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Fuel Ethanol: Background and Public Policy Issues

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Summary

Ethanol plays a key role in policy discussions about energy, agriculture, taxes, and the environment. In the United States it is mostly made from corn; in other countries it is often made from cane sugar. Fuel ethanol is generally blended in gasoline to reduce emissions, increase octane, and extend gasoline stocks. Recent high oil and gasoline prices have led to increased interest in alternatives to petroleum fuels for transportation. Further, concerns over climate change have raised interest in developing fuels with lower fuel-cycle greenhouse-gas emissions. Supporters of ethanol argue that its use can lead to lower emissions of toxic and ozone-forming pollutants, and greenhouse gases, especially if higher-level blends are used. They further argue that ethanol use displaces petroleum imports, thus promoting energy security. Ethanol's detractors argue that various federal and state policies supporting ethanol distort the market and amount to corporate welfare for corn growers and ethanol producers. Further, they argue that the energy and chemical inputs needed to turn corn into ethanol actually increase emissions and energy consumption, although most recent studies have found modest energy and emissions benefits from ethanol use relative to gasoline, depending on how the ethanol is produced.

The market for fuel ethanol is heavily dependent on federal incentives and regulations. Ethanol production is encouraged by a federal tax credit of 51 cents per gallon. This incentive allows ethanol — which has historically been more expensive than conventional gasoline — to compete with gasoline and other blending components. In addition to the above tax credit, small ethanol producers qualify for an additional production credit. It has been argued that the fuel ethanol industry could scarcely survive without these incentives.

In addition to the above tax incentives, the Energy Policy Act of 2005 (P.L. 109-58) established a renewable fuel standard (RFS). This RFS was expanded by the Energy Independence and Security Act of 2007 (P.L. 110-140), and requires the use of 9.0 billion gallons of renewable fuels in 2008, increasing each year to 36 billion gallons in 2022. Much of this requirement will likely be met with ethanol. In addition, the bill requires that an increasing share of the mandate be met with "advanced biofuels" — biofuels produced from feedstocks other than corn starch. Potential "advanced biofuels" include domestic ethanol from cellulosic material (such as perennial grasses and municipal solid waste), ethanol from sugar cane, and diesel fuel substitutes produced from a variety of feedstocks. The United States consumed approximately 6.8 billion gallons of ethanol in 2007, mostly from corn. A sigificant supply of cellulosic ethanol is likely several years off. Some analysts believe the RFS could have serious effects on motor fuel suppliers, leading to higher fuel prices.

Other issues of congressional interest include support for purer blends of ethanol as an alternative to gasoline (as opposed to a gasoline blending component), promotion of ethanol vehicles and infrastructure, and imports of ethanol from foreign countries. This report supersedes CRS Report RL30369, *Fuel Ethanol: Background and Public Policy Issues* (out of print but available from the author).

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Introduction

The promotion of alternatives to petroleum, including fuel ethanol, has been an ongoing goal of U.S. energy policy. This promotion has led to the establishment of significant federal policies beneficial to the ethanol industry, including tax incentives, import tariffs, and mandates for ethanol use. The costs and benefits of ethanol — and the policies that support it — have been questioned. Areas of concern include whether ethanol yields more or less energy than the fossil fuel inputs needed to produce it; whether ethanol decreases reliance on petroleum in the transportation sector; whether its use increases or decreases greenhouse gas emissions; and whether various federal policies should be maintained.

This report provides background and discussion of policy issues relating to U.S. ethanol production, especially ethanol made from corn. It discusses U.S. fuel ethanol consumption both as a gasoline blending component and as an alternative to gasoline. The report discusses various costs and benefits of ethanol, including fuel costs, pollutant emissions, and energy consumption. It also outlines key areas of congressional debate on policies beneficial to the ethanol industry.

Ethanol Basics

Fuel ethanol (ethyl alcohol) is made by fermenting and distilling simple sugars. It is the same compound found in alcoholic beverages. The biggest use of fuel ethanol in the United States is as an additive in gasoline. It serves as an oxygenate, to prevent air pollution from carbon monoxide and ozone; as an octane booster, to prevent early ignition, or "engine knock"; and as an extender of gasoline stocks. In purer forms, it can also be used as an alternative to gasoline in automobiles specially designed for its use. It is produced and consumed mostly in the Midwest, where corn — the main feedstock for domestic ethanol production — is grown.

The initial stimulus for ethanol production in the mid-1970s was the drive to develop alternative and renewable supplies of energy in response to the oil embargoes of 1973 and 1979. Since the 1970s, production of fuel ethanol has been encouraged through federal tax incentives for ethanol-blended gasoline. The use of fuel ethanol was further stimulated by the Clean Air Act Amendments of 1990, which required the use of oxygenated or reformulated gasoline (RFG). The Energy Policy Act of 2005 (P.L. 109-58) established a renewable fuels standard (RFS), which mandates the use of ethanol and other transportation renewable fuels.

Approximately 99% of fuel ethanol consumed in the United States is "gasohol"[1] or "E10" (blends of gasoline with up to 10% ethanol). About 1% is consumed as "E85" (85% ethanol and 15% gasoline), and alternative to gasoline.[2]

Fuel ethanol is usually produced in the United States from the distillation of fermented simple sugars (e.g. glucose) derived primarily from corn, but also from wheat, potatoes, or other vegetables.[3] However, ethanol can also be produced from cellulosic material such as switchgrass, rice straw, and sugar cane waste (known as bagasse). The alcohol in fuel ethanol is identical chemically to ethanol used for other purposes such as distilled spirit beverages and industrial products.[4]

Ethanol and the Agricultural Economy[5]

Corn constitutes about 95% of the feedstock for ethanol production in the United States. The other 5% is largely grain sorghum, along with some barley, wheat, cheese whey and potatoes. Corn is used because it is a relatively low cost source of starch that can be relatively easily converted to simple sugars, and then fermented and distilled. The U.S. Department of Agriculture (USDA) estimates that about 3.2 billion bushels of corn will be used to produce about 6 billion gallons of fuel ethanol during the 2007/2008 corn marketing year (September 2007 through August 2008).[6] This is roughly 25% of the projected 13 billion bushels of total corn utilization for all purposes.[7] However, it should be noted that ethanol production capacity is expanding rapidly, and corn demand for ethanol production may exceed USDA's projection.[8]

In the absence of the ethanol market, lower corn prices probably would stimulate increased corn utilization in other markets, but sales revenue would not be as high. The lower prices and sales revenue would likely result in higher federal spending on corn subsidy payments to farmers, as long as corn prices were to stay below the price triggering federal loan deficiency subsidies.

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[1] Technically, gasohol is any blend of ethanol and gasoline, but the term most often refers to the 10% blend.

[2] U.S. Department of Energy (DOE), Energy Information Administration (EIA), *Alternatives to Traditional Transportation Fuels 2005*, updated November 2007.

[3] In some other countries, most notably Brazil, ethanol is produced from cane sugar.

[4] Industrial uses include perfumes, aftershaves, and cleansers.

[5] For a more detailed discussion of ethanol's role in agriculture, see CRS Report RL32712, *Agriculture-Based Renewable Energy Production*, by Randy Schnepf.

[6] One bushel of corn generates approximately 2.7 gallons of ethanol.

[7] Utilization data are used, rather than production, due to the existence of carryover stocks. Corn utilization data address the total amount of corn used within a given period.

[8] As of March 2008, the Renewable Fuels Association reported U.S. production capacity at 8.3 billion gallons, with an additional 5.1 billion gallons of capacity under construction (including expansions of existing plants). See [http://www.ethanolrfa.org/industry/locations/] (updated March 17, 2008).

