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CONGRESSIONAL BUDGET OFFICE

CBO

The Renewable Fuel Standard: Issues for 2014 and Beyond

JUNE 2014

Notes

Numbers in the text and tables of this report may not add up to totals because of rounding.

The cover shows a pump offering different blends of petroleum-based and renewable fuels, surrounded by various sources of ethanol: (clockwise from the top) corn cobs, a field of switchgrass, sugarcane stalks, and the corn stover left in a field after harvesting. The corn, switchgrass, and corn stover photographs are used courtesy of the Department of Agriculture.

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The Renewable Fuel Standard: Issues for 2014 and Beyond

Summary

The Renewable Fuel Standard (RFS) establishes minimum volumes of various types of renewable fuels that must be included in the United States' supply of fuel for transportation. Those volumes—as defined by the Energy Independence and Security Act of 2007 (EISA)—are intended to grow each year through 2022. In recent years, the requirements of the RFS have been met largely by blending gasoline with ethanol made from cornstarch. In the future, EISA requires the use of increasingly large amounts of "advanced biofuels," which include diesel made from biomass (such as soybean oil or animal fat), ethanol made from sugarcane, and cellulosic biofuels (made from converting the cellulose in plant materials into fuel).

One of the main goals of the Renewable Fuel Standard is to reduce U.S. emissions of greenhouse gases, which contribute to climate change. EISA requires that the emissions associated with a gallon of renewable fuel be at least a certain percentage lower than the emissions associated with the gasoline or diesel that the renewable fuel replaces. Advanced biofuels and the subcategory of cellulosic biofuels are required to meet more stringent emission standards than those that apply to corn ethanol.

Policymakers and analysts have raised concerns about the RFS, particularly about the feasibility of complying with the standard, whether it will increase prices for food and transportation fuels, and whether it will lead to the intended reductions in greenhouse gas emissions. Because of those concerns, some policymakers have proposed repealing or revising the Renewable Fuel Standard.

In this analysis, the Congressional Budget Office (CBO) evaluates how much the supply of various types of renewable fuels would have to increase over the next several years to comply with the RFS. CBO also examines how food prices, fuel prices, and emissions would vary in an illustrative year, 2017, under three scenarios for the Renewable Fuel Standard:

- *The EISA volumes scenario*, in which fuel suppliers would have to meet the total requirement for renewable fuels, the requirement for advanced biofuels, and the cap on corn ethanol that are stated in EISA for 2017—but not the requirement for cellulosic biofuels, because the capacity to produce enough of those fuels is unlikely to exist by 2017;
- *The 2014 volumes scenario,* in which the Environmental Protection Agency (EPA)—which has some discretion to modify the mandates of EISA—would keep the RFS requirements for the next several years at the same amounts it has proposed for 2014; and
- *The repeal scenario*, in which lawmakers would immediately abolish the RFS.

The repeal scenario would require Congressional action. In the absence of such action (or of legal restrictions), CBO considers the 2014 volumes scenario much more likely than the EISA volumes scenario, which would require a large and rapid increase in the use of advanced biofuels and would cause the total percentage of ethanol in the nation's gasoline supply to rise to levels that would require significant changes in the infrastructure of fueling stations.

Full Compliance With the Mandates in EISA Poses Significant Challenges

The rising requirements in EISA would be very hard to meet in future years because of two main obstacles, which relate to the supply of cellulosic biofuels and the amount of ethanol that older vehicles are said to be able to tolerate. Fuel suppliers have had trouble meeting the annual requirements for cellulosic biofuels because making such fuels is complex, capital-intensive, and costly. Although production capacity is expanding, only a few production facilities are currently operating. The industry's capacity in coming years is projected to fall far short of what would be necessary to achieve the very rapid growth in the use of cellulosic biofuels required by EISA.

Ethanol is the most common form of renewable fuel; however, adding increasing volumes of it to the U.S. fuel supply could be difficult. Currently, most gasoline sold in the United States is actually a blend (referred to as E10) that contains up to 10 percent ethanol—the maximum concentration that is feasible to avoid corrosion damage to the fuel systems of older vehicles. EISA's growing requirements for the total gallons of renewable fuels to be used each year, combined with a projected decline in gasoline use, suggest that the average concentration of ethanol in gasoline would have to rise to well above that 10 percent "blend wall," potentially increasing to about 25 percent by 2022. More ethanol could be accommodated in the fuel supply if motorists who drive "flex-fuel" vehicles, which can run on blends that contain as much as 85 percent ethanol (referred to as E85), bought larger amounts of such fuel. But at present, fewer than 2 percent of filling stations in the United States sell high-ethanol blends. Given the design of the RFS, the cost of encouraging additional sales of high-ethanol fuel falls on the producers and consumers of gasoline and diesel.

Because of the challenges described above, EPA has eliminated or greatly reduced the annual requirements for cellulosic biofuels in the RFS in past years. For 2014, EPA has also proposed regulations that would reduce the requirements for advanced biofuels and for total renewable fuels, in recognition of the difficulties posed by the blend wall. Although scaling back those standards addresses existing compliance problems and decreases compliance costs in the short run, it also reduces incentives for companies to invest in production capacity for cellulosic and other advanced biofuels and to expand the availability of high-ethanol blends.

Meeting the Total Volumes of Advanced Biofuels Specified in EISA Would Require Extremely Large Increases in the Production of Those Fuels

For the scenario in which fuel suppliers would have to comply with the total volumes of advanced biofuels and of renewable fuels as a whole stated in EISA, CBO assumed that EPA would allow suppliers to substitute other forms of advanced biofuels for cellulosic biofuels, as it has done in the past. Fuel suppliers would most likely do so using two types of advanced biofuels: biomass-based diesel (mostly produced in the United States) and sugarcane ethanol (nearly all imported from Brazil). However, relying on that strategy for 2017 would necessitate extremely large increases in the production of those fuels: for example, more than a 100 percent rise in U.S. production of biomass-based diesel and more than a 45 percent increase in Brazil's production of sugarcane ethanol.

Food Prices Would Be Similar Whether the RFS Was Continued or Repealed

Roughly 40 percent of the U.S. corn supply is used to make ethanol. To the extent that the Renewable Fuel Standard increases the demand for corn ethanol, it will raise corn prices and put upward pressure on the prices of foods that are made with corn—ranging from corn-syrup sweeteners to meat, poultry, and dairy products. CBO expects that roughly the same amount of corn ethanol would be used in 2017 if fuel suppliers had to meet requirements equal to EPA's proposed 2014 volumes or if lawmakers repealed the RFS, because suppliers would probably find it cost-effective to use a roughly 10 percent blend of corn ethanol in gasoline in 2017 even in the absence of the RFS. Therefore, food prices would also be about the same under the 2014 volumes scenario and the repeal scenario.

By contrast, corn ethanol use in 2017 would be about 15 percent (or 2 billion gallons) higher under the EISA volumes scenario. CBO estimates that the resulting increase in the demand for corn would raise the average price of corn by about 6 percent. However, because corn and food made with corn account for only a small fraction of total U.S. spending on food, that total spending would increase by about one-quarter of one percent.

Meeting the Total Volumes of Advanced Biofuels Specified in EISA Would Have Significant Effects on Prices of Transportation Fuels

Because fuel suppliers would be likely to use roughly a 10 percent blend of corn ethanol in gasoline in 2017 even without the RFS, the overall use of renewable fuels in that year would be very similar under the 2014 volumes scenario and under the repeal scenario, CBO estimates. Consequently, prices of transportation fuels would probably be roughly the same in those two cases.

Under the EISA volumes scenario, however, fuel suppliers would have to use more than three times as many gallons of advanced biofuels, and they would have to add much more ethanol to the gasoline supply than could be accommodated by selling only a 10 percent blend. (Under all of the scenarios, CBO anticipates that EPA would sharply reduce the requirement for cellulosic biofuels, given the limited production capacity for those fuels expected to exist in 2017.) Using a range of estimates of the price premium necessary to encourage sufficient additional supplies of advanced biofuels and the price subsidy necessary to motivate sufficient sales of E85, CBO estimates that complying with the EISA volumes scenario would have the following effects on the prices of three key types of transportation fuels in 2017:

- The price of petroleum-based diesel would rise by 30 cents to 51 cents per gallon, or 9 percent to 14 percent (because the RFS requires fuel suppliers to bear the cost of ensuring that certain amounts of renewable fuels are used for each gallon of petroleum-based fuel that they sell);
- The price of E10—which is currently the most commonly used transportation fuel in the United States—would increase by 13 cents to 26 cents per gallon, or 4 percent to 9 percent; and,
- The price of E85 would decline by 91 cents to $1.27 per gallon, or 37 percent to 51 percent.

Because the changes in the production and use of renewable fuels required under the EISA volumes scenario are so large—and because little information is available about how the supply of and demand for renewable fuels respond to changes in their price—those estimates are highly uncertain. Actual price changes could fall outside the ranges described above.

Reductions in Greenhouse Gas Emissions Because of the RFS Would Be Small in the Near Term but Could Be Larger Over the Long Term

The production and use of different types of renewable fuels involve different amounts of greenhouse gas emissions. Estimates of those emissions are uncertain, and researchers' predictions vary considerably. However, available evidence suggests that replacing gasoline with corn ethanol has only limited potential for reducing emissions (and some studies indicate that it could increase emissions). The success of the RFS in reducing the emissions from transportation fuels will depend mainly on the extent to which it causes people to substitute advanced biofuels—particularly cellulosic biofuels—for gasoline or diesel over the long run. However, a trade-off exists between the goal of limiting the cost of complying with the RFS (for example, by reducing the requirements for cellulosic biofuels) and the goal of providing a strong incentive for the development of better technologies for advanced biofuels.

Overview of the Renewable Fuel Standard and Its Implementation

Lawmakers enacted the Renewable Fuel Standard in 2005 and expanded its requirements in 2007 in the Energy Independence and Security Act. The standard is imposed on suppliers (generally refiners or importers) of gasoline and diesel fuels used for transportation. It aims to foster greater use of fuels made from plants, plant products, and other renewable sources, thereby reducing the United States' dependence on petroleum and the greenhouse gas emissions from fuel use. The Environmental Protection Agency is charged with implementing the standard and ensuring compliance.

What the RFS Requires

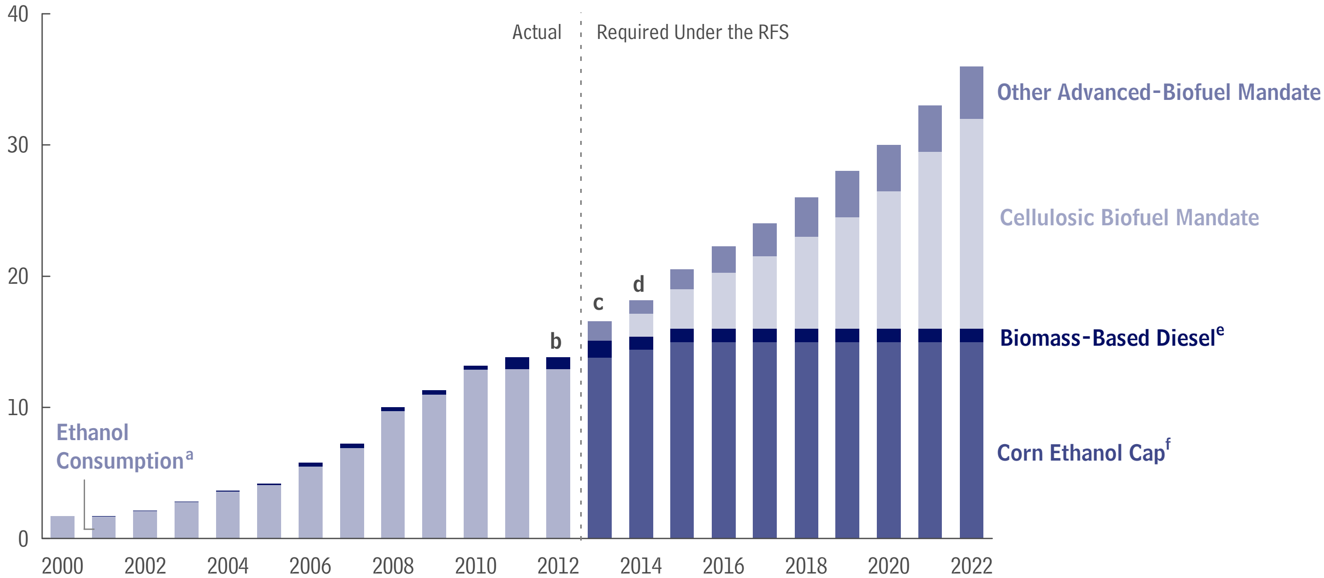
The Energy Independence and Security Act sets minimum volumes of renewable fuels that suppliers must blend into the nation's supply of transportation fuel each year. Except for corn ethanol made in certain facilities, the renewable fuels used to comply with the RFS must be certified by EPA as having greenhouse gas emissions that are at least 20 percent lower than the emissions associated with the fuels that they replace. Corn ethanol made at plants built or under construction before December 20, 2007, is exempt from the emission requirements, which means that much of the corn ethanol used today does not need to have lower emissions than gasoline. The total minimum volume of renewable fuels specified in EISA rises each year through 2022 (see Figure 1) and includes the requirement that an increasing share of that volume be met with advanced biofuels, which must have greenhouse gas emissions that are at least 50 percent lower than those of conventional fuels.

So far, fuel suppliers have been able to comply with the RFS largely by blending gasoline with corn ethanol, which is made from the starch in corn kernels. By 2022, EISA requires the use of 36 billion gallons of renewable

Figure 1.

Past Use of Renewable Fuels and Future Requirements of the Renewable Fuel Standard

(Billions of gallons)



Source: Congressional Budget Office based on data for 2000 to 2012 from Energy Information Administration, *Monthly Energy Review*, DOE/EIA-0035(2014/04) (April 2014), www.eia.gov/totalenergy/data/monthly, and requirements for 2013 to 2022 from the Energy Independence and Security Act of 2007.

Note: RFS = Renewable Fuel Standard.

a. Most of the ethanol used in the United States in the past consisted of corn ethanol, although relatively small amounts of sugarcane ethanol and other types of advanced biofuels, either produced domestically or imported, were also used.

b. Because of high corn prices in 2012, use of renewable fuels was about the same in that year as in 2011. That use was less than the amounts mandated for 2012, but fuel blenders and importers achieved compliance with the RFS by submitting "renewable identification numbers" (or RINs) that they had accumulated from exceeding their obligations in prior years.

c. For 2013, the Energy Independence and Security Act (EISA) originally required the use of 1 billion gallons each of cellulosic biofuels and biomass-based diesel. In August 2013, the Environmental Protection Agency (EPA) retroactively reduced the cellulosic biofuel requirement for that year to 6 million gallons and raised the mandate for biomass-based diesel to 1.28 billion gallons. Complete data on the actual use of renewable fuels in 2013 were not yet available when this report was published.

d. The amounts shown here for 2014 are those required under EISA. However, EPA has proposed reducing the 2014 requirement for cellulosic biofuels from 1.75 billion gallons to 17 million gallons, the requirement for advanced biofuels from 3.75 billion gallons to 2.2 billion gallons, and the cap on the amount of corn ethanol that can be used to meet the total requirement for renewable fuels from 14.4 billion gallons to 13.0 billion gallons. EPA has also proposed increasing the requirement for biomass-based diesel from 1 billion gallons to 1.28 billion gallons. Under those proposals, the total requirement for renewable fuels in 2014 would decline from 18.15 billion gallons to 15.21 billion gallons, compared with 16.55 billion gallons in 2013.

e. The amounts of biomass-based diesel shown here for 2014 and later years reflect the minimum requirement of 1 billion gallons specified in EISA. EPA will set the actual requirement for each year through future rulemaking.

f. The cap on corn ethanol represents the maximum amount of such ethanol that can used to meet the total requirement for renewable fuels under EISA.

fuels. Of those, at least 21 billion gallons must be advanced biofuels, including the following:

- At least 16 billion gallons of cellulosic biofuels, which are made from the cellulose in various plant materials, including grasses and corn stover (the residue left after corn is harvested). Cellulosic biofuels must have emissions that are at least 60 percent lower than their petroleum-based counterparts.

- At least 1 billion gallons of biomass-based diesel (typically made from soybean or other vegetable oils). EPA has the discretion to set the mandate for biomass-based diesel at a higher level.[1]

The other 4 billion gallons (or less) can consist of any type of advanced biofuel that meets the 50-percent-lower emission standard, such as noncellulosic ethanol made from sugarcane.

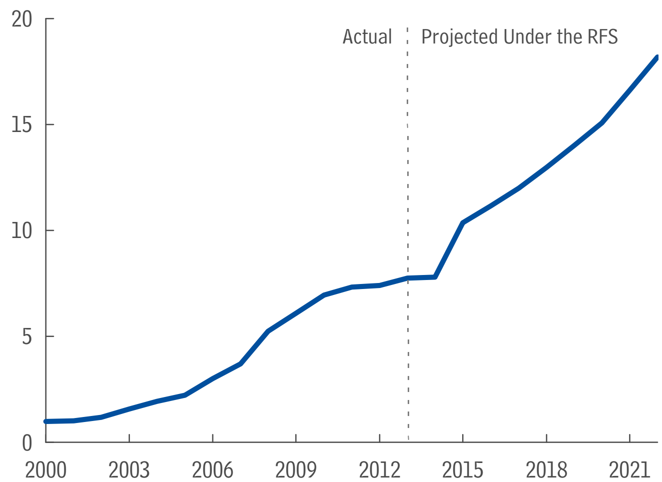
The portion of the RFS that does not have to be met with advanced biofuels—in 2022, up to 15 billion gallons—can be met with other qualifying renewable fuels, such as corn ethanol. Thus, the requirements for cellulosic biofuels and for biomass-based diesel are nested within the requirement for advanced biofuels, which in turn is nested within the overall requirement for renewable fuels.[2]

The total volume of renewable fuels mandated by EISA increases much faster than the projected growth in the use of gasoline and diesel. As a result, under the RFS, renewable fuels would make up a greater share of the U.S. supply of transportation fuel over time, rising from about 7 percent in 2013 to about 18 percent in 2022 (see Figure 2).

