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The Impact of Ethanol Use on Food Prices and Greenhouse-Gas Emissions

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Notes

Unless otherwise indicated, all years referred to in this report are calendar years.

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Preface

The production and use of ethanol in the United States have been steadily increasing since 2001, boosted in part by long-standing production subsidies. That growth has exerted upward pressure on the price of corn and, ultimately, on the retail price of food, affecting both individual consumers and federal expenditures on nutritional support programs. It has also raised questions about the environmental consequences of replacing gasoline with ethanol.

This Congressional Budget Office (CBO) analysis, which was prepared at the request of Representatives Ron Kind, Rosa DeLauro, and James McGovern, examines the relationship between increasing production of ethanol and rising prices for food. In particular, CBO estimated how much of the rise in food prices between April 2007 and April 2008 was due to an increase in the production of ethanol and how much that increase in prices might raise federal expenditures on food assistance programs. CBO also examined how much the increased use of ethanol might lower emissions of greenhouse gases. In keeping with CBO's mandate to provide objective, impartial analysis, the report contains no recommendations.

The report was written by Ron Gecan and Rob Johansson of CBO's Microeconomic Studies Division and Kathleen FitzGerald of CBO's Budget Analysis Division under the guidance of Joseph Kile, David Moore, and Sam Papenfuss. Within CBO, Robert Dennis, Terry Dinan, David Hull, Robert Shackleton, Natalie Tawil, and Thomas Woodward (who has since left the agency) provided helpful comments, as did Joseph Cooper, Ephraim Leibtag, and Paul Wescott of the Department of Agriculture; Ralph Heimlich of Agricultural Conservation Economics; Tim Searchinger of Princeton University; and Michael Wang of Argonne National Laboratory. (The assistance of external reviewers implies no responsibility for the final product, which rests solely with CBO.)

Leah Mazade edited the study, and Sherry Snyder proofread it. Maureen Costantino designed the cover and, with the assistance of Allan Keaton, prepared the study for publication. Lenny Skutnik 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

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Director

April 2009

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The use of ethanol in gasoline has increased substantially over the past decade. Currently, most ethanol in the United States is produced from domestically grown corn, and the rapid rise in the fuel's production and usage means that roughly one-quarter of all corn grown in the United States is now used to produce ethanol. Since 2006, food prices have also risen more quickly than in earlier years, affecting federal spending for nutrition programs (such as school lunches) and the household budgets of individual consumers. The increased use of ethanol accounted for about 10 percent to 15 percent of the rise in food prices between April 2007 and April 2008, the Congressional Budget Office (CBO) estimates. In turn, that increase will boost federal spending for the Supplemental Nutrition Assistance Program (SNAP, formerly the Food Stamp program) and child nutrition programs by an estimated $600 million to $900 million in fiscal year 2009. Last year, the use of ethanol reduced gasoline consumption in the United States by about 4 percent and greenhouse-gas emissions from the transportation sector by less than 1 percent.

Ethanol and Food Prices

Over the past several years, the use of ethanol as a motor fuel in the United States has grown at an annual average rate of nearly 25 percent. That growth was driven by rising prices for gasoline coupled with long-standing subsidies for producing ethanol, which encouraged makers of ethanol to increase production. All told, despite a slowdown in production in the last quarter of 2008 as a result of falling prices for gasoline, overall consumption of ethanol in the United States last year hit a record high, exceeding 9 billion gallons.

In 2008, nearly 3 billion bushels of corn were used to produce ethanol in the United States. That amount constituted an increase over the previous year of almost a billion bushels. The demand for corn for ethanol production, along with other factors, exerted upward pressure on corn prices, which rose by more than 50 percent between April 2007 and April 2008. Rising demand for corn also increased the demand for cropland and the price of animal feed.

Those effects in turn raised the price of many farm commodities (such as soybeans, meat, poultry, and dairy products) and, consequently, the retail price of food. Pushed up in part by those effects and by surges in the price of energy, food prices rose by almost 2½ percent in 2006, by 4 percent in 2007, and by more than 5 percent in 2008. That those increases coincided with higher prices for corn raises questions about the link between ethanol production, the demand for corn, and food prices.

CBO estimates that from April 2007 to April 2008, the rise in the price of corn resulting from expanded production of ethanol contributed between 0.5 and 0.8 percentage points of the 5.1 percent increase in food prices measured by the consumer price index (CPI). Over the same period, certain other factors—for example, higher energy costs—had a greater effect on food prices than did the use of ethanol as a motor fuel.

Beyond the one-year period that ended in April 2008, food prices are likely to be higher than they would have been if the United States did not use ethanol as a motor fuel. However, ethanol's effect on future food price inflation is uncertain because the forces determining that impact move in opposite directions. Federal mandates now in place require additional use of ethanol in the future, which would continue to put upward pressure on prices. In contrast, increases in the supply of corn from cultivating more cropland, increasing crop yields, or improving the technology for making ethanol from corn or other feedstocks (raw materials) would tend to lower food prices.

Ethanol, Food Prices, and Federal Food Assistance

Changes in food prices affect spending for federal food assistance.[1] The federal government administers several assistance programs that are operated at the local level by state agencies and other providers. The largest of those programs are SNAP and the National School Lunch and School Breakfast Programs. Federal reimbursements and benefits for those programs are adjusted automatically each year according to the change in various food price indexes. The change in food prices from 2007 to 2008, the period covered by this analysis, determines the benefits for those programs for fiscal year 2009. As a result, the rise in food prices attributable to increased production of ethanol will lead to higher federal spending for those programs: specifically, an estimated $600 million to $900 million of the more than $5 billion increase in spending projected for fiscal year 2009 as a result of the rising price of food.

The Special Supplemental Assistance Program for Women, Infants, and Children—better known as WIC—is another federal food assistance program whose spending could be affected by increased ethanol production. Because WIC provides a specific basket of goods to recipients—as opposed to a set cash benefit, as in SNAP—the program's costs can vary month by month. Therefore, changes in food prices in 2008 had an immediate impact on costs for the program (in contrast to nutrition assistance programs, whose reimbursements lag behind changes in prices).

Although WIC assistance is funded through a different mechanism than are SNAP and the school programs (WIC is not an entitlement program but instead receives an annual appropriation), ethanol's effects on the cost of the basket of goods available through WIC could be similar to the impact that its production has had on food prices in the other federal nutrition assistance programs. Under the assumption that the effects are much the same, increased production of ethanol would have added less than $75 million in fiscal year 2008 to the cost of serving the same number of WIC participants as in 2007.

Ethanol and Greenhouse-Gas Emissions

Research conducted by the Argonne National Laboratory (ANL) and used by federal agencies suggests that in the short run, the production, distribution, and consumption of ethanol will create about 20 percent fewer greenhouse-gas emissions than the equivalent processes for gasoline. For 2008, such a finding translates into a reduction of about 14 million metric tons of carbon dioxide and equivalent gases (a standard measure of greenhouse-gas emissions), or CO_2e.[2] In the long run, the result is less clear. If increases in the production of ethanol led to a large amount of forests or grasslands being converted into new cropland, those changes in land use could more than offset any reduction in greenhouse-gas emissions—because forests and grasslands naturally absorb more carbon from the atmosphere than cropland absorbs.

In the future, the use of cellulosic ethanol, which is made from wood, grasses, and agricultural plant wastes rather than corn, might reduce greenhouse-gas emissions more substantially, but current technologies for producing cellulosic ethanol are not commercially viable. Research by ANL suggests that increased use of cellulosic ethanol in the amounts specified in the Energy Independence and Security Act of 2007 could reduce greenhouse-gas emissions from the nation's transportation sector by as much as 130 million metric tons of CO_2e by 2022—which would equal about 6 percent of emissions from that sector or slightly more than 2 percent of total projected U.S. emissions from all sources in that year. However, that potential would be realized only if cellulosic ethanol could be produced on a large scale and if the effects of changes in land use did not offset the reduction that producing, distributing, and consuming ethanol could make in greenhouse-gas emissions.

1. Such changes also affect spending for other federal programs through their impact on the CPI, which is used to calculate annual cost-of-living adjustments in benefits for programs such as Social Security. Those effects on other programs, however, are beyond the scope of this report.

2. Individual greenhouse gases have different warming characteristics and persist in the atmosphere for different lengths of time. To simplify matters, researchers commonly refer to emissions and atmospheric concentrations of those greenhouse gases in terms of metric tons (a metric ton is approximately 2,200 pounds) of carbon dioxide equivalent, or CO_2e—the amount of carbon dioxide that would cause an equivalent amount of warming over a certain period (typically 100 years).

