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Ethanol and Biofuels: Agriculture, Infrastructure, and Market Constraints Related to Expanded Production

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Summary

High petroleum and gasoline prices, concerns over global climate change, and the desire to promote domestic rural economies have greatly increased interest in biofuels as an alternative to petroleum in the U.S. transportation sector. Biofuels, most notably corn-based ethanol, have grown significantly in the past few years as a component of U.S. motor fuel supply. Ethanol, the most commonly used biofuel, is blended in nearly half of all U.S. gasoline (at the 10% level or lower in most cases). However, current biofuel supply represents less than 4% of total gasoline demand.

While recent proposals have set the goal of significantly expanding biofuel supply in the coming decades, questions remain about the ability of the U.S. biofuel industry to meet rapidly increasing demand. Current U.S. biofuel supply relies almost exclusively on ethanol produced from Midwest corn. In 2006, 17% of the U.S. corn crop was used for ethanol production. To meet some of the higher ethanol production goals would require more corn than the United States currently produces, if all of the envisioned ethanol was made from corn.

Due to the concerns with significant expansion in corn-based ethanol supply, interest has grown in expanding the market for biodiesel produced from soybeans and other oil crops. However, a significant increase in U.S. biofuels would likely require a movement away from food and grain crops. Other biofuel feedstock sources, including cellulosic biomass, are promising, but technological barriers make their future uncertain.

Issues facing the U.S. biofuels industry include potential agricultural "feedstock" supplies, and the associated market and environmental effects of a major shift in U.S. agricultural production; the energy supply needed to grow feedstocks and process them into fuel; and barriers to expanded infrastructure needed to deliver more and more biofuels to the market. This report outlines some of the current supply issues facing biofuels industries, including the limitations on agricultural feedstocks, infrastructure constraints, energy supply for biofuel production, and fuel price uncertainties.

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Introduction

High petroleum and gasoline prices, concerns over global climate change, and the desire to promote domestic rural economies have raised interest in biofuels as an alternative to petroleum in the U.S. transportation sector. Biofuels, most notably corn-based ethanol, have grown significantly in the past few years as a component of U.S. motor fuels. For example, nearly half of all U.S. gasoline contains some ethanol (mostly blended at the 10% level or lower). However, current supply represents only about 3.6% of annual gasoline demand on a volume basis, and only about 2.4% on an energy basis. In 2006, the United States consumed roughly 5 billion gallons of biofuels (mostly ethanol); this 5 billion gallons was blended into roughly 65 billion gallons of gasoline. Total annual gasoline consumption is roughly 140 billion gallons.

Recent proposals, including President Bush's goal in his 2007 State of the Union Address, aim to significantly expand biofuel supply in the coming decades. The President's goal would be to expand consumption from 5 billion gallons in 2007 to 35 billion gallons in 2017. While this proposal included not just biofuels but alternative fuels (including fuels from coal or natural gas), it would likely mean a significant growth in biofuels production over the next 10 years. Other legislative proposals would require significant expansion of biofuels production in the coming decades; some proposals would require 30 billion gallons of biofuels alone by 2030 or 60 billion gallons by 2050.

Current U.S. biofuel supply relies almost exclusively on ethanol produced from Midwest corn. Other fuels that play a smaller role include ethanol from Brazilian sugar, biodiesel from U.S. soybeans, and ethanol from U.S. sorghum. A significant increase in U.S. biofuels would likely require a movement away from food and grain crops. For example, U.S. ethanol production in 2006 consumed roughly 17% of the U.S. corn crop. If only corn is used, expanding ethanol production to 35 billion gallons would require more corn than the United States currently produces, which would be infeasible. Corn (and other grains) have myriad other uses, and such a shift would have drastic consequences for most agricultural markets, including grains (since corn would compete with other grains for land), livestock (since the cost of animal feed would likely increase), and land (since total harvested acreage would likely increase). In addition to agricultural effects, such an increase in corn-based ethanol would likely affect fuel costs (since biofuels tend to be more expensive than petroleum fuels), energy supply (natural gas is a key input into corn production), and the environment (since the expansion of corn-based ethanol production raises many environmental questions). These constraints are discussed below

Due to the concerns with significant expansion in corn-based ethanol supply, interest has grown in expanding the market for biodiesel (a diesel substitute produced from vegetable and animal oils) and spurring the development of motor fuels produced from cellulosic materials (including grasses, trees, and agricultural and municipal wastes). However, all of these technologies are currently even more expensive than corn-based ethanol.

