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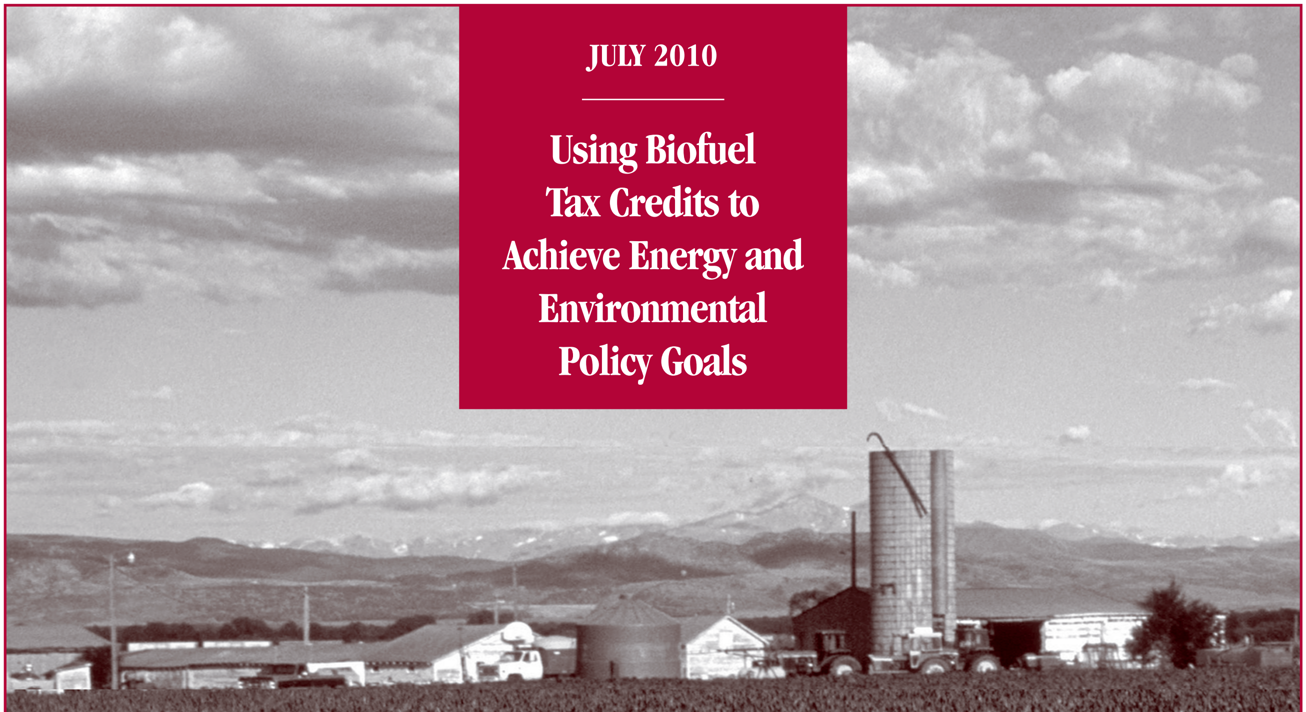
A CBO STUDY

JULY 2010

Using Biofuel Tax Credits to Achieve Energy and Environmental Policy Goals



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STUDY

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July 2010

The Congress of the United States ■ Congressional Budget Office

Notes

Unless otherwise indicated, all years referred to are calendar years.

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

Cover photos by Scott Bauer (top), courtesy of U.S. Department of Agriculture, and Maureen Costantino (bottom).

Preface

The federal government supports the use of biofuels—transportation fuels produced mainly from renewable plant matter, such as corn—in the pursuit of national energy, environmental, and agricultural policy goals. Tax credits encourage the production and sale of biofuels in the United States, effectively lowering the private costs of producing biofuels, such as ethanol or biodiesel, relative to the costs of producing their substitutes—gasoline and diesel fuel. In addition, federal mandates require the use of specified minimum amounts and types of biofuel each year through 2022. Together, the credits and mandates increase domestic supplies of energy and reduce U.S. emissions of greenhouse gases, albeit at a cost to taxpayers.

This Congressional Budget Office (CBO) study, which was prepared at the request of the Chairman of the Subcommittee on Energy, Natural Resources, and Infrastructure of the Senate Committee on Finance, assesses the incentives provided by the biofuel tax credits for producing different types of biofuels and analyzes whether they favor one type of biofuel over others. In addition, the study estimates the cost to U.S. taxpayers of reducing the use of petroleum fuels and emissions of greenhouse gases through those tax credits; it also analyzes the interaction of the credits and the biofuel mandates. In keeping with CBO's mandate to provide objective, impartial analysis, the study contains no recommendations.

The report was written by Ron Gecan of CBO's Microeconomic Studies Division and Rob Johansson, formerly of CBO, under the guidance of Joseph Kile and David Moore. Amy Petz and Zachary Epstein provided information about, respectively, the tax treatment of biofuel production, use, and sales, and biofuel-related forgone revenues and tariff collections. Paul Burnham, Terry Dinan, Mark Hadley, Dave Hull, Chayim Rosito, Frank Sammartino, Robert Shackleton, and Jennifer Smith, all of CBO, offered helpful comments, as did Joseph Cooper and William Coyle of the U.S. Department of Agriculture, Harry de Gorter of Cornell University, Jason Hill of the University of Minnesota, Gilbert Metcalf of Tufts University, and Brent Yacobucci of the Congressional Research Service. (The assistance of external reviewers implies no responsibility for the final product, which rests solely with CBO.)

Leah Mazade edited the study, and Kate Kelly proofread it. Maureen Costantino designed the cover and, with the assistance of Jeanine Rees, prepared the report for publication. Monte Ruffin printed the initial copies, Linda Schimmel handled the print distribution, and Simone Thomas prepared the electronic version for CBO's Web site (www.cbo.gov).

Douglas W. Elmendorf
Director

July 2010

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Summary

Proponents of federal support for biofuels, which are transportation fuels produced mainly from renewable plant matter, offer several rationales for that support. First, biofuels may help the nation meet energy policy goals by increasing the domestic production of fuels for transportation and reducing the United States' dependence on fossil fuels, such as oil. Second, biofuels may contribute to meeting environmental policy objectives, such as the reduction of greenhouse gas emissions. Third, federal support for biofuels can increase incomes in the agricultural sector.

The federal government began providing tax credits for various biofuels in the 1970s; in addition, laws enacted in recent years have required producers or blenders of transportation fuels to incorporate specified minimum annual amounts of biofuels—amounts that rise over time—into the fuels that they sell. Different types of biofuels have been granted different tax credits, ranging from 45 cents per gallon to approximately one dollar per gallon. Those differing credits raise questions about whether federal policy provides equal incentives for producing different kinds of biofuels and imposes equal costs on taxpayers for achieving certain energy or environmental policy goals.

Roughly 11 billion gallons of biofuels were produced and sold in the United States in 2009, and ethanol produced from corn accounted for nearly all (about 10.8 billion gallons) of that total. Blenders of transportation fuels receive a tax credit of 45 cents for each gallon of ethanol (regardless of the feedstock, or raw material) that is combined with gasoline and sold. Although the credit is provided to blenders, most of it ultimately flows to producers of ethanol and to the farmers who grow the corn—in the form of higher prices received for their products.

Most of the rest of the biofuel sold in the United States consists of biodiesel, which is made largely from soybean oil but is also produced from animal fats, recycled plant oils, and other feedstocks. Until recently, the producers of biodiesel made from new oils or animal fats received a tax credit of one dollar per gallon. Although that credit expired in December 2009, the Congressional Budget Office (CBO) included it in the analysis to provide information about the value of the credit should policymakers, as they have at other times, decide to reinstate it.

In the future, cellulosic ethanol could account for a significant share of domestic production of biofuels. Cellulosic ethanol is made from plant wastes, such as corn stover (basically the leaves and stalks of corn plants) or woodchips, or from crops grown specifically for fuel production, such as switchgrass (a tall North American grass used for hay and forage). Its producers are eligible for a tax credit of $1.01 per gallon if it is produced and blended with gasoline; even with that credit, however, cellulosic ethanol is not viable commercially today and is produced in very limited quantities.

In fiscal year 2009, the biofuel tax credits reduced federal excise tax collections by about $6 billion below what they would have been if the credits had not been in effect. This CBO study assesses the credits' contributions to achieving energy and environmental goals in the light of those forgone revenues; it does not consider any impact on farm incomes or the agricultural sector more broadly. The analysis focuses specifically on the differential effects of the various credits in achieving two objectives: displacing the use of petroleum fuel and reducing greenhouse gas emissions.

CBO's main conclusions are the following:

- The incentives that the tax credits provide to producers of biofuels differ among the fuels. After adjustments for the different energy contents of the various biofuels and the petroleum fuel used to produce them, producers of ethanol made from corn receive 73 cents to provide an amount of biofuel with the energy equivalent to that in one gallon of gasoline. On a similar basis, producers of cellulosic ethanol receive $1.62, and producers of biodiesel receive $1.08.

- The costs to taxpayers of reducing consumption of petroleum fuels differ by biofuel. Such costs depend on the size of the tax credit for each fuel, the changes in federal revenues that result from the difference in the excise taxes collected on sales of gasoline and biofuels, and the amount of biofuels that would have been produced if the credits had not been available. The costs to taxpayers of using a biofuel to reduce gasoline consumption by one gallon are $1.78 for ethanol made from corn and $3.00 for cellulosic ethanol. The cost of reducing an equivalent amount of diesel fuel (that is, a quantity having the same amount of energy as a gallon of gasoline) using biodiesel is $2.55, based on the tax policy in place through last year.

- Similarly, the costs to taxpayers of reducing greenhouse gas emissions through the biofuel tax credits vary by fuel: about $750 per metric ton of CO_2e (that is, per metric ton of greenhouse gases measured in terms of an equivalent amount of carbon dioxide) for ethanol, about $275 per metric ton of CO_2e for cellulosic ethanol, and about $300 per metric ton of CO_2e for biodiesel. Those estimates do not reflect any emissions of carbon dioxide that occur when the production of biofuels causes forests or grasslands to be converted to farmland for growing the fuels' feedstocks. If those emissions were taken into account, such changes in land use would raise the cost of reducing emissions and change the relative costs of reducing emissions through the use of different biofuels—in some cases, by a substantial amount.