Figure 2.

Renewable Fuels as a Share of the Total U.S. Supply of Transportation Fuels

(Percent)



Source: Congressional Budget Office based on Energy Information Administration, *Annual Energy Outlook 2014, With Projections to 2040,* DOE/EIA-0383(2014) (April 2014), www.eia.gov/forecasts/aeo, and *Monthly Energy Review,* DOE/EIA-0035(2014/04) (April 2014), www.eia.gov/totalenergy/data/monthly.

Notes: CBO's calculations are based on the Energy Information Administration's (EIA's) most recent projections of the use of blended gasoline and diesel fuel. EIA projects that in 2022, less renewable fuel will be used than required under the mandates specified in the Energy Independence and Security Act of 2007. CBO assumed that total use of renewable fuels would rise to the level mandated by that law, although total energy consumption of transportation fuels would remain the same. In addition, because part of the overall mandate for renewable fuels will be met with biomass-based diesel and the specific requirement for such diesel is set annually, CBO assumed that consumption of biomass-based diesel in future years would total either 1.28 billion gallons (the current requirement, which is equal to 1.92 billion compliance-equivalent gallons for the purposes of meeting the total mandate for renewable fuels), or 25 percent of the requirement for advanced biofuels, whichever is greater.

RFS = Renewable Fuel Standard.

How EPA Implements the RFS

To ensure that fuel suppliers use the mandated volumes of renewable fuels, the Environmental Protection Agency translates the yearly volume requirements in EISA into percentage standards (sometimes called blend requirements) that are based on projections of the total amount of gasoline and diesel that will be used in that year. For example, if the projected amount was 100 billion gallons and the total renewable fuel requirement was 14 billion gallons, EPA would set a 14 percent blend requirement.

1. Unless otherwise indicated, the amounts of biomass-based diesel discussed in this report are measured in "compliance-equivalent gallons." Under EISA, 1 gallon of biomass-based diesel is considered equivalent to 1.5 gallons of ethanol for purposes of complying with the RFS.

2. Cellulosic feedstocks can be used to make diesel or gasoline as well as to make biofuels. A gallon of cellulosic diesel would count toward satisfying either the cellulosic biofuel mandate or the biomass-based diesel mandate.

Further, if the nested mandates for advanced biofuels and for biomass-based diesel were 4 billion gallons and 2 billion gallons, respectively, EPA would establish a 4 percent blend requirement for advanced biofuels and a 2 percent requirement for biomass-based diesel.

To monitor suppliers' compliance with the requirements, EPA assigns a unique "renewable identification number" (RIN) to each qualifying gallon of renewable fuel. Every RIN includes a code that identifies which of the four RFS categories—total renewable fuels, advanced biofuels, cellulosic biofuels, or biomass-based diesel—the gallon satisfies. Each fuel supplier, regardless of what kind of fuel it produces or imports, must meet all of the blend requirements for a given compliance year. The supplier can do that by using the required amounts of renewable fuels itself and submitting the corresponding RINs to EPA to demonstrate compliance, by purchasing RINs from other suppliers that have excess RINs to sell, or by submitting RINs that it acquired in the previous year and saved for future use.[3] With the hypothetical requirements above, each fuel supplier would have to submit 14 RINs (including 4 for advanced biofuels and 2 for biomass-based diesel) for each 100 gallons of gasoline or diesel that it sold. Suppliers with excess biomass-based diesel RINs could either sell them or apply them toward their advanced-biofuel requirement.

EPA is also responsible for certifying that the types of renewable fuels used to comply with the RFS meet the emission requirements in EISA. Estimating the emissions associated with renewable fuels is difficult: Among other things, those emissions depend on the yields of the feedstock crops used to make the fuel, the amount of fertilizer used, the particular fuel-production technology employed, and changes in related factors (such as land use or fuel use inside or outside the United States) caused by the RFS. Predictions about those things are highly uncertain. Although EPA's predictions serve as the basis for determining whether a particular fuel can be used for complying with the RFS, actual emissions may differ from EPA's estimates. The final section of this report compares emission estimates from EPA and other researchers and discusses why they vary.

3. If a fuel supplier that is obligated to meet the RFS is out of compliance at the end of a year (after accounting for its RINs and its use of renewable fuels), EPA may fine the supplier as much as $32,500 per day, plus the savings to the supplier that result from its noncompliance. Those penalties are specified in sections 205 and 211(d) of the Clean Air Act, 42 U.S.C. §§7524, 7545(d) (2012).

Challenges in Meeting the Renewable Fuel Requirements of EISA

Complying with the Renewable Fuel Standard has raised several challenges, and EPA has modified the requirements of the RFS in past years in response to them. In particular, meeting the requirements for advanced biofuels specified in the Energy Independence and Security Act has posed two difficulties:

- The supply of cellulosic biofuels is limited because such fuels are complex and expensive to produce.
- The use of renewable fuels is constrained by a practical limit on the total amount of ethanol that can be blended into the fuel supply, given the technologies used by older vehicles and the existing fueling-station infrastructure. That limit was not a significant constraint in the past, but it is becoming one as the requirements of EISA increase and the use of transportation fuel grows more slowly than anticipated.

The way in which EPA has responded to those challenges has made it less costly for fuel suppliers to comply with the RFS. But at the same time, that response has lessened the incentives that the RFS provides for investment in renewable fuel infrastructure and for the development of improved technologies for producing advanced biofuels.

Limited Supply of Cellulosic Biofuels

To date, the greatest challenge in meeting the requirements specified in EISA has been the small supply of cellulosic biofuels. The industry that produces those fuels is in its infancy, and the volumes required by EISA far outstrip the projected growth in the industry's production capacity. EISA first set requirements for cellulosic biofuels in 2010, mandating the use of 100 million gallons in that year and larger amounts in each subsequent year. Before 2013, however, no commercial plants to produce cellulosic biofuels were in operation, and EPA virtually eliminated the requirements until that year.

Two commercial plants began making cellulosic biofuels in 2013, and more plants are expected to begin operating in 2014 and 2015. Even so, the gap between production capacity and the volumes of cellulosic biofuels mandated in EISA is expected to widen quickly. The Energy Information Administration forecasts that production of cellulosic biofuels will increase only to 327 million gallons by 2022, a small fraction of the 16 billion gallons required by EISA in that year (see Figure 3).[4]

Production capacity has been slow to expand for several reasons. Producing ethanol from cellulose is more complex than producing it from cornstarch, entails higher capital costs, and poses logistical problems. For example, commercial-scale use of cellulosic feedstocks requires that systems and equipment be developed to harvest the often-bulky materials and transport them to production facilities; for year-round production, seasonal feedstocks would also require ample storage space.

Difficulties in Using the Required Volume of Renewable Fuels

Ten percent is effectively the maximum ethanol content that blended fuel can contain and still be used by virtually all vehicles now on the road. That limit protects vehicles built before 2001, whose engines and fuel systems are thought to be vulnerable to corrosion from ethanol concentrations greater than 10 percent. For that reason, 10 percent constitutes a practical constraint, or blend wall, on how much ethanol most blended gasoline can accommodate. Many states limit ethanol concentrations to no more than 10 percent, except in fuels intended for flex-fuel vehicles, which can run on blends of as much as 85 percent ethanol.[5]

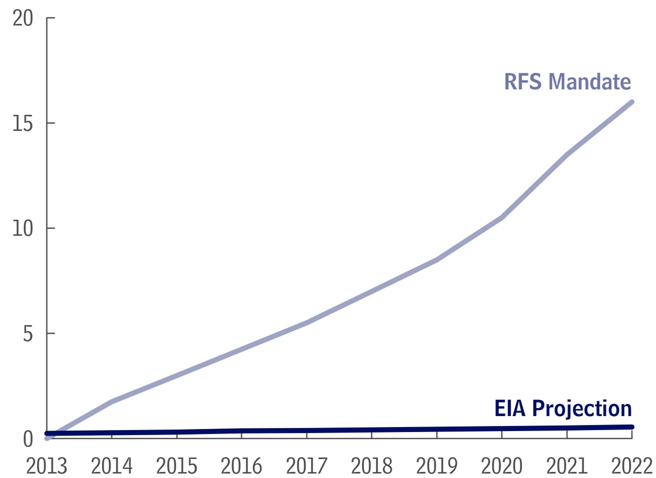
The challenges posed by the blend wall are expected to increase. When EISA was enacted, in 2007, use of blended gasoline in the United States totaled about 140 billion gallons a year and was projected to grow (see Figure 4). Thus, rising requirements for renewable fuels were not expected to raise concerns about the blend wall. Instead of growing, however, use of blended gasoline has declined slightly, to about 135 billion gallons a year, and the Energy Information Administration now projects that it will fall to about 125 billion gallons in 2022. (The agency's 2007 projection did not anticipate the decline in total annual vehicle-miles traveled and the increase in average fuel economy that have since occurred.)

If the latest projections prove accurate, the renewable fuel requirements of EISA will gradually increase the average ethanol content of the U.S. gasoline supply (including high-ethanol blends for flex-fuel vehicles) to well above 10 percent. Using illustrative assumptions about the extent to which fuel suppliers would comply with the requirement for advanced biofuels by using biomass-based diesel, CBO estimates that full compliance with the EISA mandates could require the average ethanol content

Figure 3.

Projected Use of Cellulosic Biofuels, Compared With the Use Mandated by the Renewable Fuel Standard

(Billions of gallons)



Source: Congressional Budget Office based on Energy Information Administration, *Annual Energy Outlook 2013, With Projections to 2040,* DOE/EIA-0383(2013) (April 2013), Figure 100, www.eia.gov/forecasts/archive/aeo13, and Regulation of Fuels and Fuel Additives: 2013 Renewable Fuel Standards, 78 Fed. Reg. 49794 (August 15, 2013), https://federalregister.gov/a/2013-19557.

Notes: The Energy Independence and Security Act of 2007 set annual requirements for cellulosic biofuels starting in 2010; however, the Environmental Protection Agency virtually eliminated the requirements before 2013 because of a lack of commercial production capacity for cellulosic biofuels.

RFS = Renewable Fuel Standard; EIA = Energy Information Administration.

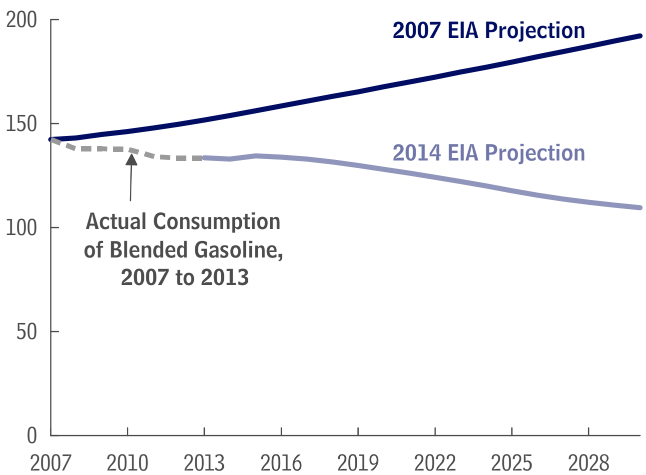
4. See Energy Information Administration, *Annual Energy Outlook 2013, With Projections to 2040*, DOE/EIA-0383(2013) (April 2013), Figure 100, www.eia.gov/forecasts/archive/aeo13.

5. Flex-fuel vehicles are identical to ordinary passenger vehicles except for slight differences in their fuel systems and, in many cases, an identifying badge on a fender or rear panel. According to the Department of Energy, many owners of flex-fuel vehicles are not aware that their vehicles can run on blends of more than 10 percent ethanol. See Department of Energy, "Alternative Fuels Data Center—Flexible Fuel Vehicles" (October 3, 2013), www.afdc.energy.gov/vehicles/flexible_fuel.html.

Figure 4.

Changing Expectations About the Future Consumption of Blended Gasoline

(Billions of gallons)



Source: Congressional Budget Office based on Energy Information Administration, *Annual Energy Outlook 2007, With Projections to 2030,* DOE/EIA-0383(2007) (February 2007), www.eia.gov/oiaf/archive/aeo07, and *Annual Energy Outlook 2014, With Projections to 2040,* DOE/EIA-0383(2014) (April 2014), www.eia.gov/forecasts/aeo.

Note: EIA = Energy Information Administration.

of blended gasoline to reach about 25 percent by 2022 (see Figure 5). For retail gasoline markets to accommodate that much ethanol—while limiting the ethanol content of the blended gasoline that most drivers use to 10 percent—a very large increase in the use of high-ethanol blends would be necessary.

One possibility for raising the total amount of ethanol that the market can accommodate is to boost both the number of flex-fuel vehicles on the road and the extent to which drivers of those vehicles refuel with E85 rather than with conventional blends, such as E10. Flex-fuel technology is relatively inexpensive—adding a few hundred dollars to the manufacturing cost of a new vehicle—so consumers would not need large incentives to buy more of those vehicles. However, substantially increasing the use of E85 would also require increasing the number of filling stations that offer such fuel. Fewer than 2 percent of stations in the United States currently sell E85, although the number has been rising steadily in recent years (it grew fivefold between 2005 and 2012, to more than 2,500 stations).[6] Another factor limiting sales of E85 is its price: Although E85 costs less than regular E10 gasoline, it also has a lower energy content, meaning that it offers fewer miles per gallon. Drivers who could use E85 would be willing to buy it only if its price was low enough relative to the price of E10 to compensate for its lower energy content and potentially for the need to drive farther to find an E85 fueling station.

Although consumption of E85 has been expanding rapidly—by more than 20 percent a year in many recent years—it still accounts for only a tiny fraction of the fuel that passenger vehicles use. If its recent growth rate continues, annual consumption of E85 will reach just 1 billion gallons by 2022, out of a total of 125 billion gallons of blended gasoline projected to be used in that year.

Another possibility for raising the average concentration of ethanol in the fuel supply above 10 percent is to make blended gasoline with up to 15 percent ethanol content (E15) widely available. EPA has certified that vehicles built since 2001—roughly 60 percent of vehicles now on the road—can run on E15 without risking corrosion damage to their fuel lines and engine parts. Many automakers disagree and have discouraged their customers from using E15.[7] However, some major manufacturers—including Ford and General Motors—have stated that their models from 2012 or 2013 and later can use E15 without risk.

Experience with vehicles running on E15 has been limited because, until mid-2012, no filling stations offered that fuel. In recent years, the Department of Agriculture provided funding (through the Rural Energy for America Program) for installing pumps that can dispense either E10 or E15; currently, a small number of stations have E15 pumps.[8] But because filling stations that would like

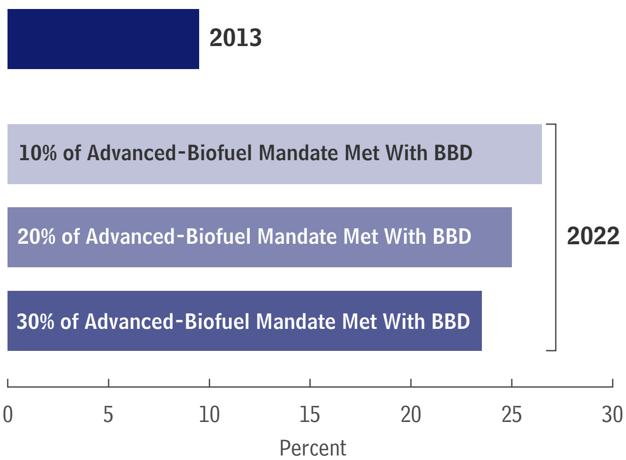
6. See Kristi Moriarty, "E85 Deployment" (presentation prepared for the Energy Information Administration's biofuels workshop by the National Renewable Energy Laboratory, March 20, 2013), www.eia.gov/biofuels/workshop/presentations/2013.

7. Industry groups challenged EPA's certification of E15 in court. The Supreme Court recently dismissed those challenges, which prompted the Alliance of Automobile Manufacturers to assert that "vehicles [built since 2001] were never designed to run on this more corrosive fuel. Automakers continue to urge consumers to check their owner's manuals for the recommended fuel to use safely in their vehicles." See Alliance of Automobile Manufacturers, "Alliance Response to Supreme Court Decision Today to Dismiss Challenges to EPA's E15 Decision" (June 24, 2013), http://tinyurl.com/q8um8eg.

8. See Joanna Schroeder, "EPA Announces 2014 RVO Numbers for RFS" (November 15, 2013), http://tinyurl.com/oh9vfo4.

Figure 5.

Ethanol as a Percentage of Blended Gasoline Under Different Assumptions About the Future Use of Biomass-Based Diesel



Source: Congressional Budget Office based on Energy Information Administration, *Annual Energy Outlook 2014, With Projections to 2040,* DOE/EIA-0383(2014) (April 2014), www.eia.gov/forecasts/aeo.