In addition to expanding domestic production of biofuels, there is some interest in expanding imports of sugar-based ethanol from Brazil and other countries. However, ethanol from Brazil is currently subject to a 54 cent-per-gallon tariff that in most years is a significant barrier to direct Brazilian imports. Some Brazilian ethanol can be brought into the United States duty free if it is dehydrated (reprocessed) in Caribbean Basin Initiative (CBI) countries. Up to 7% of the U.S. ethanol market could be supplied duty-free in this fashion, although historically ethanol dehydrated in CBI countries has only represented about 2% of the total U.S. market.

Any fuel produced from biological materials (e.g., food crops, agricultural residues, municipal waste) is generally referred to as a "biofuel." More specifically, the term generally refers to liquid transportation fuels. The most significant biofuel in the United States is ethanol produced from U.S. corn.[1] Approximately 4.9 billion gallons of ethanol were produced in the United States in 2006, mostly from corn. Other domestic feedstocks for ethanol include grain sorghum and sweet sorghum; imported ethanol (600 million gallons in 2006) is usually produced from sugar cane in Brazil. Ethanol is generally blended into gasoline at the 10% level or lower (E10). Ethanol can be used in purer forms such as E85 (85% ethanol and 15% gasoline) in vehicles specially designed for its use, although E85 represents less than 1% of U.S. ethanol consumption.

After ethanol, biodiesel is the next most significant biofuel in the United States, although 2006 U.S. production is estimated at only about 100 million gallons. Biodiesel is a diesel fuel substitute produced from vegetable and animal oils (mainly soybean oil in the United States), as well as recycled cooking grease. Other biofuels with the potential to play a role in the U.S. market include ethanol and diesel fuel substitutes produced from various biomass feedstocks containing cellulose. However, these "cellulosic" biofuels are currently prohibitively expensive relative to conventional ethanol and biodiesel. Other potential biofuels include other alcohols (e.g., methanol and butanol produced from biomass).

This report outlines some of the current supply issues facing biofuels industries, including supply limitations of agricultural feedstocks, infrastructure limitations, energy supply for fuel conversion, and fuel prices.

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[1] For more information on ethanol, see CRS Report RL33290, *Fuel Ethanol: Background and Public Policy Issues*, by Brent D. Yacobucci.

Table 1. U.S. Production of Biofuels from Various Feedstocks

Fuel	Feedstock	U.S. Production in 2006
Ethanol	Corn	4.9 billion gallons
	Sorghum	less than 100 million gallons
	Cane sugar	No production (600 million gallons imported from Brazil and Caribbean countries)
	Cellulose	No production (one demonstration plant in Canada)
Biodiesel	Soybean oil	approximately 90 million gallons
	Other vegetable oils	less than 10 million gallons
	Recycled grease	less than 10 million gallons
	Cellulose	No production
Methanol	Cellulose	No production
Butanol	Cellulose, other biomass	No production

Sources: Renewable Fuels Association; National Biodiesel Board; CRS analysis.

Issues with Corn-Based Ethanol Supply

Overview of Long-Run Corn Ethanol Supply Issues

The U.S. ethanol industry has shown rapid growth in recent years with national production increasing from 1.8 billion gallons in 2001 to 4.9 billion in 2006. This rapid growth — which is projected to continue for the foreseeable future — has important consequences for U.S. and international fuel, feed, and food markets.

Corn accounts for about 98% of the feedstocks used in ethanol production in the United States. USDA estimates that 2.15 billion bushels of corn (or 20% of the 2006 corn crop) will be used to produce ethanol during the September 2006 to August 2007 corn marketing year.[2] As of February 2, 2007, existing U.S. ethanol plant capacity was a reported 5.6 billion gallons per year (BGPY), with an additional capacity of 6.1 BGPY under construction.[3] Thus, total annual U.S. ethanol production capacity in existence or under construction as of February 2, 2007, was 11.7 billion gallons. This production capacity is well in excess of the 7.5 billion gallon supply required in 2012 by the Renewable Fuel Standard (Energy Policy Act

[2] USDA, WAOB, *World Agricultural Supply and Demand Estimates (WASDE) Report*, Jan. 12, 2007, Washington; available at [http://www.usda.gov/oce/].