Federal biofuel mandates require vendors of motor fuels to produce or blend specified minimum volumes of the different fuels with gasoline and diesel fuel; the annual targets are scheduled to rise through 2022. In the past, those requirements have not directly increased the quantity of biofuels sold in the United States because the combination of underlying economic conditions and the biofuel tax credits has caused the use of biofuels to exceed the mandated quantities. However, the mandates probably provided producers with some degree of confidence that a market for those fuels would exist, thereby encouraging investment in the facilities needed to produce them. In the future, the scheduled rise in mandated volumes would require the production of biofuels in amounts that are probably beyond what the market would produce even if the effects of the tax credits were included. To the extent that the mandates determine levels of production in the future, the biofuel tax credits would no longer be increasing production, but they would still be reducing the costs borne by producers and consumers of biofuels and shifting some of those costs to taxpayers.

Using Biofuel Tax Credits to Achieve Energy and Environmental Policy Goals

Introduction

Since the 1970s, policymakers have used tax credits and other tools to promote the production and consumption of biofuels—transportation fuels produced mainly from renewable plant matter—in pursuit of a variety of policy objectives. That support has generally been attributed to three factors: First, the use of such fuels lessens the nation's reliance on imported fuel because almost all biofuels are currently produced domestically; second, the use of biofuels addresses environmental policy goals, such as reducing greenhouse gas emissions; and third, such use bolsters incomes in the agricultural sector. Some of those policy objectives have shifted in their nature or importance over time. For example, one early environmental rationale for promoting biofuels was that ethanol could be used to reduce emissions of carbon monoxide. Today, concern about those emissions has largely been supplanted by a focus on emissions of carbon dioxide and other greenhouse gases.

The energy and environmental goals that policymakers have sought to address through support for biofuels are related to the costs that the use of petroleum imposes on society. Researchers frequently conclude that the costs that individuals incur in consuming petroleum and other fossil fuels do not reflect the costs they impose on others. Those social costs arise from emissions of greenhouse gases that are the result of both producing and burning fossil fuels; from potentially detrimental effects on national security because of continued reliance on foreign producers of oil that are, in some cases, hostile to the United States; and from other sources.[1]

Federal support for biofuels consists mainly of tax credits for the production and use of certain types of such fuels. Most of that support goes to ethanol made from corn and blended with gasoline and to biodiesel made from soybeans or other plant matter and blended with diesel fuel made from petroleum.[2] Larger tax credits are available for ethanol made from cellulose—that is, from cornstalks and other fibrous plant material—but they are not widely used because cellulosic ethanol is not now commercially viable, even with the tax credits.[3] In addition to the credits, since 2006, a number of mandates have been imposed that require ever larger quantities of biofuels to be used over time.

This Congressional Budget Office (CBO) study analyzes the biofuel tax credits to assess whether the individual credits provided for different fuels offer equal incentives to address energy and environmental policy goals or whether those credits implicitly favor some types of biofuels over others. In particular, the analysis addresses:

- Differences in the incentives faced by domestic producers of biofuels;

1. See, for example, Ian Parry, Margaret Walls, and Winston Harrington, "Automobile Externalities and Policies," *Journal of Economic Literature,* vol. 45, no. 2 (June 2007), pp. 373–399; Paul Leiby, *Estimating the Energy Security Benefits of Reduced U.S. Oil Imports*, Oak Ridge National Laboratory Report ORNL/TM-2007/028 (Department of Energy, Oak Ridge National Laboratory, July 2007); and Hillard G. Huntington, *The Oil Security Problem,* Energy Modeling Forum Paper EMF OP 62 (Stanford University, Energy Modeling Forum, February 2008).
2. The term "ethanol" in this report refers to ethanol made from corn unless otherwise specified.
3. The use of that feedstock (the raw material for making the fuel) allows cellulosic ethanol to produce fewer greenhouse gas emissions than those produced by ethanol made from corn.

Table 1.

Federal Tax Credits for Ethanol and Biodiesel

Biofuel	Description	Incentive[a]	Credit per Gallon (Dollars)	Tax Expenditures in Fiscal Year 2009[b] (Millions of dollars)	Expiration Date
Ethanol	Alcohol fuel produced from feedstocks (raw materials) containing plentiful natural sugars or starches that can be converted to sugars. Commercial production in the United States uses kernel corn as a feedstock.	A credit for ethanol (regardless of the feedstock) blended with gasoline for sale or use	0.45	5,160[c]	Dec. 31, 2010
Cellulosic Ethanol	Ethanol produced from feedstocks such as corn stover (the leaves and stalks of corn plants), switchgrass (a tall North American grass used for hay and forage), wood chips, and plant wastes. In contrast to corn ethanol, the fermentable sugars necessary to produce ethanol are provided by materials in the walls of the plants' cells.	A credit for cellulosic ethanol blended with gasoline for sale or use	1.01[d]	50[e]	Dec. 31, 2012
Biodiesel	Diesel fuel made from virgin agricultural products (such as soybean oil and animal fats) or recycled agricultural oils (such as tallow)	A credit for producing biodiesel	1.00	840[f]	Dec. 31, 2009[g]

Source: Congressional Budget Office.

a. Based on 26 U.S.C. §40, §40A, and §6426(e), or Title XI of the Omnibus Budget Reconciliation Act of 1990 (104 Stat. 1388-482); Title III of the American Jobs Creation Act of 2004 (118 Stat. 1463); Title XIII of the Energy Policy Act of 2005 (119 Stat. 986); Title XV of the Food, Conservation, and Energy Act of 2008 (122 Stat. 2274); and Division B of the Energy Improvement and Extension Act of 2008 (122 Stat. 3807).

A supplemental credit of 10 cents per gallon is currently available on the first 15 million gallons of ethanol made by "small producers" (those with a total annual productive capacity not in excess of 60 million gallons). The credit is due to expire on December 31, 2010. A 10-cent-per-gallon supplemental credit was also in place for agri-biodiesel until December 31, 2009. (Agri-biodiesel is biodiesel derived solely from virgin plant oils or animal fats.)

b. Estimates of tax expenditures (essentially, forgone revenues) for fiscal year 2009 are detailed in *Budget of the United States Government, Fiscal Year 2011: Analytical Perspectives*, Table 16-1, available at www.gpoaccess.gov/usbudget/fy11/pdf/spec.pdf.

c. Includes only the effect on excise tax receipts.

d. The cellulosic biofuel credit is $1.01 per gallon except that for cellulosic ethanol, the credit is reduced by the credits in effect for the mixture of ethanol with gasoline and for small producers. Accordingly, producers of cellulosic ethanol get the reduced cellulosic biofuel credit but are also eligible for the ethanol tax credit of $0.45 and may also qualify for the $0.10 credit for small producers.

e. Includes the credit for cellulosic biofuel production, the credit for small producers of ethanol, and other alcohol fuel credits.

f. Of that amount, $30 million results from reduced income taxes, and the remainder, $810 million, derives from reduced excise tax receipts.

g. Although the biodiesel tax credit expired at the end of 2009, CBO included it in the analysis to provide information about the value of the credit should policymakers, as they have at other times, decide to reinstate it.

- The costs to taxpayers of displacing petroleum-based fuels with biofuels and reducing greenhouse gas emissions through the use of biofuels; and

- The interaction of tax credits and mandates for those fuels.

Policies that support the production of biofuels lead to other effects and raise other issues that are not addressed in this report. For example, increased production of ethanol has probably resulted in some reduction in the price of gasoline, an increase in farm incomes, and some impact on the quality of the nation's air and water resources. Moreover, a complete evaluation of biofuels would consider alternative approaches to achieving energy and environmental objectives. Most economists, for instance, maintain that a more efficient way to reduce petroleum consumption and greenhouse gas emissions would be to impose higher taxes on petroleum products. A complete evaluation of different programs related to biofuels would examine those factors, but such an analysis is beyond the scope of this study.

Tax Credits

The tax credits provided to producers of biofuels are claimed primarily on the production and blending of ethanol (which in the United States is mostly made from corn) with gasoline and on the production of biodiesel (which in the United States is mostly made from soybean oil; see Table 1). In addition, credits are available for the production of cellulosic ethanol; for the production of ethanol (regardless of the feedstock, or raw material) and agri-biodiesel made by small businesses (those operating refineries with a total productive capacity that is not in excess of 60 million gallons annually);[4] and for the production of other fuels, such as renewable diesel or biodiesel produced from cellulose.[5]

The tax credits provide a financial incentive to produce biofuels by offsetting some of the fuels' production costs and thereby making them more competitive relative to gasoline and diesel fuel. In fiscal year 2009, tax credits for biofuels reduced federal revenues by about $6 billion.[6] In addition to those credits, the federal government and the states have provided other financial incentives for biofuels that, for example, reduce the cost of building production and fueling facilities for distributing the fuels.[7]

The federal tax credits available to producers of biofuels vary according to the type of biofuel (such as ethanol or biodiesel) produced and the feedstock used to produce that fuel:[8]

- An **ethanol** tax credit of 45 cents per gallon is available for the blending of ethanol (regardless of the feedstock) with gasoline for sale; each small producer receives an extra 10 cents per gallon on the first 15 million gallons it produces.

- In addition to corn and sugarcane, ethanol can also be produced from corn stover (basically, the leaves and stalks of corn plants), certain types of grasses, wood, and other plant material. That type of ethanol is known as **cellulosic ethanol** because of the feedstocks used to produce it and the process by which it is made, which involves breaking down the cellulose in the cell walls of plants into fermentable sugars that can then be made into ethanol. Currently, producers of cellulosic ethanol receive credits that may total either $0.91 or $1.01 per gallon: They receive a reduced cellulosic biofuel production credit that works out to 46 cents per gallon and are eligible for the 45 cent credit for blending ethanol with gasoline and, if applicable, a

4. Agri-biodiesel is biodiesel derived solely from virgin plant and animal fats.

5. Renewable diesel—a substitute for petroleum diesel fuel—is commonly produced from such feedstocks as tallow or vegetable oil. Renewable diesel has the same chemical composition as petroleum diesel and as a result is distinct from biodiesel.