Notes: CBO's calculations are based on the Energy Information Administration's most recent projection of the use of blended gasoline. CBO's estimate of the percentage of ethanol in blended gasoline depends on how much biomass-based diesel is used to comply with the mandate for advanced biofuels. In evaluating the effects of different amounts of use, CBO assumed that the total energy consumption of blended gasoline would remain the same.

BBD = biomass-based diesel.

to offer both blends would incur costs to acquire new pumps and underground storage tanks, the growth of E15 sales is expected to be slow. In addition, some station owners may be concerned about potential liability claims arising from drivers who inadvertently refuel a pre-2001 vehicle with E15.

A final possibility for addressing the blend wall is to rely more on "drop-in" fuels made from cellulose. The same sorts of cellulosic feedstocks that are used to make biofuels can also be used to produce gasoline or diesel. Those drop-in fuels are identical to conventionally made gasoline and diesel and can substitute for them in full, rather than having to be blended into conventional fuel. The technologies for making any kind of cellulosic fuel are new, however, and production remains costly. (In addition, only a small fraction of the cellulosic production plants projected to open in the next few years are expected to make drop-in fuels.) Nevertheless, to the extent that production of cellulosic gasoline and diesel grows, using more of those drop-in fuels can increase the renewable content of the nation's supply of transportation fuel without exacerbating concerns about the blend wall.

EPA's Response to Compliance Challenges

The Energy Independence and Security Act requires that EPA evaluate the Renewable Fuel Standard's requirements each year and adjust them, if necessary, on the basis of market conditions. EPA's response to the gap between the RFS mandate on cellulosic biofuels and actual production of those fuels has been to use its waiver authority to significantly alter that mandate.

For 2010, the first year the cellulosic biofuel mandate was in effect, EPA reduced the requirement of 100 million gallons stated in EISA to 6.5 million gallons—the amount that fuel suppliers could comply with using RINs they had obtained in previous years by exceeding those years' requirements. (The earlier requirements were based on a broader definition of cellulosic biofuels, as described in the Energy Policy Act of 2005.) For 2011 and 2012, EPA initially reduced the cellulosic biofuel mandates significantly. However, following negligible production of cellulosic biofuels in those years and court challenges by the petroleum industry, EPA eliminated the mandate for 2012 and has proposed doing the same for 2011.[9] In addition, the agency lowered the 2013 requirement from 1 billion gallons to less than 1 million gallons (reflecting the industry's production capacity in that year).[10] EPA did not also reduce the requirements for total renewable fuels or for advanced biofuels when it lowered those cellulosic mandates; fuel suppliers were able to make up for the lack of cellulosic biofuels mainly by using biomass-based diesel and noncellulosic ethanol made from sugarcane.[11]

9. For the legal decision about the 2012 mandate, see *API v. EPA*, 706 F.3d 474 (D.C. Cir. 2013).

10. See Environmental Protection Agency, *EPA Issues Direct Final Rule for 2013 Cellulosic Standard*, EPA-420-F-14-018 (April 2014), http://go.usa.gov/9rd3 (PDF, 151 KB).

11. EPA has not relieved suppliers of their compliance obligations for those years but instead has allowed them to satisfy the obligations in a different way. Specifically, whenever EPA has reduced the RFS mandate on cellulosic biofuels, it has offered credits for sale to fuel suppliers in an amount equal to the new, revised mandate. If suppliers plan to substitute some other advanced biofuel for cellulosic biofuel, they must buy a waiver credit from EPA as well as the gallon of that other fuel. EPA determines the price of waiver credits on the basis of the previous year's wholesale price of gasoline.

For 2014, EPA has proposed reducing the cellulosic biofuel requirement from 1.75 billion gallons to 17 million gallons.[12] For the first time, it has also proposed decreasing the RFS mandates on total advanced biofuels and total renewable fuels: Those requirements would shrink by more than 1.5 billion gallons and by nearly 3 billion gallons, respectively (from 3.75 billion to 2.2 billion gallons of advanced biofuels and from 18.15 billion to 15.21 billion gallons of renewable fuels). EPA's proposal reflects concern that the 2014 mandate on total renewable fuels in EISA would cause the average ethanol content of the nation's gasoline supply to exceed the 10 percent concentration that many non-flex-fuel vehicles can use. To maintain a proportional cap on the use of corn ethanol, EPA has also proposed reducing by more than 1 billion gallons the portion of the RFS that does not have to be met with advanced biofuels (from 14.4 billion to 13.01 billion gallons).

The annual mandates for cellulosic biofuels specified in EISA through 2022 are so much greater than the industry's projected capacity that EPA will probably continue to reduce the mandate every year, rather than impose large fines on fuel suppliers that are unable to meet the requirement because the fuels are not available. However, granting fuel suppliers a waiver for cellulosic biofuels is likely to have the unintended effect of slowing the growth of production capacity for such fuels by weakening incentives for the private sector to invest in building that capacity. Similar effects would occur for other advanced biofuels if the mandates for those fuels were reduced. In addition, if EPA continues to lower the annual requirements for total renewable fuels to avoid exceeding the blend wall, it will lessen incentives to expand the number of filling stations that offer E85, even though such expansion would help retail gasoline markets accommodate more ethanol in the fuel supply.

12. See Environmental Protection Agency, *EPA Proposes 2014 Renewable Fuel Standards, 2015 Biomass-Based Diesel Volume,* EPA-420-F-13-048 (November 2013), Table 1, p. 3, http://go.usa.gov/9rdA (PDF, 190 KB). Although EPA announced its proposal for the 2014 requirement in November 2013, it has not yet issued a final rule. The delay may reflect uncertainty because of ongoing legal challenges to its revisions to the 2013 requirement, which it finalized in August 2013.

Effects of the RFS on the Use of Renewable Fuels

Until this year, fuel suppliers were required to use the total volume of renewable fuels stated in EISA and to comply with that law's cap on the use of corn ethanol. Looking ahead, EPA or the Congress may set the total requirement for renewable fuels, the nested mandates (such as the requirement for advanced biofuels), and the corn ethanol cap at levels below those specified in EISA, as EPA has proposed doing for 2014.

To illustrate how the Renewable Fuel Standard—and potential changes to it—might affect the use of renewable fuels over the next several years, CBO estimated the amount of renewable fuels that would be consumed in 2017 under three alternative scenarios: if fuel suppliers had to comply with the requirements stated in EISA (other than the cellulosic biofuel mandate), if those requirements were set at the amounts currently proposed for 2014, and if lawmakers immediately repealed the RFS.

EISA Volumes Scenario

The first scenario represents what would be likely to occur if EPA did not alter the total requirement for renewable fuels, the advanced-biofuel mandate, the biomass-based diesel mandate, and the corn ethanol cap specified in EISA—for example, if the courts or lawmakers prevented EPA from making such modifications.

Requirements. Under the EISA volumes scenario, fuel suppliers would be required to use the following in 2017 (see Table 1):

- 24 billion gallons of renewable fuels in all, including
- 9 billion gallons of advanced biofuels, of which roughly 2 billion compliance-equivalent gallons would have to be biomass-based diesel,[13] and
- No more than 15 billion gallons of corn ethanol.

13. EISA allows EPA to set the requirement for biomass-based diesel at a volume not lower than 1 billion gallons. Each gallon of biomass-based diesel provides 1.5 RINs for the purposes of complying with the advanced-biofuel requirement, so the requirement for 1 billion gallons accounts for 1.5 billion gallons of compliance. EPA has not yet set that volume for 2017. For illustrative purposes, CBO assumed that it would be 2 billion compliance-equivalent gallons, only slightly more than the 2014 requirement.

Table 1.

Use of Renewable Fuels in 2017 Under CBO's Alternative Scenarios for the Renewable Fuel Standard

	EISA Volumes Scenario[a]		2014 Volumes Scenario[b]		Repeal Scenario[c]
	Volume Requirement (Billions of gallons)	Blend Requirement (Percent)[d]	Volume Requirement (Billions of gallons)	Blend Requirement (Percent)[d]	Estimated Volume (Billions of gallons)
Advanced Biofuels					
Biomass-based diesel[e]	2.0	1.3	1.9	1.2	Less than 1
Other advanced biofuels	7.0	4.0	0.3	0.1	f
Subtotal	9.0	5.3	2.2	1.3	Less than 1
Corn Ethanol	15.0	g	13.0	g	13[h]
Total Renewable Fuels	**24.0**	**14.5**	**15.2**	**9.2**	**13 to 14**

Source: Congressional Budget Office based on section 202 of the Energy Independence and Security Act of 2007; Environmental Protection Agency, *EPA Proposes 2014 Renewable Fuel Standards, 2015 Biomass-Based Diesel Volume,* Regulatory Announcement EPA-420-F-13-048 (November 2013), http://go.usa.gov/9rdA (PDF, 190 KB); and Energy Information Administration, "Annual Energy Outlook 2014: Market Trends—Oil/Liquids" (April 2014), www.eia.gov/forecasts/aeo/MT_liquidfuels.cfm.

a. For this scenario, CBO assumed that fuel suppliers would have to comply with the total requirement for renewable fuels and the cap on corn ethanol that are specified for 2017 in the Energy Independence and Security Act of 2007 (EISA). Those requirements mean that fuel suppliers would also be required to use 9 billion gallons of advanced biofuels, with specific quantities consisting of biomass-based diesel and cellulosic biofuels. The Environmental Protection Agency (EPA) has not yet specified the requirement for biomass-based diesel for 2017 (EISA mandates that it be at least 1.5 billion gallons, measured in compliance-equivalent gallons). For illustrative purposes, CBO assumed that fuel suppliers would be required to use 1.33 billion gallons of biomass-based diesel (which count as 2.0 billion compliance-equivalent gallons)—the amount of biomass-based diesel that the Energy Information Administration projects will be used in 2017. The 7 billion gallons of advanced biofuels not composed of biomass-based diesel would include a minimum quantity of cellulosic biofuels, which has not yet been specified by EPA.

b. For this scenario, CBO assumed that the 2017 requirements for renewable fuels would be set at the same volumes that EPA has proposed for 2014. Thus, the 0.3 billion gallons of other advanced biofuels would have to include at least 17 million gallons of cellulosic biofuels. Total use of transportation fuels in the United States is projected to be similar in 2017 and 2014, so this scenario would make the Renewable Fuel Standard about as stringent in 2017 as it is in 2014.

c. For this scenario, CBO assumed that lawmakers would repeal the Renewable Fuel Standard in 2014, so fuel suppliers would not be subject to any requirements for the use of renewable fuels in 2017.

d. EPA translates the annual volume requirements in EISA into percentage blend requirements using projections of the total amount of gasoline and diesel that will be used in a given year. Those requirements specify the percentages of various renewable fuels that suppliers must blend into gasoline or diesel to comply with the EISA mandates. CBO estimated the percentage requirements for 2017 using the relationship between the volume requirements and blend requirements that EPA calculated for 2014 (because total U.S. consumption of gasoline and diesel is projected to be similar in those two years).

e. Figures for biomass-based diesel are measured in compliance-equivalent gallons. Under EISA, 1 gallon of biomass-based diesel is considered equivalent to 1.5 gallons of other types of advanced biofuels or of corn ethanol for the purposes of complying with the Renewable Fuel Standard. EPA's proposed standard for 2014 is 1.28 billion gallons of biomass-based diesel, which would equal 1.92 billion compliance-equivalent gallons.

f. If lawmakers repealed the Renewable Fuel Standard, fuel suppliers would probably continue to use small quantities of other advanced biofuels in addition to biomass-based diesel. Those quantities would include sugarcane ethanol used to meet state requirements for renewable fuel use as well as the small amounts of cellulosic biofuels that would continue to be produced at existing plants.

g. The volume specified for corn ethanol is an upper limit on its use rather than a minimum requirement, so EPA does not calculate a percentage blend requirement for corn ethanol.

h. This figure is based on the expectation that corn ethanol will make up roughly 10 percent of the 132 billion gallons of blended gasoline projected to be used in the United States in 2017.

In addition to those requirements, EISA mandates that 5.5 billion gallons of the advanced-biofuel requirement be met using cellulosic biofuels. For this scenario, CBO assumed that EPA would continue to reduce the requirement for cellulosic biofuels to the amount that could be made from available production capacity—projected by the Energy Information Administration to be about 170 million gallons in 2017—and that fuel suppliers would be allowed to use other types of advanced biofuels to make up the remaining volume for the advanced-biofuel mandate.

Effects on Use. The requirements of EISA outlined above imply that fuel suppliers would have to use about 7 billion gallons of advanced biofuels of some sort in 2017 in addition to roughly 2 billion gallons of biomass-based diesel. What types of fuel they would use to meet that goal is highly uncertain. To date, no more than 500 million additional gallons of advanced biofuels have been required (beyond the mandate for biomass-based diesel).[14] Suppliers have met that additional quantity by using slightly more biomass-based diesel than required and by importing sugarcane ethanol. Increasing the use of those types of advanced biofuels enough to meet the 7 billion gallon requirement—especially over just a few years—would probably be challenging and costly. For example, consider the following illustrative increases in advanced biofuels:

- The Energy Information Administration currently projects that the United States will use roughly 2 billion gallons of biomass-based diesel (measured in compliance-equivalent gallons) in 2017 and expects annual consumption to remain constant through 2040.[15] To use an additional 2 billion compliance-equivalent gallons of biomass-based diesel would mean doubling the projected supply of that fuel, which would most likely require a significant increase in its price.
- To import an additional 4 billion gallons of sugarcane ethanol from Brazil (the primary source for the sugarcane ethanol used in the United States) would require a 45 percent increase in Brazil's production from the amount projected for 2017.[16] Fostering such a large increase in production in a short time would be difficult—and would probably require a significant increase in the price of sugarcane ethanol—given the time lags involved in planting and harvesting a perennial crop such as sugarcane and the need for additional production capacity and transportation infrastructure.[17]

Even such large boosts in supply—coupled with the projected 170 million gallons of production capacity for cellulosic biofuels—would leave about 1 billion gallons of the 7 billion gallon gap between EISA's mandates for advanced biofuels and biomass-based diesel in 2017 to be filled by other advanced biofuels. Rising prices for advanced biofuels could encourage the production of new supplies based on additional feedstocks, such as sorghum. However, at present, little information exists to project how large such supplies would be and how they could become available by 2017.

2014 Volumes Scenario

In the second scenario, CBO assumed that the requirements for various types of renewable fuels in the next few years would be set at the same volumes that EPA has proposed for 2014. Total U.S. consumption of transportation fuels is projected to be similar in 2017 and 2014,

14. In calculating that gap, CBO accounted for the fact that each gallon of biomass-based diesel provides 1.5 RINs for the purposes of complying with the advanced-biofuel requirement. So far, the largest gap occurred in 2012, when the requirement for advanced biofuels was set at 2 billion gallons and the requirement for biomass-based diesel was set at 1 billion gallons (1.5 billion on a compliance-equivalent basis).

15. See Energy Information Administration, *Annual Energy Outlook 2014, With Projections to 2040*, DOE/EIA-0383(2014) (April 2014), Figure MT-56, www.eia.gov/forecasts/aeo.

16. That figure is CBO's estimate based on Energy Information Administration, *International Energy Outlook 2013, With Projections to 2040,* DOE/EIA-0484(2013) (July 2013), www.eia.gov/forecasts/ieo.

17. Some industry observers have speculated that larger U.S. imports of sugarcane ethanol from Brazil could be achieved not by encouraging increased production in Brazil but by exchanging sugarcane ethanol made in that country for corn ethanol made in the United States. (That type of swap has already taken place to a limited degree, as discussed in Energy Information Administration, *Biofuels Issues and Trends*, October 2012, www.eia.gov/biofuels/issuestrends.) CBO did not estimate the cost of that approach because it would require Brazil to replace 60 percent of its consumption of domestically produced sugarcane ethanol with corn ethanol imported from the United States. Besides posing large logistical challenges, such an exchange would not increase the global use of advanced biofuels but would consume scarce resources and produce additional greenhouse gas emissions to transport the swapped ethanol supplies.

so this scenario would make the Renewable Fuel Standard about as stringent then as it is now.

In the absence of Congressional action or legal restrictions, CBO considers this scenario much more likely than the EISA volumes scenario, which would require a large and rapid increase in the use of advanced biofuels and would cause the total percentage of ethanol in the gasoline supply to rise to levels that would require significant changes in the infrastructure of fueling stations.

Requirements. Under the 2014 volumes scenario, fuel suppliers would be required to use the following in 2017:

- 15.2 billion gallons of renewable fuels in all, including
- 2.2 billion gallons of advanced biofuels, of which 1.9 billion compliance-equivalent gallons would have to be biomass-based diesel, and
- No more than about 13 billion gallons of corn ethanol.

As in the EISA volumes scenario, CBO assumed that EPA would reduce the mandate on cellulosic biofuels for 2017 to a level consistent with the production capacity currently projected for that year (about 170 million gallons).

Effects on Use. CBO expects that fuel suppliers would just meet those requirements but not exceed them.

Repeal Scenario

The final scenario represents CBO's assessment of what would happen if lawmakers immediately eliminated the RFS, and fuel suppliers used renewable fuels only to the extent that doing so was cost-effective for them.

Requirements. Under the repeal scenario, fuel suppliers would have no requirements to use specific types or amounts of renewable fuels.

