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Selected Issues Related to an Expansion of the Renewable Fuel Standard (RFS)

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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 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 more than half of all U.S. gasoline (at the 10% level or lower in most cases). However, current biofuels supply of 6.8 billion gallons only represents about 4% of total vehicle fuel demand.

The Energy Independence and Security Act of 2007 (EISA, P.L. 110-140) requires ever-larger amounts of biofuels produced from feedstocks other than corn starch, including sugarcane, oil crops, and cellulose, and promotes the development of these fuels. EISA requires the use of 36 billion gallons of renewable fuels annually in 2022, of which only 15 billion gallons can be ethanol from corn starch. The remaining 21 billion gallons are to be so-called "advanced biofuels." The previous RFS in the Energy Policy Act of 2005 (P.L. 109-58) required the use of only 7.5 billion gallons in 2012, increasing to an expected 8.6 billion gallons in 2022, of which only 250 million gallons of cellulosic biofuels would be required.

Although EISA has set the goal of significantly expanding biofuels supply and use in the coming decades, questions remain about the ability of the U.S. biofuels industry to meet the rapidly increasing mandate. Current U.S. biofuels supply relies almost exclusively on ethanol produced from Midwest corn. During the 2008 crop year, 31% of the U.S. corn crop is projected to be used for ethanol production.

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 as feedstocks. Other biofuels 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, the associated market and environmental effects of a major shift in U.S. agricultural production; the energy consumed to grow feedstocks and process them into fuel, and barriers to expanded infrastructure needed to deliver more and more biofuels to the market. Key questions are whether a renewable fuel mandate is the most effective policy to promote the above goals, if government intervention in the industry is appropriate, and, if so, what level is appropriate. This report outlines some of the current supply issues facing biofuels industries, including implications for agricultural feedstocks, infrastructure concerns, energy supply for biofuels production, and fuel price uncertainties.

This report supersedes CRS Report RL34265, *Selected Issues Related to an Expansion of the Renewable Fuel Standard (RFS)*, by Brent D. Yacobucci and Tom Capehart.

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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. More than half of all U.S. gasoline contains some ethanol (mostly blended at the 10% level or lower). However, current supply represents only about 5% of annual gasoline demand on a volume basis, and only about 3% on an energy basis. In 2007, the United States consumed roughly 6.8 billion gallons of ethanol; this 6.8 billion gallons was blended into roughly 136 billion gallons of gasoline.

In his 2007 State of the Union Address, President Bush expressed support for expanding biofuels supply significantly in the coming decades. President Bush proposed expanding consumption from 5 billion gallons in 2007 to 35 billion gallons in 2017. Although this proposal included not just biofuels but alternative fuels in general (including fuels from coal or natural gas), it suggested a significant growth in biofuels production over the next 10 years. Legislative proposals in the 110th Congress would have required significant expansion of biofuels production in the coming decades; some proposals would have required 30 billion gallons of biofuels alone by 2030 or 60 billion gallons by 2050. The Energy Independence and Security Act of 2007 (EISA, P.L. 110-140) contains a renewable fuel standard (RFS) that requires the use of 36 billion gallons in 2022, including 21 billion gallons of "advanced biofuels."[1] The law limits ethanol from corn starch under the RFS to 15 billion gallons beginning in 2015.

Current U.S. biofuels supply relies almost exclusively on ethanol produced from Midwest corn (**Table 1**). 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 2008 is projected to consume roughly 31% of the U.S. corn crop. Under the expanded RFS, the 15 billion gallon corn ethanol cap would place a call on nearly half the volume of corn produced in 2008. Corn (and other grains) have myriad other uses, and such a shift could have drastic consequences for most agricultural inputs:

- grains—because corn would compete with other grains for land;
- livestock—because the cost of animal feed would likely increase; and
- land—because total harvested acreage would likely increase.