6. Estimates of tax expenditures (essentially forgone revenues) for fiscal year 2009 are detailed in *Budget of the United States Government, Fiscal Year 2011: Analytical Perspectives,* Table 16-1, available at www.gpoaccess.gov/usbudget/fy11/pdf/spec.pdf.

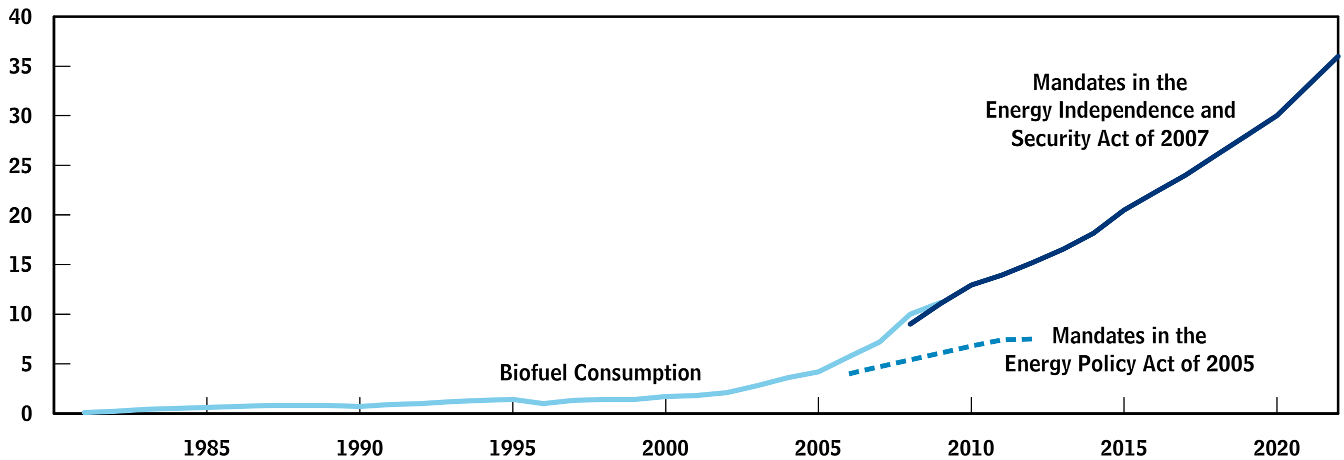
7. Doug Kaplow, *Biofuels—At What Cost?* (prepared for the Global Subsidies Initiative, International Institute for Sustainable Development, Geneva, October 2006), pp. 68–90.

8. For more information, see "Fuel Tax Credits and Refunds," Chapter 2 in *IRS Publication 510: Excise Taxes* (rev. April 2009), available at www.irs.gov/publications/p510/ch02.html; and Brent D. Yacobucci, *Biofuels Incentives: A Summary of Federal Programs,* CRS Report R40110 (Congressional Research Service, January 2010).

Figure 1.

Historical Biofuel Consumption and Mandates for Future Biofuel Use, 1981 to 2022

(Billions of gallons)



Source: Congressional Budget Office based on Energy Information Administration, *Monthly Energy Review: May 2010* (May 27, 2010), Tables 10.3 and 10.4, available at http://tonto.eia.doe.gov/FTPROOT/multifuel/mer/00351005.pdf; the Energy Policy Act of 2005 (Public Law 109-58); and the Energy Independence and Security Act of 2007 (Public Law 110-140).

Note: Beginning in 2009, the Energy Independence and Security Act of 2007 limited the amount of corn ethanol that might count toward fulfillment of the mandate in any given year. By 2022, the sale of advanced biofuels must total at least 21 billion gallons, effectively restricting the eligible amount of corn ethanol to at most 15 billion gallons. (Advanced biofuels are renewable fuels, other than ethanol produced from corn, whose life-cycle greenhouse gas emissions—those from producing and distributing the fuel as well as from burning it—are 50 percent less than the life-cycle emissions of gasoline or petroleum diesel fuel.)

supplemental credit of 10 cents per gallon for a portion of the fuel made by small producers.[9]

- Until the end of 2009, producers of **biodiesel** received a tax credit of $1 per gallon. Although that credit expired on December 31, 2009, CBO's analysis treats the biodiesel tax credit as if it were still in place, in order to provide information about the value of the credit should policymakers, as they have at other times, decide to reinstate it. Like the credit for small producers of ethanol, a tax credit of 10 cents per gallon is available for small producers of biodiesel. That credit, like the credit of $1 per gallon, expired on December 31, 2009.

Over time, certain feedstocks' eligibility for the tax credits has changed. For example, the Energy Improvement and Extension Act of 2008 (Public Law 110-343) allowed biodiesel produced from camelina, or flax, to qualify as a biofuel. That law also restricted biofuel tax credits to supplies of those fuels produced or sold for use in the United States. Those restrictions effectively eliminated a practice known as "splash and dash," whereby a small quantity of petroleum diesel is mixed with imported biodiesel to claim a tax credit for the entire mixture, which is subsequently exported.

Mandates

The Energy Policy Act of 2005 (P.L. 109-58) imposed so-called renewable fuel standards, which mandated that gasoline producers and importers blend a specified minimum volume of biofuel with gasoline to meet an annual standard for the use of such fuels. The standards in that legislation extended through 2012. Title II of the

9. See 26 U.S.C. Sec. 40(b)(6)(B). Under the law, the cellulosic biofuel credit is $1.01 per gallon except for cellulosic ethanol, for which the credit is reduced by the credits in effect for the mixture of ethanol with gasoline and for small producers. Accordingly, producers of cellulosic ethanol get the reduced cellulosic biofuel credit (46 cents) but are also eligible for the ethanol tax credit of 45 cents and may also qualify for the 10 cent credit for small producers. Also under the law, if the small-producer credit was eliminated, the value of the credits available to all producers of cellulosic ethanol would total $1.01 per gallon.

Energy Independence and Security Act of 2007, or EISA (P.L. 110-140), amended those standards to require that larger annual volumes of biofuels be used through 2012; it also extended the mandates to 2022 (see Figure 1). In addition, EISA set new requirements for the use of "advanced biofuels," which are renewable fuels other than ethanol produced from corn that over their entire "life cycle" (including production and distribution) produce greenhouse gas emissions that are 50 percent less than the life-cycle emissions of gasoline and diesel fuel.[10] Cellulosic ethanol, imported ethanol made from sugarcane, and biodiesel meet that standard.

To comply with the mandates set forth in EISA, the Environmental Protection Agency (EPA) establishes annual blending requirements for each type of biofuel using projections of motor fuel use in the United States.[11] Fuel vendors must meet those requirements by directly mixing biofuels with gasoline or diesel for sale or by purchasing credits from another vendor that has blended more biofuel with conventional fuels than the law requires.

From 2006 to 2008, the use of domestically produced and imported biofuels together exceeded the annual amounts mandated by EISA. For 2009, the renewable fuel standard for qualifying biofuels was 11.1 billion gallons, of which at least 600 million gallons had to be advanced biofuels.[12] According to preliminary estimates of biofuel production and consumption, the total biofuel mandate of 11.1 billion gallons was met in 2009, although the quantity of biodiesel consumed was insufficient to meet the mandate for advanced biofuels (see Table 2).[13]

Before enactment of the Energy Policy Act and EISA, other laws imposed regulations that spurred consumption of biofuels, particularly ethanol. Since the Clean Air Act Amendments of 1990 took effect, producers supplying regions of the United States that do not meet prevailing standards for air quality have been required to mix conventional gasoline with an oxygenate (a fuel additive that increases the oxygen content of motor fuels) to decrease tailpipe emissions of ozone-forming compounds and carbon monoxide. The two main oxygenates in use in 1990 were MTBE (methyl tertiary butyl ether) and ethanol. In 2000, approximately 3.2 billion and 1.6 billion gallons, respectively, of MTBE and ethanol were produced. The use of ethanol as an oxygenate remained secondary to the use of MTBE until leakage from storage tanks containing the chemical raised concerns about water quality and prompted several states to ban its use in fuel mixtures.[14] By 2005, production of MTBE had fallen to 2 billion gallons, and ethanol production had increased to nearly 4 billion gallons.[15]

Biofuel Tax Credits and Energy Policy Goals

In 2009, petroleum fuels and liquid biofuels together accounted for 98 percent of the total energy used in the transportation sector.[16] Domestic supplies made up about 40 percent of the petroleum fuel consumed. Nearly all of the biofuel consumed was produced domestically; however, about 2 percent is imported from countries such as

10. See Environmental Protection Agency, *EPA Lifecycle Analysis of Greenhouse Gas Emissions from Renewable Fuels,* EPA 420-F-10-006 (February 2010).

11. EPA may relax blending requirements under special conditions. See Environmental Protection Agency, "Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program (40 C.F.R. Part 80)—Final Rule No. 2060-A081" (March 2010), available at www.regulations.gov/search/Regs/contentStreamer?objectId=0900006480ac93f2&disposition=attachment&contentType=pdf.

12. See Environmental Protection Agency, *EPA Finalizes Regulations for the National Renewable Fuels Standard Program for 2010 and Beyond,* EPA 420-F-10-007 (February 2010), available at www.epa.gov/oms/renewablefuels/420f10007.htm.

13. The biodiesel mandate under the Energy Independence and Security Act of 2007 required that at least 500 million gallons of biodiesel be used in 2009 once the Renewable Fuel Standard program was in effect. However, because the program was not effective until 2010, the biodiesel mandate for 2009 was not implemented. To address that delay, EPA combined the biodiesel mandates for 2009 and 2010 (500 million and 650 million gallons, respectively) into a single 1.15 billion gallon mandate for the 2009–2010 period. See Environmental Protection Agency, "Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program; Final Rule," 40 C.F.R. Part 80, *Federal Register,* vol. 75, no. 58 (March 26, 2010), pp. 14718–14720.

14. See Environmental Protection Agency, *State Actions Banning MTBE (Statewide),* EPA 420-B-07-013 (August 2007).

15. See Energy Information Administration, "Oxygenate Production" (June 29, 2009), available at http://tonto.eia.doe.gov/dnav/pet/pet_pnp_oxy_dc_nus_mbbl_a.htm.