Table 1. Corn Utilization, 2007-2008 Forecast

	Quantity (million bushels)	Share of total use
Livestock feed & residual	5,950	45.9%
Food, seed & industrial:	4,555	35.2%
— Fuel alcohol	**3,200**	**24.7%**
— High fructose corn syrup	500	3.9%
— Glucose & dextrose	235	1.8%
— Starch	270	2.1%
— Cereals & other products	193	1.5%
— Beverage alcohol	135	1.0%
— Seed	22	0.2%
Exports	2,450	18.9%
Total Use	**12,955**	**100.0%**
Total Production	**13,074**	

Source: Basic data are from USDA, Economic Research Service, *Feed Outlook*, March 13, 2008.

Note: Annual use can exceed production through the use of stocks carried over from previous years.

Ethanol Refining and Production

According to the Renewable Fuels Association,[9] about 80% of the corn used for ethanol is processed by "dry" milling plants (which use a grinding process) and the other 20% is processed by "wet" milling plants (which use a chemical extraction process). The basic steps of both processes are similar. First, the corn is processed, with various enzymes added to separate fermentable sugars from other components such as protein and fiber; some of these other components are used to make coproducts, such as animal feed. Next, yeast is added to the mixture for fermentation to make alcohol. The alcohol is then distilled to fuel-grade ethanol that is 85%-95% pure. Then the ethanol is partially dehydrated to remove excess water. Finally, for fuel and industrial purposes the ethanol is denatured with a small amount of a displeasing or noxious chemical to make it unfit for human consumption.[10] In the United States, the denaturant for fuel ethanol is gasoline.

Ethanol is produced largely in the Midwest corn belt, with roughly 70% of the national output occurring in five states: Iowa, Nebraska, Illinois, Minnesota and South Dakota. Because it is generally less expensive to produce ethanol close to the

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[9] [http://www.ethanolrfa.org/].

[10] Renewable Fuels Association, *Ethanol Industry Outlook 2002, Growing Homeland Energy Security*.

feedstock supply, it is not surprising that the top corn-producing states in the U.S. are also the main ethanol producers. This geographic concentration is an obstacle to the use of ethanol on the East and West Coasts. Most ethanol use is in the metropolitan centers of the Midwest, where it is produced. When ethanol is used in other regions, shipping costs tend to be high, since ethanol-blended gasoline cannot travel through petroleum pipelines, but must be transported by truck, rail, or barge. However, due to Clean Air Act requirements,[11] concerns over other fuel additives, and the establishment of a renewable fuels standard, ethanol use on the East and West Coasts is growing steadily. For example, in 1999 California and New York accounted for 5% of U.S. ethanol consumption, increasing to 22% in 2003, and 33% in 2004.[12]

The potential for expanding production geographically is one motivation behind research on cellulosic ethanol. If regions could locate production facilities closer to the point of consumption, the costs of using ethanol could be lessened. Furthermore, if regions could produce fuel ethanol from local crops, there could be an increase in regional agricultural income.

Table 2. Top 10 Ethanol Producers by Capacity, March 2008
(existing production capacity — million gallons per year)

POET	1,208
Archer Daniels Midland (ADM)	1,070
VeraSun Energy Corporation	560
U.S. BioEnergy Corp.	420
Hawkeye Renewables	225
Aventine Renewable Energy	207
Abenoga Bioenergy Corp.	198
White Energy	148
Renew Energy	130
Cargill	120
All others	4,024
Total	8,310

Source: Renewable Fuels Association, U.S. Fuel Ethanol Industry Plants and Production Capacity, March 17, 2008.

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[11] P.L. 109-58 amended the Clean Air Act to eliminate the reformulated gasoline oxygenate standard, one of the key federal policies promoting the use of ethanol. However, the act also established a renewable fuels standard, effectively mandating the use of ethanol. (See “Renewable Fuels Standard” below.)

[12] U.S. Department of Transportation, Federal Highway Administration, *Highway Statistics Series*, 1999, 2003, and 2004.

Historically, ethanol production was concentrated among a few large producers. However, that concentration has declined over the past several years. **Table 2** shows that currently, the top five companies account for approximately 42% of production capacity, and the top ten companies account for approximately 48% of production capacity. Critics of the ethanol industry in general — and specifically of the ethanol tax incentives — have argued that the tax incentives for ethanol production equate to "corporate welfare" for a few large producers.[13] However, the share of production capacity controlled by the largest producers has been dropping as more producers have entered the market.

Section 1501(a)(2) of the Energy Policy Act of 2005 required the Federal Trade Commission (FTC) to study whether there is sufficient competition in the U.S. ethanol industry. The FTC concluded that "the level of concentration in ethanol production would not justify a presumption that a single firm, or a small group of firms, could wield sufficient market power to set prices or coordinate on prices or output."[14] Further, they concluded that the level of concentration has been decreasing in recent years.

Overall, at the beginning of 2008, domestic ethanol production capacity was approximately 8 billion gallons per year, and is expected to grow to 13 billion gallons per year, counting existing plants and plants under construction.[15] Under various federal and state laws and incentives, consumption has increased from 1.8 billion gallons per year in 2001 to 6.8 billion gallons per year in 2007. Domestic production capacity will continue increasing to meet the growing demand, including increased demand resulting from implementation of the renewable fuels standard established by the Energy Policy Act of 2005.

Fuel is not the only output of an ethanol facility, however. Coproducts play an important role in the profitability of a plant. In addition to the primary ethanol output, the corn wet milling process generates corn gluten feed, corn gluten meal, and corn oil, and dry milling process creates distillers grains. Corn oil is used as a vegetable oil and is priced higher than soybean oil; the other coproducts are used as livestock feed. In 2004, U.S. ethanol mills produced 7.3 million metric tons of distillers grains, 2.4 million metric tons of corn gluten feed, 0.4 million metric tons of corn gluten meal, and 560 million pounds of corn oil.[16]

Revenue from the ethanol byproducts help offset the cost of corn used in ethanol production. The net cost of corn relative to the price of ethanol and the difference between ethanol and wholesale gasoline prices are the major economic determinants

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[13] Erin M. Hymel, The Heritage Foundation, *Ethanol Producers Get a Handout from Consumers*, October 16, 2002.

[14] Federal Trade Commission, *2006 Report on Ethanol Market Concentration*, December 1, 2006. p. 2.

[15] Renewable Fuels Association, *U.S. Fuel Ethanol Industry Plants and Production Capacity*, March 2008.

[16] Renewable Fuels Association, *Ethanol Industry Outlook 2005, Homegrown for the Homeland*, February 2005.

of the level of ethanol production. Higher the corn prices lead to lower profits for ethanol producers; higher gasoline prices lead to higher profits. Recently, high corn prices have cut into corn ethanol producers' profits.

Fuel Consumption

Approximately 7 billion gallons of ethanol fuel were consumed in the United States in 2007, mainly blended into E10 gasohol (a blend of 10% ethanol and 90% gasoline). This figure represents only 5% of the approximately 140 billion gallons of gasoline consumption in the same year.[17] Under the renewable fuels standard, motor fuel will be required to contain 36 billion gallons of renewable fuel annually by 2022. It is expected that much of this requirement will be met with ethanol.

Ethanol consumption in 2007 accounted for approximately 4% of combined gasoline and diesel fuel consumption.[18] Because of its physical properties, ethanol can be more easily substituted for — or blended into — gasoline, which powers most passenger cars and light trucks. However, heavy-duty vehicles are generally diesel-fueled. For this reason, research is ongoing into ethanol-diesel blends.

A key barrier to wider use of fuel ethanol is its cost relative to gasoline. Even with tax incentives for ethanol use (see the section on Economic Effects), the fuel is often more expensive than gasoline per gallon.[19] Further, since fuel ethanol has a somewhat lower energy content per gallon, more fuel is required to travel the same distance. This energy loss leads to a 2%-3% decrease in miles-per-gallon vehicle fuel economy with 10% gasohol. This is due to the fact that there is simply less energy in one gallon of ethanol than in one gallon of gasoline, as opposed to any detrimental effect on the efficiency of the engine.[20]

However, ethanol's chemical properties make it very useful for some applications, especially as an additive in gasoline. The oxygenate requirement of the Clean Air Act Reformulated Gasoline (RFG) program provided a major boost to the use of ethanol.[21] Oxygenates are used to promote more complete combustion of gasoline, which reduces carbon monoxide (CO) emissions and may reduce volatile organic compound (VOC) emissions.[22] In addition, oxygenates can replace other chemicals in gasoline, such as benzene, a toxic air pollutant. Conversely, the higher

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[17] DOE, EIA, *Alternatives to Traditional Transportation Fuels 2005*, Table C1.