In addition to agricultural effects, such an increase in corn-based ethanol would likely have other effects, including:

- fuel costs—because biofuels tend to be more expensive than petroleum fuels;

[1] The term "advanced biofuels" comes from legislation in the 110th Congress, and is defined in Section 201 of the Energy Independence and Security Act of 2007 (EISA). In many cases, the definition of "advanced biofuels" includes mature technologies and fuels that are currently produced in large amounts. For example, the EISA definition of "advanced biofuels" potentially includes ethanol from sugarcane, despite the fact that Brazilian sugar growers have been producing fuel ethanol for decades. EISA defines "advanced biofuels" as biofuels other than ethanol derived from corn starch (kernels) having 50% lower lifecycle greenhouse gas emissions relative to gasoline. Possible fuels include biodiesel from oil seeds, ethanol from sugarcane, and ethanol from cellulosic materials (including non-starch parts of the corn plant, such as the stalk).

- energy supply—because natural gas is a key input into corn production; and
- the environment—because the expansion of corn-based ethanol production raises many environmental questions.

These concerns are discussed below.

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

Fuel	Feedstock	U.S. Production in 2007
Ethanol	Corn	6.5 billion gallons
	Sorghum	less than 100 million gallons
	Cane sugar	No production (450 million gallons imported from Brazil and Caribbean countries)
	Cellulose	No production (one demonstration plant in Canada)
Biodiesel	Soybean oil	approximately 470 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

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

Biofuels Defined

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. As stated above, the most significant biofuel in the United States is ethanol produced from corn. Approximately 6.5 billion gallons of ethanol were produced in the United States in 2007,[2] mostly from corn. Other domestic feedstocks for ethanol include grain sorghum and sweet sorghum; imported ethanol (435 million gallons in 2007) is usually produced from sugar cane in Brazil. Ethanol is generally blended into gasoline at the 10% level (E10) or lower. It 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.

Due to concerns over the 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, mainly soybean oil) and spurring the development of motor fuels produced from cellulosic materials including grasses, trees, and agricultural and municipal wastes. However, all of these

[2] An additional roughly 4 billion gallons were imported, mostly from Brazil and Caribbean Basin Initiative (CBI) countries.

so-called advanced biofuels technologies are currently even more expensive than corn-based ethanol (with the exception of ethanol produced from Brazilian sugarcane).

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 $0.54 per gallon tariff that in most years is a significant barrier to direct Brazilian imports.[3] Some Brazilian ethanol can be brought into the United States duty free if it is dehydrated (reprocessed) in Caribbean Basin Initiative (CBI) countries.[4] Up to 7% of the U.S. ethanol market could be supplied duty-free in this fashion; historically, however, ethanol dehydrated in CBI countries has only represented about 2% of the total U.S. market.

After ethanol, biodiesel is the next most significant biofuel in the United States, although 2007 U.S. production is estimated at only 491 million gallons,[5] compared to roughly 45 billion gallons of on-road diesel fuel in the same year.[6] Other biofuels with the potential to play a role in the U.S. market include diesel fuel substitutes and ethanol 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 issues related to the RFS established in the Energy Policy Act of 2005 (P.L. 109-58) and expanded in the EISA of 2007, including implications for agricultural feedstocks, infrastructure constraints, environmental concerns, energy supply issues, and fuel prices.

The Renewable Fuel Standard (RFS)

RFS in the Energy Independence and Security Act of 2007 (P.L. 110-140)

Section 202 of EISA requires the use of 9 billion gallons of renewable fuels in 2008, increasing annually to reach 36 billion gallons in 2022. Previously, the Energy Policy Act of 2005 (P.L. 109-58) required, starting in 2006, the use of 4.0 billion gallons of renewable fuels, increasing to 7.5 billion in 2012.Beginning in 2015, only 15 billion gallons can be ethanol from corn starch. Any additional volume is not credited toward the annual mandate under the RFS. The remaining 21 billion gallons in 2022 are to be so-called “advanced biofuels.” Currently, production of advanced biofuels is limited to ethanol derived from sugar and biodiesel. Although the RFS has been called an ethanol mandate, there is no explicit requirement to use ethanol. Although there are specific

3 In 2006 ethanol prices rose sharply, and direct imports from Brazil rose sharply, despite the tariff.

4 For more information on CBI imports, see CRS Report RS21930, *Ethanol Imports and the Caribbean Basin Initiative (CBI)*, by Brent D. Yacobucci.

5 DOE-EIA Annual Energy Review 2007, Report No. DOE/EIA-0384(2007), June 23, 2008, http://www.eia.doe.gov/emeu/aer/pdf/pages/sec10_11.pdf.