[3] See Renewable Fuels Association, *Industry Statistics*, at [http://www.ethanolrfa.org/industry/statistics/].

of 2005 [P.L. 109-58]). The current pace of plant construction suggests that annual corn-for-ethanol use will likely require more than 3 billion bushels in 2007 and approach, or possibly exceed, 4 billion bushels in 2008.

The ethanol-driven surge in corn demand has fueled a sharp rise in corn prices. For example, the futures contract for March 2007 corn on the Chicago Board of Trade, rose from $2.50 per bushel in September 2006 to a contract high of over $4.16 per bushel in January 2007 (a rise of 66%). This sharp rise in corn prices owes its origins largely to increasing corn demand spurred by the rapid expansion of corn-based ethanol production capacity in the United States since mid-2006. The rapid growth in ethanol capacity has been fueled by both strong energy prices and a variety of government incentives, regulations, and programs. Major federal incentives include a tax credit of $0.51 to fuel blenders for every gallon of ethanol blended with gasoline; a Renewable Fuel Standard (RFS) that mandates a renewable fuels blending requirement for gasoline suppliers that grows annually from 4 billion gallons in 2006 to 7.5 billion gallons in 2012; and a 54¢ per gallon most-favored-nation duty on most imported ethanol.[4] A recent survey of federal and state government subsidies in support of ethanol production reported that the total annual federal support fell somewhere in the range of $5.1 to $6.8 billion per year.[5]

Market participants, economists, and biofuels skeptics have begun to question the need for continued large federal incentives in support of ethanol production, particularly when the sector would have been profitable during much of 2006 without such subsidies.[6] Their concerns focus on the potential for widespread unintended consequences that might result from excessive federal incentives adding to the rapid expansion of ethanol production capacity and the demand for corn to feed future ethanol production. These questions extend to issues concerning the ability of the gasoline-marketing infrastructure to accommodate more ethanol in fuel, the likelihood of modifications in engine design, the environmental impacts, and other considerations.

Agricultural Issues

Rapidly expanding corn-based ethanol production could have significant consequences for traditional U.S. agricultural crop production. As corn prices rise, so too does the incentive to expand corn production either by expanding onto more marginal soil environments or by altering the traditional corn-soybean rotation that dominates Corn Belt agriculture. This would crowd out other field crops, primarily soybeans, and other agricultural activities. Large-scale shifts in agricultural production activities will likely have important regional economic consequences that

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[4] For more information on incentives (both tax and non-tax) for ethanol, see CRS Report RL33572, *Biofuels Incentives: A Summary of Federal Programs,* by Brent D. Yacobucci.

[5] Koplow, Doug. *Biofuels — At What Cost? Government Support for Ethanol and Biodiesel in the United States*, Global Subsidies Initiative of the International Institute for Sustainable Development, Geneva, Switzerland, October 2006; available at [http://www.globalsubsidies.org].

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

have yet to be fully explored or understood. Further, corn production is among the most energy-intensive of the major field crops. An expansion of corn area would likely have important and unwanted environmental consequences due to the resulting increase in fertilizer and chemical use and soil erosion. The National Corn Growers Association estimates that U.S. corn-based ethanol production could expand to between 12.8 and 17.8 billion gallons by 2015 without significantly affecting agricultural markets.[7] However, as noted above, other evidence suggests effects are already being felt in the current run-up in production.