[18] Ibid.

[19] However, gasoline prices have been high recently, making ethanol more attractive as a blending component.

[20] In fact, there is some evidence that the combustion efficiency of an engine improves with the use of ethanol relative to gasoline. In this way, a greater percentage of energy in the fuel is transferred to the wheels. However, this improved efficiency does not completely negate the fact that there is less energy in a gallon of ethanol than in a gallon of gasoline.

[21] Section 211, Subsection k; 42 U.S.C. 7545.

[22] CO, VOCs and nitrogen oxides are the main precursors to ground-level ozone.

volatility of ethanol-blended gasoline can in some cases lead to higher VOC emissions (see "Air Quality," below).

The two most common oxygenates are ethanol and methyl tertiary butyl ether (MTBE). Until recently, MTBE, made primarily from natural gas or petroleum products, was preferred to ethanol in most regions because it was generally much less expensive, easier to transport and distribute, and available in greater supply. Because of different distribution systems and gasoline blending processes, substituting one oxygenate for another can lead to significant transitional costs, in addition to the cost differential between the two additives.

Despite the cost differential, there are several possible advantages of using ethanol over MTBE. Since ethanol is produced from agricultural products, it has the potential to be a sustainable fuel, while MTBE is produced from fossil fuels, either natural gas or petroleum. In addition, ethanol is readily biodegradable, eliminating some of the potential concerns about groundwater contamination that have surrounded MTBE (see the section on MTBE). However, there is concern that ethanol use can increase the risk of groundwater contamination by benzene and other toxic compounds.[23]

Both ethanol and MTBE also can be blended into otherwise non-oxygenated gasoline to raise the octane rating of the fuel. High-performance engines and older engines often require higher octane fuel to prevent early ignition, or "engine knock." Other chemical additives may be used for the same purpose, but some of these alternatives are highly toxic, and some are regulated as pollutants under the Clean Air Act.[24] Furthermore, since these other additives do not contain oxygen, their use may not lead to the same emissions reductions as oxygenated gasoline.

E85 Consumption

In purer forms, such as E85, ethanol can also be used as an alternative to gasoline in vehicles specifically designed to use it. Currently, this use represents only approximately 1% of ethanol consumption in the United States. To promote the development of E85 and other alternative fuels, Congress has enacted various legislative requirements and incentives. The Energy Policy Act of 1992 requires the federal government and state governments, along with businesses in the alternative

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[23] Gasoline contains many different chemical compounds, including toxic substances such as benzene. In the case of a leaking gasoline storage tank, various compounds within the gasoline, based on their physical properties, will travel different distances through the ground. The concern with ethanol is that there is very limited evidence that plumes of benzene and other toxic substances travel farther if ethanol is blended into gasoline. However, this property has not been firmly established, as it has not been studied in depth. Susan E. Powers, David Rice, Brendan Dooher, and Pedro J. J. Alvarez, "Will Ethanol-Blended Gasoline Affect Groundwater Quality?," *Environmental Science and Technology*, January 1, 2001, p. 24A.

[24] Lead was commonly used as an octane enhancer until it was phased-out through the mid-1980s (lead in gasoline was completely banned in 1995), due to the fact that it disables emissions control devices, and because it is toxic to humans.

fuel industry, to purchase alternative-fueled vehicles.[25] In addition, under the Clean Air Act Amendments of 1990, municipal fleets can use alternative fuel vehicles as one way to mitigate air quality problems. Both E85 and E95 (95% ethanol with 5% gasoline) are currently considered alternative fuels by the Department of Energy.[26] The small amount of gasoline added to the alcohol helps prevent corrosion of engine parts and aids ignition in cold weather.

Table 3. Estimated U.S. Consumption of Fuel Ethanol, Gasoline, and Diesel
(million gasoline-equivalent gallons)

	1996	1998	2000	2002	2004
E85	1	2	7	10	22
E95	3	0[a]	0	0	0
Ethanol in Gasohol (E10)	660	890	1,110	1,120	2,052[b]
Gasoline[c]	117,800	122,850	125,720	130,740	136,370
Diesel	30,100	33,670	36,990	38,310	40,740

Source: Department of Energy, Alternatives to Traditional Transportation Fuels 1999.

a. A major drop in E95 consumption occurred between 1997 and 1998 because the number of E95-fueled vehicles in operation dropped from 347 to 14, due to the elimination of an ethanol-fueled municipal bus fleet in California. This fleet was eliminated due to higher fuel and maintenance costs. DOE currently reports that no E95 vehicles were in operation in 2004.
b. An estimated 3.4 billion gallons of ethanol were consumed in 2004. However, due to ethanol's lower energy content, the number of equivalent gallons is lower.
c. Gasoline consumption includes ethanol in gasohol.

Approximately 22 million gasoline-equivalent gallons (GEG)[27] of E85 were consumed in 2004, mostly in Midwestern states.[28] (See **Table 3**.) A key reason for the relatively low consumption of E85 is that there are relatively few vehicles that operate on E85. In 2006 the National Ethanol Vehicle Coalition estimated that there were approximately six million E85-capable vehicles on U.S. roads,[29] as compared

[25] P.L. 102-486. For example, of the light-duty vehicles purchased by a federal agency in a given year, 75% must be alternative fuel vehicles.

[26] More diluted blends of ethanol, such as E10, are considered to be "extenders" of gasoline, as opposed to alternatives.

[27] Since different fuels produce different amounts of energy per gallon when consumed, the unit of a gasoline-equivalent gallon (GEG) is used to compare total energy consumption. It takes roughly 1.4 gallons of E85 to equal the energy content in one gallon of gasoline.

[28] DOE, EIA, *Alternatives to Traditional Transportation Fuels*.

[29] National Ethanol Vehicle Coalition, *Frequently Asked Questions*, accessed February 3, 2006 [http://www.e85fuel.com/e85101/faq.php].

to approximately 230 million gasoline- and diesel-fueled vehicles.[30] Most E85-capable vehicles are "flexible fuel vehicles" or FFVs. An FFV can operate on any mixture of gasoline and 0% to 85% ethanol. A large majority of FFVs on U.S. roads are fueled exclusively on gasoline. In 2004, approximately 146,000 flexible fuel vehicles (FFVs) were actually fueled by E85.[31] Proponents of E85 and FFVs argue that even though few FFVs are operated on E85, the large number of these vehicles already on the road means that incentives to expand E85 infrastructure are more likely to be successful.

One obstacle to the use of alternative fuel vehicles is that they generally have a higher purchase price than conventional vehicles, although this margin has decreased in recent years with newer technology. Another obstacle is that, as stated above, fuel ethanol is often more expensive than gasoline or diesel fuel. In addition, there are very few fueling sites for E85, especially outside of the Midwest. As of February 2006, there were 556 fuel stations with E85, as compared to roughly 120,000 gasoline stations across the country. Further, 362 (65%) of these stations were located in the five highest ethanol-producing states: Minnesota, Illinois, Iowa, South Dakota, and Nebraska. In February 2006, there were only 60 stations in 10 states along the east and west coasts, where population — and thus fuel demand — is higher. However, E85 capacity is expanding rapidly, and the number of E85 stations nearly tripled (to 1,365) between February 2006 and March 2008, and the number along the coasts had increased to 146 stations in 13 states (although roughly half of all stations are still in the top five ethanol-producing states).