6 U.S. Energy Information Administration, *U.S. Product Supplied for Crude Oil and Petroleum Products*, Washington, DC, July 28, 2008, http://tonto.eia.doe.gov/dnav/pet/pet_cons_psup_dc_nus_mbbl_a.htm.

requirements for the use of biodiesel and other renewable fuels, it is expected that, in the early years, the vast majority of the RFS will be met using ethanol produced from corn starch.

This report examines the specific issues regarding the implementation of the expanded RFS contained in EISA, but does not address the broader public policy issue surrounding how best to support U.S. energy policy.

RFS as Public Policy

The expansion in the RFS could have significant policy implications. Issues include questions of energy/petroleum security, pollutant and greenhouse gas emissions, agricultural commodity and food market effects, land use and conservation, and infrastructure costs. Proponents of mandated biofuels use respectively claim that an RFS would promote the general public interest on several different policy fronts, while opponents disagree. For example, supporters of an RFS claim it would serve several public policy interests including:

- reduced investment risk by guaranteeing demand for a projected period (such risk would otherwise keep significant investment capital on the sidelines);
- enhanced energy security via the production of liquid fuel from a renewable domestic source resulting in decreased reliance on imported fossil fuels (the U.S. currently imports over half of its petroleum, two-thirds of which is consumed by the transportation sector); and
- enhanced environmental benefits (most biofuels are non-toxic, biodegradable, use renewable resources, etc.).

Critics of an RFS have taken issue with many specific aspects of biofuels production and use, but a general public policy criticism of the RFS is that, by picking the "winner," policymakers may exclude or retard the development of other, potentially more preferable alternative energy sources.[7] They contend that biofuels are given a huge advantage via billions of dollars of annual subsidies which distort investment markets by redirecting venture capital and other investment dollars away from competing alternative energy sources. Instead, these critics have argued for a more "technology neutral" policy such as a carbon tax, a cap-and-trade system of carbon credits, or a floor price on imported petroleum.

The Expanded RFS Defined

The expanded RFS includes all motor fuel, as well as heating oil (**Table 2**). It reaches 13.2 billion gallons (bgal.) in 2012 (compared with the previous RFS of 7.5 bgal.); 15 bgal. by 2015; and 36 bgal. in 2022. However, the corn based ethanol share of the expanded RFS is capped at 15 bgal. in 2015, and all subsequent annual increases are to be derived entirely from advanced biofuels—defined as biofuels derived from feedstocks other than corn starch. The advanced biofuels volume under the RFS reaches 21 bgal. by 2022.

[7] For example, see Bruce A. Babcock, "High Crop Prices, Ethanol Mandates, and the Public Good: Do They Coexist?" *Iowa Ag Review*, Vol. 13, No. 2, Spring 2007; and Robert Hahn and Caroline Cecot, "The Benefits and Costs of Ethanol," Working Paper 07-17, AEI-Brookings Joint Center for Regulatory Studies, November 2007.

The expanded RFS requires that renewable fuels produced in facilities that commence operation after enactment must achieve at least a 20% reduction in life-cycle greenhouse gas emissions relative to gasoline. This requirement rises to 50% for advanced biofuels, and 60% for cellulosic biofuels.

Table 2. EISA 2007 Expansion of the Renewable Fuel Standard

Year	Previous RFS in EPAct of 2005 (billion gallons)	Biofuel mandate for motor fuel, home heating oil, and boiler fuel (billion gallons)	Portion to be from advanced biofuels (i.e., not corn starch) (billion gallons)	Cap on corn starch-derived ethanol (billion gallons)
2006	4.0	4.00	0.00	4.0
2007	4.7	4.70	0.00	4.7
2008	5.4	9.00	0.00	9.0
2009	6.1	11.10	0.60	10.5
2010	6.8	12.95	0.95	12.0
2011	7.4	13.95	1.35	12.6
2012	7.5	15.20	2.00	13.2
2013	7.6 (est.)	16.55	2.75	13.8
2014	7.7 (est.)	18.15	3.75	14.4
2015	7.8 (est.)	20.50	5.50	15.0
2016	7.9 (est.)	22.25	7.25	15.0
2017	8.1 (est.)	24.00	9.00	15.0
2018	8.2 (est.)	26.00	11.00	15.0
2019	8.3 (est.)	28.00	13.00	15.0
2020	8.4 (est.)	30.00	15.00	15.0
2021	8.5 (est.)	33.00	18.00	15.0

Source: EISA, Section 202.