Implications of Ethanol Use for Food Prices and Greenhouse-Gas Emissions

Over little more than a decade, the use of ethanol as a motor fuel in the United States has expanded nearly sevenfold.[1] Ethanol production rose by 34 percent between 2006 and 2007 and by another 42 percent between 2007 and 2008.[2] Last year, overall consumption of ethanol in the United States reached a record high, exceeding 9 billion gallons, which reduced the nation's demand for gasoline by nearly 5 percent.[3] Mandates for increased usage included in the Energy Independence and Security Act of 2007 (EISA) are slated to keep ethanol production high in the future.[4]

Much of the increased production and usage in recent years was spurred by a steady rise in the price of gasoline from 2006 to the record highs of the summer of 2008. Those high prices, in addition to long-standing subsidies for producing ethanol, encouraged ethanol producers to boost production despite the rise in prices for corn during the same period, which would generally lead to cuts in production. To meet the rapidly increasing demand for ethanol, producers used nearly 1 billion more bushels of corn in 2008 than they did during the previous year—an increase of about 40 percent.

The increase in the amount of corn used to produce ethanol has exerted upward pressure on corn prices, boosted the demand for cropland, and raised the price of animal feed. Those effects, in turn, have lifted the prices of many farm commodities (for example, soybeans, meat, poultry, and dairy products) and, consequently, the retail price of food. The rise in food prices has affected not only the costs to individual consumers but also spending for the federal government's food assistance programs.

This Congressional Budget Office (CBO) paper examines the period from April 2007 to April 2008, during which the rapidly increasing production of ethanol coincided with rising prices for corn, food, and fuel. In particular, CBO estimates how much of the rise in food prices during that time was due to an increase in the consumption of ethanol and how much the rise in food prices would have boosted federal expenditures on food assistance programs. In addition, CBO examines how the increased use of ethanol may lower emissions of greenhouse gases.

Domestic production and consumption of ethanol may lead to other effects that are not addressed in this report. For example, increased production of ethanol has probably led to some reduction in oil imports and the price of gasoline, to an increase in average farm income, and to some impact on the quality of the nation's air and water resources. In addition, ethanol usage may affect other areas of the federal budget. The rise in food prices during the 2007–2008 period, some of which was attributable to ethanol, boosted the consumer price index, which is used to calculate annual cost-of-living adjustments in benefits for such programs as Social Security, military and civilian retirement, and Supplemental Security Income. Evaluating the pros and cons of ethanol production and consumption in the United States would also include

1. Renewable Fuels Association, "Statistics: Historic U.S. Fuel Ethanol Production," available at www.ethanolrfa.org/industry/statistics.
2. Ibid.
3. Energy Information Administration, "Annual Energy Outlook 2009" (March 2009), available at www.eia.doe.gov/oiaf/aeo/aeoref_tab.html.
4. Public Law 110-140, 141 Stat. 1492.

examining those factors, but that analysis is beyond the scope of this paper.

Ethanol Production in the United States

Ethanol is produced from some form of sugar and can be readily derived from sugar crops, most notably sugarcane and sugar beets. In the United States, however, the potential to grow sugar crops as a feedstock (that is, the raw material) for ethanol production is limited; growing conditions are not as favorable here as in Brazil, for example, which has a thriving ethanol industry based on sugarcane.[5] As a result, almost all of the ethanol that is commercially produced in the United States (which is known as corn or conventional ethanol) is derived from cornstarch, or the corn kernel. Ethanol can also be produced from cellulose; however, the production process is more difficult than that for corn because the sugars contained within cellulose are tightly bound in the fibrous materials that give potential cellulosic sources—such as cornstalks and trees—their sturdiness.

The more than 9 billion gallons of ethanol that Americans consumed during 2008 displaced about 6 billion gallons of gasoline. The difference in the number of gallons of ethanol on the one hand and gasoline on the other arises because the energy content of a gallon of gasoline is greater than that of a gallon of ethanol. About 1.5 gallons of ethanol are required to provide as much energy as 1 gallon of gasoline.[6]

The federal government has supported the development and use of ethanol since the late 1970s through programs that subsidize the production of ethanol, impose tariffs on ethanol imports, and mandate particular amounts of consumption. Those programs provide support because, when the two fuels are assessed on the basis of their energy content, ethanol has often been more expensive than gasoline to produce in the United States.

5. Department of Agriculture, *The Economic Feasibility of Ethanol Production from Sugar in the United States* (July 2006), available at www.usda.gov/oce/reports/energy/EthanolSugarFeasibilityReport3.pdf.

6. According to the Energy Information Administration ("Errata for Biofuels in the U.S. Transportation Sector as of 10/15/07," available at www.eia.doe.gov/oiaf/analysispaper/errata_biofuels.html), a gallon of ethanol contains about 84,000 British thermal units, or Btus (the standard measure for the amount of energy that a fuel contains); a gallon of gasoline has about 125,000 Btus.

The Production Subsidy

Since 1978, firms that blend ethanol with gasoline have received a tax incentive from the federal government. The incentive has been adjusted periodically; today, ethanol blenders receive a tax credit of 45 cents for each gallon of ethanol blended into the supply of gasoline. The subsidy has helped keep ethanol competitive with gasoline, even when prices for corn are high (see Box 1). In 2007, the cost of the credit in forgone federal tax revenues was $3 billion.[7]

Import Tariffs

The production subsidy for ethanol applies to both domestic and imported ethanol, but the United States charges importers of ethanol a tariff of 54 cents per gallon and an ad valorem tariff of 2.5 percent of the value of the imported ethanol. (Prices for ethanol sold in the United States fluctuated between $1.61 and $2.90 per gallon in 2008, resulting in ad valorem tariffs that ranged from 4 cents to 7 cents per gallon.)[8] The two tariffs effectively offset the production subsidy for imported ethanol unless the imports arrive duty-free. The United States imports a relatively small amount of ethanol duty-free from countries that participate in the Caribbean Basin Initiative: an annual amount equal to as much as 7 percent of the nation's ethanol consumption over the previous 12-month period ending on the preceding September 30.[9]

In 2007, domestic production accounted for about 95 percent of the U.S. ethanol supply. Imports amounting to approximately 330 million gallons accounted for the rest.[10] (Half of that imported ethanol came from Brazil, either directly or indirectly, on a duty-free basis, through a Caribbean nation.) The Energy Information Administration (EIA) has estimated that imports of ethanol remained about the same in 2008 as in 2007.

7. Energy Information Administration, *Federal Financial Interventions and Subsidies in Energy Markets 2007,* SR/CNEAF/2008-01 (April 2008).

8. See, for example, the monthly data from the Nebraska Energy Office, "Ethanol and Unleaded Gasoline Average Rack Prices," available at www.neo.ne.gov/statshtml/66.html.

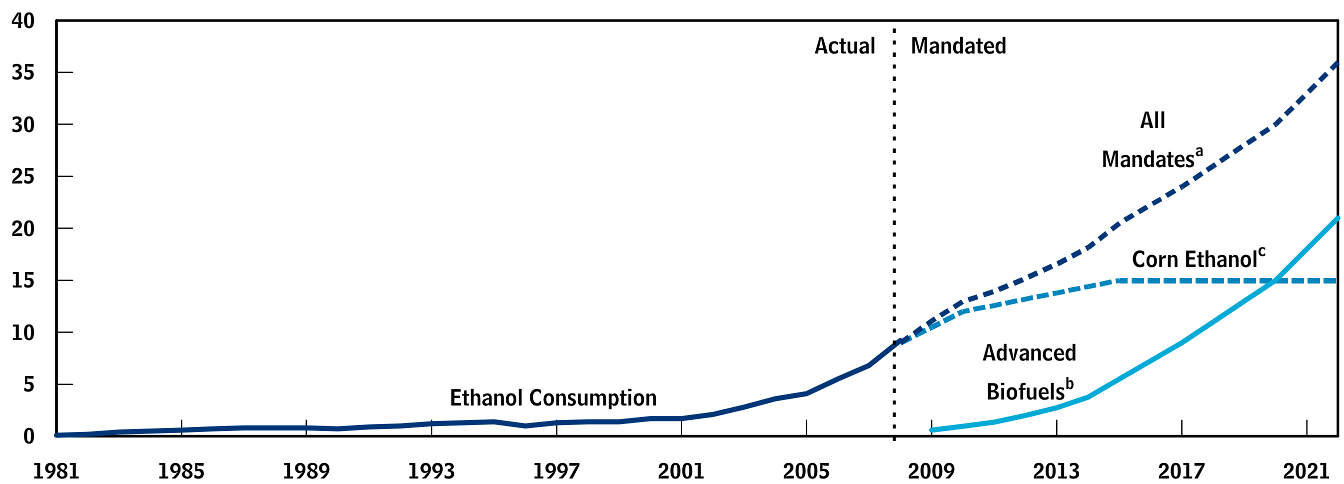
9. For information about that trade agreement, see Brent D. Yacobucci, *Ethanol Imports and the Caribbean Basin Initiative (CBI),* CRS Report for Congress RS21930 (Congressional Research Service, March 2008).

10. Energy Information Administration, "Annual Energy Outlook 2009," Table 11.

Figure 1.