16. Natural gas supplied the remaining 2 percent. See Energy Information Administration, *Monthly Energy Review: April 2010* (April 30, 2010), Table 2.5, available at http://tonto.eia.doe.gov/FTPROOT/multifuel/mer/00351004.pdf.

Table 2.

The Supply of Biofuels in the United States

(Billions of gallons)

	2006	2007	2008	2009
Biofuels Supplied				
Domestic ethanol	4.9	6.5	9.3	10.8
Imported ethanol	0.7	0.4	0.5	0.2
Domestic biodiesel[a]	0.3	0.5	0.7	0.5
Total	**5.9**	**7.5**	**10.5**	**11.5**
Memorandum:				
Mandates for Biofuel Use				
All biofuels	4.0	4.7	9.0	11.1
Advanced biofuels[b]	n.a.	n.a.	n.a.	0.6

Source: Congressional Budget Office based on Energy Information Administration, *Monthly Energy Review: May 2010* (May 27, 2010), Tables 10.3 and 10.4, available at http://tonto.eia.doe.gov/FTPROOT/multifuel/mer/00351005.pdf.

Note: n.a. = not applicable.

a. A portion of domestic biodiesel production—on net, about 100 million gallons in 2007, 400 million gallons in 2008, and 200 million gallons in 2009—is exported.

b. Renewable fuels, other than ethanol produced from corn, whose life-cycle greenhouse gas emissions—those from producing and distributing the fuel as well as from burning it—are 50 percent less than the life-cycle emissions of gasoline or petroleum diesel fuel.

Brazil, where sugarcane is used as a feedstock.[17] Thus, one reason to encourage the production of biofuels would be to increase the supply of domestically produced fuels that can be used for transportation.

The federal biofuel tax credits offer an incentive to producers to increase the amount of biofuel they make and thus support the energy policy goals of increasing the domestic production of energy and decreasing the consumption of petroleum fuels. The amount of transportation fuel that a particular biofuel adds to the domestic supply varies according to its basic chemistry and the amount of petroleum fuel required to produce it. This study took those variations into account in estimating the effects of the tax incentives provided to producers of different types of biofuels.

17. The United States imposes a tariff of 2.5 percent plus 54 cents per gallon on ethanol (regardless of the feedstock) imported from most other nations. Those tariffs discourage the importation of ethanol produced in those countries.

CBO's analysis considered two main questions regarding the effect of the biofuel tax credits on the attainment of energy goals. Those questions are posed from different perspectives—that of the producer and that of the taxpayer. However, the answers rely on the same set of facts.

- Do the tax credits provide different incentives to the producers of different biofuels to increase the supply of those fuels? In answering that question, CBO analyzed the credits on the basis of the energy content of the fuels and the amount of petroleum used to produce them.

- What are the costs to U.S. taxpayers of using the biofuel tax credits to encourage the consumption of biofuels in place of petroleum fuels? In answering that question, CBO assessed the costs of different biofuels on the basis of the fuels' energy contents, the changes in the excise tax revenues collected when biofuels displace gasoline and diesel fuels, and the amount of total biofuel consumption that can be attributed to the credits. In particular, CBO looked at whether the cost for achieving energy goals was the same for different biofuels or whether achieving those goals was more costly with one biofuel than with another.

Incentives for Producers of Biofuels

The incentives that the biofuel tax credits provide to increase the supply of biofuels depend in part on the credit that producers receive for supplying an additional gallon of such fuel. However, the impact of those incentives also depends on two characteristics of biofuels that differ from one fuel to another: the amount of energy in each gallon of fuel and the amount of energy from petroleum that is used to produce that gallon of fuel. Therefore, to compare the incentives for adding a given amount to the total supply of liquid fuels by producing different biofuels, CBO made two adjustments to the value of the tax credits. First, to account for the differences in the energy content of the various fuels, CBO calculated the incentives for producing quantities of different biofuels containing an amount of energy equal to that in a gallon of gasoline—125,000 British thermal units (Btus). Second, to account for the differences in the amount of petroleum required to produce the different kinds of biofuel, CBO calculated the incentives for producing quantities of different biofuels with that same net increase in energy after deducting the petroleum energy used to produce the fuels. That analysis indicates that the tax credits provide larger incentives for increasing liquid fuel supplies through the use of biodiesel and cellulosic ethanol than for increasing them through the use of ethanol.

Blenders that mix ethanol with gasoline receive 45 cents for each gallon of ethanol so blended. One gallon of ethanol contains about 85,000 Btus of energy, or about two-thirds the energy in a gallon of gasoline; put differently, it takes 1.48 gallons of ethanol to provide the same energy as 1 gallon of gasoline. Consequently, the 45 cent credit for each gallon of ethanol is the same as paying blenders 67 cents for every 125,000 Btus of ethanol blended with gasoline (see Table 3).

To produce that quantity of ethanol—that is, the amount that will provide 125,000 Btus of energy—requires close to 11,000 Btus of energy from petroleum fuels. Thus, to yield a net increase of 125,000 Btus in the nation's liquid fuel supply, ethanol containing more than 125,000 Btus—about 10 percent more—must be produced. Consequently, the credit received by blenders is 73 cents for increasing the supply of transportation fuels by 125,000 Btus, the same amount of energy provided by a gallon of gasoline. The corresponding amounts for biodiesel and cellulosic ethanol, calculated on the basis of the tax credits in place as of December 2009, are significantly higher—$1.08 and $1.62, respectively.

CBO's analysis focused on the supply of liquid fuels because they are the predominant source of energy used in transportation and because a goal of the biofuel tax credits is to reduce imports of petroleum (which currently provide most of the supply of such energy). Another issue of potential interest is the amount of energy from all fossil fuels—including but not limited to petroleum—that is used during the production of biofuels. Producing ethanol from corn requires much more energy from natural gas or coal than does producing petroleum fuel, cellulosic ethanol, or biodiesel. As a result, the incentive that producers of ethanol receive for increasing the domestic supply of energy will be larger per Btu than the incentive provided to producers of other biofuels.[18] Because the production of ethanol draws so much energy from coal and natural gas, it can be thought of as a method for converting natural gas or coal to a liquid fuel that can be used for transportation. The production of cellulosic ethanol, in contrast, is expected to need much less energy from fossil fuels because wastes from feedstocks that are not used to produce the ethanol could be used as fuel in those production plants.

Costs to Taxpayers of Reducing the Use of Petroleum Fuels

The cost to taxpayers of reducing the consumption of petroleum fuels by using tax credits to encourage the production of biofuels depends on several factors: the cost of the credits for biofuels, the changes in the consumption of biofuels and petroleum that can be attributed to the credits, and the changes in excise tax receipts that result from the displacement of petroleum fuels by biofuels. CBO estimates that through those tax credits, taxpayers incur a cost of $1.78 for replacing 125,000 Btus of energy supplied by petroleum fuels with 125,000 Btus supplied by ethanol. Similarly, the costs to taxpayers of displacing a gallon of gasoline with an equivalent amount of cellulosic ethanol would total $3.00, CBO estimates, and the costs of displacing petroleum diesel with biodiesel would total approximately $2.55 for an equivalent amount of biodiesel (under the credit formerly in place).

Impact of the Tax Credits on the Consumption of Biofuels and Petroleum Fuel. Although the federal tax credits encourage the production of biofuels, some of that fuel would be produced even if those credits were not available. However, determining how much biofuel production would have occurred in the absence of those credits is not straightforward. Researchers at the Food and Agricultural Policy Research Institute (FAPRI) examined the impact on biofuel production of policies that provide incentives for the consumption of ethanol and biodiesel in the United States—including the federal tax credits, mandates requiring minimum volumes of biofuel

18. Jason Hill and others, "Environmental, Economic, and Energetic Costs and Benefits of Biodiesel and Ethanol Biofuels," *Proceedings of the National Academy of Sciences,* vol. 103, no. 30 (July 2006); Michael Wang, May Wu, and Hong Huo, "Life-Cycle Energy and Greenhouse Gas Emission Impacts of Different Corn Ethanol Plant Types," *Environmental Research Letters,* vol. 2, no. 2 (2007); Environmental Protection Agency, *Regulatory Impact Analysis: Renewable Fuel Standard Program,* EPA 420-R-07-004 (April 2007); Hong Huo and others, "Life-Cycle Assessment of Energy Use and Greenhouse Gas Emissions of Soybean-Derived Biodiesel and Renewable Fuels," *Environmental Science and Technology,* vol. 43, no. 3 (2009); and Adam J. Liska and others, "Improvements in Life Cycle Energy Efficiency and Greenhouse Gas Emissions of Corn-Ethanol," *Journal of Industrial Ecology,* vol. 13, no. 1 (2009).

Table 3.

Production Incentives for Increasing Liquid Fuel Supplies

	Corn Ethanol	Cellulosic Ethanol	Biodiesel[a]
		Production Incentives After Adjusting for the Energy Content of Each Biofuel	
Federal Biofuel Tax Credit (Dollars per gallon of biofuel)	0.45	1.01[b]	1.00
Multiplied by: Gallons of Biofuel per 125,000 Btus of Energy	1.48	1.48	0.97
Equals: Adjusted Biofuel Tax Credit (Dollars per 125,000 Btus of energy)	0.67	1.50	0.97
		Production Incentives After Adjusting for the Petroleum Fuel Used to Produce Each Biofuel[c]	
Adjusted Biofuel Tax Credit (Dollars per 125,000 Btus of energy)	0.67	1.50	0.97
Multiplied by: An Adjustment for Measuring the Tax Credits to Reflect the Petroleum Fuel Used in Producing the Biofuel[d]	1.10	1.08	1.11
Equals: Production Incentive for Increasing Liquid Fuel Supplies by 125,000 Btus (Dollars)	0.73	1.62	1.08

Source: Congressional Budget Office based on Michael Wang, May Wu, and Hong Huo, "Life-Cycle Energy and Greenhouse Gas Emission Impacts of Different Corn Ethanol Plant Types," *Environmental Research Letters,* vol. 2, no. 2 (2007); Environmental Protection Agency, *Regulatory Impact Analysis: Renewable Fuel Standard Program,* EPA 420-R-07-004 (April 2007); M.R. Schmer and others, "Net Energy of Cellulosic Ethanol from Switchgrass," *Proceedings of the National Academy of Sciences,* vol. 105, no. 2 (January 2008); Hong Huo and others, "Life-Cycle Assessment of Energy Use and Greenhouse Gas Emissions of Soybean-Derived Biodiesel and Renewable Fuels," *Environmental Science and Technology,* vol. 43, no. 3 (2009); and Adam J. Liska and others, "Improvements in Life Cycle Energy Efficiency and Greenhouse Gas Emissions of Corn-Ethanol," *Journal of Industrial Ecology,* vol. 13, no. 1 (2009).