Development of Cellulosic Feedstocks

A key barrier to ethanol's expanded role in U.S. fuel consumption is its price differential with gasoline. Since a major part of the total production cost is the cost of feedstock, reducing feedstock costs could lead to lower wholesale ethanol costs. For this reason, there is a great deal of interest in producing ethanol from cellulosic feedstocks. Cellulosic materials include low-value waste products such as recycled paper and rice hulls, or dedicated fuel crops, such as switchgrass[32] and fast-growing trees. A dedicated fuel crop would be grown and harvested solely for the purpose of fuel production.

However, as the name indicates, cellulosic feedstocks are high in cellulose. Cellulose forms a majority of plant matter, but it is generally fibrous and cannot be

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[30] Federal Highway Administration, *Highway Statistics 2003*, November 2004.

[31] DOE, EIA, *Alternatives to Traditional Transportation Fuels*. In 1997, some manufacturers began making flexible E85/gasoline fueling capability standard on some models. However, some owners may not be aware of their vehicles' flexible fuel capability.

[32] Switchgrass is a tall, fast-growing perennial grass native to the North American tallgrass prairie. It is of key interest because it readily grows with limited fertilizer use in marginal growing areas. Further, its cultivation can improve soil quality.

directly fermented.[33] It must first be broken down into simpler molecules, which is currently expensive. A 2000 study by USDA and the National Renewable Energy Laboratory (NREL) estimated a 70% increase in production costs with large-scale ethanol production from cellulosic biomass compared with ethanol produced from corn.[34] Therefore, federal research has focused on both reducing the process costs for cellulosic ethanol and improving the availability of cellulosic feedstocks. The Natural Resources Defense Council estimates that with mature technology, advanced ethanol production facilities could produce significant amounts of fuel at $0.59 to $0.91 per gallon (before taxes) by 2012, a price that is competitive with Energy Information Administration (EIA) projections for gasoline prices in 2012.[35]

Other potential benefits from the development of cellulosic ethanol include lower greenhouse gas and air pollutant emissions and a higher energy balance[36] than corn-based ethanol.[37] Further, expanding the feedstocks for ethanol production could allow areas outside of the Midwest to produce ethanol with local feedstocks.

In his 2006 State of the Union Address, President Bush announced an expansion of biofuels research at the Department of Energy.[38] A stated goal in the speech is to make cellulosic ethanol "practical and competitive within six years," with a potential goal of reducing Middle East oil imports by 75% by 2025.[39] This goal would require an increase in ethanol consumption to as much as 60 billion gallons, from 4.9 billion gallons in 2004.[40] As part of the FY2007 DOE budget request, the Administration sought an increase of 65% above FY2006 funding for "Biomass and Biorefinery Systems R&D," which includes research into cellulosic ethanol.[41] In his 2007 State of the Union Address, President Bush further defined a goal of increasing the use of

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[33] Lee R. Lynd, Dartmouth College, *Cellulosic Ethanol Fact Sheet*, June 13, 2003. For the National Commission on Energy Policy Forum: The Future of Biomass and Transportation Fuels.

[34] Andrew McAloon, Frank Taylor, and Winnie Yee (USDA), and Kelly Ibsen and Robert Wolley (NREL), *Determining the Cost of Producing Ethanol from Corn Starch and Lignocellulosic Feedstocks*, October 2000.

[35] Nathanael Greene, Natural Resources Defense Council, *Growing Energy - How Biofuels Can Help End America's Oil Dependence*, December 2004, Table 18.

[36] The ratio of the energy needed to produce a fuel to that fuel's energy output. For more details, see section below on "Energy Balance."

[37] Alexander E. Farrell, Richard J. Plevin, Brian T. Turner, Andrew D. Jones, Michael O'Hare, and Daniel M. Kammen, "Ethanol Can Contribute to Energy and Environmental Goals," *Science*, January 27, 2006, pp. 506-508.

[38] President George W. Bush, *State of the Union Address*, January 31, 2006, [http://www.whitehouse.gov/news/releases/2006/01/20060131-10.html].

[39] Ibid.

[40] Peter Rhode, "Bush Biofuel Goal Likely Means Speeding Current Plans By Decades," *New Fuels and Vehicles.com*, February 3, 2006.

[41] The FY2006 appropriation was $91 million; the FY2007 request is $150 million. DOE, *FY2007 Congressional Budget Request*, February 2006, vol. 3, p. 141.

renewable and alternative fuels to 35 billion gallons by 2017.[42] This would mean a roughly seven-fold increase from 2006 levels. Such an increase would most likely be infeasible using corn and other grains as feedstocks. Therefore, the President's goal will likely require significant breakthroughs in technology to convert cellulose into motor fuels.

As stated above, the Energy Independence and Security Act of 2007 (P.L.110-140) expanded the renewable fuel standard (RFS). Further, starting in 2016, and increasing share of the RFS must come from "advanced biofuels," such as cellulosic ethanol, ethanol from sugar cane, and biodiesel. Further, of the advanced biofuel mandate (which reaches 21 billion gallons in 2022), there is a specific carve-out for cellulosic biofuels (reaching 16 billion gallons in 2022).

Economic Effects

Ethanol's relatively high price is a major constraint on its use as an alternative fuel and as a gasoline additive. As a result, ethanol has not been competitive with gasoline except with incentives. Wholesale ethanol prices, excluding incentives from the federal government and state governments, are significantly higher than wholesale gasoline prices. With federal and state incentives, however, the effective price of ethanol is reduced. Furthermore, gasoline prices have risen recently, making ethanol more attractive as both a blending component and as an alternative fuel.

Before 2004, the primary federal incentive supporting the ethanol industry was a 5.2 cents per gallon exemption that blenders of gasohol (E10) received from the 18.4¢ federal excise tax on motor fuels. Because the exemption applied to blended fuel, of which ethanol comprises only 10%, the exemption provided for an effective subsidy of 52 cents per gallon of pure ethanol. The 108th Congress replaced this exemption with an income tax credit of 51 cents per gallon of pure ethanol used in blending (P.L. 108-357).[43] **Table 4** shows that ethanol and gasoline prices are competitive on a per gallon basis when the ethanol tax credit is factored in. However, the energy content of a gallon of ethanol is about one third lower than a gallon of gasoline. As Table 4 shows, on an equivalent energy basis, ethanol can be significantly more expensive than gasoline, even with the tax credit.

The comparative cost figures in **Table 4** are for ethanol as a blending component in gasoline. However, the use of E85 in flexible fuel vehicles has been associated with improved combustion efficiency. The National Ethanol Vehicle Coalition estimates that FFVs run on E85 experience a 5% to15% decrease in miles-per-gallon fuel economy,[44] as opposed to the 29% drop in Btu content per gallon. Therefore, on a per-mile basis, E85's cost premium is likely in the middle of these above estimates.

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[42] President George W. Bush, *State of the Union Address*, January 23, 2007, [http://www.whitehouse.gov/news/releases/2007/01/20070123-2.html].

[43] 26 U.S.C. 40.

[44] National Ethanol Vehicle Coalition, *op. cit.*

Table 4. Wholesale Price of Pure Ethanol Relative to Gasoline
(August 2006 to January 2008)

	Relative price by volume	**Relative price on an equivalent energy basis**[c]
Ethanol Wholesale Price[a]	150 to 250 cents/gallon	227 to 379 cents/equivalent gallon
Alcohol Fuel Tax Incentive	51 cents/gallon	77 cents/equivalent gallon
Effective Price of Ethanol	99 to 199 cents/gallon	150 to 302 cents/equivalent gallon
Gasoline Wholesale Price[b]	135 to225 cents/gallon	135 to 225 cents/gallon
Wholesale Price Difference[d]	(-)101 to (+)39 cents/gallon	(-)50 to (+)142 cents/gallon

Source: CRS analysis of Chicago Board of Trade, *Ethanol Derivatives, Updated through January 2008*, February 13, 2008; "US Wholesale Posted Prices," *Platt's Oilgram Price Report*. August 1, 2006, through January 31, 2007.

a. This is the average Chicago daily terminal price for pure ("neat") ethanol.
b. This is the average Chicago price for regular gasoline.
c. A gallon of gasoline contains 115,000 British thermal units (Btu) of energy, while a gallon of ethanol contains 76,000 Btu. Therefore it takes roughly 1.51 gallons of pure ethanol to equal the Btu content of one gallon of gasoline.
d. The wholesale price difference is computed on a daily basis.