Effect of Mandates in the Energy Independence and Security Act of 2007 on the Consumption of Biofuels

(Billions of gallons)



Source: Congressional Budget Office based on data from the Energy Information Administration.

a. The mandates enacted in the Energy Independence and Security Act of 2007, or EISA (Public Law 110-140), require that by 2022, a total of 36 billion gallons of renewable biofuels (fuels made from biological raw materials) be consumed annually. The law also requires that corn ethanol make up no more than 15 billion gallons of that total.

b. Advanced biofuels are renewable fuels not made from cornstarch that reduce greenhouse-gas emissions over the "life cycle" of the fuel (its production, distribution, and use) by at least 50 percent relative to emissions from gasoline.

c. The Energy Information Administration estimates that annual corn ethanol usage will be 15 billion gallons between 2015 and 2022.

Federal Mandates

The Energy Policy Act of 2005 laid out a schedule of mandates through 2012 for increasing the amount of biofuels used in the United States.[11] The Energy Independence and Security Act of 2007 expanded the mandates and extended them through 2022 (see Figure 1). Under those laws, federal mandates requiring the use of biofuels are intended to encourage the domestic production of ethanol and other biofuels; the mandates also seek to generate increasingly large reductions in greenhouse-gas emissions from the transportation sector.[12]

Specifically, those mandates require usage of biofuels in the United States to be at least 20.5 billion gallons annually by 2015, or more than double the country's usage in 2008. Of that total, not more than 15 billion gallons may be refined from cornstarch. By 2022, the total amount of biofuels used (including conventional and cellulosic ethanol as well as biodiesel and other advanced biofuels) must be at least 36 billion gallons. By contrast, the United States' current capacity for producing biofuels stands at 15 billion gallons, 12.4 billion gallons of which represents capacity for producing corn ethanol.[13]

Ethanol Production and Consumption Under Subsidies, Tariffs, and Mandates

To date, ethanol usage has exceeded the amounts required by federal mandates, indicating that the mandates have not yet forced additional production or imports in any

11. A biofuel, such as ethanol or biodiesel (diesel fuel made from plants), is composed of or produced from biological raw materials. In contrast, a fossil fuel, such as oil or coal, is formed in the earth from plant or animal remains.

12. EISA directed the Environmental Protection Agency to issue rules that ensured that biofuels would be sold or introduced into commerce in the United States, but it also gave the agency discretion to relax the standards if they were shown to result in severe economic or environmental harm to any state or region.

13. Renewable Fuels Association, "Biorefinery Locations," available at www.ethanolrfa.org/industry/locations.

Box 1.

The Economic Viability of Producing Corn Ethanol

The economic viability of producing corn ethanol—whether manufacturers can show a profit—is intrinsically linked to the price of gasoline (for which ethanol is a substitute) and to the price that ethanol producers pay for corn. The Congressional Budget Office's (CBO's) analysis of current technologies and prices suggests that, without subsidies for producing ethanol, the "break-even ratio" of the price per gallon of retail gasoline to the price per bushel of corn is currently about 0.9.[1] In other words, when the price of a gallon of gasoline is more than 90 percent of the price of a bushel of corn, it is profitable to produce ethanol. At that point, revenues from the sale of ethanol would be sufficient to cover the fixed and variable costs of producing it. (Fixed costs include a return on the investment required to build the ethanol plant; variable costs include the cost of natural gas or coal to run an ethanol plant.) When ratios are above 0.9, producers have an incentive to invest in new structures and equipment to expand their capacity to make ethanol. But when ratios are lower than 0.9, the costs of producing ethanol exceed the fixed and variable costs of production unless subsidies are provided.

It is unlikely that, on average, ethanol producers over the past several decades would have turned a profit if they had not received production subsidies. The average ratio of a gallon of gasoline to the price of a bushel of corn fluctuates substantially from year to year and has exceeded 0.9 only once, in 2005 (see the figure to the right). However, fluctuations in the ratio of corn and gasoline prices are even more extensive within each year, suggesting that at different times, conditions will be more or less favorable for producing and selling ethanol. That volatility stems in large part from the sensitivity of corn prices to variability in weather patterns, both in the United States and in other countries. Uncertainty about future corn and gasoline prices makes it hard for ethanol producers to predict what their profits or losses will be and to determine whether they should plan on expanding their businesses or reducing production. Moreover, in any given year or month, a combination of increasing global demand for corn, a reduction (actual or expected) in the supply of corn because of bad weather, or a drop in the global demand for petroleum could raise the price of corn relative to the real (inflation-adjusted) price of gasoline, making it more difficult for ethanol producers to generate profits. All three of those phenomena occurred at different times in 2007 and 2008.

Over time, the ratio of gasoline to corn prices has shown a slight upward trend, indicating that the production of ethanol from corn could become more profitable in the future. That trend has been reinforced as the detection and extraction of new supplies of petroleum become more costly and corn yields per acre increase. However, other economic conditions

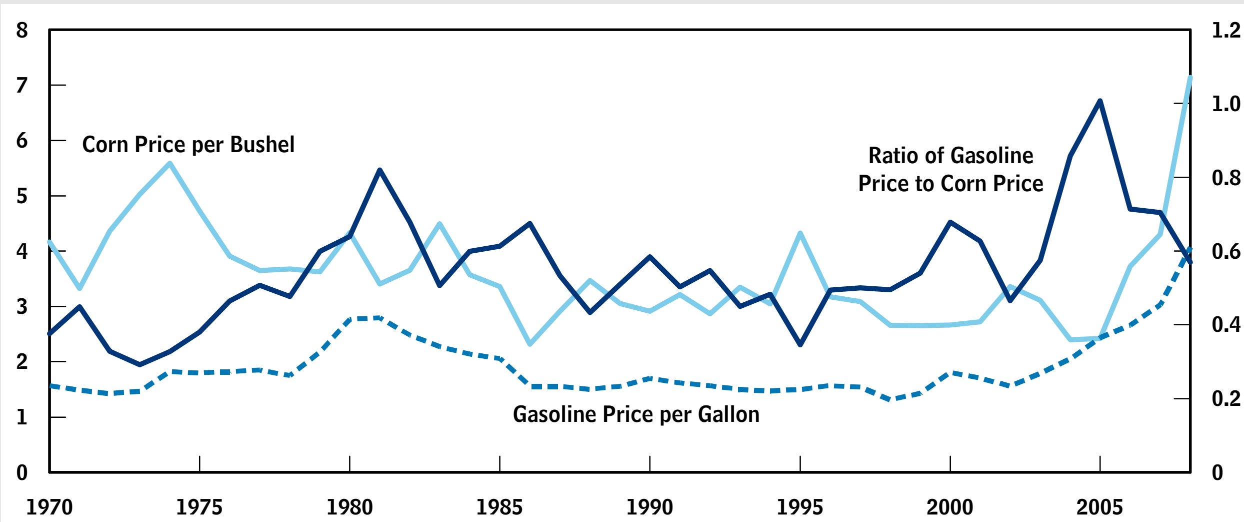
1. Values for fixed and variable costs and for distillers' grain prices were derived from Gary Schnitkey, Darrel Good, and Paul Ellinger, *Crude Oil Price Variability and Its Impact on Break-Even Corn Prices,* Report No. FEFO 07-11 (University of Illinois at Urbana-Champaign, Farmdoc [Farm Decision Outreach Central], May 30, 2007); Wallace E. Tyner and Farzad Taheripour, "Future Biofuels Policy Alternatives" (presentation at the Farm Foundation/Department of Agriculture conference on biofuels, food, and feed trade-offs, St. Louis, Missouri, April 2007); Amani Elobeid and others, *The Long-Run Impact of Corn-Based Ethanol on the Grain, Oilseed, and Livestock Sectors: A Preliminary Assessment*, Briefing Paper 06-BP 49 (Ames, Iowa: Iowa State University, Center for Agricultural and Rural Development, November 2006); and Vernon R. Eidman, "Renewable Liquid Fuels: Current Situation and Prospects," *Choices,* vol. 21, no. 1 (2006), pp. 15–19. Assumptions regarding refining efficiency were taken from Simla Tokgoz and others, *Emerging Biofuels: Outlook of Effects on U.S. Grain, Oilseed, and Livestock Markets*, Staff Report 07-SR 101 (Ames, Iowa: Iowa State University, Center for Agricultural and Rural Development, July 2007).

Continued

Box 1. **Continued**

The Economic Viability of Producing Corn Ethanol

The Relationship Between the Price of Corn and the Price of Gasoline, 1970 to 2008



Source: Congressional Budget Office based on data from the Energy Information Administration (average annual retail prices for motor gasoline, available at www.eia.doe.gov/emeu/aer/txt/ptb0524.html) and the Department of Agriculture (average annual prices for corn, available at www.ers.usda.gov/Data/Feedgrains).

Note: The "break-even ratio" (of the price per gallon of retail gasoline to the price of a bushel of corn) indicates the point at which it is profitable to expand ethanol production capacity in the absence of subsidies for ethanol production. In CBO's estimation, that figure is currently about 0.9.

could make it more difficult for the production of ethanol to be profitable. For example, increases in the cost of the natural gas or coal required to run an ethanol plant would push the break-even ratio higher.