Effects on Use. CBO estimates that in the absence of the Renewable Fuel Standard, fuel suppliers would use less than 1 billion gallons of biomass-based diesel in 2017 and roughly 13 billion gallons of corn ethanol. That amount of biomass-based diesel is less than half the consumption (measured in compliance-equivalent gallons) that is projected for 2014, including the effects of the RFS. That decline would occur, in CBO's estimation, because about half of all biomass-based diesel is made from soybean oil, and available evidence suggests that the cost of producing diesel from soybean oil is higher than the wholesale price of petroleum-based diesel.[18] Biomass-based diesel is also made from several other materials, such as recycled vegetable oil or animal fat. Some of those types of biomass-based diesel (particularly diesel made from waste products) would probably remain cost-effective even without the incentives created by the RFS because the production materials are generally available at a relatively low cost.[19]

Consumption of corn ethanol would be about the same under the repeal scenario as under the 2014 volumes scenario, CBO estimates. Because ethanol is expected to cost less per gallon than gasoline in 2017, fuel suppliers would probably find it profitable to use 13 billion gallons of ethanol in that year—the volume that corresponds to the maximum blend of ethanol in gasoline (10 percent) that virtually all vehicles now on the road can use.[20] Even if ethanol did not have a price advantage, it would probably continue to be in demand to some extent because of its other benefits. In particular, adding ethanol helps suppliers ensure that their fuel meets emission limits for carbon monoxide (an air pollutant regulated by EPA) and octane requirements (for improved vehicle performance).

Over the longer term, the effect of a repeal on the use of ethanol could be greater. For example, the per-gallon

18. See Scott Irwin and Darrel Good, "Recent Trends in Biodiesel Prices and Production Profits" (Department of Agricultural and Consumer Economics, University of Illinois Urbana-Champaign, September 18, 2013), http://farmdocdaily.illinois.edu/2013/09; and Don Hofstrand, "Tracking Biodiesel Profitability" (Iowa State University Extension and Outreach, July 2012), www.extension.iastate.edu/agdm/energy/html/d1-15.html.

19. See Ralph Groschen, *Overview of the Feasibility of Biodiesel From Waste/Recycled Greases and Animal Fats* (Minnesota Department of Agriculture, October 2002), http://tinyurl.com/l6222gb (PDF, 319 KB).

20. For expectations that ethanol will cost less per gallon than gasoline in 2017, see CME Group, "RBOB Gasoline Futures" and "CBOT Denatured Fuel Ethanol Futures" (accessed June 23, 2014), www.cmegroup.com. The price of ethanol is about the same as that of gasoline per British thermal unit (Btu) of energy content; however, analysts generally believe that for blends of 10 percent ethanol or less, fuel suppliers make choices based on the per-gallon cost of the two fuels rather than the per-Btu cost. See Scott Irwin and Darrel Good, "Ethanol Blending Margins, RFS2 Compliance, and the Price of Gasoline" (AgFax, April 3, 2012), http://tinyurl.com/qj6ltg7.

price of corn ethanol might rise above that of gasoline, causing fuel suppliers to reduce the concentration of ethanol in gasoline below current levels. Another possibility is that future advances in technology could allow the development of cost-effective octane-enhancing substitutes for ethanol, which could cause fuel blenders to favor the use of those substitutes. If so, ethanol consumption under the repeal scenario could fall short of that under the other scenarios by growing amounts.

Effects of the RFS on Prices and Spending for Food

To the extent that the Renewable Fuel Standard raises the demand for ethanol made from cornstarch, it will increase corn prices and thus prices for the wide variety of foods that are produced with corn—ranging from corn syrup sweeteners to meat, dairy, and poultry products.[21] Some policymakers have expressed concern about the size of those potential price increases and their effects on households' food spending. Although food prices depend on many uncertain factors, CBO's analysis suggests that differences in food prices and spending under the agency's three scenarios for the RFS would probably be small. Specifically, CBO estimated that total U.S. food expenditures in 2017 would be higher under the EISA volumes scenario than under the other two scenarios by $3.5 billion, or about 0.2 percent of the approximately $1.8 trillion in spending on food expected in 2017.[22] The basis for that estimate is described below (the calculations are discussed in detail in the appendix).

How the RFS Affects the Use of Corn Ethanol

A key consideration when evaluating the effect of the renewable fuel mandates on food prices is the extent to which the use of corn ethanol differs among the scenarios. As described above, CBO expects that consumption of corn ethanol would be about the same whether the RFS was repealed or the 2017 requirements were set at the proposed 2014 volume of 13 billion gallons. If, by contrast, fuel suppliers had to meet the 2017 requirements specified in EISA, corn ethanol use would total 15 billion gallons in that year, CBO estimates. That additional 2 billion gallons would raise the total demand for corn.

How the Demand for Corn Ethanol Affects the Price of Corn

Of the U.S. corn supply, roughly 15 percent is used for food products, 40 percent for animal feed, and 40 percent for ethanol production (the rest is exported). Thus, any significant change in the demand for corn ethanol that resulted from the RFS could have a noticeable effect on corn prices. The extent to which corn prices would be affected would depend on how sensitive the supply of and demand for corn are to changes in its price. Analysts have produced a range of estimates for that sensitivity (known as an elasticity). Using estimates that are in the middle of that range, CBO projects that consumption of an extra 2 billion gallons of corn ethanol under the EISA volumes scenario would increase corn prices in 2017 by about 25 cents per bushel (roughly 6 percent) compared with prices under the other two scenarios. That estimate takes into account the extent to which higher prices would boost corn production and reduce nonethanol uses of corn (such as for food or animal feed), both of which would limit some of the price increase that would otherwise result.

The difference in corn prices between the scenarios could be larger over the longer term. If, following the repeal of the RFS, the ethanol content of the gasoline supply fell below 10 percent, the gap between ethanol use under that standard and in its absence would widen. As a result, differences in the consumption of corn ethanol, and thus in the price of corn, between the EISA volumes scenario and the repeal scenario would grow over time.

How the Price of Corn Affects the Cost of Food

Higher corn prices would increase food prices directly because of the large variety of food products that contain corn. Higher corn prices would also operate indirectly through two different mechanisms. First, higher prices for corn used as animal feed would lead to price increases for meat, poultry, and dairy products. Second, higher corn prices would cause farmers to produce corn in place of other crops, such as soybeans, and decreased production of those crops would in turn raise their prices.

21. For an earlier study on that topic, see Congressional Budget Office, *The Impact of Ethanol Use on Food Prices and Greenhouse Gas Emissions* (April 2009), www.cbo.gov/publication/41173.

22. An increase in the prices of certain types of food would cause consumers to reduce the amount of those foods that they purchased. But because the effects on food prices in this analysis are small, any reduction in the amounts of certain types of food consumed would also be small, and it would be offset at least in part by increased consumption of other types of food. Thus, CBO's calculations reflect the assumption that the total quantity of food purchased would be unaffected by the increase in food prices.

With both direct and indirect effects included, full compliance with the EISA mandates would increase total spending on food in 2017 by $3.5 billion, CBO estimates, relative to spending under the other two scenarios. With total U.S. food expenditures expected to be roughly $1.8 trillion in 2017, that increase would represent a rise of about 0.2 percent.

Changes in food prices could affect federal programs that are linked to those prices, such as the Supplemental Nutrition Assistance Program, or SNAP (formerly known as Food Stamps), and various programs that provide meals to children at school and in other settings. Once a year, the government adjusts the benefits paid under SNAP and the child nutrition programs on the basis of shifts in food prices. As a result, changes in food prices would lead to roughly proportionate changes in spending on such benefits.

Effects of the RFS on Prices of Transportation Fuels

The Renewable Fuel Standard boosts the use of renewable fuels by requiring fuel suppliers to obtain a specific number of RINs (with each RIN corresponding to a gallon of renewable fuel that has been blended into the fuel supply) for every gallon of petroleum-based gasoline or diesel that they use. How that requirement affects the prices of various fuels depends on a fuel's composition of petroleum-based and renewable elements. To better understand the potential size of those effects over the next several years, CBO estimated how the price of diesel and E10—the two most commonly consumed transportation fuels—and the price of E85 would differ in 2017 among its three scenarios for the RFS.

Effects Under the 2014 Volumes Scenario or the Repeal Scenario

CBO concludes that prices for diesel, E10, and E85 would probably be essentially the same in 2017 whether the RFS requirements were kept at the amounts proposed for 2014 or the RFS was repealed. As explained above, fuel suppliers would probably use roughly 13 billion gallons of corn ethanol (corresponding to a 10 percent blend) under the repeal scenario—the same amount that they would be required to use under the 2014 volumes scenario. The main difference in consumption of renewable fuels in 2017 between those two scenarios is that the 2014 volumes scenario would require the use of up to 2 billion more gallons of biomass-based diesel than fuel suppliers would use under the repeal scenario. However, that additional use would probably not have a significant effect on the prices of transportation fuels because the increase would be small relative to the total volume of fuel.

Effects Under the EISA Volumes Scenario

If EPA set the total requirement for renewable fuels and the cap on corn ethanol at the 2017 volumes stated in EISA, fuel suppliers would have to use up to 11 billion gallons more of renewable fuels than they would choose to use under the repeal scenario (see Table 1 on page 11). Those extra gallons would consist of the following:

- 2 billion additional gallons of corn ethanol; and
- Up to 9 billion additional gallons of advanced biofuels, which could be made up of biomass-based diesel, sugarcane ethanol, or other qualifying fuels.

Prices for diesel and E10 would probably be higher under the EISA volumes scenario than in the absence of the RFS, whereas the price of E85 would probably be significantly lower.[23] CBO reached those conclusions by examining the requirements that suppliers of those fuels would face and the costs of meeting the requirements.

Compliance Requirements. To implement the Renewable Fuel Standard, EPA translates the volume requirements stated in EISA into percentage blend requirements, which equal the mandated volume of each category of renewable fuel divided by the projected volume of

23. Some studies have estimated that the RFS would result in only a small increase, or even a decrease, in the price of E10. See, for example, Antonio M. Bento, Richard Klotz, and Joel Landry, "Are There Carbon Savings from U.S. Biofuel Policies? The Critical Importance of Accounting for Leakage in Land and Fuel Markets," *Energy Journal* (forthcoming), http://dx.doi.org/10.2139/ssrn.2219503; and Deepak Rajagopal and Richard J. Plevin, "Implications of Market-Mediated Emissions and Uncertainty for Biofuel Policies," *Energy Policy,* vol. 56 (May 2013), pp. 75–82, http://dx.doi.org/10.1016/j.enpol.2012.09.076. Those studies reached different conclusions than CBO did for several reasons, including the following: They allowed a longer time (10 to 15 years) for the market to adjust to a required increase in the use of renewable fuels; they assumed that gasoline could absorb an ethanol concentration of up to 20 percent without encountering problems with the availability of filling stations or the demand for that blend of fuel (although such problems would probably arise); and they did not model all of the compliance requirements of the RFS (for example, they did not account for the fact that suppliers of E10 would need to buy biomass-based diesel RINs).

gasoline and diesel that is subject to EISA. Those percentage obligations are applied to each fuel supplier's actual sales of gasoline and diesel to determine the number of RINs that the supplier must submit. Fuel suppliers obtain RINs by purchasing qualifying gallons of renewable fuels and blending them into the fuel they sell or by purchasing RINs from suppliers that have accumulated excess RINs by using more renewable fuel than the RFS requires.

Given the percentage blend requirements of the EISA volumes scenario (shown in Table 1 on page 11), for each 100 gallons of diesel or gasoline that a fuel supplier used in 2017, it would need to submit 14.5 RINs to EPA, of which 5.3 would have to qualify as advanced biofuels. Of those 5.3 advanced-biofuel RINs, at least 1.3 would have to be biomass-based diesel RINs. Thus, taking into account the nested nature of the standard, for each 100 gallons of diesel or gasoline it used, a fuel supplier would have to submit the following to EPA:

- 1.3 biomass-based diesel RINs,
- 4.0 advanced-biofuel RINs (the total of 5.3 advanced-biofuel RINs minus the 1.3 biomass-based diesel RINs), and
- 9.2 renewable fuel RINs (the total of 14.5 renewable fuel RINs minus the 5.3 total of advanced-biofuel RINs).

Estimating the effects of the EISA volumes scenario on the prices of diesel, E10, and E85 requires estimating how the Renewable Fuel Standard would affect the price of each type of RIN. It also involves calculating RIN requirements on the basis of the percentages of petroleum-based and renewable fuels in the fuel that a supplier sells.

Effect on the Price of a Renewable Fuel RIN. In past years, fuel suppliers have been able to comply with the RFS (other than the mandate on biomass-based diesel) largely by mixing corn ethanol into gasoline and selling that blend as E10. As a result, renewable fuel RINs have been plentiful, and their price has been low (less than 10 cents in 2011 and 2012).[24] If fuel suppliers had to comply with the EISA volumes scenario, however, the amount of ethanol that would need to be blended into the fuel supply in 2017 would significantly exceed the amount that could be sold as E10. As a result, the price of renewable fuel RINs would rise as suppliers sought to buy more RINs than could be generated through sales of E10. Higher RIN prices would create an incentive for fuel suppliers to sell high-ethanol blends, such as E85, which would yield excess RINs that they could sell. CBO expects that E85 suppliers would use some of the profits they obtained by selling those excess RINs to cover the capital costs necessary to modify more stations to carry E85 (estimated at roughly 10 cents per gallon of E85) and would pass the remaining profits on to consumers in the form of lower E85 prices to encourage sales of that fuel.[25]

With consumption of blended gasoline projected to total 132 billion gallons in 2017, the amount of ethanol that would be blended into the fuel supply under the EISA volumes scenario would exceed the amount used in E10 (13 billion gallons) by at least 6 billion gallons, under CBO's illustrative assumption that 4 billion gallons of the advanced-biofuel requirement would be met using sugarcane ethanol. The remaining 2 billion of those additional 6 billion gallons of ethanol would be corn ethanol. The total amount of additional ethanol used could be greater than 6 billion gallons because CBO assumed the use of 1 billion gallons of unspecified advanced biofuels, which could include ethanol made from other feedstocks, such as sorghum.

For the gasoline supply to absorb an additional 6 billion gallons of ethanol—without exceeding a 10 percent blend in the most commonly used fuel—the use of E85 by flex-fuel vehicles would need to be roughly seven times

24. The price of renewable fuel RINs rose in 2013—briefly spiking above $1 in the summer of that year—because market participants were buying RINs and saving them to use in 2014 in the expectation that the RFS would push the required use of ethanol beyond the 10 percent blend wall in 2014 (as would happen if EPA set the mandates at the 2014 volumes stated in EISA). Fuel suppliers responded to that rise in part by buying additional biomass-based diesel RINs. When it seemed likely that EPA would modify the renewable fuel requirement so that the blend wall would not be exceeded, the price of renewable fuel RINs dropped. See Scott Irwin, "Will the EPA Reverse Itself on the Write Down of the Renewable Mandate for 2014? The Message From the RINs Market" (Department of Agricultural and Consumer Economics, University of Illinois Urbana-Champaign, February 19, 2014), http://farmdocdaily.illinois.edu/2014/02.

25. For a discussion of the 10 cent per gallon estimate, see Bruce A. Babcock and Sebastien Pouliot, *Impact of Sales Constraints and Entry on E85 Demand*, Policy Brief 13-PB 12 (Center for Agricultural and Rural Development, Iowa State University, August 2013), http://tinyurl.com/k6df9lu.

greater in 2017 than the amount anticipated for 2014. Such an increase would require a large expansion in the number of fueling stations equipped to sell E85. It would also mean that the drivers of the roughly 17 million flex-fuel vehicles expected to be on the road in 2017 would have to refuel almost exclusively with E85—which would require them to refuel more often (because of the lower energy content of E85) and possibly to drive much farther to obtain E85.[26]

Using data from Brazil, where E85 fueling stations are plentiful, researchers estimated that the fuel cost of driving a mile on E85 had to be 15 percent less than the fuel cost of driving a mile on E10 to induce 80 percent of Brazilian owners of flex-fuel vehicles to use E85.[27] However, given the limited availability of E85 pumps in the United States and the unprecedented expansion in the use of E85 that would be necessary to absorb 6 billion additional gallons of ethanol, CBO estimates that savings on fuel costs for E85 drivers in the United States would have to be more substantial—probably about 30 percent to 50 percent lower than the fuel cost of driving with E10.[28] Moreover, filling stations would need to install additional E85 pumps. CBO estimates that a price of roughly $1.45 to $2.00 for renewable fuel RINs would be necessary to cover the average capital costs that filling station owners would incur to install more pumps (about 10 cents per gallon of E85 sold) and to subsidize the price of E85 enough to make the cost of driving a mile with that fuel about 30 percent to 50 percent lower than the cost of driving a mile with E10.[29]

In addition to those subsidy costs, the price of a renewable fuel RIN for a gallon of corn ethanol would have to include an increase of 10 cents per gallon in the price of corn ethanol—the increase that CBO estimates would be necessary to bring about the additional 2 billion gallons of corn ethanol required under the EISA volumes scenario.[30] With all of those price components combined, supplying and using those extra 2 billion gallons of corn ethanol would necessitate a price range of $1.55 to $2.10 for renewable fuel RINs.

Effect on the Price of an Advanced-Biofuel RIN. The EISA volumes scenario would require fuel suppliers to use up to 9 billion more gallons of advanced biofuels than they would in the absence of the RFS, CBO estimates (see Table 1 on page 11). As noted above, those additional gallons would probably consist mainly of biomass-based diesel and sugarcane ethanol, although other advanced biofuels, such as sorghum ethanol, could make up some of the supply. For this analysis, CBO assumed that 4 billion gallons of sugarcane ethanol and 2 billion gallons of biomass-based diesel would be used to help meet the advanced-biofuel mandate (in addition to the 2 billion gallons used to comply with the mandate for biomass-based diesel).