Feed Markets. Prolonged higher corn prices could have significant consequences for traditional feed markets and the livestock industries that depend on those feed markets. Corn has traditionally represented about 57% of feed concentrates and processed feedstuffs fed to animals in the United States.[8] As corn-based ethanol production increases, so do total corn demand and corn prices. Dedicating an increasing share of the U.S. corn harvest to ethanol production will likely lead to higher prices for all grains and oilseeds that compete for the same land, resulting in higher feed costs for cattle, hog, and poultry producers. In addition, supply distortions are likely to develop in protein-meal markets related to expanding production of the ethanol processing by-product Distiller's Dried Grains (DDG), which averages about 30% protein content and can substitute in certain feed and meal markets.[9] While DDG use would substitute for some of the lost feed value of corn used in ethanol processing, about 66% of the original weight of corn is consumed in producing ethanol and is no longer available for feed. Furthermore, not all livestock species are well adapted to dramatically increased consumption of DDG in their rations — dairy cattle appear to be best suited to expanding DDG's share in feed rations; poultry and pork are much less able to adapt. Also, DDG must be dried before it can be transported long distances, adding to feed costs. There may be some potential for large-scale livestock producers to relocate near new feed sources, but such relocation would likely have important regional economic effects.

Exports. The United States is the world's leading producer and exporter of corn. Increased use of corn for ethanol production could diminish U.S. capacity for exports. Since 1980 U.S. corn production has accounted for over 40% of world production, while U.S. corn exports have represented nearly a 66% share of world corn trade during the past decade. In the 2006/2007 marketing year, the United States is expected to export about 21% of its corn production.[10] Higher corn prices would likely result in lost export sales. It is unclear what type of market adjustments would occur in global feed markets, since several different grains and feedstuffs are

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[7] National Corn Growers Association, *How Much Ethanol Can Come From Corn?*, November 9, 2006, Washington.

[8] USDA, ERS, *Feed Situation and Outlook Yearbook*, FDS-2003, Apr. 2003, Washington.

[9] For a discussion of potential feed market effects due to growing ethanol production, see Bob Kohlmeyer, "The Other Side of Ethanol's Bonanza," *Ag Perspectives* (World Perspectives, Inc.), Dec. 14, 2004; and R. Wisner and P. Baumel, "Ethanol, Exports, and Livestock: Will There be Enough Corn to Supply Future Needs?," *Feedstuffs*, no. 30, vol. 76, July 26, 2004.

[10] USDA, WAOB, *WASDE Report*, Jan. 12, 2007; available at [http://www.usda.gov/oce/].

relatively close substitutes. Price-sensitive corn importers may quickly switch to alternative, cheaper sources of feed, depending on the availability of supplies and the adaptability of animal rations. In contrast, less price-sensitive corn importers, such as Japan and Taiwan, may choose to pay a higher price in an attempt to bid the corn away from ethanol plants. There could be significant economic effects to U.S. grain companies and to the U.S. agricultural sector if ethanol-induced higher corn prices caused a sustained reshaping of international grain trade.

Food vs. Fuel. A sustained rise in grain prices driven by ethanol feedstock demand could lead to higher U.S. and world food prices. Most corn grown in the United States is used for animal feed. Higher feed costs ultimately lead to higher meat prices. The feed-price effect will first translate into higher prices for poultry and hogs which are less able to use alternate feedstuffs. Dairy and beef cattle are more versatile in their ability to shift to alternate feed sources, but eventually a sustained rise in corn prices will push their feed costs upward as well. The price of corn is also linked to the price of other grains, including those destined for food markets, through competition in the feed marketplace and in the producer's planting choices for limited acreage. The price run-up in the U.S. corn market has already spilled over into price increases in the markets for soybeans and soybean oil.

Since food costs represent a relatively small share of consumer spending for most U.S. households, the price run-up is relatively easily absorbed in the short run. However, the situation is very different for lower-income households, as well as in many foreign markets, where food expenses can represent a larger portion of the household budget. Due to trade linkages, the increase in U.S. corn prices has become a concern for international markets, as well. In January, Mexico experienced riots following a nearly 30% price increase for tortillas, the country's dietary staple. In China, where corn is also an important food source, the government has recently put a halt to its planned ethanol plant expansion due to the threat it poses to the country's food security. Similarly, humanitarian groups have expressed concern for the potential difficulties that higher grain prices imply for developing countries that are net food importers.