The break-even ratio is also affected by technology, and improvements in the technologies and processes for refining ethanol would cause the ratio to fall. In 1989, for instance, with the technology then available, each bushel of corn yielded about 2.5 gallons of ethanol. Today, with better technologies, a bushel of corn yields 2.8 gallons of ethanol, and newer facilities may improve yields to 3.0 gallons per bushel.[2] At yields of 3.0 gallons per bushel, the break-even ratio would fall to 0.8.

The break-even ratio also depends on federal policies. At the current subsidy of 45 cents per gallon of ethanol produced, the break-even ratio that would allow producers to cover their fixed and variable costs falls to 0.7. Similarly, policies in the future that provided incentives for reducing greenhouse-gas emissions would lower the break-even ratio if the production and burning of ethanol resulted in lower greenhouse-gas emissions than did the production and burning of gasoline.

2. See Tokgoz and others, *Emerging Biofuels*.

given year. EIA estimates that domestic production of ethanol in 2008 was 8.9 billion gallons, an increase of nearly 45 percent from the 6.2 billion gallons produced in 2007. The federal government's production subsidies and the relatively high prices for gasoline during most of 2008 made that level of production profitable (see Box 1). However, individual producers may still suffer losses. Lags occur between the time producers make decisions about purchasing inputs to the production process (such as corn) and when they can sell their product at the pump. When coupled with potential volatility in the commodity markets as a result of weather and economic conditions, such lags can lead to losses and idled production capacity.[14]

In the future, the amount of ethanol produced will be determined by the interaction of conditions in the commodity markets, production incentives, and mandates for ethanol consumption. During periods when gasoline prices are high relative to corn prices, the impact of mandates and production incentives is likely to be smaller than in periods when the opposite is true.

Recent developments in the commodity markets indicate that prices for gasoline and corn will most likely be lower during the 2008–2009 corn marketing year (September 2008 through the end of August 2009) than they were during the previous marketing year:

- As of March 10, 2009, EIA's "Short Term Energy Outlook" projected an average price of gasoline of $2.05 per gallon during the 2008–2009 corn marketing year; and

- On March 30, quotes from the Chicago Board of Trade on futures prices for corn for the rest of the marketing year (May and July deliveries) averaged $3.91 per bushel.[15]

Under those prices (a ratio of gasoline to corn prices of about 0.5) and the current amount of federal support for domestic ethanol production, producers might not find it profitable to increase production of ethanol in existing facilities or to invest in new facilities. An estimated 2 billion gallons of ethanol production capacity was idled in early 2009 in response to economic pressures.[16] Yet the increases in mandated ethanol consumption and other factors may lead to a rise in production or imports. In fact, EIA estimates that domestic production of ethanol will climb to 10.5 billion gallons in 2009, an amount that will exceed the mandate for that year when coupled with production of biodiesel. By 2015, EIA projects, ethanol production and imports will top 16 billion gallons.[17]

Ethanol Production and Food Prices

Producing ethanol for use in motor fuels increases the demand for corn, which ultimately raises the prices that consumers pay for a wide variety of foods at the grocery store, ranging from corn syrup sweeteners found in soft drinks to meat, dairy, and poultry products. In addition, the demand for corn may help push up the prices of other commodities, such as soybeans. (Farmers that increase the number of acres they plant with corn to meet rising demand will most likely plant fewer acres with other crops.) From April 2007 to April 2008, the increasing demand for corn to produce ethanol contributed, in CBO's estimation, between 0.5 and 0.8 percentage points to the 5.1 percent increase in the price of food overall as measured by the component of the consumer price index for all urban consumers (CPI-U) that measures food prices.[18] That is, the growing use of corn for ethanol accounted for about 10 percent to 15 percent of the increase in the CPI-U for food over the April-to-April period. That estimate has two parts: an assessment of how the boost in ethanol production contributed to increases in the price of corn, animal products, and soybeans; and a reckoning of how higher prices for those commodities contributed to the price of the foods measured in the CPI-U for food.

14. See, for example, Mark Steil, "VeraSun Bankruptcy Hitting Minnesota Farmers in the Wallet," *Minnesota Public Radio*, November 21, 2008, available at http://minnesota.publicradio.org/display/web/2008/11/21/verasun/?refid=0.

15. A futures contract is a legal agreement, traded on an exchange, to make or take delivery of a commodity (such as corn) at a fixed future date and at a price determined at the time of dealing.

16. Joseph W. Glauber, Chief Economist, Department of Agriculture, "Prospects for the U.S. Farm Economy in 2009" (speech at the Department of Agriculture's 85th annual Agricultural Outlook Forum, February 26, 2009), available at www.usda.gov/oce/forum/2009_Speeches/Speeches/Glauber.pdf.

17. Energy Information Administration, "Annual Energy Outlook 2009," Table 11.

18. The CPI-U is maintained by the Bureau of Labor Statistics. For percentage changes over the period, see Bureau of Labor Statistics, *CPI Detailed Report: Data for April 2008,* available at www.bls.gov/cpi/cpid0804.pdf.

The Increased Price of Corn

In estimating how the growing demand for corn affected what consumers paid at the grocery store, CBO used a range of estimates from the economics literature about the responsiveness, or "elasticity," of the supply of corn to increases in its price. The upswing in the demand for corn to be used in producing domestic ethanol raised the commodity's price, CBO estimates, by between 50 cents and 80 cents per bushel between April 2007 and April 2008.[19] That range is equivalent to between 28 percent and 47 percent of the increase in the price of corn, which rose from $3.39 per bushel to $5.14 per bushel during the same period.

That price increase occurred despite an increase in corn production—that is, in the amount of corn grown, harvested, and marketed.[20] During the 2007–2008 corn marketing year, the United States harvested a record 13.1 billion bushels of corn. Of that total, approximately 3 billion bushels, or nearly a quarter (another record), was used to produce ethanol. Moreover, the total U.S. supply of corn—the 13.1 billion bushels that were harvested plus inventories of corn from previous years—rose from 12.5 billion bushels in the 2006–2007 marketing year to 14.4 billion bushels in the 2007–2008 marketing year.

Globally, other countries' biofuels policies—for example, those of Brazil and member countries of the European Union—also put upward pressure on prices for corn and other food commodities. (Those countries, together with the United States, account for 90 percent of worldwide production of biofuels.)[21] One analysis of increasing ethanol production domestically and globally found that the rise in the United States' production of ethanol could account for about 20 percent of the increase in corn prices in 2008, but that global ethanol production—including the effects of ethanol production in the United States and increases in the production of ethanol in other countries—could account for 35 percent of the price increase.[22] Measured over a longer period, global production of ethanol and other biofuels has tripled since 2000, which has raised demand for many biofuel feedstocks (such as corn and sugarcane for ethanol production and soybeans and rapeseed for biodiesel). Analysis from the International Food Policy Research Institute suggests that global biofuel production could account for 40 percent of the rise in corn prices between 2000 and 2007.[23]

In addition to the expanding demand for corn to produce ethanol, several other factors contributed to the rising price of corn in the United States between April 2007 and April 2008:[24]

- Growing global demand for meat increased the demand for animal feed.

19. CBO used a range of 0.3 to 0.5 for the elasticity of the supply of corn to changes in its price. Estimates of elasticity were taken from Harry de Gorter and David R. Just, *The Welfare Economics of an Excise-Tax Exemption for Biofuels,* Working Paper No. 2007-13 (Ithaca, N.Y.: Cornell University, Department of Applied Economics and Management, February 2007); Bruce Gardner, "Fuel Ethanol Subsidies and Farm Price Support," *Journal of Agricultural and Food Industrial Organization,* vol. 5, no. 2 (2007); Andrew Schmitz, Charles B. Moss, and Troy G. Schmitz, "Ethanol: No Free Lunch," *Journal of Agricultural and Food Industrial Organization,* vol. 5, no. 2 (2007); 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 (2003), pp. 565–608. Data on corn prices are available from the Department of Agriculture, Economic Research Service, "Feed Grains Database," available at www.ers.usda.gov/data/feedgrains.

20. Department of Agriculture, Economic Research Service, "Feed Grains Database." Global production of corn increased between the 2006–2007 and 2007–2008 marketing years, but the percentage increase in the United States was much larger than the increase in the rest of the world. See Department of Agriculture, Office of the Chief Economist, *World Agricultural Demand and Supply Estimates,* Report No. WASDE-464 (November 10, 2008).

21. Department of Agriculture, Economic Research Service, "Corn Trade," available at www.ers.usda.gov/Briefing/Corn/trade.htm.

22. See the statement of Edward Lazear, Chairman, Council of Economic Advisers (CEA), before the Senate Foreign Relations Committee, *Responding to the Global Food Crisis,* May 14, 2008. The price data and assumptions about the elasticity of the corn supply that the CEA used for its estimate were not described in the statement.

23. See the statement of Mark W. Rosegrant, Director, Environment and Production Technology Division, International Food Policy Research Institute, before the Senate Committee on Homeland Security and Governmental Affairs, *Fuel Subsidies: Is There an Impact on Food Supply and Prices?* May 7, 2008). Also, the International Monetary Fund (IMF) estimated that 70 percent of the rise in corn prices could be due to global biofuels policies, but the period that the IMF's analysts considered is unclear. See the remarks of John Lipsky, First Deputy Managing Director, IMF, on "Commodity Prices and Global Inflation," at the Council on Foreign Relations, New York, N.Y., May 8, 2008).