26. That estimate of 17 million is based on the current number of flex-fuel vehicles on the road and the average annual net increase in their numbers in recent years.

27. See Bruce A. Babcock and Sebastian Pouliot, *Price It and They Will Buy: How E85 Can Break the Blend Wall*, Policy Brief 13-PB 11 (Center for Agricultural and Rural Development, Iowa State University, August 2013), http://tinyurl.com/nodq3k5.

28. That range is based on a study in which researchers estimate that a 40 percent cost savings may be necessary to cause the market to accommodate an additional 6 billion gallons of ethanol by 2015. Their calculation is based on the assumptions that vehicle owners will drive up to 10 miles out of their way to obtain E85 and that existing E85 pumps can deliver as much additional fuel as needed to meet local demand. See Bruce A. Babcock and Sebastian Pouliot, *Price It and They Will Buy: How E85 Can Break the Blend Wall*, Policy Brief 13-PB 11 (Center for Agricultural and Rural Development, Iowa State University, August 2013), http://tinyurl.com/nodq3k5. Those authors' subsequent research concluded that existing pumps would be insufficient to supply an additional 6 billion gallons. However, given the longer time frame available for compliance in this analysis (2017 rather than 2015), CBO expects that sufficient pumps could become available by 2017.

29. That calculation is based on the Energy Information Administration's projection that the wholesale price of E10 will be about $3 per gallon in 2017 and CBO's estimate that corn prices will average about $4.80 per bushel in 2017 if the corn ethanol mandate is met in full. See Energy Information Administration, *Annual Energy Outlook 2014, With Projections to 2040*, DOE/EIA-0383(2014) (April 2014), www.eia.gov/forecasts/aeo. The calculation of the RIN price necessary to generate the required level of savings follows the approach used in Bruce A. Babcock and Sebastian Pouliot, *Price It and They Will Buy: How E85 Can Break the Blend Wall*, Policy Brief 13-PB 11 (Center for Agricultural and Rural Development, Iowa State University, August 2013), http://tinyurl.com/nodq3k5.

30. On the basis of its most recent agricultural outlook (summarized in Congressional Budget Office, "USDA Mandatory Farm Programs—April 2014 Baseline," www.cbo.gov/publication/44202), CBO estimates that consuming roughly 2 billion additional gallons of corn ethanol would raise the average price of corn in 2017 by about 25 cents per bushel (as explained in the appendix). A bushel of corn yields about 2.5 gallons of ethanol, so the 25 cent rise in the price of corn—if entirely passed on to consumers in the form of higher prices for finished products—would increase the price of corn ethanol by about 10 cents per gallon.

If, as CBO assumes, fuel suppliers did rely on advanced forms of ethanol (such as sugarcane ethanol) to meet 4 billion gallons of the advanced-biofuel requirement, the price of an advanced-biofuel RIN would include the aforementioned $1.45-to-$2.00 subsidy necessary to increase sales of E85 enough to absorb the additional 6 billion gallons of ethanol used under the EISA volumes scenario. However, fuel suppliers would avoid the need to subsidize the use of high-ethanol blends to the extent that they used biomass-based diesel to meet the advanced-biofuel requirement. Thus, the price that suppliers would be willing to pay for RINs generated from biomass-based diesel would include the value of that avoided cost. More generally, as long as fuel suppliers complied with the RFS by using more biomass-based diesel RINs than those necessary to meet the biomass-based diesel mandate (with the additional ones being used to meet the advanced-biofuel mandate), biomass-based diesel RINs would sell for the same price as advanced-biofuel RINs.

Besides the E85 subsidy value, the second component of the price of an advanced-biofuel RIN would be the price premium necessary to cover producers' incremental costs of increasing the supply of advanced biofuels. Complying with the EISA volumes scenario would require a very large increase in the supply of advanced biofuels, so that price premium would probably be large. To expand the supply of biomass-based diesel 2 billion gallons beyond the amount needed to satisfy the mandate for that fuel would require doubling U.S. production of biomass-based diesel. Likewise, importing 4 billion gallons of sugarcane ethanol would require a 45 percent increase in Brazil's production of such ethanol (if Brazil's own consumption did not change) and a more than fourfold increase in the country's exports of sugarcane ethanol from the 2013 level.[31] Even with those increases, complying with the EISA volumes scenario would still require an additional 1 billion gallons of advanced biofuels. (A small fraction of that requirement would be met using cellulosic biofuels, whose production capacity is projected to be 170 million gallons in 2017. CBO assumes that the remaining gallons would be of an unspecified type of advanced biofuel, supplied at the same price as the sugarcane ethanol and the additional biomass-based biodiesel.)

For illustrative purposes, CBO considered the implications for fuel prices if the price premium necessary to induce an additional 7 billion gallon supply of advanced biofuels under the EISA volumes scenario was in the range of $1.50 to $4.00 per gallon. The lower end of that range is 50 cents higher than the average spot price (roughly $1) of an advanced-biofuel RIN or biomass-based diesel RIN in 2011 and 2012. (Because the market did not expect the blend wall to be exceeded in 2011 or 2012, that average RIN price included only the price premium necessary to increase the supply of those fuels to the amounts required by the RFS in those years and did not include any subsidy to increase the consumption of E85.) The upper end of the range was chosen because the price premium that might be needed to induce such large increases in the supply of advanced biofuels in 2017 might be several times higher than that 2011–2012 average. Adding the $1.50-to-$4.00 price premium to the $1.45-to-$2.00 per-gallon subsidy for E85 suggests that each of the additional 7 billion advanced-biofuel RINs required under the EISA volumes scenario would be valued at roughly $3.00 to $6.00.

Effect on the World Price of Oil. Because renewable fuels substitute for gasoline and diesel, they reduce consumption of those fuels in the United States, which could lower the world price of oil and thus the price that fuel suppliers pay for petroleum-based fuels. CBO did not account for that effect in this analysis, for two reasons. First, any such reduction in world oil prices would most likely be small—because, for example, the 10 billion to 11 billion more gallons of renewable fuels consumed under the EISA volumes scenario than under the repeal scenario amount to only about one-half of one percent of the global supply of oil. Second, any policy that tended to reduce U.S. demand for oil, and thus the world price of oil, could be offset if large suppliers of crude oil strategically reduced their production to prevent that price from falling and if consumers worldwide responded to a temporary decline in oil prices by increasing their use of petroleum products.[32]

Effect on the Prices of Transportation Fuels in the United States. The Renewable Fuel Standard affects the

31. Brazil exported about 2.9 million cubic meters (750 million gallons) of ethanol in 2013. The United States, the European Union, and Caribbean countries received the largest shares of those exports. See Brazilian Sugarcane Industry Association, "Monthly Report of Brazilian Ethanol Exports, Calendar Year 2014," http://tinyurl.com/ktawewp (accessed April 24, 2014).

32. See Gal Hochman, Deepak Rajagopal, and David Zilberman, "The Effect of Biofuels on the International Oil Market," *Applied Economic Perspectives and Policy*, vol. 33, no. 3 (Autumn 2011), pp. 402–407, http://dx.doi.org/10.1093/aepp/ppr016; and Congressional Budget Office, *Energy Security in the United States* (May 2012), www.cbo.gov/publication/43012.

prices that consumers pay for various types of fuels differently depending on the mix of petroleum-based and renewable elements used to produce a given fuel. CBO estimated the effects of the EISA volumes scenario on the prices of the two fuels most widely used for transportation in the United States, petroleum-based diesel and E10, as well as on the price of E85. Unless otherwise noted, CBO's calculations reflect the expectation that the prices fuel suppliers pay for RINs, or the profits they receive from selling RINs, will be passed on fully to consumers.

Price of Petroleum-Based Diesel. CBO estimated the effect of the EISA volumes scenario on the price of diesel fuel by applying the range of RIN prices described above to the additional cost components identified for suppliers of diesel. Thus, for each 100 gallons of diesel that a fuel supplier sold, the additional cost that it would incur because of the RFS under the EISA volumes scenario would be the sum of the following:

- 1.3 x the $3.00-to-$6.00 price of a biomass-based diesel RIN,
- 4.0 x the $3.00-to-$6.00 price of an advanced-biofuel RIN, and
- 9.2 x the $1.55-to-$2.10 price of a renewable fuel RIN.

Those costs would add about $30 to $51 for each 100 gallons of petroleum-based diesel, which would raise the average cost of producing diesel in 2017 by 30 cents to 51 cents per gallon, or 9 percent to 14 percent.[33] Price increases would probably be smaller over the longer run, because the substantial increase in RIN prices necessary to cause large changes in renewable fuel use by 2017 would diminish as the market adjusted over time.

Price of E10. For each 100 gallons of E10 that a fuel supplier sells, it uses 90 gallons of petroleum-based gasoline and 10 gallons of corn ethanol. Its RIN requirements are based only on its consumption of gasoline, so those requirements are 10 percent less than if it sold 100 gallons of purely petroleum-based gasoline. In addition to the RIN requirements associated with the 90 gallons of petroleum-based gasoline used, an E10 supplier would pay 10 cents more for each of the 10 gallons of corn ethanol that it used in 2017 under the EISA volumes scenario (the price increase necessary to induce the extra 2 billion gallons of corn ethanol consumed in that scenario). In total, for each 100 gallons of E10 that the supplier sold, the higher cost resulting from the RFS under the EISA volumes scenario would be the sum of the following:

- 0.9 x (1.3 x the $3.00-to-$6.00 price of a biomass-based diesel RIN),
- 0.9 x (4.0 x the $3.00-to-$6.00 price of an advanced-biofuel RIN),
- 0.9 x (9.2 x the $1.55-to-$2.10 price of a renewable fuel RIN), and
- 10 x the $0.10 per gallon increase in the price of corn ethanol.

Those costs would add $28 to $47 for each 100 gallons of E10. However, those higher costs would be partly offset by RINs that the E10 supplier obtained along with each gallon of corn ethanol that it bought. Because the supplier would blend 10 gallons of corn ethanol into every 90 gallons of its fuel supply, it would receive 10 renewable fuel RINs. When that ethanol was blended into the fuel supply, each of those RINs would be worth $1.55 to $2.10.[34] (The E10 supplier would use 8.3, or 0.9 x 9.2, of those renewable fuel RINs to meet its own compliance obligations—offsetting the cost that it would otherwise incur to obtain RINs—and would sell the remaining 1.7.) The value of those 10 RINs ($15.50 to $21) would reduce the additional cost for 100 gallons of E10 to about $13 to $26.[35] Thus, on net, the EISA volumes scenario

33. The percentage increases in cost are based on the Energy Information Administration's most recent forecast for the retail price of diesel in 2017. See Energy Information Administration, *Annual Energy Outlook 2014, With Projections to 2040,* DOE/EIA-0383(2014) (April 2014), Table A12, "Petroleum and Other Liquids Prices," www.eia.gov/forecasts/aeo.

34. That value includes the additional 10 cents per gallon that the fuel supplier would pay for each gallon of corn ethanol. Thus, the supplier would receive $1.45 to $2.00 of net revenue for any RIN that it sold. Likewise, the opportunity cost if the supplier used a RIN for its own compliance purposes would be $1.45 to $2.00.

35. That example uses E10 made with corn ethanol; however, the price increase for E10 would not depend on whether corn ethanol or sugarcane ethanol was used. Instead, the cost of complying with the RFS would depend on the quantities of corn ethanol and sugarcane ethanol that the standard required. That compliance cost, with the estimates used in this analysis, would be $13 to $26 for each 100 gallons of E10.

would raise the average cost of producing a gallon of E10 by 13 cents to 26 cents per gallon in 2017, or 4 percent to 9 percent.[36] As with the price of petroleum-based diesel, the rise in the price of E10 caused by the RFS would probably diminish over time as the market adjusted.

Price of E85. The category of fuel referred to as E85 generally contains between 51 percent and 83 percent ethanol, depending on the season (winter blends have less ethanol to help vehicles start in cold weather). For this analysis, CBO anticipates that E85 will contain an average of 75 percent ethanol and 25 percent gasoline, consistent with recent projections by the Energy Information Administration.[37] Thus, for each 100 gallons of E85 that a fuel supplier sold, it would use 25 gallons of petroleum-based gasoline and 75 gallons of corn ethanol. Its RIN requirements would be based only on its consumption of gasoline, so those requirements would be 75 percent less than if it sold 100 gallons of petroleum-based gasoline. The additional cost that it would incur as a result of the RFS under the EISA volumes scenario would be the sum of the following:

- 0.25 x (1.3 x the $3.00-to-$6.00 price of a biomass-based diesel RIN),
- 0.25 x (4.0 x the $3.00-to-$6.00 price of an advanced-biofuel RIN),
- 0.25 x (9.2 x the $1.55-to-$2.10 price of a renewable fuel RIN),
- 75 x the $0.10 per gallon increase in the price of corn ethanol, and
- 100 x the $0.10 per gallon increase necessary to cover the average capital costs of adding E85 pumps.

Those costs would add $25 to $30 for each 100 gallons of E85, but they would be more than offset by the value of an E85 supplier's renewable fuel RINs. Because the supplier would mix 75 gallons of corn ethanol into every 25 gallons of its fuel supply, it would receive 75 renewable fuel RINs. Once that ethanol was blended into the fuel supply, each RIN would have a value of $1.55 to $2.10. (The supplier would use 2.3, or 0.25 x 9.2, of those RINs to meet its own compliance obligations, leaving 72.7 excess renewable fuel RINs to sell.) The value of those 75 RINs ($116 to $157) would more than offset the fuel suppliers' compliance costs. Thus, on net, the EISA volumes scenario would *decrease* the average cost of a gallon of E85 by 91 cents to $1.27 per gallon in 2017, or 37 percent to 51 percent.[38] The necessary subsidy for E85 would be likely to decrease over time as the availability of E85 pumps grew and the need for drivers to travel out of their way to find E85 declined.

Effects of the RFS on Emissions

EISA sets requirements for how much lower the greenhouse gas emissions associated with renewable fuels must be—relative to the emissions of the gasoline or diesel that they displace—to qualify for use in complying with the RFS. Those requirements vary for different types of renewable fuels:

- Cellulosic biofuels must have emissions that are least 60 percent lower than those of conventional gasoline or diesel fuel.
- Biomass-based diesel and sugarcane ethanol—the main fuels used to comply with the advanced-biofuel mandate—must have emissions that are at least 50 percent lower.
- All other renewable fuels (except those produced at plants operating, or under construction, by December 31, 2007) must have emissions that are at least 20 percent lower. Corn ethanol is the primary renewable fuel in that category.

EPA's estimates of emissions provide the official determination of which biofuels qualify for compliance purposes; however, numerous researchers have estimated the emissions associated with renewable fuels, and their results vary widely. A review of those estimates suggests that total U.S. emissions of greenhouse gases in 2017 would probably be only slightly lower under the EISA volumes

36. The percentage increases in cost are based on the Energy Information Administration's most recent forecast for the retail price of blended gasoline in 2017. See Energy Information Administration, *Annual Energy Outlook 2014, With Projections to 2040,* DOE/EIA-0383(2014) (April 2014), Table A12, "Petroleum and Other Liquids Prices," www.eia.gov/forecasts/aeo.

37. Ibid., Table 11.

38. The percentage increases in cost are based on the Energy Information Administration's most recent forecast for the retail price of E85 in 2017. See Energy Information Administration, *Annual Energy Outlook 2014, With Projections to 2040,* DOE/EIA-0383(2014) (April 2014), Table A12, "Petroleum and Other Liquids Prices," www.eia.gov/forecasts/aeo.

scenario than under the other two scenarios described above.

Key Factors That Determine Emissions

Estimating the greenhouse gas emissions associated with the increased use of renewable fuels is complicated, and the results are far from certain. Estimates depend crucially on researchers' projections of many factors, including the following:

- *Crop yields*—In general, higher yields per acre of crops used to produce renewable fuels lead to lower emissions by requiring less land to grow a given amount of feedstocks.

- *Fertilizer use*—Nitrogen, a fertilizer generally used on corn, releases nitrous oxide, a greenhouse gas.

- *Changes in land use and soil carbon*—Carbon is stored in soil and vegetation, and some of it is released as carbon dioxide when previously unfarmed land (such as pasture, grassland, or forest) is brought into production.[39] The RFS can cause the release of stored carbon directly, when crops for renewable fuels are grown on previously unfarmed land, or indirectly, when those crops compete for land that had been used to grow other commodities, leading to higher commodity prices, which encourage growers to put more new land into production. (For example, corn grown for ethanol may displace corn grown for animal feed or human consumption, leading to higher corn prices and causing previously unfarmed land in the United States or elsewhere to be devoted to growing corn.)

  Estimates of the emissions resulting from changes in land use are sometimes large but are also very uncertain. They depend on the type of land brought into production (for instance, carbon dioxide emissions would be much greater if crops were grown on land that had been forest rather than pasture) and, in the case of indirect emissions, on predictions of net changes in land use worldwide. Even changes in crop management practices, such as removing plant residue to produce ethanol, can affect the amount of carbon in the soil.

- *The efficiency of the process for converting feedstocks into fuel*—More-efficient production methods produce more renewable fuels from a given amount of feedstocks and thus generally involve fewer emissions (by requiring less land, fertilizer use, and so forth). Estimates of the efficiency of the production processes for cellulosic biofuels are particularly uncertain because those technologies are still being developed.