Note: Btu = British thermal unit.

a. Although the biodiesel tax credit expired on December 31, 2009, CBO included it in the analysis to provide information about the value of the credit should policymakers, as they have at other times, decide to reinstate it. (Biodiesel is diesel fuel made from virgin agricultural products, such as soybean oil and animal fats, or recycled agricultural oils, such as tallow.)

b. Reflects the 45 cent credit for blending ethanol with gasoline, the reduced cellulosic biofuel credit that calculates to 46 cents for producing ethanol from cellulose, and the 10 cent credit available to small producers (refineries with total productive capacity that is not in excess of 60 million gallons annually). Cellulosic ethanol is made from wood, grasses, or agricultural plant wastes; in contrast to corn ethanol, the fermentable sugars necessary to produce cellulosic ethanol are provided by materials in the walls of the plants' cells. The biofuel is not as yet in large-scale commercial production. As a result, it is likely that most of what is being initially produced will be eligible for the small-producer credit.

c. The amount of energy from petroleum that is used to produce a quantity of biofuel containing 125,000 Btus of energy is estimated to be 10,900, 9,300, and 12,400 Btus for corn ethanol, cellulosic ethanol, and biodiesel, respectively. Subtracting those amounts from 125,000 Btus gives the net energy provided by each 125,000 Btu unit of fuel produced: specifically, 114,100, 115,700, and 112,600 Btus for corn ethanol, cellulosic ethanol, and biodiesel, respectively.

d. Because different biofuels increase liquid fuel supplies by different amounts, an adjustment is necessary to compare the production incentives on a consistent basis. The adjustment factor for each biofuel ensures that the production incentives are measured in terms of what biofuel producers receive for increasing total liquid fuel supplies by 125,000 Btus. (As an example, the production of corn ethanol increases liquid fuel supplies by 114,100 Btus for every 125,000 Btus of biofuel produced. CBO thus used a ratio of 125,000 to 114,100 Btus to arrive at an adjustment factor of 1.10.)

to be sold, and tariffs on ethanol imports—and projected the consumption of various fuels over a seven-year period beginning in 2011. On the basis of FAPRI's results, CBO calculated that if no other biofuel policies were in place, eliminating the biofuel tax credits would reduce ethanol consumption by 32 percent and biodiesel consumption by 38 percent.[19] (All calculations for biodiesel incorporated the assumption that the tax credit in place in 2009 had been reauthorized.)

The basis for evaluating the extent to which the tax credit for cellulosic ethanol production will help increase domestic supplies of liquid fuels is limited because that fuel is not yet produced commercially. But production of cellulosic ethanol is expected to grow in coming years, and on the basis of FAPRI's recent projections, CBO estimates that the tax credit for cellulosic ethanol will be responsible for 47 percent of projected production.[20]

Other analysts have also estimated the relationship between the tax credits and biofuel consumption, but those studies have not been as comprehensive as FAPRI's. For example, researchers at Iowa State University estimated that the tax credit for the production of ethanol was responsible for about 15 percent of the biofuel's current use in the United States.[21] And, after accounting for gasoline blending requirements, another study found that the credit was responsible for about 25 percent of the nation's consumption of ethanol in 2005 and 2006.[22]

However, neither of those assessments evaluated the effects of the tax credits for biodiesel and cellulosic ethanol, and neither examined the consumption of biofuels for longer than two years. Consequently, CBO relied on the FAPRI study's estimates in its calculations.

Determining the share of biofuel production that depends on the current federal biofuel tax credits is complicated by the history of support for biofuels and the blending mandates established by the Energy Independence and Security Act. Earlier subsidies supported the development of biofuel production facilities. More recently, EISA's blending mandates have encouraged continued investment in such facilities by providing greater certainty to investors that there will be a market for their product. Because of those factors, the amount of biofuel consumption today that is attributable to the *current* tax credits is smaller than it would be if the facilities for biofuel production had not already been built—in part because of *previous* tax credits. In other words, current consumption of biofuels would probably be much less if the tax credits had never existed than if the credits were removed now, after the existing production capacity has been built.[23]

Tax credits that increase the supply of biofuels, everything else being equal, reduce the prices of liquid fuels used for transportation and cause producers of petroleum to reduce the amount they make. The decline in liquid fuel prices also boosts the quantity of fuel demanded; the size of that increase depends on how responsive demand is to changes in market prices. Studies have shown that the consumption of liquid fuels for transportation does not respond much to such changes. As a result, an increase in the supply of biofuels and the attendant decrease in liquid fuel prices would cause little change in the overall

19. Food and Agricultural Policy Research Institute-University of Missouri, *Biofuels: Impact of Selected Farm Bill Provisions and Other Biofuel Policy Options,* FAPRI-MU Report 06-08 (June 2008), Tables 13a and 14a, available at www.fapri.missouri.edu/outreach/publications/2008/FAPRI_MU_Report_06_08.pdf.

20. Food and Agricultural Policy Research Institute-University of Missouri, *U.S. Baseline Briefing Book: Projections for Agricultural and Biofuel Markets,* FAPRI-MU Report 01-10 (March 2010), p. 65, available at www.fapri.missouri.edu/outreach/publications/2010/FAPRI_MU_Report_01_10.pdf.

21. Lihong Lu McPhail and Bruce A. Babcock, *Short-Run Price and Welfare Impacts of Federal Ethanol Policies,* Working Paper 08-WP 468 (Center for Agricultural and Rural Development, Iowa State University, June 2008), Table 2(1).

22. Gilbert E. Metcalf, "Using Tax Expenditures to Achieve Energy Policy Goals," *American Economic Review: Papers and Proceedings 2008,* vol. 98, no. 2 (2008), pp. 90–94.

23. Since the EISA mandates were instituted, domestic production and imports of biofuels together have exceeded the mandated amounts, suggesting that the tax credits and not the mandates have been more important thus far in determining the annual consumption of biofuels. Accordingly, CBO concluded that with the credits in place, the mandates were not binding (that is, they did not affect the amount of biofuels produced). Had they been binding, CBO's estimates of the amount of biofuel consumption attributable to the tax credits would be smaller than those presented here.

quantity of liquid fuels being consumed.[24] The primary effect, then, of encouraging the production of additional supplies of biofuels through the use of the tax credits is to reduce the consumption of petroleum fuels by about the same amount.

Cost to Taxpayers of Substituting Biofuels for Petroleum Fuels. The cost to taxpayers of displacing a gallon of gasoline with a quantity of ethanol that provides the same amount of energy as a gallon of gasoline is $1.78, by CBO's estimate (see Table 4). That calculation has three steps:

- Because 1.48 gallons of ethanol are required to provide as much energy as a gallon of gasoline, the 45 cent credit for each gallon of ethanol is equivalent to paying blenders 67 cents for each gallon of gasoline that ethanol displaces (see page 6).
- Substituting ethanol for petroleum increases receipts from the federal excise tax on motor fuels because a greater volume of fuel is necessary to supply the same amount of energy. Specifically, the government forgoes 18.4 cents in receipts for each gallon reduction in sales of petroleum fuel but collects an additional 27.2 cents for the sale of an equivalent amount of ethanol. That 9 cent increase in receipts reduces taxpayers' costs for the biofuel credit to 58 cents per gallon of gasoline displaced.
- The above factors are applicable only to the portion of total biofuel consumption that can be attributed to the tax credit—but the tax credit applies to all biofuels, including the amount that would be produced if there were no credit. On the basis of the FAPRI researchers' work, CBO concludes that about 32 percent of current consumption of ethanol is attributable to the biofuel tax credit. Thus, the revenue loss of 58 cents yields a reduction of less than a third of a gallon in gasoline consumption. Adjusting the 58 cents by that factor results in a cost to taxpayers of $1.78 for replacing a gallon of petroleum fuel with an equivalent amount of energy (125,000 Btus) supplied by ethanol.

Similarly, CBO estimates that the costs to taxpayers of displacing gasoline with cellulosic ethanol will total $3.00 per gallon and the costs of displacing petroleum diesel with biodiesel will total approximately $2.55 for an equivalent amount of biodiesel (under the credit that was formerly in place).

Those estimates of taxpayers' costs are quite sensitive to judgments about the proportions of consumption that are attributable to the tax credits. If CBO had used the Iowa State study's finding that about 15 percent of ethanol consumption arose from the tax credits rather than the finding of 32 percent derived from the FAPRI study, those estimated costs would be roughly twice as high—about $4.00 per gallon rather than $1.78. However, over the long term, that 32 percent might be too low because it represents the amount of biofuel consumption today that is attributable to the *current* tax credits and is smaller than it would be if the facilities for biofuel production had not already been built—in part because of *previous* tax credits. Using a higher percentage would make taxpayers' costs for reducing petroleum consumption less than those CBO has estimated. For example, if the biofuel tax credit for ethanol was responsible for 45 percent of current consumption, the cost to taxpayers of decreasing gasoline consumption would be about 50 cents per gallon lower than the costs based on the findings of the FAPRI study.

Biofuel Tax Credits and Environmental Policy Goals

Encouraging the additional consumption of biofuels can be a means of pursuing the environmental policy goal of reducing greenhouse gas emissions. The use of biofuels in place of petroleum fuels generally reduces emissions; the amount of the reduction, though, depends on the biofuel and on whether its production has changed how land is being used (whether, for instance, rangeland or forested land is being converted to farmland).

24. For discussions of the lack of responsiveness in transportation fuel consumption, see Jonathan E. Hughes, Christopher R. Knittel, and Daniel Sperling, *Evidence of a Shift in the Short-Run Price Elasticity of Gasoline Demand*, Research Report UCD-ITS-RR-06-16 (University of California at Davis, Institute of Transportation Studies, 2006); Kenneth A. Small and Kurt Van Dender, "Fuel Efficiency and Motor Vehicle Travel: The Declining Rebound Effect," *Energy Journal*, vol. 28, no. 1 (2007), pp. 25–51; and Martijn Brons and others, "A Meta-Analysis of the Price Elasticity of Gasoline Demand: A SUR Approach," *Energy Economics*, vol. 30, no. 5 (September 2008), pp. 2105–2122.