24. Ronald Trostle, *Global Agricultural Supply and Demand: Factors Contributing to the Recent Increase in Food Commodity Prices,* Report No. WRS-0801 (Department of Agriculture, Economic Research Service, May 2008).

- The depreciation of the U.S. dollar increased the demand for U.S. corn abroad. Exports rose approximately 14 percent between the 2006–2007 and 2007–2008 marketing years.[25]

- Concerns about a poor harvest because of unfavorable weather for spring planting caused corn prices to rise during the spring of 2008.[26]

Production rose despite the increased costs for producing corn that were caused by rapid hikes in the price of fuel, especially oil and natural gas. (Oil is used to produce diesel fuel and gasoline, both of which are used in growing, harvesting, and transporting corn to market; natural gas is used to produce fertilizers and to dry corn for storage.) Between 2007 and 2008, corn producers' expenditures on energy (specifically, for fuel, machinery lubricants, and electricity) grew by 35 percent; expenditures on fertilizer climbed by 50 percent. Overall, during that period, the cost of producing corn rose by 31 percent.[27] But rising demand allowed producers to pass along the increase in costs to consumers, who proved willing to pay the higher prices.

As the mandated use of biofuels rises over time, increased production of ethanol and biodiesel will probably continue to push up prices for corn and soybeans. According to an estimate by the Department of Agriculture, 3.7 billion bushels of corn will be used to produce ethanol during the 2008–2009 marketing year.[28] That estimate represents an increase of about 0.7 billion bushels over the total for the previous marketing year, which could increase the price of corn by 10 percent to 17 percent over the 2008–2009 period, all else being equal.[29] In the long run, upward pressure on prices caused by increasing ethanol production may be alleviated by planting additional acres in corn and soybeans, increasing crop yields per acre in the United States and abroad, and improving the technologies used at refineries to allow more ethanol to be produced from each bushel of corn.[30]

The Impact of Higher Corn Prices on the Cost of Food

The impact of higher commodity prices on how much consumers pay for food at the retail level depends on the portion of that food that comes from such commodities. Higher prices for corn can increase food prices directly because of the wide variety of food products that contain corn. Higher corn prices can also operate indirectly, through two different mechanisms. First, they can increase the price of meat, for which corn is used as an animal feed. Second, higher corn prices can raise the price of food by indirectly lifting the prices of other crops—for example, soybeans—if farmers take land that had been planted with those other crops and plant it instead with corn.

The CPI-U for food comprises all of the retail costs of food and can be broken down to show the shares of that total that the various components account for. The cost of farm commodities, notably corn, is one of those components, as are the costs of transportation, energy, labor, and other elements required to produce food. The cost of commodities makes up about 19 percent of the price of food that originates on U.S. farms and that is sold in stores (see Figure 2). Consequently, an increase of 10 percent in the cost of all commodities would push retail food prices up by approximately 2 percent. Similarly, an overall increase of 10 percent in the cost of energy and transportation, which account for a smaller share of retail food prices, would push those prices up by 0.8 percent.

To estimate the impact of changing corn prices on the CPI-U for food, CBO calculated how much U.S. consumers spent overall on food and how much corn was

25. Department of Agriculture, Economic Research Service, "Feed Grains Database."

26. See, for example, Michael Woolverton, "Corn Planting Delay Pushes Price Higher" (Kansas State University, Department of Agricultural Economics, May 2, 2008).

27. CBO's analysis of data from Department of Agriculture, Economic Research Service, "Commodity Costs and Returns," available at www.ers.usda.gov/Data/CostsAndReturns.

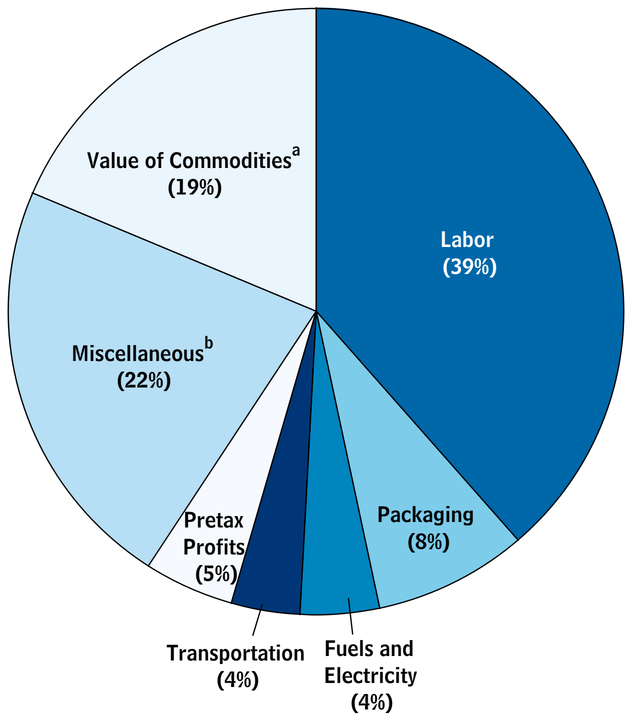
28. Department of Agriculture, Office of the Chief Economist, *World Agricultural Supply and Demand Estimates,* Report No. WASDE-465 (March 11, 2009), available at www.usda.gov/oce/commodity/wasde/latest.pdf.

29. By the last quarter of 2008, corn prices had fallen dramatically from their highs during the summer. In the absence of increasing demand for corn to produce ethanol, it is likely that the average price for corn in 2008 would have been even lower.

30. See 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), available at www3.interscience.wiley.com/cgi-bin/fulltext/121647166/HTMLSTART.

Figure 2.

Components of Consumers' Expenditures on Farm Foods, 2006



Source: Congressional Budget Office based on data from the Department of Agriculture's Economic Research Service (available at www.ers.usda.gov/Data/FarmToConsumer/Data/componentstable06.xls).

Note: Consumers' expenditures on farm foods represent the market value of domestically produced farm foods consumed both at home and away from home (for example, in restaurants or institutions).

a. Payments to farms for fruits, vegetables, field crops (for example, corn and soybeans), dairy products, and so on.

b. Includes depreciation, rent, advertising and promotion, interest, taxes, licenses, insurance, professional services, local for-hire transportation, food service (in schools, colleges, hospitals, and other institutions), and other items.

used in food production. Total expenditures on food in the United States in 2007 were $1.1 trillion.[31] About 1.4 billion bushels of corn were used in food production in that year (see Table 1). The increase in the average price of corn resulting from ethanol production in that year—about 50 cents to 80 cents per bushel—directly increased expenditures on food by between $700 million and $1.1 billion, or by about 0.1 percent.[32] The higher prices for corn boosted food expenditures even more by affecting the cost of meat, dairy, and poultry products. Under the assumption that farmers passed along to consumers the increases that occurred in animal feed prices, the higher prices for corn resulting from the production of ethanol increased consumers' expenditures on food by an additional 0.2 percent to 0.4 percent, in CBO's estimation.[33]

Additional demand for corn can also affect the price of food indirectly by causing producers of corn to switch some of the acreage they have planted in other crops, primarily soybeans, to corn.[34] Between the 2006–2007 and 2007–2008 marketing years, the number of acres planted in corn increased by about 15 million, whereas the number of acres planted in soybeans fell by about 11 million. The increase of nearly 1 billion bushels in the corn used for producing ethanol required farmers to plant and

31. Department of Agriculture, Economic Research Service, "Food CPI, Prices and Expenditures: Food and Alcoholic Beverages—Total Expenditures" (briefing, June 17, 2008), available at www.ers.usda.gov/Briefing/CPIFoodAndExpenditures/Data/table1.htm.

32. That computation used a "snapshot" from 2007 of the consumption and use of corn in the United States. As prices for different commodities change, consumers will tend to adjust and reallocate their purchases accordingly.

33. The Department of Agriculture has estimated that the production of biofuels could have raised food prices by between 0.1 percent and 0.2 percent in 2007, rising to as much as 0.9 percent after accounting for the increase in livestock feed prices. (See the letter from Samuel Bodman, Secretary of Energy, and Edward Schafer, Secretary of Agriculture, to the Honorable Jeff Bingaman, June 11, 2008, Appendix IV, available at www.energy.gov/media/Secretaries_Bodman_and_Schafer_Ltr_to_Sen_Bingaman.pdf.) Initially, the prices of animal products would be expected to decline in response to higher prices for feed because farmers would slaughter more animals for market. After that initial response, the prices of animal products would rise as a smaller supply resulted in higher prices (see Jerry Light and Thomas Shevlin, "The 1996 Grain Price Shock: How Did It Affect Food Inflation?" *Monthly Labor Review,* August 1998, pp. 3–19). Because feed prices have been steadily increasing since 2004, CBO assumed that rising corn prices would increase prices for animal products during the period examined for this analysis.

34. Paul Westcott, *Ethanol Expansion in the United States: How Will the Agricultural Sector Adjust?* Outlook Report No. FDS-07D-01 (Department of Agriculture, Economic Research Service, May 2007).