- *The generation of electricity credits*—Some methods for producing cellulosic biofuels separate the components of the plants that are converted into sugars, and then into ethanol, from a residual material (called lignin) that can be used to generate electricity. In such cases, most researchers "credit" the production of the biofuel with any reduction in greenhouse gas emissions that occurs when lignin-based generation of electricity is assumed to displace fossil-fuel-based generation.

In addition, because renewable fuels substitute for gasoline, they reduce U.S. consumption of gasoline, which could lead to a slight decline in the world price of oil. Any price decline, in turn, would trigger a "rebound effect"—an increase in oil consumption and emissions—inside and outside the United States.[40] The magnitude of such a rebound effect is very uncertain. It depends on the extent to which the RFS might decrease the global demand for oil, which is dependent on the particular requirements of the RFS and is complicated by uncertainty about whether large suppliers of crude oil (such as the Organization of Petroleum Exporting Countries) would prevent the price of oil from falling by reducing their production.[41] If the RFS did lead to a decline in the

39. For example, carbon dioxide is released when soil is disturbed, when trees are burned, or when the residue left from harvests decays. Such changes typically cause a large, one-time release of greenhouse gases initially, which means that producing and consuming ethanol can result in a very different time profile of emissions than producing and consuming gasoline. To account for that difference, researchers typically compare the emissions from ethanol and gasoline over an extended period (generally 30 years). Estimating emission reductions over longer periods allows more years for a one-time release of carbon dioxide to be offset by later emission reductions that occur through production and consumption.

40. If everything else is equal, a lower world price of oil will reduce the price of gasoline in the United States. The effect of the RFS on the price of blended fuel could be positive or negative, however, depending on the relative magnitude of the decrease in the wholesale price of gasoline and the increase in the marginal cost of producing renewable fuels.

41. See Gal Hochman, Deepak Rajagopal, and David Zilberman, "The Effect of Biofuels on the International Oil Market," *Applied Economic Perspectives and Policy*, vol. 33, no. 3 (Autumn 2011), pp. 402–407, http://dx.doi.org/10.1093/aepp/ppr016.

world price of oil, that decline would probably be small (for example, the 10 billion to 11 billion additional gallons of renewable fuels used in 2017 under the EISA volumes scenario, compared with the 2014 volumes scenario, equal roughly one-half of one percent of the global supply of oil). Nevertheless, that small price reduction would affect oil consumption around the world.

Researchers' estimates of the rebound effect differ greatly. One recent review of past studies found a range of estimates, suggesting that the rebound effect could offset 29 percent to 85 percent of the reduction in the consumption of crude oil that the RFS would otherwise bring about.[42] Those studies' authors typically assumed a competitive global market for oil; the rebound effect would be smaller if large oil suppliers behaved strategically to limit a price drop.

Most researchers' estimates of the emissions associated with various types of renewable fuels indicate the percentage reduction in emissions that might occur when one gallon of renewable fuel replaced an equivalent amount of gasoline; they do not take any potential rebound effect into account.[43] To the extent that such an effect occurred, it would modify the emission estimates described below—tending to lower estimates of the emission savings, or raise estimates of the emission increases, that additional use of renewable fuels might bring about.

Even without accounting for the rebound effect, researchers produce widely differing estimates of the emission implications of replacing petroleum-based fuels with renewable fuels. Those differences highlight the sensitivity of such estimates to the factors described above.

Emission Estimates for Various Types of Renewable Fuels

Estimates of the greenhouse gas emissions that result from making and using renewable fuels (including emissions created by changes in land use) vary widely according to the feedstocks used to produce the fuel. Much of the research on emission estimates has focused on corn ethanol and cellulosic ethanol, so the discussion below presents more emission estimates for those types of renewable fuels than for others, such as sugarcane ethanol and biomass-based diesel.

Corn Ethanol. EPA estimates that by 2022, the emissions associated with a gallon of corn ethanol would be 21 percent lower than those associated with a gallon of gasoline —just meeting the 20 percent minimum reduction threshold established by EISA.[44] That estimate is calculated assuming that ethanol is produced using the technologies projected to be available in 2022. Accounting for uncertainty in its estimates of the emissions resulting from changes in land use, EPA concludes that there is a 95 percent chance that the actual emission reduction from using corn ethanol in place of gasoline would be between 7 percent and 32 percent (see Figure 6 on page 24). That range is referred to as the 95 percent prediction range.

Critics of EPA's analysis note that its assumption that corn ethanol is produced using the technologies projected to exist in 2022 is likely to overstate the emission reductions caused by the RFS before then.[45] Researchers who do not explicitly assume 2022 technologies have estimated a variety of outcomes. For example, a 2011 report

42. Most of the studies reviewed estimated a range of possible outcomes. The 29 percent to 85 percent span represents the highest and lowest estimates from those ranges. See Deepak Rajagopal, "The Fuel Market Effects of Biofuel Policies and Implications for Regulations Based on Lifecycle Emissions," *Environmental Research Letters*, vol. 8, no. 2 (April 2013), http://dx.doi.org/10.1088/1748-9326/8/2/024013.

43. Those estimates take into account differences in the energy content of renewable fuels and petroleum-based fuels. Because renewable fuels have lower energy content than petroleum-based gasoline or diesel, each gallon of renewable fuel replaces less than one full gallon of gasoline or diesel.

44. See Environmental Protection Agency, *Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis*, EPA-420-R-10-006 (February 2010), www.epa.gov/otaq/renewablefuels/420r10006.pdf (17 MB).

45. See National Research Council, *Renewable Fuel Standard: Potential Economic and Environmental Effects of U.S. Biofuel Policy* (National Academies Press, 2011), http://tinyurl.com/89yfx36. Other researchers say that an advantage of EPA's approach is that it uses a unified modeling framework to determine the changes in emissions associated with production and consumption of renewable fuels and food crops, capturing potential market interactions that might otherwise be missed. In contrast, most other estimates of net emissions are obtained by combining independently derived estimates of direct reductions and indirect effects. For more discussion, see Deepak Rajagopal, "Consequential Life Cycle Assessment of Policy Vulnerability to Price Effects," *Journal of Industrial Ecology*, vol. 18, no. 2 (April 2014), pp. 164–175, http://dx.doi.org/10.1111/jiec.12058; and Richard J. Plevin, Mark A. Delucchi, and Felix Creutzig, "Using Attributional Life Cycle Assessment to Estimate Climate Change Mitigation Benefits Misleads Policymakers," *Journal of Industrial Ecology*, vol. 18, no. 1 (February 2014), pp. 73–83, http://dx.doi.org/10.1111/jiec.12074.

by the National Research Council cites three studies that conclude that substituting corn ethanol for gasoline increases emissions and one study that concludes that such substitution reduces emissions.[46] Another study published that year used simulations to account for the uncertainty in the ethanol production process as well as for the uncertainty associated with changes in land use. It estimated that the emissions resulting from the production and use of corn ethanol were 20 percent *higher* than those resulting from gasoline, with a 95 percent prediction range of 32 percent lower than gasoline to 85 percent higher.[47]

In contrast to that analysis, a 2012 study by another set of researchers estimated that the emissions associated with a gallon of corn ethanol are 34 percent lower than the emissions associated with the gasoline that it displaces (with an 80 percent prediction range of 19 percent to 48 percent lower).[48] The authors stated that their emission estimates were lower than those of other studies because they accounted for recent improvements in corn yields and in the technology used to produce corn ethanol, as well as incorporating improved estimates of emissions resulting from changes in land use.[49]

Sugarcane Ethanol. The sugarcane ethanol used in the United States is generally made in Brazil, and estimates of its emissions include the emissions associated with shipping it to the United States. EPA estimates that sugarcane ethanol emissions would be 61 percent lower than gasoline emissions by 2022, with a 95 percent prediction range of 52 percent to 71 percent lower—exceeding the 50 percent minimum reduction threshold for advanced biofuels. EPA's estimate does not include emissions caused by indirect changes in land use that might be triggered by increased consumption of sugarcane ethanol.[50] Another set of researchers, who did include an estimate of those emissions, concluded that the emissions associated with sugarcane ethanol were 51 percent lower than those associated with gasoline, with an 80 percent prediction range of 40 percent to 62 percent lower.[51]

Soybean Diesel. About half of the biomass-based diesel consumed in the United States is made from soybean oil. (The next three largest sources of such diesel—corn oil, yellow grease, and alcohol—each account for less than 10 percent of total consumption.)[52] EPA estimates that soybean oil diesel has emissions that are 57 percent lower than those of petroleum-based diesel, with a 95 percent prediction range of 22 percent to 85 percent lower.

Cellulosic Ethanol. The emissions associated with cellulosic biofuels are generally estimated to be low because relatively little energy is needed to grow cellulosic feedstocks and convert them into ethanol (although the conversion is capital-intensive and costly). Moreover, one method for producing cellulosic ethanol—a biochemical process—also results in an organic polymer called lignin, which can be used to generate electricity.

46. See National Research Council, *Renewable Fuel Standard: Potential Economic and Environmental Effects of U.S. Biofuel Policy* (National Academies Press, 2011), http://tinyurl.com/89yfx36. One of the studies estimated a 90 percent increase in emissions for each gallon of ethanol used in place of gasoline; however, that study relied on estimates of land-use-related emissions that have been criticized in recent years. For a discussion of those criticisms, see Roger A. Sedjo, Brent Sohngen, and Anne Riddle, *Wood Bioenergy and Land Use: A Challenge to the Searchinger Hypothesis*, Discussion Paper RFF DP 13-33 (Resources for the Future, November 2013), www.rff.org/RFF/Documents/RFF-DP-13-33.pdf (711 KB).

47. See Kimberley A. Mullins, W. Michael Griffin, and H. Scott Matthews, "Policy Implications of Uncertainty in Modeled Life-Cycle Greenhouse Gas Emissions of Biofuels," *Environmental Science and Technology*, vol. 45, no. 1 (January 1, 2011), pp. 132–138, http://dx.doi.org/10.1021/es1024993. The study measured emissions over a 30-year period and did not discount future emission reductions.

48. See Michael Q. Wang and others, "Well-to-Wheels Energy Use and Greenhouse Gas Emissions of Ethanol From Corn, Sugarcane, and Cellulosic Biomass for U.S. Use," *Environmental Research Letters*, vol. 7, no. 4 (October–December 2012), http://dx.doi.org/10.1088/1748-9326/7/4/045905.

49. See Michael Q. Wang and others, "Energy and Greenhouse Gas Emission Effects of Corn and Cellulosic Ethanol With Technology Improvements and Land Use Changes," *Biomass and Bioenergy*, vol. 35, no. 5 (May 2011), pp. 1885–1896, http://dx.doi.org/10.1016/j.biombioe.2011.01.028; and Jennifer B. Dunn and others, "Land-Use Change and Greenhouse Gas Emissions From Corn and Cellulosic Ethanol," *Biotechnology for Biofuels,* vol. 6, no. 51 (April 2013), http://dx.doi.org/10.1186/1754-6834-6-51.

50. See Environmental Protection Agency, *Renewable Fuel Standard (RFS2) Regulatory Impact Analysis*, EPA-420-R-10-006 (February 2010), p. 337, www.epa.gov/otaq/renewablefuels/420r10006.pdf (17 MB).

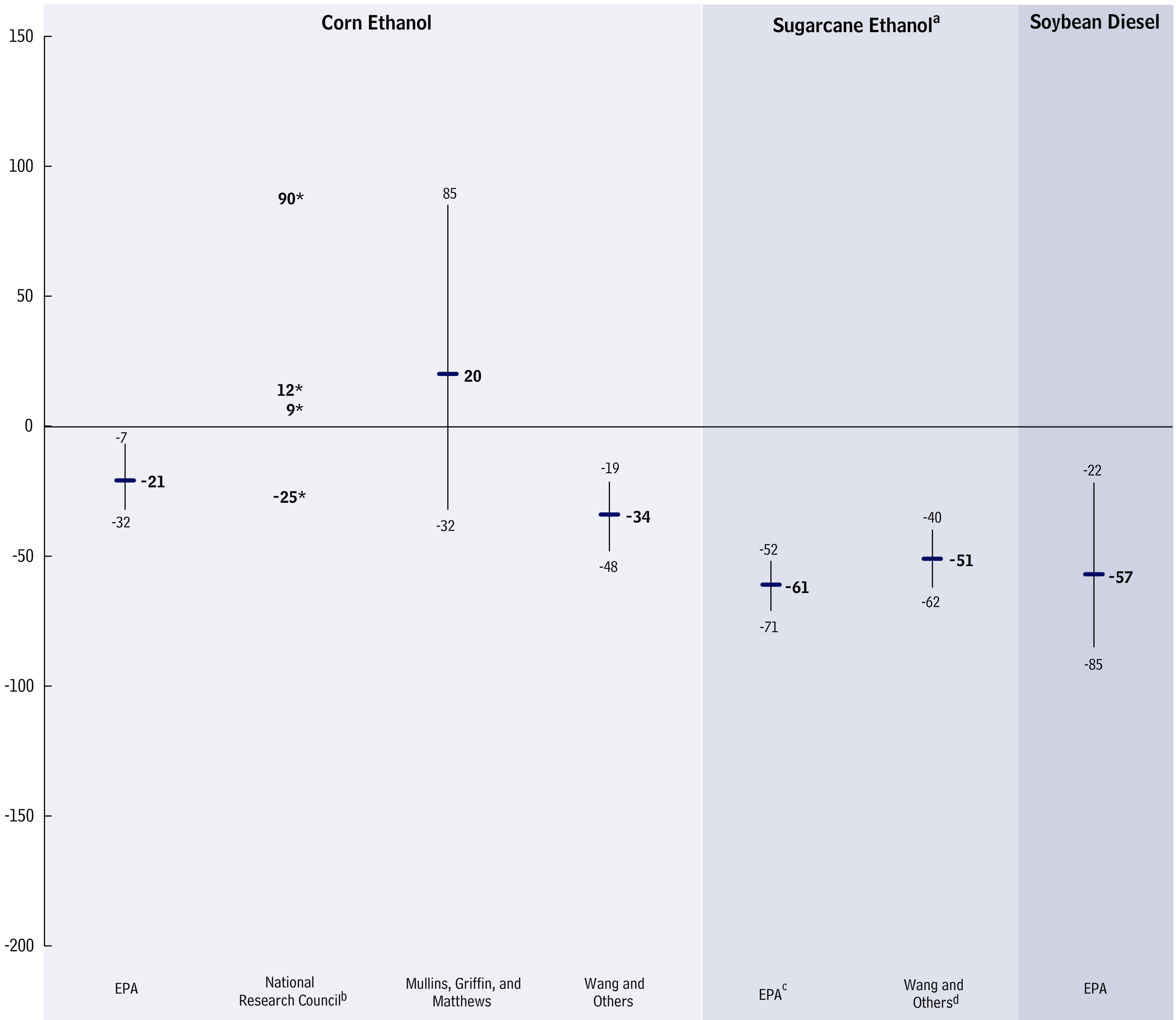
51. See Michael Q. Wang and others, "Well-to-Wheels Energy Use and Greenhouse Gas Emissions of Ethanol From Corn, Sugarcane, and Cellulosic Biomass for U.S. Use," *Environmental Research Letters*, vol. 7, no. 4 (October–December 2012), http://dx.doi.org/10.1088/1748-9326/7/4/045905.

52. Based on total use in 2013 as reported in Energy Information Administration, "Monthly Biodiesel Production Report" (January 2014), www.eia.gov/biofuels/biodiesel/production.

Figure 6.