Many proponents and opponents agree that the ethanol industry might not survive without tax incentives. An economic analysis conducted in 1998 by the Food and Agriculture Policy Research Institute, concurrent with the congressional debate over extension of the excise tax exemption, concluded that elimination of the exemption would cause annual ethanol production from corn to decline roughly 80% from 1998 levels.[45]

The tax incentives for ethanol are criticized by some as "corporate welfare,"[46] encouraging the inefficient use of agricultural and other resources and depriving the government of needed revenues.[47] In 1997, the General Accounting Office estimated that the excise tax exemption reduced Highway Trust Fund by $7.5 to $11 billion over the 22 years from FY1979 to FY2000.[48]

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[45] Food and Agriculture Policy Research Institute, *Effects on Agriculture of Elimination of the Excise Tax Exemption for Fuel Ethanol*, Working Paper 01-97, April 8, 1997.

[46] Erin Hymel, *op. cit.*

[47] U.S. General Accounting Office (GAO), *Effects of the Alcohol Fuels Tax Incentives*, March 1997.

[48] Jim Wells, GAO, *Petroleum and EthanolFuels: Tax Incentives and Related GAO Work*, (continued...)

Proponents of the tax incentive argue that ethanol leads to better air quality and reduced greenhouse gas emissions, and that substantial benefits flow to the agriculture sector due to the increased demand for corn to produce ethanol. Furthermore, they argue that the increased market for ethanol reduces oil imports and strengthens the U.S. trade balance.

Air Quality

One often-cited benefit of ethanol use is improvement in air quality. The Clean Air Act Amendments of 1990 (P.L. 101-549) created the Reformulated Gasoline (RFG) program, which was a major impetus to the development of the U.S. ethanol industry. The Energy Policy Act of 2005 (P.L. 109-58) made significant changes to that program that directly affect U.S. markets for gasoline and ethanol.

Before the Energy Policy Act of 2005. Through 2005, ethanol was primarily used in gasoline to meet a minimum oxygenate requirement for RFG.[49] RFG is used to reduce vehicle emissions in areas that are in severe or extreme nonattainment of National Ambient Air Quality Standards (NAAQS) for ground-level ozone.[50] Ten metropolitan areas, including New York, Los Angeles, Chicago, Philadelphia, and Houston, are covered by this requirement, and many other areas with less severe ozone problems have opted into the program, as well.[51] In these areas, RFG is used year-round.

EPA states that RFG has led to significant improvements in air quality, including a 17% reduction in volatile organic compound (VOC) emissions from vehicles, and a 30% reduction in emissions of toxic air pollutants.[52] Furthermore, according to EPA, "ambient monitoring data from the first year (1995) of the RFG program also showed strong signs that RFG is working. For example, detection of benzene (one of the air toxics controlled by RFG, and a known human carcinogen) declined dramatically, with a median reduction of 38% from the previous year."[53]

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[48] (...continued)
September 25, 2000.

[49] Clean Air Act, Section 211, Subsection k; 42 U.S.C. 7545.

[50] Ground-level ozone is an air pollutant that causes smog, adversely affects health, and injures plants. It should not be confused with stratospheric ozone, which is a natural layer some 6 to 20 miles above the earth and provides a degree of protection from harmful radiation.

[51] Under new ozone standards recently promulgated by EPA, the number of RFG areas will likely increase.

[52] The RFG program defines "toxic air pollutants" as benzene, 1,3-butadiene, polycyclic organic matter, acetaldehyde, and formaldehyde.

[53] Margo T. Oge, Director, Office of Mobile Sources, U.S. EPA, *Testimony Before the Subcommittee on Energy and Environment of the Committee on Science, U.S. House of Representatives*, September 14, 1999.

However, the benefits of oxygenates in RFG have been questioned. Although oxygenates lead to lower emissions of carbon monoxide (CO), in some cases they may lead to higher emissions of nitrogen oxides (NO_X) and VOCs. Since all three contribute to the formation of ozone, the National Research Council concluded that while RFG certainly leads to improved air quality, the oxygenate requirement in RFG may have little overall impact on ozone formation.[54] In fact, in some areas, the use of low-level blends of ethanol (10% or less) may actually lead to increased ozone formation due to atmospheric conditions in that specific area.[55] Some argue that the main benefit of oxygenates is that they displace other, more dangerous compounds found in gasoline such as benzene. Furthermore, high gasoline prices have also raised questions about the cost-effectiveness of the RFG program.

Evidence that the most widely used oxygenate, methyl tertiary butyl ether (MTBE), contaminates groundwater led to a push by some to eliminate the oxygen requirement in RFG. MTBE has been identified as an animal carcinogen, and there is concern that it is a possible human carcinogen. In California, New York, and Connecticut, MTBE was banned as of January 2004, and several states have followed suit.

Some refiners claimed that the environmental goals of the RFG program could be achieved through cleaner, although potentially more costly, gasoline that does not contain any oxygenates.[56] These claims added to the push to remove the oxygenate requirement and allow refiners to produce RFG in the most cost-effective manner, whether or not that includes the use of oxygenates. However, since oxygenates also displace other harmful chemicals in gasoline, some environmental groups were concerned that eliminating the oxygenate requirements would compromise air quality gains resulting from the current standards. This potential for "backsliding" is a result of the fact that the current performance of RFG is substantially better than the Clean Air Act requires. If the oxygenate standard were eliminated, environmental groups feared that refiners would only meet the requirements of the law, as opposed to maintaining the current overcompliance. The amendments to the RFG program in P.L. 109-58 require refiners to blend gasoline in a way that maintains the toxic emissions reductions achieved in 2001 and 2002.[57]

Following the Energy Policy Act of 2005. P.L. 109-58 made substantial changes to the RFG program. Section 1504(a) eliminated the RFG oxygenate standard as of May 2006, and required EPA to revise its regulations on the RFG

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[54] National Research Council, *Ozone-Forming Potential of Reformulated Gasoline*, May, 1999.

[55] Wisconsin Department of Natural Resources, Bureau of Air Management, *Ozone Air Quality Effects of a 10% Ethanol Blended Gasoline in Wisconsin*, September 6, 2005.

[56] Al Jessel, Senior Fuels Regulatory Specialist of Chevron Products Company, *Testimony Before the House Science Committee Subcommittee on Energy and Environment*, September 30, 1999.

[57] P.L. 109-58, Section 1504(b).

program to allow the sale of non-oxygenated RFG. This revision is effective May 6, 2006 in most areas of the country.[58]

E85 and Air Quality. The air quality benefits from purer forms of ethanol can be substantial. Compared to gasoline, use of E85 can result in a significant reduction in ozone-forming vehicle emissions in urban areas.[59] And while the use of ethanol also leads to increased emissions of acetaldehyde, a toxic air pollutant, as defined by the Clean Air Act, these emissions can be controlled through the use of advanced catalytic converters.[60] However, as stated above, purer forms of ethanol have not been widely used.