Table 1.

The Supply and Uses of Corn in the United States

(Billions of bushels)

	Marketing Year[a] 2006-2007	2007-2008	Percentage Change
		Supply	
Beginning Stocks	2.0	1.3	-35
Production	10.5	13.1	25
		Uses	
Animal Feed	5.6	6.0	7
Ethanol	2.1	3.0	43
Exports	2.1	2.4	14
Food[b]	1.4	1.3	-5
Stocks	1.3	1.6	23

Sources: Congressional Budget Office based on data from the Department of Agriculture (available at www.usda.gov/oce/commodity/wasde/latest.txt and www.ers.usda.gov/Data/Feedgrains/FeedGrainsQueriable.aspx).

a. The marketing year for corn runs from September 1 of the first year through August of the following year.

b. Includes corn for seed, which totaled about 0.02 billion bushels in each year.

harvest about 6 million additional acres of cropland. Under the assumption that those acres came from cropland previously planted in soybeans (typically, corn and soybeans are grown in rotation on the same land), the increase in the price per bushel of soybeans caused by planting 6 million fewer acres was between $1.09 and $1.82.[35] Such an increase in soybean prices raised expenditures on food by between 0.2 percent and 0.3 percent, bringing the total effect to between 0.5 percent and 0.8 percent.

The impact on food prices resulting from hikes in the price of corn related to ethanol production was smaller than the effect of higher prices for energy, which contribute to the CPI-U for food directly through higher costs for transportation and electricity and indirectly through higher costs for producing commodities. As an example, the CPI-U for energy rose by 16 percent between April 2007 and April 2008.[36] Given the contributions that the prices of transportation, fuel, and electricity make to the CPI-U for food, the increase in the CPI-U for energy implies a direct boost in the CPI-U for food of 1.1 percentage points (22 percent) of the 5.1 percent increase in food prices during the April 2007–April 2008 period. Alternatively, the producer price index for intermediate energy products could be used as a measure (and may better reflect the costs that the retail food sector faces for energy). Using that measure leads to an increase in energy prices between April 2007 and April 2008 of 25 percent, which implies a direct increase in the CPI-U for food of 1.8 percentage points (36 percent) of the increase in food prices during that period.[37]

The impact of higher prices for food will probably be greater in other countries than in the United States because the percentage of households' income that is spent on food in those other nations is larger and the value of commodities makes up a bigger share of the cost of food. (In 2007, the share of spending for goods and services that a household allocated to food purchases for consumption at home was less than 6 percent in the United States but more than 32 percent in India.)[38] In contrast to countries that export commodities, countries that import a large percentage of their food will also be adversely affected by rising global prices for commodities. The United Nations' Food and Agriculture Organization has estimated that, in contrast to steadily declining real (inflation-adjusted) prices for food commodities between 1974 and 2000, real prices for commodities (including corn, soybeans, and sugarcane) increased by 135 percent between January 2000 and April 2008.[39]

35. That calculation is based on the following: an assumed elasticity of supply for soybeans ranging from 0.3 to 0.5, as reported in William Lin and others, *Supply Response Under the 1996 Farm Act and Implications for the U.S. Field Crops Sector,* Report No. TB1888 (Department of Agriculture, Economic Research Service, September 2000); soybean production totaling 76 million acres in the 2006–2007 marketing year; and a price for soybeans of $6.88 per bushel in April 2007. CBO did not consider how the relatively small amount of biodiesel produced in 2007 and 2008 affected prices for corn and soybeans.

36. Bureau of Labor Statistics, *CPI Detailed Report,* Table A.

37. Bureau of Labor Statistics, *PPI Detailed Report: Data for April 2008—Mining, Manufacturing, and Services,* Table B, available at www.bls.gov/ppi/ppidr200804.pdf.

38. Department of Agriculture, Economic Research Service, "Food CPI, Prices and Expenditures: Expenditures on Food, by Selected Countries, 2007" (briefing, updated December 19, 2008), available at www.ers.usda.gov/Briefing/CPIFoodAndExpenditures/Data/2007table97.htm.

39. U.N. Food and Agriculture Organization, "Food Outlook: Global Market Analysis—The FAO Price Index" (June 2008), available at www.fao.org/docrep/010/ai466e/ai466e16.htm.

Ethanol, Food Prices, and Federal Food Assistance

The federal government oversees a number of food assistance programs, including the Supplemental Nutrition Assistance Program, or SNAP (formerly known as the Food Stamp program), and various child nutrition programs to provide meals to school-age children.[40] Those programs are operated at the local level by state and local governments and other public and private providers. In SNAP, the federal government provides participants with a cash benefit each month to purchase food for their household. Institutions that participate in one of the child nutrition programs are entitled to a federal cash reimbursement for each meal they provide (the reimbursement varies by the type of meal served and the household income of the child). Those benefits are adjusted automatically each year depending on changes in various indexes of food prices.

Any increase in food prices attributable to a rise in the production of ethanol will result in higher spending for the federal government's food assistance programs. It will also increase spending for certain other federal programs—such as Social Security, military and civilian retirement programs, and Supplemental Security Income—through its effects on the CPI, which is used to calculate annual cost-of-living adjustments in those programs' benefits. (This report does not address increases in such spending.) For programs such as SNAP, in which reimbursements and benefits are adjusted automatically each year with changes in food price inflation, the use of ethanol as a motor fuel, in CBO's estimation, will result in an increase of 1 percent to 1.5 percent in spending for fiscal year 2009. The use of ethanol could have a similar effect on spending for such programs as the Special Supplemental Assistance Program for Women, Infants, and Children—better known as WIC—which serves postpartum or pregnant women, infants, and children up to the age of 5.

40. The name of the Food Stamp program was changed by the Food, Conservation, and Energy Act of 2008 (Public Law 110-246, 122 Stat. 1651).

Supplemental Nutrition Assistance and the Federal Child Nutrition Programs

Once a year, the government adjusts the benefits paid under SNAP and the child nutrition programs. Each October, the maximum benefit for SNAP is adjusted by the June-to-June percentage change in the cost of the Thrifty Food Plan, which constitutes a nutritious diet for one month at a minimal cost, as determined by the Department of Agriculture. In June 2008, the cost of the Thrifty Food Plan for a family of four was $588, an increase of 8.5 percent over the cost of the plan in June 2007. (The recently enacted American Recovery and Reinvestment Act of 2009 increased the maximum SNAP benefit for the second half of fiscal year 2009 by 13.6 percent, to $668.) Each July, the government also adjusts the payments it makes to institutions for most of the meals served through programs such as the National School Lunch Program and the School Breakfast Program; the adjustment constitutes the May-to-May percentage change in the component of the CPI-U that measures inflation in the price of food consumed away from home.[41]

Because reimbursement payments for nutrition programs are determined by changes from the prior year, the effect of price changes over the 2007–2008 period will not be felt until fiscal year 2009. CBO projects that for 2009, increases in food prices will result in a boost in spending for those programs of about $5.3 billion (see Table 2). Of that projected increase, which excludes the effects of greater participation in the program and other factors, increased production of ethanol most likely accounts for an estimated $600 million to $900 million, or roughly

41. In addition to the cash reimbursement, the National School Lunch Program (and certain other federal food assistance programs) provide a specified quantity of commodities for every meal, the value of which is adjusted annually. In addition to the lunch and breakfast programs, several smaller food programs authorized by the Child Nutrition Act and the Richard B. Russell School Lunch Act use the same or similar indexes to adjust their reimbursement rates for inflation.

Table 2.

Federal Spending for Selected Food Assistance Programs

(Billions of dollars)

	SNAP[a]	Child Nutrition Programs[b]	Total
Actual Outlays, 2008	39.3	13.9	53.2
Projected Outlays, 2009[c]	54.4	15.4	69.8
Total Change in Outlays	15.1	1.5	16.6
Memorandum:			
Change Attributable to Increased Food Prices[d]	4.7	0.6	5.3
Change Attributable to Ethanol Production	0.5 to 0.8	0.1	0.6 to 0.9

Source: Congressional Budget Office.

Note: The years referred to in this table are federal fiscal years.

a. The Supplemental Nutrition Assistance Program, formerly known as the Food Stamp program.

b. Includes the National School Lunch Program, the School Breakfast Program, and other, smaller, programs.

c. CBO baseline projections as of March 2009. Estimates include the effects of the American Recovery and Reinvestment Act of 2009 (Public Law 111-5), which added almost $5 billion to SNAP spending for 2009.

d. Does not include legislative changes, changes as a result of increases or decreases in program participation, and other factors.

10 percent to 15 percent of the change in federal spending for those programs as a result of higher food prices.[42]

The Special Supplemental Assistance Program for Women, Infants, and Children

Unlike SNAP and the child nutrition programs, WIC is not an entitlement program; that is, lawmakers do not set aside funds to allow every eligible individual to participate in the program. Rather, WIC is a federal grant program for which a specific amount of funding is appropriated each year for the program's operations. The Food and Nutrition Service, which administers the program at the federal level, provides those funds to WIC state agencies (state health departments or comparable agencies) to pay for food, nutrition education, and administrative costs.