Estimated Difference Between the Greenhouse Gas Emissions Associated With Various Biofuels and the Emissions Associated With the Gasoline or Diesel They Replace

(Percent)



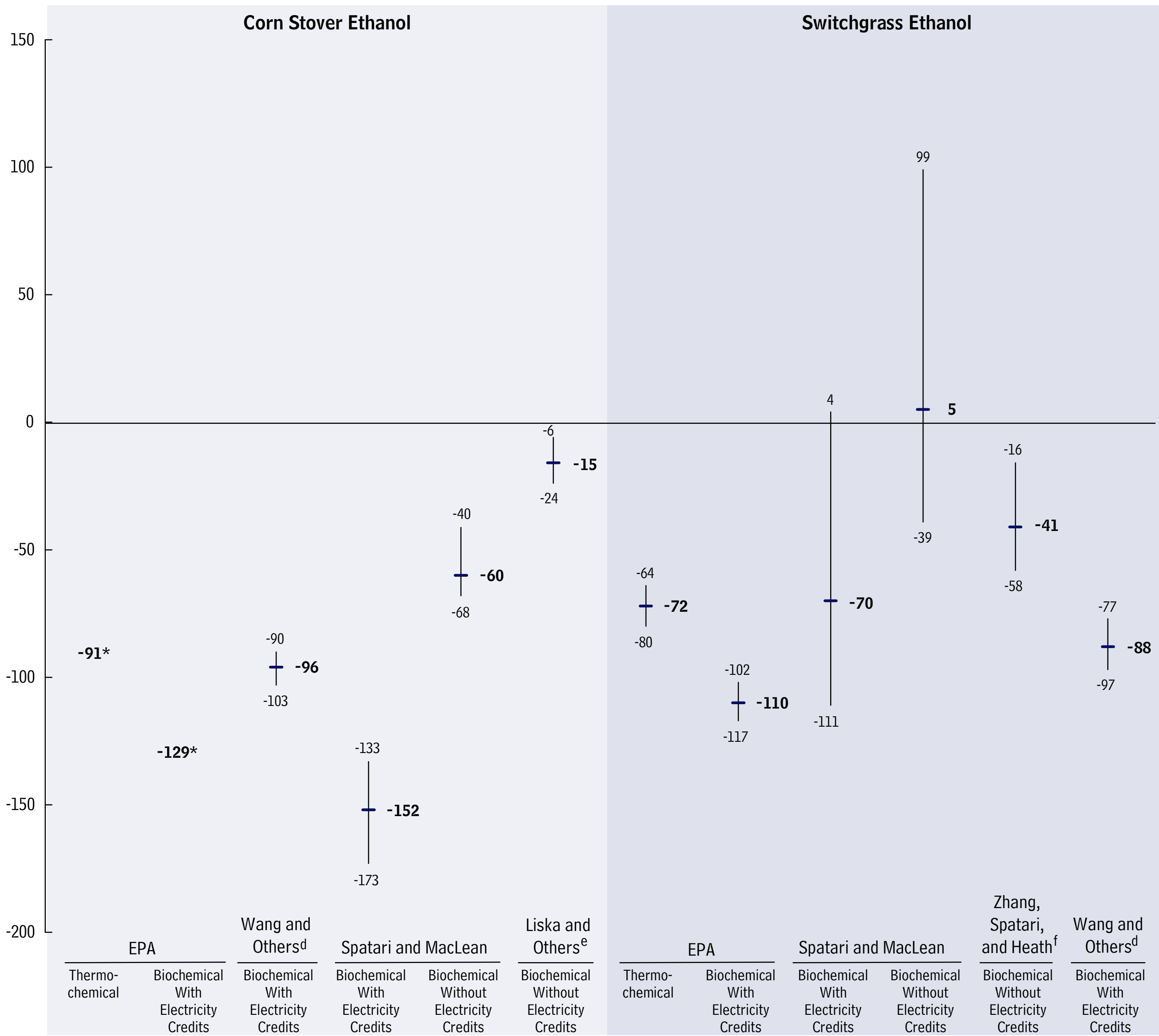
Source: Congressional Budget Office based on Environmental Protection Agency, *Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis,* EPA-420-R-10-006 (February 2010), www.epa.gov/otaq/renewablefuels/420r10006.pdf (17 MB); National Research Council, *Renewable Fuel Standard: Potential Economic and Environmental Effects of U.S. Biofuel Policy* (National Academies Press, 2011), http://tinyurl.com/89yfx36; Kimberley A. Mullins, W. Michael Griffin, and H. Scott Matthews, "Policy Implications of Uncertainty in Modeled Life-Cycle Greenhouse Gas Emissions of Biofuels," *Environmental Science and Technology,* vol. 45, no. 1 (January 1, 2011), pp. 132–138, http://dx.doi.org/10.1021/es1024993; Michael Q. Wang and others, "Well-to-Wheels Energy Use and Greenhouse Gas Emissions of Ethanol From Corn, Sugarcane, and Cellulosic Biomass for U.S. Use," *Environmental Research Letters,* vol. 7, no. 4 (October–December 2012), http://dx.doi.org/10.1088/1748-9326/7/4/045905; Sabrina Spatari and Heather L. MacLean, "Characterizing Model Uncertainties in the Life Cycle of Lignocellulose-Based Ethanol Fuels," *Environmental Science and Technology,* vol. 44, no. 22 (November 15, 2010), pp. 8773–8780, http://dx.doi.org/10.1021/es102091a; Adam J. Liska and others, "Biofuels From Crop Residue Can Reduce Soil Carbon and Increase CO_2 Emissions," *Nature Climate Change,* vol. 4 (April 20, 2014), http://dx.doi.org/10.1038/nclimate2187; and Yimin Zhang, Sabrina Spatari, and Garvin Heath, "Are We Ready for Consequential LCA-Based Regulations?" (presentation prepared by the National Renewable Energy Laboratory for the American Center for Life Cycle Assessment's LCA X Conference, Portland, Oregon, November 2, 2010), www.lcacenter.org/LCAX/presentations-final/145.pdf (746 KB).

Continued

Figure 6. **Continued**

Estimated Difference Between the Greenhouse Gas Emissions Associated With Various Biofuels and the Emissions Associated With the Gasoline or Diesel They Replace

(Percent)



Notes: Unless otherwise noted, the ranges of results shown for individual studies are the 95 percent prediction ranges, with the median estimate indicated. "Electricity credits" denote that the ethanol production process was credited with emission reductions that occurred when components of the feedstocks that could not be used to make ethanol were used to generate electricity, which was then assumed to displace fossil-fuel-fired electricity. Those electricity credits allow emission estimates for cellulosic ethanol (such as corn stover ethanol or switchgrass ethanol) to be more than 100 percent lower than emission estimates for gasoline or diesel. Unless otherwise noted, all estimates include emissions from policy-induced changes in land use.

EPA = Environmental Protection Agency; * = point estimate.

a. Made in Brazil and shipped to the United States.

b. Point estimates for national average outcomes found in studies cited by the National Research Council.

c. Does not include emissions from price-induced changes in land use resulting from the increased demand for sugarcane.

d. Results show the 80 percent prediction range, with the median estimate indicated.

e. Results show the average outcome plus and minus two standard deviations; according to that study, actual emission reductions would be likely to lie within that range.

f. Uses the same model and assumptions as Spatari and MacLean but does not include emissions associated with changes in land use.

Most emission estimates for ethanol produced using that process credit the ethanol with emission reductions that occur under the assumption that the lignin-generated electricity is sold to the electrical grid, displacing power generated from fossil fuels. Those "electricity credits" allow emission estimates for cellulosic ethanol to be more than 100 percent lower than emission estimates for gasoline or diesel.

Corn Stover. Most researchers conclude that ethanol produced from corn stover—the material left over when corn is harvested—has lower emissions than any other type of cellulosic biofuel. The reason is that corn stover is not expected to trigger any changes in land use (either directly to produce it or indirectly through changes in corn prices) and thus would not generate any land-use-related emissions. The volume of ethanol that can be produced from corn stover is limited by the demand for corn and by the amount of corn stover that can be removed from fields without significantly reducing the productivity of the soil.

EPA predicts (on the basis of technologies expected to be available in 2022) that emissions associated with ethanol made from corn stover would be 91 percent lower than those associated with gasoline if the ethanol was produced using a thermochemical process, or 129 percent lower if it was made using the biochemical process that results in lignin (taking into account electricity credits). Factoring in key uncertainties about the production process, other researchers estimated that emissions resulting from corn stover ethanol (produced using a biochemical process and with electricity credits taken into account) would be 90 percent to 103 percent lower than those from gasoline (based on an 80 percent prediction range).[53] A different set of researchers showed the sensitivity of emission estimates to assumptions about electricity credits.[54] Their median estimate was that the emissions associated with making corn stover ethanol using a biochemical process would be 152 percent lower than the emissions associated with gasoline if credits were included for emission reductions from selling excess electricity to the grid, or 60 percent lower if such credits were not included.

Compared with those estimates, a new study reports a much less favorable outlook for reducing emissions by substituting corn stover ethanol for gasoline. Its different conclusions reflect the authors' estimate that removing corn stover from fields increases emissions because that material releases some of its carbon into the atmosphere at a faster rate when used in biofuel production than when left to decay into the soil. Accounting for the increases in emissions of carbon dioxide that would occur over 10 years, they estimate that, on average, the emissions associated with corn stover ethanol would be 15 percent less than those associated with gasoline, with a likely range of 6 percent to 24 percent lower.[55] Because losses in soil carbon diminish over time, those researchers' findings are sensitive to the time horizon considered. They estimate that average losses in soil carbon over 10 years are 30 percent less than average losses over 5 years; other studies that have examined emissions caused by land-use-related changes in carbon dioxide emissions estimated them over a 30-year time horizon.

Critics of the new study argue that the results are based on the removal of all corn stover from a field, which is inconsistent with farmers' practices.[56] The authors, however, say that their results are insensitive to the percentage of stover that is removed. Both the critics and the authors agree that results are sensitive to a variety of soil- and crop-management practices. For example, farmers could reduce losses in soil carbon by using no-till cover crops or by applying compost or manure. Finally, as other studies have demonstrated, estimates of the emissions associated

53. See Michael Q. Wang and others, "Well-to-Wheels Energy Use and Greenhouse Gas Emissions of Ethanol From Corn, Sugarcane, and Cellulosic Biomass for U.S. Use," *Environmental Research Letters*, vol. 7, no. 4 (October–December 2012), http://dx.doi.org/10.1088/1748-9326/7/4/045905.

54. See Sabrina Spatari and Heather L. MacLean, "Characterizing Model Uncertainties in the Life Cycle of Lignocellulose-Based Ethanol Fuels," *Environmental Science and Technology,* vol. 44, no. 22 (November 15, 2010), pp. 8773–8780, http://dx.doi.org/10.1021/es102091a. Calculations are based on the 50th percentile outcome in Figure 1 of that study.

55. See Adam J. Liska and others, "Biofuels From Crop Residue Can Reduce Soil Carbon and Increase CO_2 Emissions," *Nature Climate Change*, vol. 4 (April 20, 2014), http://dx.doi.org/10.1038/nclimate2187. That range represents plus or minus two standard deviations from the mean estimate of 15 percent; according to that study, actual emission reductions would be likely to lie within that range.

56. See, for example, National Corn Growers Association, "Federal Agencies, Others Dispute Report on Corn Stover Ethanol and Climate Change," *National Journal* (April 23, 2014), www.nationaljournal.com/library/143649; and Donnelle Eller, "Experts Say Ethanol Study Used Bad Model," *Des Moines Register* (April 21, 2014), http://tinyurl.com/qfppjyj.

with corn stover would be lower if the lignin (the part of corn stover that typically contributes to soil carbon if the stover is left on the field) was used to generate electricity.

Switchgrass. Ethanol can also be produced from the cellulose in some perennial grasses, such as switchgrass. That type of ethanol is generally expected to result in lower emissions than corn ethanol but somewhat higher emissions than ethanol made from corn stover.

Based on a thermochemical process that it expects to be available in 2022, EPA projects that the emissions associated with switchgrass would be 72 percent lower than those associated with gasoline, with a 95 percent prediction range of 64 percent to 80 percent lower. Based on a biochemical process that it expects to be available in 2022 (and assuming that excess electricity is sold to the grid), EPA projects that switchgrass ethanol emissions would be 110 percent lower than gasoline emissions, with a 95 percent prediction range from 102 percent to 117 percent lower.

A second study, which used a simulation approach that accounted for numerous sources of uncertainty, estimated a much wider range of possible outcomes for switchgrass ethanol.[57] With a biochemical process (and electricity credits factored in), emissions from switchgrass ethanol could range from 111 percent less to 4 percent more than emissions from gasoline (based on a 95 percent prediction interval). Those authors also demonstrated the importance of electricity credits for such estimates. If the same biochemical process did not generate electricity credits, they concluded, the emissions associated with switchgrass ethanol could be as much as 99 percent higher than those associated with gasoline (their median estimate was 5 percent higher).

A third study, which used the same model and assumptions as the second study, showed how important emissions from changes in land use are to emission estimates for renewable fuels.[58] The third study concluded that if land-use-related emissions were not accounted for, the emissions from making and using switchgrass ethanol would be 16 percent to 58 percent lower than those from gasoline, even without electricity credits included, compared with a corresponding prediction range of 99 percent higher to 39 percent lower in the second study. Estimates of the emissions associated with changes in land use are very uncertain, however, which is why the 95 percent prediction ranges in the two studies differ so much.

Including electricity credits and recent estimates of land-use-related emissions (which tend to be lower than the estimates used by some earlier studies), another group of researchers estimated that emissions from switchgrass ethanol would be 77 percent to 97 percent lower than those from gasoline (based on an 80 percent prediction range).[59]

Effects of the Alternative Scenarios on Emissions

Available evidence suggests that using corn ethanol in place of gasoline has only limited potential to reduce greenhouse gas emissions (and some researchers estimate that it could actually increase emissions). Moreover, the emission estimates described above do not account for the rebound effect, in which the substitution of renewable fuels for gasoline in the United States could lead to a decrease in the price of crude oil, resulting in a rise in the global consumption of gasoline and its associated emissions. That rise in emissions elsewhere would offset some of the reduction in emissions caused by the substitution of renewable fuels for gasoline in this country. The potential of the RFS to reduce greenhouse gas emissions worldwide is generally thought to be greater to the extent that it causes gasoline and diesel to be replaced by advanced biofuels, which have relatively low emissions, rather than by corn ethanol. Such substitutions are more likely to offset any indirect increases in emissions that the RFS might trigger, including emissions resulting from changes in land use or fuel consumption elsewhere in the world.

57. See Sabrina Spatari and Heather L. MacLean, "Characterizing Model Uncertainties in the Life Cycle of Lignocellulose-Based Ethanol Fuels," *Environmental Science and Technology*, vol. 44, no. 22 (November 15, 2010), pp. 8773–8780, http://dx.doi.org/10.1021/es102091a.

58. See Yimin Zhang, Sabrina Spatari, and Garvin Heath, "Are We Ready for Consequential LCA-Based Regulations?" (presentation prepared by the National Renewable Energy Laboratory for the American Center for Life Cycle Assessment's LCA X Conference, Portland, Oregon, November 2, 2010), www.lcacenter.org/LCAX/presentations-final/145.pdf (746 KB).

59. See Michael Q. Wang and others, "Well-to-Wheels Energy Use and Greenhouse Gas Emissions of Ethanol From Corn, Sugarcane, and Cellulosic Biomass for U.S. Use," *Environmental Research Letters*, vol. 7, no. 4 (October–December 2012), http://dx.doi.org/10.1088/1748-9326/7/4/045905.

CBO estimates that emissions in 2017 would be essentially the same whether the RFS was repealed or its requirements were kept at the proposed 2014 volumes, because those two scenarios would result in the use of very similar amounts of renewable fuels. Consumption of corn ethanol would be about the same in both scenarios, and consumption of biomass-based diesel would be, at most, not quite 2 billion gallons greater in the 2014 volumes scenario than in the repeal scenario.

Complying with the requirements stated in EISA for 2017, rather than the lower 2014 volumes, would increase the total use of renewable fuels in that year by 9 billion gallons, CBO estimates, with 7 billion of the additional gallons consisting of advanced biofuels. As a result, the potential reduction in emissions because of the RFS would be larger under that scenario than under the 2014 volumes scenario. Nonetheless, even under the EISA volumes scenario, that reduction would constitute a very small fraction of the total emissions from transportation fuels: Adding 9 billion gallons of renewable fuels to the transportation fuel supply would reduce consumption of gasoline and diesel by only about 3 percent.[60]

The effects of EISA on fuel consumption and emissions in 2017 are highly uncertain, however. For example, consumption of petroleum-based fuels could decline by more than 3 percent if increases in the prices of E10 and diesel because of the RFS led to decreases in the number of vehicle-miles traveled or to increases in the efficiency of the vehicle fleet as a whole. That decline in total fuel consumption would further decrease emissions, beyond any reduction resulting from the substitution of renewable fuels for petroleum-based fuels. Conversely, the additional increases in the use of advanced biofuels (such as sugarcane ethanol) required under the EISA volumes scenario could lead to larger increases in land-use-related emissions than have been associated with those fuels so far. That outcome would be particularly likely if farmers ran out of land with relatively small amounts of stored carbon (such as marginal farmland) and grew the additional feedstocks for those advanced biofuels on land with larger amounts of stored carbon (such as woodland).

The RFS's potential to reduce emissions will be greater over the longer term if it encourages improvements in the technology for producing fuels with relatively low emissions, such as cellulosic biofuels—particularly drop-in cellulosic gasoline or diesel that can be added to the supply of transportation fuels without encountering problems with the 10 percent blend wall. As noted above, however, tension exists between the goals of limiting the near-term cost of complying with the RFS (by issuing waivers for cellulosic biofuels, for example) and providing a strong incentive for the development of better technology.

60. That calculation is based on the Energy Information Administration's projections of gasoline and diesel consumption in 2017 and on the assumptions that renewable fuels have two-thirds of the energy content of petroleum fuels and that the RFS does not alter the total energy content of transportation fuels.

Appendix: Details About CBO's Estimates for Food Prices and Spending

This technical appendix provides details about the estimates and assumptions that the Congressional Budget Office (CBO) used to evaluate how the Renewable Fuel Standard (RFS) might affect total U.S. spending on food in an illustrative year, 2017. The size of that effect depends on a number of factors, such as how much corn ethanol would be used in the absence of the RFS, how the production and consumption of corn respond to changes in its price, and how farmers alter their planting decisions for corn and other crops when demand for corn ethanol changes. The effect of the RFS on ethanol use is among the most important of those factors: If the RFS requirement for corn ethanol does not influence the amount of that fuel consumed in the United States, it will have no effect on food prices, regardless of other assumptions.

CBO expects that there would be little difference in the use of corn ethanol—and therefore in total spending on food—in 2017 if the requirements for renewable fuels were set at the amounts currently proposed for 2014 (the 2014 volumes scenario) or if lawmakers eliminated the RFS (the repeal scenario). Thus, this appendix focuses on the effect that the RFS would have on food spending in 2017 if the requirements for that year specified in the Energy Independence and Security Act of 2007 were met in full (the EISA volumes scenario).