The RFS as amended in EISA involves two distinct components—a corn-starch-ethanol RFS and a non-corn-starch-ethanol RFS—that are best analyzed separately because the various supply and demand factors affecting their development also are fairly distinct.

Potential Issues with the Expanded RFS

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 6.5 billion gallons in 2007. This rapid growth has important consequences for U.S. and international fuel, feed, and food markets.

Corn accounts for about 97% of the feedstocks used in ethanol production in the United States. USDA projects that 3.7 billion bushels of corn (or 31% of the 2008 corn crop) will be used to produce ethanol during the September 2008 to August 2009 corn marketing year.[8] In 2007, U.S. corn production was a record 13.1 billion bushels and production in 2008 is projected pull back to 12.0 billion bushels. As of December 2008, existing U.S. ethanol plant capacity was a reported 10.8 billion gallons per year, with an additional capacity of 2.4 billion gallons under construction or available for expansion.[9] Thus, total annual U.S. ethanol production capacity in existence or under construction as of December 2008, was 13.2 billion gallons. This potential production capacity exceeds the 13.0 billion gallon supply required in 2010 by EISA. The current pace of plant construction suggests that annual corn-for-ethanol use will likely approach, or possibly exceed, 5 billion bushels by 2010.[10] However, low gasoline prices in late 2008 and the recession's impact on the industry may slow new plant construction and plant expansions.

The ethanol-driven surge in corn demand has been associated with a sharp rise in corn prices. For example, the futures contract for March 2007 corn on the Chicago Board of Trade rose 66% from $2.50 per bushel in September 2006 to a contract high of over $4.16 per bushel in January 2007. Although a record U.S. corn harvest eased upward pressure on corn prices slightly during 2007, by November 2007 prices for 2008 futures contracts were again trading at more than $4.00 per bushel. However, in the summer of 2008, Central Illinois corn prices skyrocketed to a record high $6.55 per bushel.[11] In late 2008, prices fell to below $2.00 per bushel. Volatility in the corn market is largely attributed to the link between the use of corn for both food and fuel. Both USDA and the Food and Agricultural Policy Research Institute (FAPRI) (**Table 3**), in their annual agricultural baseline reports, project corn prices to remain well above $3.00 per bushel through 2016 compared with an average farm price of $2.15 per bushel during the previous 10-year period (1997-2006).

This sharp rise in corn prices owed 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 51 cents to fuel blenders for every gallon of ethanol blended with gasoline; the Renewable Fuel Standard; and the 54 cents per gallon duty on most imported ethanol.[12] A recent survey of federal and state government subsidies in support of ethanol production reported that total annual federal support fell somewhere in the range of $5.4 to $6.6 billion per year—nearly $1 per gallon.[13]

[8] USDA, WAOB, *World Agricultural Supply and Demand Estimates (WASDE) Report*, December 11, 2008, Washington; available at [http://www.usda.gov/oce/].

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

[10] FAPRI, *Baseline Update for U.S. Agricultural Markets*, FAPRI-MU report #28-07,August 2007.

[11] No. 2 yellow, Central Illinois; USDA Agricultural Marketing Service; Ethanol are rack, f.o.b. Omaha, Nebraska Ethanol Board, Lincoln, NE., Nebraska Energy Office, Lincoln, NE.

[12] The blender's tax credit declines to $0.45 per gallon the first year following that in which annual production and imports exceed 7.5 billion gallons. This level is expected to have been reached in 2008 making the reduction effective in 2009. 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.

[13] Ronald Steenblik. *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, September 2007, p. 37; available at http://www.globalsubsidies.org.

The new RFS in EISA will increase these subsidies dramatically during the life of the program. Based on CRS calculations, federal biofuels subsidies will exceed $25 billion in 2022. Total liability from 2008 through 2022 is estimated at $200 billion.