In contrast to SNAP, in which recipients receive a cash benefit to purchase food, the WIC program provides specific food packages tailored to supplement the diets of pregnant or postpartum mothers and children age 5 or younger. Participants receive checks or vouchers to purchase specific foods each month. (A few state agencies distribute the WIC foods through warehouses or deliver the foods to participants' homes.) The foods provided are high in one or more of the following nutrients: protein, calcium, iron, and vitamins A and C—the nutrients frequently lacking in the diets of the program's target population. The cost of those foods can vary monthly; consequently, the rise in food prices in 2008 had an immediate impact on the WIC program's costs.

In fiscal year 2008, policymakers appropriated roughly $6 billion in funding for the WIC program. Because the program is funded through an annual appropriation, there is no well-defined relationship between changes in funding and changes in food costs. Nevertheless, the effect of increased ethanol production on the cost of the basket of goods available through WIC could be similar to the impact that ethanol production has had on food prices in the SNAP and school meals programs. Under the assumptions that increases in domestic ethanol production contributed about 10 percent to 15 percent of the increase in the cost of the WIC food package and that participation in the program remained roughly constant, increased production of ethanol would have accounted for less than $75 million of the program's spending for fiscal year 2008, CBO estimates.

Ethanol Production and Greenhouse-Gas Emissions

Research suggests that the use of ethanol currently reduces greenhouse-gas emissions relative to the use of gasoline because, over the "life cycle" of the two fuels—that is, during their production, distribution, and combustion—ethanol uses less fossil fuel energy than does gasoline. Yet if ethanol production continues to increase, whether use of the fuel reduces greenhouse-gas

42. To calculate the change in expenditures for those federal programs, CBO estimated the changes in the CPI-U categories for food consumed at home and food consumed away from home that were attributable to increased production of ethanol. Those calculations incorporated the assumption that 66 percent of calories were consumed at home and 34 percent of calories were consumed away from home. See Biing-Hwan Lin, Elizabeth Frazão, and Joanne Guthrie, *Away-From-Home Foods Increasingly Important to Quality of American Diet,* Report No. AIB749 (Department of Agriculture, Economic Research Service, 1999).

emissions will also depend on changes in land use that might offset the potential reduction in emissions. For example, a substantial amount of carbon already stored in forests or grasslands could be released if those lands were converted into land to grow crops (such as corn) that would be used to make ethanol, or to grow crops that had been displaced by the ethanol feedstocks.

Greenhouse-Gas Emissions During a Fuel's Life Cycle

Analysis of greenhouse-gas emissions from ethanol and gasoline depends on measurements during all stages of their product life cycles, including production, distribution, and combustion of the fuels. In that regard, ethanol has advantages over gasoline during certain stages but disadvantages during others. On balance, the use of corn ethanol that has been produced at plants fueled by natural gas (which accounts for most of the United States' production of ethanol) is estimated to generate fewer greenhouse-gas emissions than the use of gasoline.

Producing ethanol from corn and distributing it emits more greenhouse gases than producing gasoline from crude oil and distributing it. (That is, planting, fertilizing, and harvesting corn as an ethanol feedstock uses more fossil-fuel energy than does drilling for petroleum, refining it into gasoline, and delivering it to customers.) But the relationship is reversed for other phases of the fuels' life cycles: After accounting for the carbon dioxide that is removed from the atmosphere when the corn is grown, net emissions from the combustion of gasoline are greater than those from burning ethanol.

Looking at the entire life cycle of the two fuels, research conducted at Argonne National Laboratory (ANL) compared the greenhouse-gas emissions of ethanol and gasoline.[43] That research, which has been widely accepted by federal agencies, found that the use of corn ethanol as it is currently produced—using coal-fired and natural gas-fired plants—reduces life-cycle greenhouse-gas emissions by about 20 percent when compared with the use of gasoline.[44] Calculated on the basis of the volume of ethanol used in the United States last year, that percentage reduction is equivalent to about 14 million metric tons of carbon dioxide and equivalent gases, or CO_2e.[45] That amount is about 0.7 percent of the total greenhouse-gas emissions generated in the transportation sector during 2008.[46]

The reduction in greenhouse-gas emissions depends critically on which fuel is used to produce ethanol. The ANL researchers found that if corn ethanol was produced at a plant that used natural gas to fuel its production processes, the life-cycle greenhouse-gas emissions for ethanol would be about 30 percent lower than those for gasoline. In contrast, corn ethanol that was produced by using energy derived from burning coal would increase life-cycle greenhouse-gas emissions by 3 percent compared with gasoline (because the burning of coal produces a much greater volume of emissions than does the burning of natural gas). 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.

The ANL researchers' finding that ethanol releases fewer life-cycle greenhouse-gas emissions than gasoline releases has been challenged by some analysts. An alternative viewpoint is that the production of corn ethanol produces more life-cycle greenhouse-gas emissions than gasoline does because the production of such ethanol relies more heavily on fossil fuels than the ANL researchers'

43. 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).

44. ANL's estimate of the reduction in life-cycle greenhouse-gas emissions from using corn ethanol in place of gasoline is consistent with a range of other recent estimates. For example, a 2006 study found that the use of corn ethanol reduced life-cycle greenhouse-gas emissions by 12 percent (see 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 25, 2006), whereas a 2009 study found a reduction of 50 percent to 60 percent (see 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).

45. Individual greenhouse gases have different warming characteristics and persist in the atmosphere for different lengths of time. To simplify matters, researchers commonly refer to emissions and atmospheric concentrations of those greenhouse gases in terms of metric tons (a metric ton is approximately 2,200 pounds) of carbon dioxide equivalent, or CO_2e—the amount of carbon dioxide that would cause an equivalent amount of warming over a certain period (typically 100 years).

46. Energy Information Administration, "Annual Energy Outlook 2009," Table 18.

estimates recognize.[47] Such analysts also contend that the reductions in greenhouse-gas emissions derived from using by-products of ethanol production to displace the production of other goods—such as animal feeds or fertilizer—are smaller than those assumed in the ANL analysis.[48] Those criticisms are not widely embraced, however. Some observers argue that such contentions are based on outdated data, on overestimates of how much fossil fuel is used in farming and in ethanol production, and on underestimates of the extent to which the use of by-products from ethanol production reduces the amount of fossil fuels used for producing other goods.[49]

Cellulosic ethanol—produced by using switchgrass (a North American grass used for hay and forage), corn stover (the leaves and stalks of the corn plant), or forest residues (in general, small or dead wood items not useful for resale and wastes from lumber operations) as feedstocks—offers the potential for greater reductions in greenhouse-gas emissions (see Figure 3). Relative to corn ethanol, cellulosic ethanol is expected to produce fewer net greenhouse-gas emissions because cellulosic wastes (rather than fossil fuels) might be used as a source of energy for an ethanol plant's operations or in cogeneration facilities (facilities that produce electricity as well as steam that can be used for the plant's operations). Electricity produced by such facilities could be transmitted to the electric grid, which might reduce the use of fossil fuels in coal-fired or natural gas-fired power plants.[50]

According to researchers, cellulosic ethanol, if successfully developed, could reduce greenhouse-gas emissions by 85 percent to 95 percent relative to emissions associated with the production of gasoline.[51] In the long run, if cellulosic ethanol could be produced on a large scale and if that fuel along with corn ethanol was substituted for gasoline at the levels called for under the EISA mandate, greenhouse-gas emissions might be reduced by about 130 million metric tons of CO_2e by 2022, or 6 percent of total projected emissions from the transportation sector and 2 percent of total emissions generated in the United States.[52]

The technology for large-scale commercial production of the fuel, however, has not yet been developed. Estimates of the reductions in emissions that might be gained from producing and using cellulosic ethanol reflect assumptions about potential future technology and production processes. Considerable technical hurdles must be overcome—to access the sugars within the cellulose and convert them into ethanol—before commercial production of the fuel can occur on a large scale. EIA projects that those technological constraints are substantial enough that the federal mandate for the use of advanced biofuels, including cellulosic ethanol, in 2022—21 billion gallons—will not be met until 2027.[53]

Changes in Land Use

In addition to the life-cycle considerations that form the basis of the ANL research, changes in patterns of land use could also affect the total greenhouse-gas emissions associated with producing and using ethanol. Increased production of ethanol may cause direct changes in such

47. David Pimentel and Tad W. Patzek, "Ethanol Production Using Corn, Switchgrass, and Wood; Biodiesel Production Using Soybean and Sunflower," *Natural Resources Research*, vol. 14, no. 1 (March 2005).

48. Coproduct credits—ethanol by-products that reduce the amount of fossil-fuel energy used in other industries—are assumed to reduce the net amount of fossil-fuel energy consumed in producing ethanol. The use of distillers' dried grains as animal feed, for example, displaces some production of other feeds and reduces the overall use of fossil fuels. The resulting decrease in greenhouse-gas emissions is credited to the production of ethanol.