Energy Supply Issues

Ethanol is not a primary energy source. Energy stored in biological material (through photosynthesis) must be converted into a more useful, portable fuel. This conversion requires energy. The amount and types of energy used to produce ethanol, and the feedstocks for ethanol production, are of key concern. Because of the input energy requirements, the energy and environmental benefits of corn ethanol may be limited.

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. However, while corn ethanol use displaces petroleum, its overall effect on total energy consumption is less clear. 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. Some studies find a significant positive energy balance of 1.5 or greater — in other words, the energy contained in a gallon of corn ethanol is 50% higher than the amount of energy needed to produce and distribute it. However, other studies suggest that the amount of energy needed to produce ethanol is roughly equal to the amount of energy obtained from its combustion. A review of research studies on ethanol's energy balance and greenhouse gas emissions found that most studies give corn-based ethanol a slight positive energy balance of about 1.2.[11]

Natural Gas Demand. As ethanol production increases, the energy needed to process the corn into ethanol, which is derived primarily from natural gas in the United States, can be expected to increase. For example, if the entire 4.9 billion gallons of ethanol produced in 2006 used natural gas as a processing fuel, it would have required an estimated 240 to 290 billion cubic feet (cu. ft.) of natural gas.[12] If the entire 2006 corn crop of 10.5 billion bushels were converted into ethanol, the energy requirements would be equivalent to approximately 1.4 to 1.7 trillion cu. ft. of natural gas. This would have represented about 6% to 8% of total U.S. natural gas consumption, which was an estimated 22.2 trillion cu. ft. in 2005.[13] The United States has been a net importer of natural gas since the early 1980s. Because natural gas is used extensively in electricity production in the United States, a significant increase in its use as a processing fuel in the production of ethanol would likely increase prices and imports of natural gas.

Energy Security. Despite the fact that ethanol displaces gasoline, the benefits to energy security from corn-based ethanol are not certain. As was stated above, while roughly 20% of the U.S. corn crop is used for ethanol, ethanol only accounts for approximately 2.4% of gasoline consumption on an energy equivalent basis.[14] The import share of U.S. petroleum consumption was estimated at 54% in 2004, and is expected to grow to 70% by 2025.[15] Further, as long as ethanol remains dependent on the U.S. corn supply, any threats to this supply (such as 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.

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[11] 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*, Jan. 27, 2006, pp. 506-508.

[12] CRS calculations based on energy usage rates of 49,733 Btu/gal of ethanol from Shapouri (2004), roughly 60,000 Btu/gal from Farrell (2006). Hosein Shapouri and Andrew McAloon, USDA, Office of the Chief Economist, *The 2001 Net Energy Balance of Corn-Ethanol*, 2004, Washington; Farrell, op. cit.

[13] U.S. Department of Energy (DOE), Energy Information Administration (EIA), *Annual Energy Outlook 2006 with Projections to 2030*, Table 1-Total Energy Supply and Disposition Summary, Washington; at [http://www.eia.doe.gov/oiaf/aeo/index.html].

[14] By volume, ethanol accounted for approximately 3.6% of gasoline consumption in the United States in 2006.

[15] DOE, EIA, *Annual Energy Outlook 2004 with Projections to 2025*, Washington.

Further, expanding corn-based ethanol production to levels needed to significantly promote U.S. energy security is likely to be infeasible. If the entire 2006 U.S. corn crop of 10.5 billion bushels were used as ethanol feedstock, the resultant 28 billion gallons of ethanol (18.9 billion gasoline-equivalent gallons (GEG)) would represent about 13.4% of estimated national gasoline use of approximately 141 billion gallons.[16] In 2006, an estimated 71 million acres of corn were harvested. Nearly 137 million acres would be needed to produce enough corn (20.5 billion bushels) and resulting ethanol (56.4 billion gallons or 37.8 billion GEG) to substitute for roughly 20% of petroleum imports.[17] Since 1950, the U.S. corn-harvested acreage has never reached 76 million acres. Thus, barring a drastic realignment of U.S. field crop production patterns, corn-based ethanol's potential as a petroleum import substitute appears to be limited by crop area constraints, among other factors.[18]

Infrastructure and Distribution Issues

In addition to the above concerns about raw material supply for ethanol production (both corn and energy), there are additional issues involving ethanol distribution and infrastructure. Expanding ethanol production will likely strain existing supply infrastructure. Further, expansion of ethanol use beyond certain levels will require investment in entirely new infrastructure that would be necessary to handle a higher and higher percentage of ethanol in gasoline.