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 and 2007 without such subsidies;[14] currently, profitability is less certain, and varies from company to company depending on the amount of debt carried by each company. In addition to opportunity costs, 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 and auto fleet to accommodate higher ethanol concentrations in gasoline, the likelihood of modifications in engine design, environmental impacts of increased ethanol production and use, and other considerations.

Overview of Non-Corn-Starch-Ethanol RFS Issues

Although most references to "advanced biofuels" involve cellulosic ethanol, much of the "advanced biofuels" component of the EISA RFS may be met by essentially any non-corn-starch-derived biofuels. News reports often refer to cellulosic ethanol as "nearing a break-through" or "just around the corner," but the reality is that there is considerable uncertainty about the speed with which this technology may become commercially viable even with substantial government support. A major barrier to cellulosic fuel production is that production costs remain significantly higher than for corn ethanol or other alternative fuels. Many scientists still suggest that commercialization of cellulosic ethanol is 5 to 15 years down the road.[15] Although research is ongoing, presently no commercial-scale cellulosic biofuel plants exist in the United States, and there are only a few demonstration-scale plants in the United States and Canada.[16] Currently, various production processes are prohibitively expensive, including physical, chemical, enzymatic, and microbial treatment and conversion of these feedstocks into motor fuel. For more information on cellulosic biofuels, please see CRS Report RL34738, *Cellulosic Biofuels: Analysis of Policy Issues for Congress*, by Tom Capehart.

Unintended Policy Outcomes of the "Advanced Biofuels" Mandate

Because the advanced biofuel mandate in the RFS is a fixed mandate, irrespective of prices, the above uncertainties about the production of cellulosic ethanol could have significant implications for fuel supply and fuel prices. If cellulosic ethanol production is unable to advance rapidly

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

[15] For example, the Department of Energy's goal is to make cellulosic biofuels cost-competitive with corn ethanol by 2012. Other groups are less optimistic.

[16] However, on February 28, 2007, DOE announced availability of $385 million in grant funding for six commercial-scale 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, D.C. Subsequently, 2 projects were cancelled by the recipients.

enough to meet the RFS mandate for non-corn-starch ethanol, then other unexpected biofuels sources may step in and fill the void, such as:

- domestic sorghum-starch ethanol, production of which may expand across the prairie states and in other regions less suitable for corn production;
- domestic sugar-beet ethanol or even costlier domestic biodiesel production may be undertaken to fill the mandate, and could be costly; or
- imports of Brazilian sugar-cane ethanol could expand.

Potential Benefits of the Mandate

Ethanol and biodiesel produced from cellulosic feedstocks, such as prairie grasses and fast-growing trees or agricultural waste, have the potential to improve the energy and environmental effects of U.S. biofuels while offering significant cost savings on the production side (e.g., high-yielding, grown on marginal land, perennial rather than annual). Further, moving away from feed and food crops to dedicated energy crops could avoid some of the agricultural supply and price concerns associated with corn ethanol (as discussed later in this report).

A key potential benefit of many cellulosic feedstocks is that many can be grown without chemicals. Reducing or eliminating chemical fertilizers would address one of the largest energy inputs for corn-based ethanol production. Using biomass to power a biofuels production plant could further reduce fossil fuel inputs. Improving the net energy balance of ethanol would also reduce net fuel-cycle greenhouse gas emissions, although land use change has also been raised as a potential cause of increased greenhouse gas emissions, depending on the type of land used for the feedstock production.

Cellulosic Biofuels Production Uncertainties

There are substantial uncertainties regarding both the costs of producing cellulosic feedstock as well as the costs of producing biofuels from them. Perennial crops are often slow to establish and can take several years before a marketable crop is produced. Crops heavy in cellulose tend to be bulky and represent significant problems in terms of harvesting, transporting, and storing. Seasonality issues involving the operation of a biofuels plant year-round based on a four- or five-month harvest period of biomass suggest that bulkiness is likely to matter a great deal. In addition, most marginal lands (i.e., the low-cost biomass production zones) are located far from major urban markets, making it difficult to reconcile plant location with the cost of fuel distribution.