Energy Consumption and Greenhouse Gas Emissions

Energy Balance. A frequent argument for the use of ethanol as a motor fuel is that it reduces U.S. reliance on oil imports, making the U.S. less vulnerable to a fuel embargo of the sort that occurred in the 1970s. To analyze the net energy consumption of ethanol, the entire fuel cycle must be considered. The fuel cycle consists of all inputs and processes involved in the development, delivery and final use of the fuel. For corn-based ethanol, these inputs include the energy needed to produce fertilizers, operate farm equipment, transport corn, convert corn to ethanol, and distribute the final product. According to a fuel-cycle study by Argonne National Laboratory, with current technology the use of corn-based E10 leads to a 3% reduction in fossil energy use per vehicle mile relative to gasoline, while use of E85 leads to roughly a 40% reduction in fossil energy use.[61]

However, other studies question the Argonne study, suggesting that the amount of energy needed to produce ethanol is roughly equal to the amount of energy obtained from its combustion. Since large amounts of fossil fuels are used to make fertilizer for corn production and to run ethanol plants, ethanol use could lead to little or no net reduction in fossil energy use. Nevertheless, a recent meta-study of

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[58] Environmental Protection Agency, "Regulation of Fuels and Fuel Additives: Removal of Reformulated Gasoline Oxygen Content Requirement and Revision of Commingling Prohibition to Address Non-Oxygenated Reformulated Gasoline, Direct Final Rule," *71 Federal Register 8973*, February 22, 2006.

[59] It should be noted that the overall fuel-cycle ozone-forming emissions from corn-based E85 are roughly equivalent to those from gasoline. However, some of the emissions attributable to E85 are in rural areas where corn is grown and the ethanol is produced — areas where ozone formation is potentially less of a concern. Norman Brinkman and Trudy Weber (General Motors Corporation), Michael Wang (Argonne National Laboratory), and Thomas Darlingon (Air Improvement Resource, Inc.), *Well-to-Wheels Analysis of Advanced Fuel/Vehicle Systems — A North American Study of Energy Use, Greenhouse Gas Emissions, and Criteria Pollutant Emissions*, May 2005.

[60] California Energy Commission, *Ethanol-Powered Vehicles*.

[61] M. Wang, C. Saricks, and D. Santini, "Effects of Fuel Ethanol on Fuel-Cycle Energy and Greenhouse Gas Emissions," Argonne National Laboratory, January 1999.

research on ethanol's energy balance and greenhouse gas emissions found that most studies give corn-based ethanol a slight positive energy balance.[62] However, because most of the energy used to produce ethanol comes from natural gas or electricity, most studies conclude that overall *petroleum* dependence (as opposed to *energy* dependence) can be significantly diminished through expanded use of ethanol.

Despite the fact that ethanol displaces gasoline, the benefits to energy security from corn-based ethanol are not certain. As stated above, fuel ethanol only accounts for approximately 2.5% of gasoline consumption in the United States by volume. In terms of energy content, ethanol accounts for approximately 1.5%. This small market share led the Government Accountability Office (formerly the General Accounting Office) to conclude that the ethanol tax incentive has done little to promote energy security.[63] Further, as long as ethanol remains dependent on the U.S. corn supply, any threats to this supply (e.g. drought), or increases in corn prices, would negatively affect the supply and/or cost of ethanol. In fact, that happened when high corn prices caused by strong export demand in 1995 contributed to an 18% decline in ethanol production between 1995 and 1996.

Cellulosic Ethanol Energy Balance. Because cellulosic feedstocks require far less fertilizer for their production, the energy balance and other benefits of cellulosic ethanol could be significant. The Argonne study concluded that with advances in technology, the use of cellulose-based E10 could reduce fossil energy consumption per mile by 8%, while cellulose-based E85 could reduce fossil energy consumption by roughly 70%.[64]

Greenhouse Gas Emissions. Directly related to fossil energy consumption is the question of greenhouse gas emissions. Proponents of ethanol argue that over the entire fuel cycle it has the potential to reduce greenhouse gas emissions from automobiles relative to gasoline, therefore reducing the risk of possible global warming.

Fuel Cycle Analysis. Because ethanol contains carbon,[65] combustion of the fuel necessarily results in emissions of carbon dioxide (CO_2), the primary greenhouse gas. Further, greenhouse gases are emitted through the production and use of nitrogen-based fertilizers, as well as the operation of farm equipment and vehicles to transport feedstocks and finished products. However, since photosynthesis (the process by which plants convert light into chemical energy) requires absorption of CO_2, the growth cycle of the feedstock crop can serve — to some extent — as a "sink" to absorb some fuel-cycle greenhouse emissions.

According to the Argonne study, overall fuel-cycle greenhouse gas emissions from corn-based E10 (measured in grams per mile) are approximately 1% lower than

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[62] Farrell, et al., p. 506.

[63] U.S. General Accounting Office, *Effects of the Alcohol Fuels Tax Incentives*, March 1997.

[64] Wang, et al., table 7.

[65] The chemical formula for ethanol is C_2H_5OH.

from gasoline, while emissions are approximately 20% lower with E85.[66] Other studies that conclude higher fuel-cycle energy consumption for ethanol production also conclude higher greenhouse gas emissions for the fuel. The meta-study on energy consumption and greenhouse gas emissions concluded that pure ethanol results in 13% lower greenhouse gas emissions, with approximately a 10% reduction using E85.[67]

Fuel Cycle Emissons from Cellulosic Ethanol. Because of the limited use of fertilizers, fossil energy consumption — and thus greenhouse gas emissions — is significantly reduced with ethanol production from cellulosic feedstocks. The Argonne study concludes that with advances in technology, cellulosic E10 could reduce greenhouse gas emissions by 7% to 10% relative to gasoline, while cellulosic E85 could reduce greenhouse gas emissions by 67% to 89%.[68] The meta-study of energy consumption and greenhouse gas emissions found a similar potential for greenhouse gas reductions.[69]

Lifecycle Analysis. A key criticism of fuel-cycle analyses is that they generally do not take changes in land use into account. For example, if a previously uncultivated piece of land is tilled to plant biofuel crops, some of the carbon stored in the field could be released. In that case, the overall GHG benefit of biofuels could be compromised. One study estimates that taking land use into account (a lifecycle analysis as opposed to a fuel-cycle analysis), the GHG reduction from corn ethanol is less than 3% per mile relative to gasoline,[70] while cellulosic biofuels have a life-cycle reduction of 50%.[71] Other recent studies indicate even smaller GHG reductions.

This is of key interest because under the RFS, as amended by P.L. 110-140, to qualify under the mandate, all fuels from new biofuel refineries must achieve at least a 20% reduction in *lifecycle* greenhouse gas emissions. Further, to qualify as advanced biofuels, they must achieve a 50% reduction in lifecycle emissions. EPA is tasked with developing regulations to rate fuels on their lifecycle emissions, and determining which fuels qualify under the new standard.

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[66] Wang, et al., table 7.

[67] Farrell, et al., p. 506.

[68] Wang, et al., table 7.

[69] Farrell, et al., p. 507.

[70] Mark A. Delucchi, *Draft Report: Life cycle Analyses of Biofuels*. 2006.

[71] While a 50% life-cycle reduction is still significant, it is far less than the 90% reduction suggested by fuel-cycle analyses.

Policy Concerns and Congressional Activity

Recent congressional interest in ethanol fuels has mainly focused on six policies and issues: (1) the renewable fuel standard; (2) "boutique" fuels; (3) the alcohol fuel tax incentives; (4) ethanol imports through Caribbean Basin Initiative (CBI) countries; (5) fuel economy credits for dual fuel vehicles; and (6) the role of biofuels in the upcoming Farm Bill. In the 109th and 110th Congresses, several of these issues were debated during consideration of the Energy Policy Act of 2005 (P.L. 109-58) and the Energy Independence and Security Act of 2007 (P.L. 110-140).

Renewable Fuel Standard (RFS)

The renewable fuels standard requires motor fuel to contain a minimum amount of fuel produced from renewable sources such as biomass, solar, or wind energy. Proposals to establish an RFS gained traction as part of the discussion over comprehensive energy policy. Supporters argued that demand for ethanol creates jobs, and that there are major environmental and energy security benefits to using renewable fuels. However, opponents argued that any renewable fuel standard would only exacerbate a situation of artificial demand for ethanol created by tax incentives and fuel quality standards. Any requirement above the existing level for ethanol would require the construction and/or expansion of ethanol plants, and likely would lead to increased fuel prices and further instability in an already tight fuel supply chain. Further, they argued that a renewable fuel standard would lead to increased corn prices caused by higher demand.