49. For example, see the discussion in Environmental Protection Agency, Office of Transportation and Air Quality, *Regulatory Impact Analysis: Renewable Fuel Standard Program,* Report No. EPA420-R-07-004 (April 2007), p. 226.

50. 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.

51. Wang, Wu, and Huo, "Life-Cycle Energy and Greenhouse Gas Emission Impacts"; M.R. Schmer and others, "Net Energy of Cellulosic Ethanol from Switchgrass," *Proceedings of the National Academy of Sciences,* vol. 105, no. 2 (January 13, 2008), p. 464; and May Wu, Michael Wang, and Hong Huo, *Fuel-Cycle Assessment of Selected Bioethanol Production Pathways in the United States,* ANL/ESD/06-7 (Chicago: Argonne National Laboratory, Center for Transportation Research, Energy Systems Division, November 2006), p. 41.

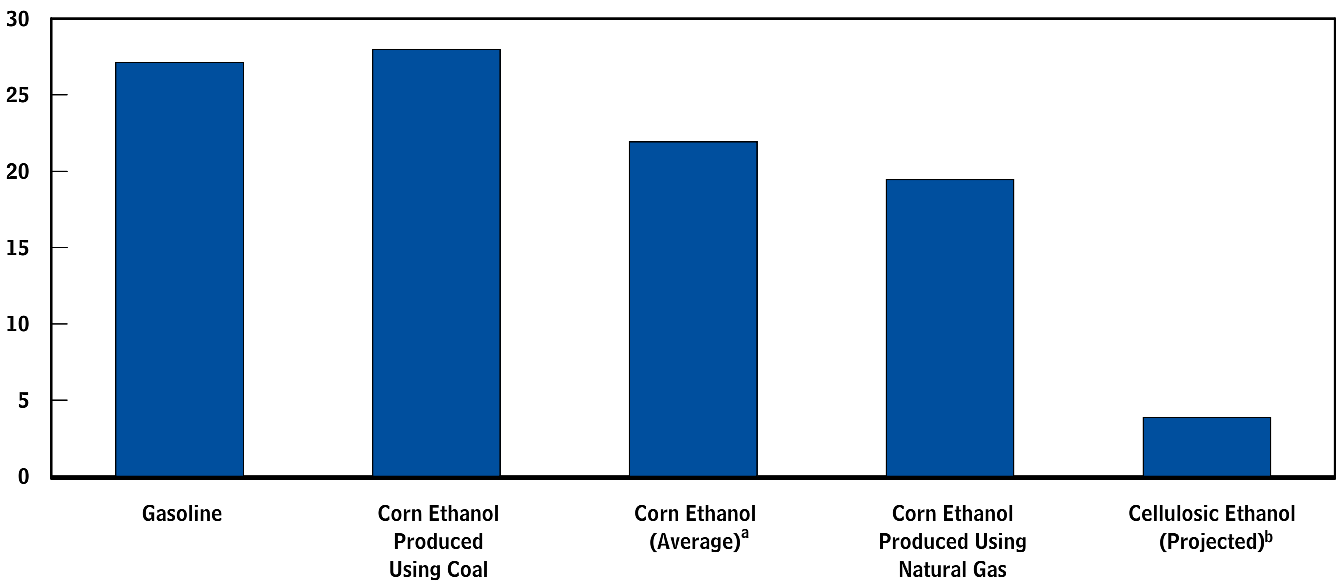
52. That estimate is based on the Energy Information Administration's forecast of total greenhouse-gas emissions from transportation (available at www.eia.doe.gov/oiaf/aeo/excel/aeotab_18.xls) and incorporates the assumption that the ethanol mandates for 2022 under EISA are fully met.

53. Energy Information Administration, *Annual Energy Outlook 2009,* DOE/EIA-0383(2009) (March 2009), p. 81, available at www.eia.doe.gov/oiaf/aeo/pdf/0383(2009).pdf.

Figure 3.

Life-Cycle Greenhouse-Gas Emissions from Selected Fuels

(Pounds of CO_2e per energy-equivalent gallon of gasoline)



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).

Notes: Life-cycle emissions are those generated during production, distribution, and consumption of gasoline and ethanol.

For the ethanol-based fuels, greenhouse-gas emissions are measured as the pounds of carbon dioxide equivalent (CO_2e) generated by the amount of ethanol—generally about 1.5 gallons—whose energy content corresponds to that of a gallon of gasoline. (Because individual greenhouse gases vary in their warming characteristics and persistence in the atmosphere, researchers commonly measure emissions in CO_2e—an amount of carbon dioxide that would cause an equivalent amount of warming over 100 years.)

Plants that produce ethanol require a source of thermal energy for their operations. Most ethanol-producing plants in the United States that use corn as a feedstock are natural gas-fired facilities. The remainder use either coal or both coal and natural gas.

a. Reflects average greenhouse-gas emissions generated from the mix of U.S. coal- and natural gas-fired facilities that produce corn ethanol.

b. Emissions expected from the use of a future technology that would allow ethanol to be produced from switchgrass.

patterns. For example, land that was not previously used for farming may be brought under cultivation to grow corn or other ethanol feedstocks. Increased ethanol production may also cause indirect changes in land use; for instance, new farmland may be cultivated to grow crops that have been displaced elsewhere by the growing of ethanol feedstocks.

Some researchers believe that if sufficient grasslands and forests are converted into cropland for producing ethanol feedstocks and for producing the crops displaced by those feedstocks, the potential benefits of ethanol in terms of lower greenhouse-gas emissions will be reduced or eliminated. Those researchers contend that the conversion of those lands releases greenhouse gases and reduces their ability to sequester carbon—that is, to capture and store carbon to prevent its release into the atmosphere—because cropland absorbs less carbon than do grasslands and forests. The use of ethanol produced from land that had previously been grassland or forest can reduce greenhouse-gas emissions relative to the use of gasoline only after offsetting both the carbon released by converting that land into new farmland and the reduction in the future carbon sequestration those lands will provide.[54]

54. Congressional Budget Office, *The Potential for Carbon Sequestration in the United States* (September 2007).

Table 3.

How Land Conversion to Grow Crops for Ethanol Production May Delay Reductions in Greenhouse-Gas Emissions Resulting from the Use of Ethanol

Biofuel/Land Converted	Location	Years Until Net Carbon Reduction	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
Prairie Biomass[a]/Abandoned Cropland	United States	1	Fargione and others
Sugarcane Ethanol			
Forest	Brazil	17	Fargione and others
Grazing Land	Brazil	4	Searchinger and others
Rainforest	Brazil	45	Searchinger and others
Grassland	Brazil	3 to 10	Renewable Fuels Agency
Forest	Brazil	15 to 39	Renewable Fuels Agency
Switchgrass Ethanol[b]/Cropland	United States	52	Searchinger and others
Wheat Ethanol			
Grassland	United Kingdom	20 to 34	Renewable Fuels Agency
Forest	United Kingdom	80 to 140	Renewable Fuels Agency

Source: Congressional Budget Office based on Joseph Fargione and others, "Land Clearing and the Biofuel Carbon Debt," *Science,* vol. 319, no. 5867 (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, no. 5867 (2008), pp. 1238–1240; and Renewable Fuels Agency, *The Gallagher Review of the Indirect Effects of Biofuels Production* (study commissioned by the Secretary of State for Transport, United Kingdom, July 2008).

a. Prairie biomass constitutes mixtures of native perennial prairie grasses and other flowering plants.

b. Switchgrass is a type of grass native to North America and used primarily as rangeland forage and hay.

The impact on net greenhouse-gas emissions from changing the way land is used depends on the feedstock harvested to produce ethanol and the type of land converted (see Table 3). For example, some research indicates that the use of ethanol produced from switchgrass may require more than 50 years to offset the carbon being released into the atmosphere by converting land to agricultural use, and that the use of ethanol made from corn grown on land converted from forests and grassland may require almost 170 years to achieve that outcome.

The effects of changes in land use—such as converting forests into cropland—would reduce or eliminate some of the greenhouse-gas emission benefits that the ANL researchers found for ethanol. Yet critics of the view that land-use changes would greatly reduce biofuels' ability to reduce greenhouse-gas emissions maintain that such potential changes represent a worst-case scenario and that improved land-management practices will prevent them from having a large impact on the net reduction in greenhouse-gas emissions to be gained from the use of biofuels. Furthermore, certain land-use changes are highly unlikely; for example, switchgrass will probably not be grown on cropland previously used to grow corn because a nonfood crop is likely to remain less valuable than a food crop.[55] In addition, critics assert that estimates of changes in greenhouse-gas emissions that might result from changes in land use depend on complicated and uncertain economic relationships and are necessarily imprecise.

55. Department of Energy, "New Studies Portray Unbalanced Perspective on Biofuels: DOE Committed to Environmentally Sound Biofuels Development" (news release, May 23, 2008), available at www1.eere.energy.gov/biomass/news_detail.html?news_id=11794. See also Roger A. Sedjo, "Biofuels: Think Outside the Cornfield" (letter), *Science,* vol. 320, no. 5882 (2008), pp. 1420–1421.