Further, increases in per-acre yields would be required to make most cellulosic 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 annually for bioenergy production (including electricity from biomass, and fuels from corn and cellulose).[17] From that, enough biofuels could be produced to replace roughly 70 billion

[17] 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.

gallons of gasoline per year (about 4.5 million barrels per day). However, this projection assumes technological breakthroughs and 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.[18]

In addition to the above concerns, other potential environmental drawbacks associated with cellulosic fuels will need to be addressed, such as the potential for soil erosion, runoff, and the spread of invasive species (many potential biofuels crops are invasive species when introduced into non-native localities). In the near term, the obvious choice of using corn stover[19] to fuel existing corn ethanol plants has its own set of environmental trade-offs, paramount of which is the dilemma of sacrificing soil fertility gains from no- or minimum-tillage corn production.

Energy Supply Issues

Biofuels are not primary energy sources. 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 biofuels, and the feedstocks for biofuels production, are of key concern. Because of the input energy requirements, the energy and environmental benefits of biofuels and corn ethanol, particularly, 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 disruptions of U.S. oil imports. However, while use of corn ethanol as an alternative fuel 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 greater than 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.[20]

If, instead, cellulosic biomass or other feedstocks were used to produce biofuels, the energy balance could be improved. It is expected that most biofuels feedstocks other than corn in the future will require far less nitrogen fertilizer (produced from natural gas) when grown at large scale. Further, if biomass were used to provide process energy at the biofuels refinery, then the

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

[19] Stover is the above-soil part of the corn plant excluding the kernels.

[20] 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.

energy balance could be even greater. Some estimates are that cellulosic ethanol could have an energy balance of 8.0 or more.[21] Similarly high energy balances have been calculated for sugarcane ethanol and biodiesel.

An expanded RFS would certainly displace petroleum consumption, but the overall effect on lifecycle fossil fuel consumption is questionable, especially if there is a large reliance on corn-based ethanol. EISA requires an increasing amount of "advanced biofuels" resulting in reduced fossil fuel consumption relative to gasoline on a per-mile basis. As the share of advanced biofuels grows, this effect accelerates. However, by 2022, advanced biofuels will likely represent less than 10% of gasoline energy demand, so the total amount of fossil energy displaced would be less than the expected growth in fossil energy consumption from passenger transportation over the same time period.[22]

Natural Gas Demand

As ethanol production increases, the energy needed to process the corn into ethanol, which is produced primarily using natural gas in the United States, can be expected to increase. For example, if the entire 6.5 billion gallons of ethanol produced in 2007 used natural gas as a processing fuel, it would have required an estimated 315 to 380 billion cubic feet (cu. ft.) of natural gas.[23] If the entire 2007 corn crop of 13.1 billion bushels were converted into ethanol, the energy requirements would be equivalent to approximately 1.8 to 2.1 trillion cu. ft. of natural gas. This would have represented about 8% to 9% of total U.S. natural gas consumption, which was an estimated 23.1 trillion cu. ft. in 2007.[24] The United States has been a net importer of natural gas since the early 1980s. A significant increase in its use as a processing fuel in the production of ethanol—and a feedstock for fertilizer production—would likely increase U.S. demand for natural gas.

The EISA RFS proposal boosts corn ethanol production to 15 billion gallons by 2015, requiring an increase in natural gas and/or fertilizer consumption. After 2015, annual eligible corn-starch ethanol under the RFS is capped at 15 billion gallons and advanced biofuels account for increases in renewable fuel use. At that point, demand for natural gas in the biofuels sector will likely stabilize along with ethanol production.

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21 David Andress, *Ethanol Energy Balances*. November 2002.

22 For example, EIA projects that motor gasoline consumption will increase 22% between 2007 and 2011. EIA, *Annual Energy Outlook*. Table 11.

23 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.

24 U.S. Department of Energy (DOE), Energy Information Administration (EIA), *Annual Energy Outlook 2007 with Projections to 2030*, Table 1, Total Energy Supply and Disposition Summary, Washington; at http://www.eia.doe.gov/oiaf/aeo/index.html.