On August 8, 2005, President Bush signed the Energy Policy Act of 2005 (P.L. 109-58). Section 1501 required the use of at least 4.0 billion gallons of renewable fuel in 2006, increasing to 7.5 billion gallons in 2012 (see **Table 5**). Through 2007 the requirement was largely met using ethanol, although other fuels such as biodiesel played a limited role.[72] The law directed EPA to establish a credit trading system to provide flexibility to fuel producers. Further, under the RFS, ethanol produced from cellulosic feedstocks was granted extra credit: a gallon of cellulosic ethanol counted as 2.5 gallons of renewable fuel under the RFS. Also, P.L. 109-58 required that 250 million gallons of cellulosic ethanol be blended in gasoline annually starting in 2013.[73] The Energy Independence and Security Act of 2007 (P.L. 110-140), signed by President Bush on December 19, 2007, significantly expanded the RFS, requiring the use of 9.0 billion gallons of renewable fuel in 2008, increasing to 36 billion gallons in 2022. Further, P.L. 110-140 requires an increasing amount of the mandate be met with "advanced biofuels" — biofuels produced from feedstocks other than corn starch (and with 50% lower lifecycle greenhouse gas emissions than petroleum fuels). Within the advanced biofuel mandate, there are specific carve-outs for cellulosic biofuels and bio-based diesel substitutes (e.g., biodiesel).

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[72] Biodiesel is a synthetic diesel fuel made from oils such as soybean oil. For more information, see CRS Report RL30758, *Alternative Transportation Fuels and Vehicles: Energy, Environment, and Development Issues*, by Brent D. Yacobucci.

[73] Currently, world production of cellulosic ethanol is limited. No plants currently exist in the United States, although some small plants are in the planning phase.

Table 5. Expanded Renewable Fuel Standard Requirements Under P.L. 110-140

Year	Previous RFS (billion gallons)	Expanded RFS (billion gallons)	Advanced Biofuel Mandate (billion gallons)[a]	Cellulosic Biofuel Mandate (billion gallons)[b]	Biomass-Based Diesel Fuel (billion gallons)[b]
2006	4.0				
2007	4.7				
2008	5.4	**9.0**			
2009	6.1	**11.1**	0.6		0.5
2010	6.8	**12.95**	0.95	0.1	0.65
2011	7.4	**13.95**	1.35	0.25	0.8
2012	7.5	**15.2**	2.0	0.5	1.0
2013	7.6 (est.)	**16.55**	2.75	1.0	1.0
2014	7.7 (est.)	**18.15**	3.75	1.75	1.0
2015	7.8 (est.)	**20.5**	5.5	3.0	1.0
2016	7.9 (est.)	**22.25**	7.25	4.25	1.0
2017	8.1 (est.)	**24.0**	9.0	5.5	1.0
2018	8.2 (est.)	**26.0**	11.0	7.0	1.0
2019	8.3 (est.)	**28.0**	13.0	8.5	1.0
2020	8.4 (est.)	**30.0**	15.0	10.5	1.0
2021	8.5 (est.)	**33.0**	18.0	13.5	1.0
2022	8.6 (est.)	**36.0**	21.0	16.0	1.0

a. The advanced biofuel (i.e. non-corn-starch ethanol) mandate is a subset of the expanded RFS. The difference between the expanded RFS mandate and the advanced biofuel mandate — 15 billion gallons in 2015 onward) is effectively a cap on corn ethanol.

b. The cellulosic biofuel and biomass-based diesel fuel mandates are subsets of the advanced biofuel mandate.

Ethanol producers are rapidly expanding capacity in order to meet the increased demand created by the RFS. Between January 2005 and January 2008, U.S. ethanol production capacity expanded from 3.6 billion gallons per year to 7.2 billion gallons per year.

EPA is required to establish a system for suppliers to generate and trade credits earned for exceeding the standard in a given year. Credits can then be purchased by other suppliers to meet their quotas. On May 1, 2007, EPA released a final rulemaking for 2007 and beyond. Included in the rule were provisions for credit trading, as well as provisions for generating credits from the sale of biodiesel and other fuels.[74] Because of the changes in the RFS from P.L. 110-140, EPA will need to publish new rules to reflect those changes. Perhaps most importantly, EPA will need to develop rules for determining the lifecycle greenhouse gas emissions (see "Greenhouse Gas Emissions," above). Fuels from new biorefineries must achieve at least a 20% lifecycle greenhouse gas reduction relative to petroleum fuels, and advanced biofuels must achieve at least a 50% reduction.

The effects of such an increase in ethanol production could be significant, especially if that ethanol comes from corn.[75] These effects include increased corn demand and higher corn prices, leading to higher costs for food (especially in places where corn is a significant part of the local diet) and higher animal feed prices (and higher meat prices). Expanded ethanol use could also strain an already tight ethanol distribution system that is dependent on rail cars for transport, since ethanol may not be transported by pipeline in the United States. Other concerns include the potential for increased water use for corn cultivation and the increased use of chemical fertilizers and pesticides.[76]

"Boutique" Fuels[77]

As a result of the federal reformulated gasoline requirements, as well as related state and local environmental requirements, gasoline suppliers may face several different standards for gasoline quality in different parts of one state or in adjacent states. These different standards sometimes require a supplier to provide several different fuel formulations in a region.[78] These different formulations are sometimes

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[74] Environmental Protection Agency, "Regulation of Fuels and Fuel Additives: Renewable Fuel Standard Program; Final Rule," *72 Federal Register* 23899-23948, May 1, 2007.

[75] For more information, see CRS Report RL33928, *Ethanol and Biofuels: Agriculture, Infrastructure, and Market Constraints Related to Expanded Production*, by Brent Yacobucci and Randy Schnepf.

[76] For more information on some of the potential concerns from an expanded RFS, see CRS Report RL34265, *Selected Issues Related to an Expansion of the Renewable Fuel Standard (RFS)*, by Brent D. Yacobucci and Tom Capehart.

[77] For more information on boutique fuels, see CRS Report RL31361, *"Boutique Fuels" and Reformulated Gasoline: Harmonization of Fuel Standards*, by Brent D. Yacobucci.

[78] These various formulations should not be confused with gasoline "grades" — "regular," "mid-grade," and "premium" octane level fuels — which are not required by federal law but

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referred to as "boutique" fuels.[79] Because of varying requirements, if there is a disruption to the supply of fuel in one area, refiners producing fuel for other nearby areas may not be able to supply fuel quickly enough to meet the increased demand.

EPA conducted a study on the effects of harmonizing standards and released a staff white paper in October 2001.[80] EPA modeled several scenarios, some with limited changes to the existing system, others with drastic changes. In its preliminary analysis, EPA concluded that some minor changes could be made that might mitigate supply disruptions without significantly increasing costs or adversely affecting vehicle emissions. However, all of the changes modeled in EPA's study would require amendments to various provisions in the Clean Air Act.

Congressional interest has centered on the question of whether the various standards could be harmonized to reduce the number of gasoline formulations. Section 1504(c) of P.L. 109-58 consolidates two summertime RFG formulations into one fuel, eliminating one class of fuel. Further, P.L. 109-58 prohibits the number of state fuel blends from exceeding the number as of September 1, 2004. However, many of the larger systemic issues were not addressed.

Alcohol Fuel Tax Incentives[81]

As stated above, the ethanol tax incentives are controversial. The incentives allow fuel ethanol to compete with other additives, since the wholesale price of ethanol is so high. Proponents of ethanol argue that the incentives lower dependence on foreign imports, promote air quality, and benefit farmers.[82]

Opponents argue that the tax incentives support an industry that could not exist on its own. Despite objections from opponents, Congress in 1998 extended the motor fuels excise tax exemption through 2007, but at slightly lower rates.[83] To eliminate concerns over Highway Trust Fund revenue losses, the 108th Congress replaced the excise tax exemption with an income tax credit, effectively transferring

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[78] (...continued)
are desired by consumers and required in some engine designs.