Table 4.

Cost to Taxpayers of Displacing Petroleum Fuels Through Use of the Federal Biofuel Tax Credits

	Corn Ethanol	Cellulosic Ethanol	Biodiesel[a]
	Production Incentives After Adjusting for the Energy Content of Each Biofuel		
Federal Biofuel Tax Credit (Dollars per gallon of biofuel)	0.45	1.01 [b]	1.00
Multiplied by: Gallons of Biofuel per 125,000 Btus of Energy	1.48	1.48	0.97
Equals: Adjusted Biofuel Tax Credit (Dollars per 125,000 Btus of energy)	0.67	1.50	0.97
	Changes in Tax Receipts per 125,000 Btus of Energy Provided by Each Biofuel		
Adjusted Biofuel Tax Credit (Dollars per 125,000 Btus of energy)	0.67	1.50	0.97
Minus: Change in Excise Tax Receipts Because of Differences in Biofuel and Petroleum Fuel Volumes[c] (Dollars per 125,000 Btus of energy)	0.09	0.09	0.02
Equals: Cost of the Biofuel Tax Credit After Adjusting for Changes in Tax Receipts (Dollars per 125,000 Btus of energy)	0.58	1.41	0.96
	Cost to Taxpayers of Displacing Petroleum Fuels After Adjusting for the Share of Biofuel Consumption Attributable to the Tax Credit		
Cost of the Biofuel Tax Credit After Adjusting for Changes in Tax Receipts (Dollars per 125,000 Btus of energy)	0.58	1.41	0.96
Divided by: Share of Total Biofuel Consumption Attributable to the Tax Credit	0.32	0.47	0.38
Equals: Cost to Taxpayers of Displacing Petroleum with Biofuels (Dollars per 125,000 Btus of energy)	1.78	3.00	2.55

Source: Congressional Budget Office.

Notes: In CBO's calculations, corn ethanol and cellulosic ethanol are assumed to displace gasoline, and biodiesel is assumed to displace petroleum diesel. Cellulosic ethanol is produced from feedstocks such as corn stover (the leaves and stalks of corn plants), switchgrass (a tall North American grass used for hay and forage), wood chips, and plant wastes. In contrast to corn ethanol, the fermentable sugars necessary to produce cellulosic ethanol are provided by materials in the walls of the plants' cells. Biodiesel is diesel fuel made from virgin agricultural products (such as soybean oil and animal fats) or recycled agricultural oils (such as tallow).

Btu = British thermal unit.

a. Although the biodiesel tax credit expired on December 31, 2009, CBO included it in the analysis to provide information about the value of the credit should policymakers, as they have at other times, decide to reinstate it.

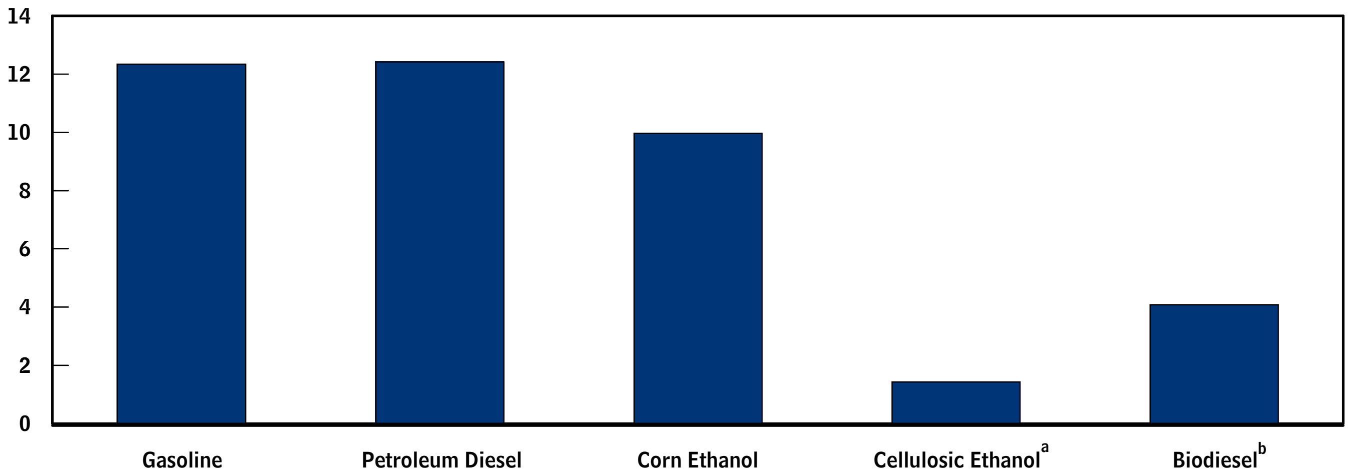
b. Reflects the 45 cent credit for blending ethanol with gasoline, the reduced cellulosic biofuel credit that calculates to 46 cents for producing ethanol from cellulose, and the 10 cent credit available to small producers (refineries with total productive capacity that is not in excess of 60 million gallons annually). Cellulosic ethanol is not as yet in large-scale commercial production. As a result, it is likely that most of what is being initially produced will be eligible for the small-producer credit.

c. Federal excise taxes on sales of petroleum fuels do not depend on the amount of energy contained in a gallon of those fuels. As a result, selling biofuels in place of petroleum fuels affects total excise tax receipts because of differences in the energy contents of those fuels. For a quantity of ethanol providing 125,000 Btus of energy that is sold in place of gasoline, excise tax receipts (excluding the effects of the biofuel tax credit) would increase by 9 cents—that is, 18.4 cents multiplied by 1.48 (gallons of biofuel per 125,000 Btus of energy) minus 18.4 cents times 1.0 (gallons of gasoline per 125,000 Btus of energy). The comparable increase in excise tax receipts for biodiesel is 2 cents—24.4 cents multiplied by 0.97 (gallons of biofuel per 125,000 Btus of energy) minus 24.4 cents times 0.90 (gallons of petroleum diesel per 125,000 Btus of energy).

Figure 2.

Life-Cycle Greenhouse Gas Emissions for Petroleum Fuels and Biofuels

(Kilograms of carbon dioxide equivalent per 125,000 Btus of fuel)



Source: Congressional Budget Office based on Michael Wang, May Wu, and Hong Huo, "Life-Cycle Energy and Greenhouse Gas Emission Impacts of Different Corn Ethanol Plant Types," *Environmental Research Letters,* vol. 2, no. 2 (2007); and Hong Huo and others, "Life-Cycle Assessment of Energy Use and Greenhouse Gas Emissions of Soybean-Derived Biodiesel and Renewable Fuels," *Environmental Science and Technology,* vol. 43, no. 3 (2009).

Note: Life-cycle emissions are those generated during production, distribution, and consumption of petroleum fuels and biofuels. Life-cycle greenhouse gas emissions are measured as the kilograms of carbon dioxide equivalent (the amount of carbon dioxide causing an equivalent amount of warming over 100 years) that are generated by producing, distributing, and consuming 125,000 Btus of fuel—about 1 gallon of gasoline, 1.5 gallons of ethanol, 0.9 gallons of petroleum diesel, and about 1 gallon of biodiesel.

a. Ethanol that is produced from feedstocks such as corn stover (the leaves and stalks of corn plants), switchgrass (a tall North American grass used for hay and forage), wood chips, and plant wastes. In contrast to corn ethanol, the fermentable sugars necessary to produce cellulosic ethanol are provided by materials in the walls of the plants' cells.

b. Diesel fuel made from virgin agricultural products (such as soybean oil and animal fats) or recycled agricultural oils (such as tallow).

CBO's analysis addressed two questions:

- Given the characteristics of the various biofuels, what are the costs to U.S. taxpayers of reducing greenhouse gas emissions through the use of the different biofuel tax credits?
- How does accounting for changes in land use affect the answers to that question?

Effects on Greenhouse Gas Emissions When Land Use Does Not Change

Substituting a biofuel for gasoline or petroleum diesel fuel reduces greenhouse gas emissions when all of the emissions that result from producing, distributing, and burning the fuels (their so-called life-cycle emissions) are taken into consideration. That conclusion, however, rests on the assumption that patterns of land use are not affected by increased production of the biofuel. For example, producing ethanol from corn and distributing the fuel result in more greenhouse gas emissions than producing and distributing gasoline made exclusively from crude oil, because planting, fertilizing, and harvesting corn uses more energy from fossil fuels than does drilling for petroleum, refining it into gasoline, and delivering it to customers. But the relationship is reversed over other portions of the fuels' life cycles: The growing of corn removes carbon dioxide from the atmosphere, whereas the extraction of crude oil from the ground does not. And the two fuels produce similar amounts of greenhouse gas emissions in the remaining portion of their life cycle—that is, when they are being used. According to research conducted at Argonne National Laboratory (ANL), gasoline and petroleum diesel fuel each generate about 12 kilograms of greenhouse gases over their life cycles (measured in terms of an equivalent amount of carbon dioxide, or CO_2e) for every 125,000 Btus of energy consumed, whereas corn ethanol generates about 10 kilograms, or 20 percent less (see Figure 2).[25]

Taking that difference into account, CBO estimates that taxpayers' costs for reducing greenhouse gas emissions through the ethanol tax credit are $754 per metric ton of CO_2e (see Table 5). Taxpayers' costs for reducing greenhouse gas emissions under the now expired biodiesel tax credit would total $306 per metric ton of CO_2e; their costs for cellulosic ethanol would be somewhat lower.

It bears emphasizing that those conclusions are based on the current mix of fuels used to provide the energy to make biofuels in the United States. The method by which ethanol and other biofuels are produced affects not only the amount of any reduction in emissions but even whether emissions are reduced at all. For example, ethanol produced at a plant fueled by natural gas generates about 30 percent fewer life-cycle greenhouse gas emissions than gasoline would have created—but ethanol produced at a similar plant that is coal fired generates about 3 percent more.[26] In fact, most ethanol plants in the United States are fueled by natural gas; the rest are coal fired or fired jointly by coal and natural gas.