Energy Security[25]

Despite the fact that ethanol displaces gasoline, the benefits to energy security from ethanol are not certain. As stated above, while roughly 31% of the U.S. corn crop is used for ethanol, ethanol only accounts for approximately 3% of gasoline consumption on an energy equivalent basis.[26] The import share of U.S. petroleum consumption was estimated at 60% in 2007, and is expected to grow to 70% by 2025.[27] Further, as long as ethanol remains dependent on U.S. agricultural supplies, any threats to these supplies (such as drought), or increases in crop prices, would negatively affect the feedstock supply and raise the cost of producing enough biofuels to meet the mandate. In fact, in 1995 high corn prices—due to strong export demand—contributed to an 18% decline in ethanol production between 1995 and 1996.

Moreover, expanding corn-based ethanol production to levels needed to significantly promote U.S. energy security is likely to be infeasible. If the entire 2007 U.S. corn crop of 13.1 billion bushels were used as ethanol feedstock, the resultant 37 billion gallons of ethanol (24.6 billion gasoline-equivalent gallons (GEG)) would represent about 17% of estimated national gasoline use of approximately 143 billion gallons.[28] In 2008, a projected 78.2 million acres of corn were harvested (second largest since 1944). 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.[29] 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.[30]

The specific definition of "advanced biofuels" also affects the overall energy security picture for biofuels. For example, if ethanol from sugarcane is imported under an expanded RFS; this provides an incentive to increase imports of sugarcane ethanol, especially from Brazil. The expanded RFS also provides an incentive for imports of biodiesel and other renewable diesel substitutes from tropical countries.

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[25] A key question in evaluating the energy security benefits or costs of an expanded RFS is "what is the definition of energy security." For many policymakers, "energy security" and "energy independence" (i.e., producing all energy within our borders) are synonymous. For others, "energy security" means guaranteeing that we have reliable supplies of energy regardless of their origin. For this section, the former definition is used.

[26] By volume, ethanol accounted for approximately 4.6% of gasoline consumption in the United States in 2006, but a gallon of ethanol yields only 67% of the energy of a gallon of gasoline.

[27] DOE, EIA, Annual Energy Review 2007, Washington, June 2008, Table 5.1.

[28] This estimate is based on USDA's November 10, 2008, *World Agricultural Supply and Demand Estimates (WASDE) Report*, and using comparable conversion rates.

[29] 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 bushels per acre and an ethanol yield of 2.75 gal/bu.

[30] 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.

Energy Prices

The effects of the expanded RFS on energy prices are uncertain. If wholesale biofuels prices remain higher than gasoline prices (after all economic incentives are taken into account), then mandating higher and higher levels of biofuels would likely lead to higher gasoline pump prices. However, if petroleum prices—and thus gasoline prices—are high, the use of some biofuels might help to mitigate high gasoline prices.

Current production costs are so high for some biofuels, especially cellulosic biofuels and biodiesel from algae, that significant technological advances—or significant increases in petroleum prices—are necessary to lower their production costs to make them competitive with gasoline. Without cost reductions, mandating large amounts of these fuels would likely raise fuel prices. If a price were placed on greenhouse gas emissions—perhaps through the enactment of a cap and trade bill—then the economics could shift in favor of these fuels despite their high production costs, as they have lower fuel-cycle and life-cycle greenhouse gas emissions (see below).

Greenhouse Gas Emissions

Biofuels proponents argue that a key benefit of biofuels use is a decrease in greenhouse gas (GHG) emissions. However, some question the overall GHG benefit of biofuels, especially corn-based ethanol. There is a wide range of fuel-cycle estimates for greenhouse gas reductions from corn-based ethanol. However, most studies have found that corn-based ethanol reduces fuel-cycle GHG emissions by 10%-20% per mile relative to gasoline.[31] These estimates vary depending on several factors including the cultivation practice (e.g., minimum-tillage versus normal tillage) used to grow the corn and the fuel used to process the corn into ethanol (e.g., natural gas versus coal). These same studies find that biofuels produced from sugar cane or cellulosic biomass could reduce fuel-cycle GHG emissions by as much as 90% per mile relative to gasoline.

However, fuel-cycle analyses generally do not take changes in land use into account. For example, if a previously uncultivated piece of land is tilled to plant biofuels crops, some of the carbon stored in the field could be released. In that case, the overall GHG benefit of biofuels could be compromised.[32] One study estimates that taking land use into account (a life-cycle analysis, as opposed to a fuel-cycle analysis), the GHG reduction from corn ethanol is less than 3% per mile relative to gasoline,[33] while cellulosic biofuels have a life-cycle reduction of 50%.[34] Other recent studies indicate even smaller GHG reductions.