Distribution Issues. Ethanol-blended gasoline tends to separate in pipelines. Further, ethanol is corrosive and may damage existing pipelines. Therefore, unlike petroleum products, ethanol and ethanol blended gasoline cannot be shipped by pipeline in the United States. Another issue with pipeline transportation is that corn ethanol must be moved from rural areas in the Midwest to more populated areas, which are often located along the coasts. This shipment is in the opposite direction of existing pipeline transportation, which moves gasoline from refiners along the coast to other coastal cities and into the interior of the country. While some studies have concluded that shipping ethanol or ethanol-blended gasoline via pipeline could be feasible, no major U.S. pipeline has made the investments to allow such shipments.[19]

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[16] Based on USDA's Jan. 12, 2007, *World Agricultural Supply and Demand Estimates (WASDE) Report*, and using comparable conversion rates.

[17] This represents roughly half of gasoline's share of imported petroleum. However, petroleum imports are primarily unrefined crude oil, which is then refined into a variety of products. CRS calculations assume corn yields of 150 bushel per acre and an ethanol yield of 2.75 gal/bu.

[18] Two recent articles by economists at Iowa State University examine the potential for obtaining a 10 million acre expansion in corn planting: Bruce Babcock and D. A. Hennessy, "Getting More Corn Acres From the Corn Belt"; and Chad E. Hart, "Feeding the Ethanol Boom: Where Will the Corn Come From?" *Iowa Ag Review*, Vol. 12, No. 4, Fall 2006.

[19] Some small, proprietary ethanol pipelines do exist. American Petroleum Institute, *Shipping Ethanol Through Pipelines*. Available at [http://www.api.org/aboutoilgas/sectors /pipeline/upload/pipelineethanolshipment-2.doc]

Thus, the current distribution system for ethanol is dependent on rail cars, tanker trucks, and barges. These deliver ethanol to fuel terminals where it is blended with gasoline before shipment via tanker truck to gasoline retailers. However, these transport modes lead to higher prices than pipeline transport, and the supply of current shipping options (especially rail cars) is limited. For example, according to industry estimates, the number of ethanol carloads has tripled between 2001 and 2006, and the number is expected to increase by another 30% in 2007.[20] A significant increase in corn-based ethanol production would further strain this tight transport situation.

Because of these distribution issues, some pipeline operators are seeking ways to make their systems compatible with ethanol or ethanol-blended gasoline. These modifications could include coating the interior of pipelines with epoxy or some other, corrosion-resistant material. Another potential strategy could be to replace all susceptible pipeline components with newer, hardier components. However, even if such modifications are technically possible, they will likely be expensive, and could further increase ethanol transportation costs.

Higher-Level Ethanol Blends. One key benefit of gasoline-ethanol blends up to 10% ethanol is that they are compatible with existing vehicles and infrastructure (e.g., fuel tanks, retail pumps, etc.). All automakers that produce cars and light trucks for the U.S. market warranty their vehicles to run on gasoline with up to 10% ethanol (E10). As a major producer of ethanol for its domestic market, Brazil has a mandate that all of its gasoline contain 20-25% ethanol. For the United States to move to E20 (20% ethanol, 80% gasoline), it may be that few (if any) modifications would need to be made to existing vehicles and infrastructure. Vehicle testing, however, would be necessary to determine whether new vehicle parts would be required, or if existing vehicles are compatible with E20. Similar testing would be necessary for terminal tanks, tanker trucks, retail tanks, pumps, etc.

There is also interest in expanding the use of E85 (85% ethanol, 15% gasoline). Current E85 consumption represents only approximately 1% of ethanol consumption in the United States. A key reason for the relatively low consumption of E85 is that relatively few vehicles operate on E85. The National Ethanol Vehicle Coalition estimates that there are approximately six million E85-capable vehicles on U.S. roads,[21] as compared to approximately 230 million gasoline- and diesel-fueled vehicles.[22] Most E85-capable vehicles are "flexible fuel vehicles" or FFVs. An FFV can operate on any mixture of gasoline and between 0% and 85% ethanol. However, owners of a large majority of the FFVs on U.S. roads choose to fuel them exclusively

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[20] Ilan Brat and Daniel Machalaba, "Can Ethanol Get a Ticket to Ride?," *The Wall Street Journal*, Feb. 1, 2007, p. B1.