Cellulosic ethanol offers the potential for greater reductions in greenhouse gas emissions, although its impact on emissions is more uncertain because of the limited quantities of cellulosic ethanol produced to date. Relative to ethanol made from corn, cellulosic ethanol would produce about one-fourth of the emissions, because cellulosic wastes (rather than fossil fuels) might be used as a source of energy for an ethanol plant's operations or for the production of ethanol in cogeneration facilities (which produce electricity as well as steam from a fuel source). In addition, electricity produced by such facilities could be transmitted to the electric power grid, which might reduce the use of fossil fuels in coal-fired or natural gas-fired power plants and thereby cut greenhouse gas emissions from those plants.[27]

Biodiesel used as a substitute for petroleum diesel produces about 70 percent fewer life-cycle emissions of greenhouse gases for an equivalent amount of energy consumed. However, the overall reduction in emissions from that substitution is quite small because only about 350 million gallons of biodiesel were consumed in the United States in 2009, compared with total diesel fuel consumption of about 60 billion gallons. Moreover, biodiesel's share of total liquid fuel consumption is likely to remain small in coming years. The Energy Information Administration (EIA) projects that less than about 2 billion gallons of biodiesel will be used per year through 2020.[28]

Like CBO's analysis of the costs to taxpayers of displacing petroleum consumption with biofuels, its assessment of the costs of reducing greenhouse gas emissions measures the cost of the tax credits relative to the reduction in emissions from the additional amount of biofuels produced because of the credits. In addition, CBO's estimate of costs is again a net calculation that recognizes that consuming additional quantities of biofuels in place of petroleum fuels affects revenues from the excise tax on sales of fuels. To incorporate those factors in the estimated costs to taxpayers of reducing greenhouse gas emissions, CBO adjusted its estimates of the cost of reducing petroleum consumption to account for the differences among biofuels in life-cycle greenhouse gas emissions.

Specifically, using ethanol in place of gasoline lowers greenhouse gas emissions by 2.4 kilograms of CO_2e for each gallon of gasoline displaced; therefore, ethanol would have to displace about 424 gallons of gasoline to reduce greenhouse gas emissions by 1 metric ton. The

25. Wang, Wu, and Huo, "Life-Cycle Energy and Greenhouse Gas Emissions Impacts of Different Corn Ethanol Plant Types"; and Huo and others, "Life-Cycle Assessment of Energy Use and Greenhouse Gas Emissions." Although a fair degree of variability is evident in findings that biofuels produce lower life-cycle emissions than do petroleum fuels, the estimates of the ANL researchers have been widely accepted at federal agencies and are consistent with a range of other recent estimates. For example, a 2006 study by Hill and others ("Environmental, Economic, and Energetic Costs and Benefits of Biodiesel and Ethanol Biofuels") reported that the use of ethanol reduced life-cycle greenhouse gas emissions by 12 percent, whereas a 2009 study by Liska and others ("Improvements in Life Cycle Energy Efficiency and Greenhouse Gas Emissions of Corn-Ethanol") reported a reduction of 50 percent to 60 percent.

26. Wang, Wu, and Huo, "Life-Cycle Energy and Greenhouse Gas Emissions Impacts of Different Corn Ethanol Plant Types."

27. See, for example, R.V. Morey, D.G. Tiffany, and D.L. Hatfield, "Biomass for Electricity and Process Heat at Ethanol Plants," *Applied Engineering in Agriculture,* vol. 22, no. 5 (2006), pp. 723–728.

28. Energy Information Administration, *Annual Energy Outlook 2010 with Projections to 2035,* DOE/EIA-0383(2010) (April 2010), Table A17.

Table 5.

Cost to Taxpayers of Reducing Greenhouse Gas Emissions Through Use of the Federal Biofuel Tax Credits

	Corn Ethanol	Cellulosic Ethanol	Biodiesel[a]
Cost to Taxpayers of Displacing Petroleum with Biofuels[b] (Dollars per 125,000 Btus of energy)	1.78	3.00	2.55
Multiplied by: Units of Petroleum Fuel (Each Having 125,000 Btus of Energy) That Would Need to Be Displaced to Reduce Greenhouse Gas Emissions by 1 Metric Ton of Carbon Dioxide Equivalent	424 [c]	92 [d]	120 [e]
Equals: Cost to Taxpayers of Reducing Greenhouse Gas Emissions Through the Biofuel Tax Credits (Dollars per metric ton of greenhouse gases measured as carbon dioxide equivalent)	754	276	306

Source: Congressional Budget Office based on Michael Wang, May Wu, and Hong Huo, "Life-Cycle Energy and Greenhouse Gas Emission Impacts of Different Corn Ethanol Plant Types," *Environmental Research Letters,* vol. 2, no. 2 (2007); and Hong Huo and others, "Life-Cycle Assessment of Energy Use and Greenhouse Gas Emissions of Soybean-Derived Biodiesel and Renewable Fuels," *Environmental Science and Technology,* vol. 43, no. 3 (2009).

Notes: In CBO's calculations, corn ethanol and cellulosic ethanol are assumed to displace gasoline, and biodiesel is assumed to displace petroleum diesel. Cellulosic ethanol is produced from feedstocks such as corn stover (the leaves and stalks of corn plants), switchgrass (a tall North American grass used for hay and forage), wood chips, and plant wastes. In contrast to corn ethanol, the fermentable sugars necessary to produce cellulosic ethanol are provided by materials in the walls of the plants' cells. Biodiesel is diesel fuel made from virgin agricultural products (such as soybean oil and animal fats) or recycled agricultural oils (such as tallow).

Because individual greenhouse gases vary in their warming characteristics and persistence in the atmosphere, researchers commonly measure emissions in kilograms or metric tons of carbon dioxide equivalent—the amount of carbon dioxide that would cause an equivalent amount of warming over 100 years.

Btu = British thermal unit.

a. Although the biodiesel tax credit expired on December 31, 2009, CBO included it in the analysis to provide information about the value of the credit should policymakers, as they have at other times, decide to reinstate it.

b. For details of these costs, see Table 4 on page 11.

c. For every 125,000 Btus of fuel consumed, corn ethanol is estimated to produce 2.4 kilograms fewer greenhouse gas emissions over its life cycle (which includes emissions from its production and distribution) than gasoline produces. To reduce emissions by 1 metric ton (1,000 kilograms), ethanol must displace 424 gallons of gasoline (1,000 divided by 2.4).

d. For every 125,000 Btus of fuel consumed, cellulosic ethanol is estimated to produce 10.9 kilograms fewer greenhouse gas emissions over its life cycle than gasoline produces. To reduce emissions by 1 metric ton, cellulosic ethanol must displace 92 gallons of gasoline (1,000 divided by 10.9).

e. For every 125,000 Btus of fuel consumed, biodiesel is estimated to produce 8.3 kilograms fewer greenhouse gas emissions over its life cycle than petroleum diesel produces. To reduce emissions by 1 metric ton, biodiesel must displace 120 units of petroleum diesel, each having 125,000 Btus of energy (1,000 divided by 8.3).

cost to taxpayers of displacing gasoline with ethanol is $1.78 per gallon (equivalent to 125,000 Btus of energy; see the last line of Table 4 on page 11 and the first line of Table 5). As a result, by CBO's calculations, taxpayers' costs for reducing greenhouse gas emissions through the ethanol tax credit are $754 per metric ton of CO_2e ($1.78 per gallon multiplied by 424 gallons).

A similar calculation shows that taxpayers' costs for reducing greenhouse gas emissions under the now expired biodiesel tax credit total $306 per metric ton of CO_2e, or less than half the costs under the ethanol tax credit. The amount of the biodiesel credit (when it was in place and after adjustments for the energy content of the fuel and the additional excise tax receipts from sales of biodiesel in place of petroleum diesel) was about 65 percent greater than the amount of the adjusted credit for ethanol, but that larger cost was offset by biodiesel's greater capacity to reduce emissions—about 3.5 times greater than ethanol's. Cellulosic ethanol is expected to reduce greenhouse gas emissions at a cost similar to that for biodiesel and about 65 percent less than the cost for ethanol.

Those estimates are very sensitive to the portion of biofuel consumption attributable to the tax credits. For example, if CBO had estimated that the ethanol tax credit was responsible for 15 percent of ethanol consumption—the finding of the Iowa State researchers—the costs to taxpayers of reducing emissions through the credits would be about $1,700 per metric ton of CO_2e, rather than roughly $750. However, over the long term, the estimate of 32 percent that CBO used might be too low because it represents the amount of biofuel consumption today that is attributable to the *current* tax credits and is smaller than it would be if the facilities for biofuel production had not already been built—in part because of *previous* tax credits. In that case, taxpayers' costs for reducing greenhouse gas emissions would be less than those CBO has estimated.

Such estimates of the cost of using the biofuel tax credits to reduce greenhouse gas emissions are not comparable to estimates of the price of allowances under a cap-and-trade program for reducing emissions.[29] The costs reported here represent the average forgone tax revenue; the price of allowances under a cap-and-trade program represents the cost of avoiding the last, or marginal, ton of emissions under the specific requirements of the program.[30] In general, the costs of reducing greenhouse gas emissions through a biofuel tax credit would be higher than the costs resulting from a policy that imposed a price on those emissions, such as a cap-and-trade system or a tax on emissions. With a price on emissions, the market would determine how to reduce emissions throughout the economy, and that would generally be cheaper than reductions resulting from a tax credit that encouraged specific actions in fewer sectors of the economy. Moreover, the wide variation in the cost of reducing emissions with the tax credits suggests that those emissions could be reduced more cheaply through some actions than through others.

Greenhouse Gas Emissions When Land Use Does Change

Because of uncertainty about how land-use patterns are affected by increased production of biofuels, CBO's estimates of the costs of reducing emissions through the biofuel tax credits considered only the life-cycle emissions associated with producing and using biofuels and did not account for changes in land use. However, if such changes were substantial, the costs of reducing emissions through the credits would exceed those that CBO has estimated, possibly by a large margin.