[79] EPA, Office of Transportation and Air Quality, *Staff White Paper: Study of Unique Gasoline Fuel Blends ("Boutique Fuels"), Effects on Fuel Supply and Distribution and Potential Improvements*, October 2001.

[80] Harmonization refers to an attempt to aggregate fuels with similar requirements under a single requirement, thus limiting the number of possible formulations.

[81] For more information, see CRS Report RL32979, *Alcohol Fuels Tax Incentives*, by Salvatore Lazzari.

[82] U.S. General Accounting Office (GAO), *Effects of the Alcohol Fuels Tax Incentives*, March 1997.

[83] P.L. 105-178.

the effects of the incentive from the Highway Trust Fund to the general treasury, and extending the incentive through 2010.[84]

Ethanol Imports

There is growing concern over ethanol imports among some stakeholders. Because of lower production costs and/or government incentives, ethanol prices in Brazil and other countries can be significantly lower than in the United States. To offset the U.S. tax incentives that all ethanol (imported or domestic) receives, most imports are subject to a relatively small 2.5% ad valorem tariff, but more significantly an added duty of $0.54 per gallon. This duty effectively negates the tax incentives for covered imports, and has been a significant barrier to ethanol imports.

However, under certain conditions imports of ethanol from Caribbean Basin Initiative (CBI) countries are granted duty-free status.[85] This is true even if the ethanol was actually produced in a non-CBI country. In this scenario the ethanol is dehydrated in a CBI country, then shipped to the United States.[86] This avenue for avoiding the duty by imported ethanol has been criticized by some stakeholders, including some Members of Congress.

On December 20, 2006, President Bush signed the Tax Relief and Health Care Act of 2006 (P.L. 109-432). Among other provisions, the act extended the duty on imported ethanol through December 31, 2008.

Fuel Economy Credits for Dual Fuel Vehicles

The Energy Policy and Conservation Act (EPCA) of 1975[87] requires Corporate Average Fuel Economy (CAFE) standards for motor vehicles.[88] Under EPCA, the average fuel economy of all vehicles of a given class that a manufacturer sells in a model year must be equal to or greater than the standard for that class. These standards were first enacted in response to the desire to reduce petroleum consumption and promote energy security after the Arab oil embargo. The model year 2007 standard for passenger cars is 27.5 miles per gallon (mpg), while the standard for light trucks is 22.2 mpg.

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[84] P.L. 108-357.

[85] The CBI countries include Costa Rica, Jamaica, and El Salvador, which represent a significant percentage of U.S. fuel ethanol imports. For more information on ethanol imports from CBI countries, see CRS Report RS21930, *Ethanol Imports and the Caribbean Basin Initiative*, by Brent D. Yacobucci.

[86] Dehydration is the final step in the ethanol production process. Excess water is removed from the ethanol to make it usable as motor fuel. For more information, see section above on "Ethanol Refining and Production."

[87] P.L. 94-163.

[88] For more information on CAFE standards, see CRS Report RL33413, *Automobile and Light Truck Fuel Economy: The CAFE Standards*, by Brent D. Yacobucci and Robert Bamberger.

EPCA (and subsequent amendments to it) provides manufacturing incentives for alternative fuel vehicles, including ethanol vehicles.[89] For each alternative fuel vehicle a manufacturer produces, the manufacturer generates credits toward meeting the CAFE standards. These credits can be used to increase the manufacturer's average fuel economy. Credits apply to both dedicated and dual fuel vehicles. Dual fuel vehicles can be operated on both a conventional fuel (gasoline or diesel) and an alternative fuel, usually ethanol. Opponents have raised concerns that while manufacturers are receiving credits for production of these dual fuel vehicles, they are generally operated solely on gasoline, because of the cost and unavailability of alternative fuels. This claim is supported by the fact that EIA estimates that only about 2% of flexible fuel vehicles are currently operated on E85. Supporters of the credits counter that the incentives are necessary for the production of alternative fuel vehicles, and that as the number of vehicles increases, the infrastructure for alternative fuels will grow. However, the success of this strategy has been limited to date.

The credits were set to expire at the end of the 2004 model year. However, in 2004 the Department of Transportation (DOT) issued a final rule extending the credits through model year 2008.[90] Section 772 of P.L. 109-58 extended the credits through model year 2010, and extended DOT's authority (to continue the credits) through 2014.

The 2008 Farm Bill

It is expected that the 110th Congress will reauthorize existing farm programs and promote new programs as part of a new Farm Bill. Most of the provisions of the most recent Farm Bill — The Farm Security and Rural Investment Act of 2002 (P.L. 107-171) — expired in 2007. On July 27, 2007, the House approved a new farm bill, H.R. 2419. Title IX would expand and extend several provisions from the 2002 farm bill's energy title, with substantial increases in funding and a heightened focus on developing cellulosic energy production, and a move away from corn-starch-based ethanol. The Senate passed its version on December 14, 2007. The Senate version would expand 2002 Farm Bill programs, create new tax incentives for cellulosic ethanol, and require studies on expanded biofuel infrastructure. As of March 2008, a conference on the House and Senate bills was pending.[91]

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[89] 49 U.S.C. 32905.

[90] 60 *Federal Register* 7689, February 19, 2004.

[91] For more information on biofuel provisions in the Farm Bill, see CRS Report RL34239, *Biofuels in the 2007 Energy and Farm Bills: A Side-by-Side Comparison*, by Brent D. Yacobucci, Randy Schnepf, and Tom Capehart.

Conclusion

Although the use of fuel ethanol has been limited to date (only about 3% to 5% of gasoline consumption), it has the potential to significantly displace *petroleum* demand. However, the overall benefits in terms of *energy* consumption and greenhouse gases are limited, especially in the case of corn-based ethanol. With only a slight net energy benefit from the use of corn-based ethanol, transportation energy demand is essentially transferred from one fossil fuel (petroleum) to another (natural gas and/or coal). There may be strategic benefits from this transfer, especially if the replacement fuel comes from domestic sources or from foreign sources in more stable areas. However, the benefits in terms of greenhouse gas emissions reductions is limited.

Cellulosic feedstocks have the potential to dramatically improve the benefits of fuel ethanol. Their use could significantly decrease the energy (from all sources) required to produce the fuel, as well as decreasing associated greenhouse gases. However, technologies to convert cellulose to ethanol at competitive costs seem distant. For this reason, there is wide support for increased federal R&D.

Federal incentives for ethanol use — including tax incentives, the RFG oxygenate standard, and the renewable fuels standard — have promoted significant growth in the ethanol market. Annual U.S. ethanol production increased from 175 million gallons in 1980 to 6.8 billion gallons in 2007, largely as a result of these incentives. Federal incentives drive demand for the fuel, as well as making its price competitive with gasoline.

Enacted as part of the Energy Policy Act of 2005 and expanded by the Energy Independence and Security Act of 2007, the renewable fuels standard will continue to drive growth in the ethanol market, as it mandates a minimum annual amount (increasing yearly) of renewable fuel in gasoline. While other fuels will be used to some extent to meet the standard, the a large share of the mandate will be met with ethanol. The increasing demand for ethanol may lead to price pressures on motor fuel. These price pressures — and ethanol supply concerns in general — could increase interest in eliminating the tariff on imported ethanol.

Congress will likely continue to show interest in ethanol's energy and environmental costs and benefits, as well as its effects on U.S. fuel markets. Any discussion of U.S. energy policy includes promotion of alternatives to petroleum. With limited petroleum supplies, high prices, and instability in some oil-producing regions, these discussions are unlikely to end any time soon.