Effects on Corn Ethanol Use

In CBO's estimation, the amount of corn ethanol used in 2017 would be higher under the EISA volumes scenario than under the other two scenarios by about 1.8 billion bushels, or 14 percent. In total, the RFS requires that 24 billion gallons of renewable fuels be blended into the nation's supply of gasoline and diesel in 2017. However, no more than 15 billion gallons of that requirement can be satisfied by using ethanol produced from cornstarch, leaving at least 9 billion gallons to come from other renewable fuels. CBO expects 2 billion of those 9 billion gallons to be biomass-based diesel, which means that at least 7 billion gallons would have to come from other advanced biofuels (expected to be mainly ethanol made from sugarcane and other sources of sugar).[1] Because the United States produces large quantities of corn ethanol, and because existing mandates for ethanol (which can be met with any type) are met almost entirely through the use of corn ethanol, CBO expects that under the EISA volumes scenario, fuel suppliers would use corn ethanol up to the 15 billion gallon cap specified for 2017.

Given the availability of domestically produced corn ethanol and the preponderance of its use in meeting current requirements, CBO expects that if the RFS did not exist or if its mandates were greatly reduced, fuel suppliers would want to use as much corn ethanol as possible given the constraints of the 10 percent blend wall (the fact that many older vehicles cannot operate effectively on blends of more than 10 percent ethanol). Thus, CBO projects that under either the repeal scenario or the 2014 volumes scenario, fuel suppliers would find it profitable to use 13 billion gallons of corn ethanol (an estimate based on the Energy Information Administration's forecast that

1. The RFS requires at least 1 billion gallons of biomass-based diesel be used to meet the 2017 mandate, although the exact amount will depend on future rulemaking. One gallon of biomass-based diesel can be used in place of 1.5 gallons of ethanol for purposes of complying with the RFS, which is why CBO expects that about 2 billion gallons of biomass-based diesel will be used in 2017.

U.S. consumption of blended fuel will total 132 billion gallons in 2017).[2]

Effects on the Price of Corn and on Spending for Food

The greater U.S. ethanol consumption that CBO envisions under the EISA mandates, compared with the repeal and 2014 volumes scenarios, would raise the demand for and price of corn. How much that price would increase depends on supply and demand elasticities for corn—measurements of how sensitive the production and consumption of corn are to changes in its price. An elasticity measures the percentage change in production or consumption of a good when the price changes by 1 percent.

Supply and Demand Elasticities for Corn

On the basis of various studies, CBO used values of 0.4 for the elasticity of the supply of corn and -0.25 for the elasticity of the demand for corn.[3] Those values imply that a 1 percent increase in the price of corn would raise corn production by 0.4 percent and reduce consumption by 0.25 percent. Changes to the ethanol mandate would have smaller effects on prices if supply and demand are more elastic (with elasticities farther from zero) than if they are more inelastic (with elasticities closer to zero). More elastic conditions imply that markets can absorb changes in desired quantities bought or sold with comparatively little effect on market prices. Inelastic conditions, by contrast, imply that market prices will shift dramatically if decisions about consumption and production change, possibly even if those changes are small.

Given supply and demand elasticities, the percentage change in the market price of corn resulting from a change in the mandate for corn ethanol follows from this relationship:

$$\%\Delta P_{corn} = \frac{\%\Delta S_{corn}}{\left(\varepsilon_s - \varepsilon_d\left(\frac{S_{corn} - S^E_{corn}}{S_{corn}}\right)\right)}$$

Where S_{corn} refers to the amount of corn produced before the change in the mandate, $\%\Delta S_{corn}$ refers to the percentage change in the supply of corn stemming from the change in the mandate, ε_S and ε_d refer to the supply and demand elasticities for corn, and S^E_{corn} refers to the amount of corn used to produce ethanol before the change in the mandate.[4] The last term in the denominator,

$$\frac{S_{corn} - S^E_{corn}}{S_{corn}}$$

denotes the percentage of U.S. corn production that is used for purposes other than making ethanol.

Changes in U.S. Ethanol Production and Their Effect on the Demand for Corn

On the basis of its most recent agricultural outlook, CBO estimates that the United States would produce about 14 billion bushels of corn in 2017 under the 2014 volumes scenario or the repeal scenario, with about 5 billion of those bushels used to make ethanol.[5] The 14 percent higher U.S. ethanol production assumed to occur under

2. See Energy Information Administration, *Annual Energy Outlook 2014, With Projections to 2040,* DOE/EIA-0383(2014) (April 2014), www.eia.gov/forecasts/aeo.

3. Estimates of elasticity were taken from Harry de Gorter and David R. Just, *The Welfare Economics of an Excise-Tax Exemption for Biofuels and the Interaction Effects With Farm Subsidies*, Working Paper 2007-13 (Cornell University, Department of Applied Economics and Management, December 2007), http://tinyurl.com/poyu732 (PDF, 427 KB); Bruce Gardner, "Fuel Ethanol Subsidies and Farm Price Support," *Journal of Agricultural and Food Industrial Organization*, vol. 5, no. 2 (December 2007), http://dx.doi.org/10.2202/1542-0485.1188; Andrew Schmitz, Charles B. Moss, and Troy G. Schmitz, "Ethanol: No Free Lunch," *Journal of Agricultural and Food Industrial Organization*, vol. 5, no. 2 (December 2007), http://dx.doi.org/10.2202/1542-0485.1186; Scott Baier and others, *Biofuels Impact on Crop and Food Prices: Using an Interactive Spreadsheet*, International Finance Discussion Papers 967 (Board of Governors of the Federal Reserve System, March 2009), www.federalreserve.gov/pubs/ifdp/2009/967/default.htm; and Paul W. Gallagher and others, "Some Long-Run Effects of Growing Markets and Renewable Fuel Standards on Additives Markets and the U.S. Ethanol Industry," *Journal of Policy Modeling,* vol. 25, no. 6–7 (September 2003), pp. 585–608, http://dx.doi.org/10.1016/S0161-8938(03)00055-3.

4. See Scott Baier and others, *Biofuels Impact on Crop and Food Prices: Using an Interactive Spreadsheet,* International Finance Discussion Papers 967 (Board of Governors of the Federal Reserve System, March 2009), www.federalreserve.gov/pubs/ifdp/2009/967/default.htm.

5. That outlook is summarized in Congressional Budget Office, "USDA Mandatory Farm Programs—April 2014 Baseline" (April 2014), www.cbo.gov/publication/44202.

Table A-1.

Production and Price of Corn in 2017 Under CBO's Alternative Scenarios for the Renewable Fuel Standard

	2014 Volumes Scenario and Repeal Scenario[a]	EISA Volumes Scenario[b]	Percentage Difference Between the EISA Volumes Scenario and the Other Two Scenarios
Projected U.S. Corn Production in 2017 (Billions of bushels)	14.1	14.4	2
Projected Average Price of Corn in 2017 (Dollars per bushel)	4.25	4.50	6[c]

Source: Congressional Budget Office.

a. For the 2014 volumes scenario, CBO assumed that the 2017 requirements for renewable fuels would be set at the same volumes that the Environmental Protection Agency (EPA) has proposed for 2014. For the repeal scenario, CBO assumed that lawmakers would repeal the Renewable Fuel Standard in 2014, so fuel suppliers would not be subject to any requirements for the use of renewable fuels in 2017. CBO projects that total use of corn ethanol in the United States would be about the same under both scenarios.

b. For this scenario, CBO assumed that fuel suppliers would have to comply with the various requirements for renewable fuels that are specified for 2017 in the Energy Independence and Security Act of 2007 (except the requirement for cellulosic biofuels, which EPA is assumed to reduce to a volume consistent with the projected production capacity for those fuels).

c. This calculation is based on assumed elasticities of 0.4 for the supply of corn and -0.25 for the demand for corn and on CBO's projection that 5 billion bushels of corn will be used to produce ethanol in 2017. Those elasticities imply that a 1 percent increase in the price of corn would raise corn production by 0.4 percent and reduce corn consumption by 0.25 percent. (For more about those elasticities, see the text.)

the EISA volumes scenario would raise the demand for corn for ethanol production by about 0.7 billion bushels.

The overall demand for corn under that scenario would increase by a smaller amount, however. The reason is that ethanol production creates byproducts that are used as animal feed (1 bushel of corn used in ethanol production produces roughly 0.3 bushels of animal feed).[6] With more of those byproducts available, the amount of corn used as animal feed would decline somewhat. Accounting for those byproducts means that the net change in total demand for corn under the EISA volumes scenario (in the absence of any other changes in the quantity demanded once the market price rises) would be an increase of about 0.4 billion bushels—or roughly 3 percent of the U.S. corn production that would occur in 2017 without the RFS, CBO estimates. With changes in demand caused by higher corn prices factored in, the net increase in corn production would be smaller, about 0.3 billion bushels, or 2 percent.

6. See Dusan Drabik, *The Theory of Biofuel Policy and Food Grain Prices*, Working Paper 2011-20 (Cornell University, Charles H. Dyson School of Applied Economics and Management, March 2012), http://tinyurl.com/q2kj54g (PDF, 580 KB).

Effects on the Price of Corn

With the elasticities for corn used in this analysis, CBO estimates that the 14 percent higher production of corn ethanol under the EISA volumes scenario than under the other scenarios means that the price of corn would be about 6 percent higher under the EISA volumes scenario. CBO projects that the price of corn will average about $4.25 per bushel in 2017 under the 2014 volumes scenario or the repeal scenario, so that 6 percent increase would raise the price per bushel by about 25 cents (see Table A-1).

Effects on the Cost of Food

The estimated increase in the price of corn would cause total U.S. spending on food in 2017 to be $3.5 billion higher under the EISA volumes scenario than under the other two scenarios, CBO estimates. That rise represents about one-quarter of one percent of the roughly $1.8 trillion expected to be spent on food in the United States during 2017 under the repeal scenario or the 2014 volumes scenario. CBO's estimate is based on the ways in which a higher corn price would affect the costs of food products that contain corn, food products from animals that eat corn, and agricultural products whose production would be displaced by corn.

Table A-2.

Effects of the EISA Volumes Scenario on Food Prices and Spending in 2017

	Change Under the EISA Volumes Scenario
Estimated Change in the Average Price of Corn (Dollars per bushel)	0.25
Effects of the Higher Corn Price on Food Prices	
Direct effects through the cost of corn products	
Total amount of corn used in food in 2017 (Billions of bushels)	1.5
Change in spending on food products that contain corn (Billions of dollars)	**0.4**
Indirect effects through the cost of meat, poultry, and dairy products	
Total amount of corn used in animal feed in 2017 (Billions of bushels)	5.4
Change in spending on meat, poultry, and dairy products (Billions of dollars)	**1.3**
Indirect effects through the cost of soybean products	
Change in U.S. corn production (Billions of bushels)	0.3
Average corn yield (Bushels per acre)	170
Change in total acres planted in corn (Millions)	1.9
Change in U.S. soybean production (Percent)	-2
Change in the average price of soybeans (Dollars per bushel)	1.00
Total U.S. soybean production (Billions of bushels)	1.8
Change in spending on soybeans (Billions of dollars)	**1.8**
Total Change in Spending on Food (Billions of dollars)	**3.5**
Projected 2017 Food Expenditures (Billions of dollars)	1,770
Percentage Change in Spending on Food	**0.2**

Source: Congressional Budget Office.

Notes: For the EISA volumes scenario, CBO assumed that fuel suppliers would have to comply with the various requirements for renewable fuels that are specified for 2017 in the Energy Independence and Security Act of 2007 (except the requirement for cellulosic biofuels, which the Environmental Protection Agency is assumed to reduce to a volume consistent with the projected production capacity for those fuels).

These calculations are based on the effect of the EISA volumes scenario on the average price of corn in 2017 as shown in Table A-1. The calculations assume that increases in the prices of corn and soybeans are passed on fully to consumers in the form of higher prices for food.

Spending on Corn Products. CBO expects that roughly 1.5 billion of the 14 billion bushels of corn produced in the United States in 2017 under either the 2014 volumes scenario or the repeal scenario would be used directly in food. That quantity includes corn consumed on its own, corn used in breakfast cereals and other food products, and corn used to produce corn syrup and other sweeteners. With the price of corn about 25 cents higher per bushel under the EISA volumes scenario, direct spending on corn products in 2017 would be about $0.4 billion higher than under the other scenarios, if the higher corn price was fully passed on to consumers in the form of higher prices for food (see Table A-2). The difference in overall spending on corn products would be smaller if some of the higher cost of corn was absorbed by intermediaries at various stages of production, transportation, packaging, or marketing.

Spending on Meat, Poultry, and Dairy Products. CBO expects 5.4 billion bushels of corn to be used as animal feed in 2017 under the 2014 volumes scenario or the repeal scenario.[7] Because more corn is used for animal

7. See Congressional Budget Office, "USDA Mandatory Farm Programs—April 2014 Baseline" (April 2014), www.cbo.gov/publication/44202.

feed than is used directly for food production, higher costs for meat, poultry, and dairy products would probably have a larger effect on food prices overall than would higher costs for corn products. If farmers passed the full increase in animal feed prices along to retail consumers, the higher price of corn in the EISA volumes scenario would increase consumers' total spending on meat, poultry, and dairy products in 2017 by about $1.3 billion, CBO estimates. As with consumers' spending on corn products, the rise in spending would be smaller if intermediaries absorbed some of the cost increases as feed prices rose.

Spending on Other Agricultural Products. Higher demand for corn can also affect the price of food indirectly as farmers increase the amount of land they use to grow corn and reduce the amount they use for other crops, thus raising the prices of those other crops. How many acres would be converted under the EISA volumes scenario depends on how much more corn would be produced domestically and on the average yield per acre of corn. CBO expects corn yields to average about 170 bushels per acre in 2017.[8] Producing 1.8 billion more gallons of corn ethanol and 0.3 billion more bushels of corn (the net effect of more corn used for ethanol production and less used for other purposes because of higher market prices) would require almost 2 million more acres of U.S. farmland to be used for corn production in the EISA volumes scenario than in the other two scenarios.

Much of that land would formerly have been used for growing other crops. A lesser supply of those crops would increase their prices, further pushing up the cost of food. After corn, soybeans and wheat are the two crops grown in the greatest amounts in the United States.[9] Thus, most of the additional acreage that would be used for corn under the EISA volumes scenario would otherwise have been used for growing those crops. Corn and soybeans are typically planted in rotation (with a crop of one followed by a crop of the other on the same land), so CBO expects that all of the additional land that would be used to grow corn under the EISA volumes scenario in 2017 would previously have been used to grow soybeans. (If some of that available land had been used to produce other crops, CBO's conclusions would not be affected substantially.)

Using almost 2 million fewer acres to grow soybeans would reduce projected soybean production by about 2 percent. CBO estimates that the price elasticity of demand for soybeans is the same as for corn, -0.25.[10] Thus, a 2 percent reduction in soybean production would raise the price of soybeans by about 10 percent—or $1.00 per bushel, based on CBO's projection of the price of soybeans in 2017 under the repeal scenario or the 2014 volumes scenario. With 1.8 billion bushels of soybeans expected to be harvested in that year under either the repeal scenario or the 2014 volumes scenario, CBO estimates that the higher soybean price under the EISA volumes scenario would add $1.8 billion to total spending on food in 2017, if the price increase is passed on fully to consumers in the form of higher food costs.

8. See Congressional Budget Office, "USDA Mandatory Farm Programs—April 2014 Baseline" (April 2014), www.cbo.gov/publication/44202.

9. See Department of Agriculture, National Agricultural Statistics Service, *Crop Production* (September 12, 2013), http://tinyurl.com/oavucc5 (PDF, 792 KB).

10. Estimated elasticities for soybeans were taken from Scott Baier and others, *Biofuels Impact on Crop and Food Prices: Using an Interactive Spreadsheet*, International Finance Discussion Papers 967 (Board of Governors of the Federal Reserve System, March 2009), www.federalreserve.gov/pubs/ifdp/2009/967/default.htm; and William Lin and others, *Supply Response Under the 1996 Farm Act and Implications for the U.S. Field Crops Sector*, Technical Bulletin TB-1888 (Department of Agriculture, Economic Research Service, September 2000), http://go.usa.gov/kkVz.

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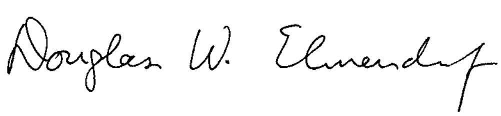
About This Document

This Congressional Budget Office (CBO) report was prepared at the request of the Chairman of the House Committee on Energy and Commerce. In keeping with CBO's mandate to provide objective, impartial analysis, the report makes no recommendations.

The analysis was prepared by Terry Dinan, Ron Gecan, and David Austin—in collaboration with Dave Hull, Kathleen FitzGerald, and Elizabeth Cove Delisle and assisted by Vi Nguyen (formerly of CBO)—with guidance from Joseph Kile and Chad Shirley. Mark Booth, Daniel Fried, and Andrew Stocking of CBO provided helpful comments.

Antonio Bento and Harry de Gorter of Cornell University, Christopher Hurt and Wallace Tyner of Purdue University, Robert Johansson and Seth Meyer of the Department of Agriculture, Richard Plevin of the University of California at Davis, Deepak Rajagopal of the University of California at Los Angeles, and Brent Yacobucci of the Congressional Research Service reviewed the report. Jennifer Dunn of Argonne National Laboratory, Adam Liska of University of Nebraska at Lincoln, Kimberly Mullins of Carnegie Mellon University, and Sabrina Spatari of Drexel University provided data. The assistance of external participants implies no responsibility for the final product, which rests solely with CBO.

Jeffrey Kling and Robert Sunshine reviewed the report, Christian Howlett edited it, Jeanine Rees prepared the report for publication, and Maureen Costantino designed the cover. The report is available on CBO's website (www.cbo.gov/publication/45477).



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Director

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