Using biofuels produced from what had previously been grassland or forest in place of petroleum fuels would reduce greenhouse gas emissions only if the reductions in life-cycle emissions exceeded both the carbon released when that land was converted into new farmland and the reduction in carbon sequestration those lands would have provided in the future.[31] The timing and magnitude of such effects depend critically on the feedstock that is grown and how the land was being used before the change. Overall, some researchers maintain that the changes in emissions from alterations in land use are large enough that it might take decades or even centuries before the reduced life-cycle emissions from the use of biofuels offset the emissions associated with land-use changes (see Table 6).[32] However, other researchers

29. A cap-and-trade program would set annual limits, or caps, on total emissions and require entities regulated by the program to hold rights, or allowances, to emit greenhouse gases. After such allowances were initially distributed, entities would be free to buy and sell them (the trade part of the program). Cap-and-trade proposals generally specify caps that gradually decrease over time in absolute terms; as a result, households and firms incur gradually rising costs for reducing emissions. For more information, see Congressional Budget Office, *How Regulatory Standards Can Affect a Cap-and-Trade Program for Greenhouse Gases,* Issue Brief (September 16, 2009), and *The Costs of Reducing Greenhouse-Gas Emissions,* Issue Brief (November 23, 2009).

30. For additional information, see, for example, Congressional Budget Office, cost estimate for H.R. 2454, American Clean Energy and Security Act of 2009 (June 5, 2009).

31. Compared with cropland, grasslands and forests have a greater capacity to sequester carbon—that is, to capture and store it.

32. See Joseph Fargione and others, "Land Clearing and the Carbon Debt," *Science,* vol. 319 (2008), pp. 1235–1238; Renewable Fuels Agency, *The Gallagher Review of the Indirect Effects of Biofuels Production* (study commissioned by the Secretary of State for Transport, U.K., July 2008); and Timothy Searchinger and others, "Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change," *Science*, vol. 319 (2008), pp. 1238–1240.

Table 6.

The Time Required for Biofuel Use to Lower Emissions When Changes in Land Use Occur

Land Converted	Location	Years Until Net Carbon Reduction[a]	Study
		Corn Ethanol	
Grassland	United States	93	Fargione and others
Abandoned Cropland	United States	48	Fargione and others
Mix of Forest and Grassland	United States	167	Searchinger and others
Mix of Forest and Grassland	United States	14	Environmental Protection Agency
		Sugarcane Ethanol	
Forest	Brazil	17	Fargione and others
Forest	Brazil	15 – 39	Renewable Fuels Agency
Forest	Brazil	44	Lapola and others
Grassland	Brazil	3 – 10	Renewable Fuels Agency
Grazing Land	Brazil	4	Searchinger and others
Rainforest	Brazil	45	Searchinger and others
Grassland	Brazil	2	Environmental Protection Agency
		Switchgrass Ethanol[b]	
Cropland	United States	52	Searchinger and others
Mix of Forest and Grassland	United States	1	Environmental Protection Agency
		Palm Biodiesel	
Forest	Brazil	86	Fargione and others
Forest	Malaysia	18 – 38	Renewable Fuels Agency
Grassland	Malaysia	0 – 11	Renewable Fuels Agency
		Soybean Biodiesel	
Forest	Brazil	246	Lapola and others
Forest	Brazil	319	Fargione and others
Grassland	Brazil	37	Fargione and others
Forest	United States	179 – 481	Renewable Fuels Agency
Grassland	United States	14 – 96	Renewable Fuels Agency
Mix of Forest and Grassland	United States	9	Environmental Protection Agency

Source: Congressional Budget Office based on Joseph Fargione and others, "Land Clearing and the Carbon Debt," *Science,* vol. 319 (2008), pp. 1235–1238; Timothy Searchinger and others, "Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change," *Science,* vol. 319 (2008), pp. 1238–1240; Environmental Protection Agency, "Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis" (February 2010), Table 2.6-2; Renewable Fuels Agency, *The Gallagher Review of the Indirect Effects of Biofuels Production* (study commissioned by the Secretary of State for Transport, U.K., July 2008); and David M. Lapola and others, "Indirect Land-Use Changes Can Overcome Carbon Savings from Biofuels in Brazil," *Proceedings of the National Academy of Sciences* (February 2010).

a. These estimates, which take into account changes in land use, represent the number of years that a biofuel must be used before the lower emissions from that consumption reduce greenhouse gas emissions relative to those that would be produced if petroleum fuels were being used. Total emissions from biofuel consumption would be higher before that time than if petroleum fuels were used and lower in the years following that break-even date.

b. Switchgrass is a tall North American grass used for hay and forage.

conclude that the use of biofuels could result in net reductions in emissions over much shorter periods.

The conclusions reached by different analysts about the consequences of land-use changes for greenhouse gas emissions in the United States are illustrative. One study implies that ethanol produced from corn grown on land that was previously grassland would require nearly 100 years to compensate for the greenhouse gases emitted in changing grassland to farmland. Another analysis suggests that it would take from nearly 200 years to almost 500 years before the use of biodiesel produced from soybeans grown on previously forested land reduced emissions. In contrast, the Environmental Protection Agency, although agreeing that emissions related to land use are an important concern in assessing the impact of biofuels on greenhouse gas emissions, concluded that, in general, less time might be necessary for such fuels to offset emissions from changes in land use and to cause overall emissions to decline. For example, the agency found that it would take 14 years for ethanol produced from corn to offset the impact of land-use changes; biodiesel produced from soybeans would require 9 years.[33]

Although changes in land use generally boost overall emissions from the production and use of a given biofuel, the size of that increase can be difficult for researchers to assess, for several reasons:

- The increased use of some biofuels is not expected to cause changes in land-use patterns. For example, biodiesel made from recycled animal or vegetable fats and cellulosic ethanol produced from corn stover are likely to result in few or no changes to land use because those feedstocks are by-products of other processes.
- Some changes in land use are unlikely to release large amounts of greenhouse gases. For instance, cultivating algae for the production of biodiesel, a method currently being studied, could cause changes in land use, but those changes might produce few additional emissions because the land (if deserts were used, for example) might not have absorbed large amounts of carbon before being converted to algae cultivation.
- Determining the proportion of overall changes in land use that are attributable to increased production of biofuels is difficult. Greater production may indirectly result in land-use changes elsewhere, but some of that new acreage might have been developed even if no such production had occurred.
- Even if the extent of the land-use changes from added biofuel production was known, the effects of such changes on emissions would still be difficult to estimate because they would depend on the type of land converted and the types of crops to be farmed there, not only in this country but in others as well. Assessing the increase in emissions would require a detailed understanding of international farming practices, local economies in other nations, and prospective farming patterns at home and abroad.[34]

Nevertheless, emissions resulting from changes in land use are likely to grow in coming years as the statutory mandates spur increases in the production of biofuels. The mandates for 2015 under EISA, for instance, call for the use of 20.5 billion gallons of biofuels; up to 15 billion gallons of that amount—or about 40 percent more than current ethanol production—may be ethanol produced from corn grown in the United States. That quantity of fuel would require planting about 31 million acres of corn for the sole purpose of producing ethanol—or about one-fourth more than the acreage used for ethanol production today. Although a portion of that increased acreage could come from currently idle cropland or from the displacement of other crops—neither of which would directly cause a large amount of emissions to be

33. Environmental Protection Agency, *Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis* (February 2010), Table 2.6-2, available at www.epa.gov/oms/renewablefuels/420r10006.pdf. EPA's recent assessment of the emissions from changes in land use illustrates the uncertainty involved in quantifying such emissions. The agency's estimate that no more than 14 years would be required before the use of ethanol or biodiesel produced from soybeans could offset emissions from land-use changes is about half the time that EPA had estimated less than a year earlier. For those earlier estimates, see Environmental Protection Agency, *Draft Regulatory Impact Analysis: Changes to Renewable Fuel Standard Program* (May 2009), p. 285, available at www.epa.gov/oms/renewablefuels/420d09001.pdf.

34. Bruce Babcock, "Measuring Unmeasurable Land-Use Changes from Biofuels," *Iowa Ag Review,* vol. 15, no. 3 (Summer 2009), available at www.card.iastate.edu/iowa_ag_review/summer_09/article2.aspx. For example, some of EPA's findings are based on its estimate of fewer emissions—relative to the assumptions underlying other analyses—from domestic and international changes in land use.

released—some of the increased acreage would result from devoting more land to agricultural production, which would lessen some of the reduction in emissions that would otherwise be achieved by using biofuels in place of petroleum fuels. In addition, the displacement of crops that are themselves not used to produce biofuels may cause changes in land use elsewhere in the world, causing additional releases of greenhouse gases.

The Interaction of Tax Credits and Mandates

The production of biofuels in the United States depends on the market conditions for those fuels coupled with the tax credits and the mandates for use of specific minimum amounts of biofuel. For some combinations of the prices of conventional fuels, the costs of producing biofuels, the biofuel tax credits, and the mandates, the quantity of biofuels produced will exceed the mandated amounts. That has been the case in the United States since the mandates were adopted.

For example, domestic consumption of ethanol in 2009 totaled about 10.8 billion gallons when the mandate required the use of 10.5 billion gallons. Even during that period, however, the mandates have helped assure farmers and biofuel refiners that there will be a market for their products, which in turn has encouraged the investment decisions that have made significant biofuel production possible. In particular, the mandates have increased farmers' incentive to grow feedstocks and producers' incentive to invest in facilities and equipment.

For other combinations of conventional fuel prices, biofuel production costs, tax credits, and mandates, the quantity of biofuels produced will fall short of the mandated amounts. That is more likely to be the situation in the future, because the mandates currently in place require ever larger amounts of biofuels to be used over time. Specifically, the mandated amounts of biofuels rise to 36 billion gallons by 2022. Of that total, only 15 billion gallons of conventional ethanol can be used to meet the renewable fuel standards; the remainder is mandated to consist of advanced biofuels (such as biodiesel produced from soybean oil) whose life-cycle greenhouse gas emissions are 50 percent less than those associated with burning gasoline or diesel fuel. In the future, the scheduled increase in mandated volumes would require biofuels to be produced in amounts that are probably beyond what the market would produce even if the effects of the tax credits were included. To the extent that the mandates determine future production levels, the biofuel tax credits would no longer be increasing production. However, they would still be reducing the costs borne by producers and consumers of biofuels and shifting some of those costs to taxpayers.