerns that the RFS mandates will be binding in 2013 or 2014 and that there will be a scarcity of RINs.[87]

Conclusion

There is continuing interest in expanding the U.S. biofuels industry as a strategy for promoting energy security and achieving environmental goals. However, it is possible that increased biofuel production may place desired policy objectives in conflict with one another. There are limits to the amount of biofuels that can be produced from current feedstocks and questions about the net energy and environmental benefits they might provide. Further, rapid expansion of biofuels production may have many unintended and undesirable consequences for agricultural commodity costs, fossil energy use, and environmental degradation. Owing to these concerns, alternative strategies for energy conservation and alternative energy production are widely seen as warranting consideration.

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

[86] "Ethanol & Gasoline Component Spot Market Prices," *OPIS Ethanol and Biodiesel Information Service*, January 14, 2013 and March 11, 2013.

[87] "Soaring RIN Values Unleash New Interest in Evolving Market," *OPIS Ethanol and Biodiesel Information Service*, vol. 10, no. 10 (March 11, 2013), pp. 3-4.