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

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

with gasoline, largely due to higher per-mile fuel cost[23] and lower availability of E85.

However, E85 capacity is expanding rapidly, with the number of E85 stations roughly doubling between February 2006 and February 2007. But those stations still represent less than 1% of U.S. gasoline retailers. Further expansion will require significant investments, especially at the retail level. If a new E85 pump and underground tank are necessary, they can cost as much as $100,000 to $200,000 to install.[24] However, if existing equipment can be used with little modification, the cost could be less than $10,000.

Sugar Ethanol

Excluding feedstock costs, producing ethanol from sugar cane can be less costly than producing it from corn. This is because the starch in corn must first be broken down into sugar, before it can be fermented, adding costly processing. Further, sugar cane waste (bagasse) can be burned to provide process energy for the ethanol plant, reducing associated energy costs, and improving sugar ethanol's energy balance relative to corn ethanol. Using sugar cane, Brazil produces nearly as much ethanol as the United States, but its passenger vehicle fuel demand is roughly 90% lower.

Brazil's success at integrating sugar ethanol into the fuel supply has stimulated interest in adopting Brazilian practices in the United States. However, differences in market prices for sugar in the two countries cause the economics of sugar-based ethanol to differ significantly. USDA concluded that producing sugar cane ethanol in the United States would be more than twice as costly as U.S. corn ethanol and nearly three times as costly as Brazilian sugar ethanol.[25] Feedstock costs accounted for most of this price differential. Therefore, the USDA study shows that while sugar ethanol may be a positive energy strategy in other countries, it may not be economical in the United States.

Because of the above cost advantage, it is expected that any sugar ethanol used in the United States will continue to be Brazilian ethanol reprocessed in Caribbean Basin Initiative (CBI) countries or imported directly from Brazil. Up to 7% of the U.S. ethanol market can be met duty-free with Brazilian ethanol dehydrated in CBI countries.[26] While only about 2% of the U.S. market historically has been supplied in this manner, there is growing interest among investors in expanding CBI dehydration capacity to approach the 7% quota. Further, high ethanol prices in recent

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[23] Ethanol has a lower energy content than gasoline per gallon. Therefore, FFVs tend to have lower fuel economy when operating on E85. For the use of E85 to be economical, the pump price for E85 must be low enough to make up for the decreased fuel economy relative to gasoline. Generally, to have equivalent per-mile costs, E85 must cost 20% to 30% less per gallon at the pump than gasoline.

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

[25] USDA, *The Economic Feasibility of Ethanol Production from Sugar in the United States*, July 2006, Washington.

[26] For more information, see CRS Report RS21930, *Ethanol Imports and the Caribbean Basin Initiative*, by Brent D. Yacobucci.

years (mostly brought on by the elimination of MTBE, another gasoline blending component) have led to a significant increase in direct imports from Brazil despite the tariff.

Biodiesel

Biodiesel is a diesel fuel substitute produced from agricultural products. While the term is generally used to refer to fuel produced from vegetable oils (such as soybean oil or palm oil), it can also be produced from animal fats and recycled cooking grease.[27] Further, research is underway on gasification and other processes to convert cellulose and biomass waste products into synthetic diesel fuel. Biodiesel has the key advantage of being largely compatible with existing infrastructure and vehicles. Most diesel engines can run on low-percentage blends of biodiesel and conventional diesel, and most new diesel engines can likely tolerate significantly higher percentage blends.[28] Further, although there is little experience with transporting biodiesel in pipelines, the fuel may be more compatible with existing infrastructure than ethanol.

Currently, U.S. biodiesel production and consumption are significantly lower than ethanol: approximately 100 million gallons of biodiesel were produced in 2006, compared to roughly 5 billion gallons of ethanol. However, in relative terms, biodiesel production has been expanding rapidly, with U.S. production roughly quadrupling between 2004 and 2006. Like ethanol, there are limits on the amount of biodiesel that could be produced from existing agricultural products. If all U.S. oilseed production, available animal fats, and recycled grease were used for biodiesel production, only about 4 billion gallons of biodiesel could be produced annually — less than current U.S. production of corn-based ethanol.[29]

Despite the limitations on current feedstock supply for biodiesel, like ethanol there is the potential in the future to produce a significantly greater amount of biodiesel from cellulosic materials.

Cellulosic Biofuels

Ethanol and biodiesel produced from cellulosic feedstocks, such as prairie grasses and fast-growing trees, have the potential to improve the energy and environmental effects of U.S. biofuels. Further, moving away from feed and food crops to dedicated energy crops could avoid some of the agricultural supply and price concerns discussed above. Although research is ongoing, there are no demonstration- or commercial-scale cellulosic biofuel plants in the United States at this time, and

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[27] For more information on biodiesel, see CRS Report RL32712, *Agriculture-Based Renewable Energy Production*, by Randy Schnepf.

[28] Currently, few engine and vehicle manufacturers warranty their engines at levels higher than B5 (5% biodiesel, 95% conventional diesel), but research and testing are ongoing.

[29] Randy Schnepf, *Agriculture-Based Renewable Energy Production*, CRS Report RL32712, January 8, 2007.

there is only one demonstration-scale plant in Canada.[30] A major barrier to cellulosic fuel production is that production costs still remain significantly higher than for corn ethanol or other alternative fuels. Currently, various production processes are prohibitively expensive, including physical, chemical, enzymatic, and microbial treatment and conversion of these feedstocks into motor fuel.

A key potential benefit of energy crops (e.g., prairie grasses, fast-growing trees) is that they can be grown without the need for chemicals. Reducing or eliminating the need for chemical fertilizers would address one of the largest energy inputs for corn-based ethanol production. Using biomass to power a biofuel production plant could further reduce fossil fuel inputs. Improving the net energy balance of ethanol would also reduce net fuel cycle greenhouse gas emissions.

However, increases in per-acre yields would be required to make energy crops for fuel production economically competitive. Questions remain whether high yields can be achieved without the use of fertilizers and pesticides. Another question is whether there is sufficient feedstock supply available. USDA estimates that by 2030 1.3 billion tons of biomass could be available for bioenergy production (including electricity from biomass, and fuels from corn and cellulose).[31] From that, enough biofuels could be produced to replace roughly 70 billion gallons of gasoline per year. However, this projection assumes significant increases in per-acre yields and, according to USDA, should be seen as an upper bound on what is possible. Further, new harvesting machinery would need to be developed to guarantee an economic supply of cellulosic feedstocks.[32]

In addition to the above concerns, other potential environmental drawbacks associated with cellulosic fuels must be addressed, such as the potential for soil erosion, runoff, and the spread of invasive species.

Conclusion

There is continuing interest in expanding the U.S. biofuel industry as a strategy for promoting energy security and environmental goals. However, there are limits to the amount of biofuels that can be produced and questions about the net energy and environmental benefits they would provide. Further, rapid expansion of biofuel production may have many unintended and undesirable consequences for agricultural

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[30] However, on February 28, 2007, DOE announced $385 million in grant funding for six cellulosic ethanol plants in six states. If operational, combined capacity of these six plants would be 130 million gallons per year. DOE, *DOE Selects Six Cellulosic Ethanol Plants for Up to $385 Million in Federal Funding*, February 28, 2007, Washington.

[31] Oak Ridge National Laboratory for DOE and USDA, *Biomass as a Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply*, April 2005, Oak Ridge, TN.

[32] For example, the study assumes roughly 400 million tons of biomass from agricultural residues. To economically supply those residues to biofuel producers, farm equipment manufacturers would likely need to develop one-pass harvesters that could collect and separate crops and crop residues at the same time.

commodity costs, fossil energy use, and environmental degradation. As policies are implemented to promote ever-increasing use of biofuels, the goal of replacing petroleum use with agricultural products must be weighed against these other potential consequences.