Biofuels produced at facilities commencing operations after the date of enactment must have a 20% life-cycle emissions reduction to qualify under the EISA expanded RFS. However, it is expected that this provision may not be relevant to a large share of conventional ethanol since

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[31] EPA, Greenhouse Gas Impacts of Expanded Renewable and Alternative Fuels Use, April 2007; Farrell et al.

[32] See Timothy Searchinger, Ralph Heimlich, and R. A. Houghton, et al., "Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change," *Science*, vol. 319, no. 5867 (February 2008).

[33] Mark A. Delucchi, Draft Report: Life Cycle Analyses of Biofuels, 2006.

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

much of the capacity to meet the 15 billion gallon cap currently exists or will come from expansions of existing plants.

Agricultural Issues

A continued expansion of corn-based ethanol production could have significant consequences for traditional U.S. agricultural crop production and rural economies. Supporters of an expanded RFS claim that increased biofuels production and use would have enormous agricultural and rural economic benefits by increasing farm and rural incomes and generating substantial rural employment opportunities.[35] However, large-scale shifts in agricultural production activities will likely also have important regional economic consequences that have yet to be fully considered or understood. As corn prices rise, so too does the incentive to expand corn production either by expanding production to more marginal soil environments or by altering the traditional corn-soybean rotation that characterizes Corn Belt agriculture. This shift could displace other field crops, primarily soybeans, and other agricultural activities. 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 increases 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.[36] However, as noted below, other evidence suggests effects, such as higher commodity prices, are already being felt in the current expansion in corn production.

Food versus Fuel

Many critics of federal biofuels subsidies and the RFS argue that a sustained rise in grain prices driven by ethanol feedstock demand likely will lead to higher U.S. and world food prices with potentially harmful effects on consumer budgets and nutrition.[37] As evidence they cite USDA's estimate that the U.S. Consumer Price Index (CPI) for all food was forecast to increase 5%-6% in 2008, and increased 4.0% in 2007, and 2.4% in 2006.[38] The average rate of increase for 1997-2006 was 2.5%.[39] Lower fuel and commodity prices are forecast to lower the increase in the CPI for all food to 3.5% to 4.5% in 2009.[40] However, in analyzing this argument it is important to distinguish between prices of farm-level crops and retail-level food products because most "food" prices are largely determined by costs and profits after the commodities leave the farm.[41] Basic

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[35] For example, see John M. Urbanchuk (Director, LECG LLC), *Contribution of the Ethanol Industry to the Economy of the United States*, white paper prepared for National Corn Growers Assoc., February 21, 2006.

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

[37] For a discussion, see the National Corn Growers Association's online "Food versus Fuel Debate," at http://www.ncga.com/news/OurView/pdf/2006/FoodANDFuel.pdf.

[38] USDA Economic Research Service, Food CPI, Prices, and Expenditures Briefing Room, http://www.ers.usda.gov/briefing/cpifoodandexpenditures/Data/cpiforecasts.htm.

[39] ERS, USDA, Briefing Room "Food CPI, Prices, and Expenditures," at http://www.ers.usda.gov/Briefing/CPIFoodAndExpenditures/consumerpriceindex.htm.

[40] Ibid.

[41] Helen H. Jensen and Bruce A. Babcock, "Do Biofuels Mean Inexpensive Food Is a Thing of the Past?" *Iowa Ag Review*, Spring 2007, Vol. 13, No. 2, pp. 1-3.

economics suggests that the price of a particular retail food item varies with a change in the price of an underlying ingredient in direct relation to the relative importance (in value terms) of that ingredient. For example, if the value of wheat in a $1.00 loaf of bread is about 10 cents, then a 20% rise in the price of wheat translates into a 2-cent rise in a loaf of bread.

As a result of corn's relatively small value-share in most retail food product prices, it is unlikely that the ethanol-driven corn price surge is a major factor in current food price inflation estimates.[42] Furthermore, economists generally agree that most retail food price increases are not due to ethanol-driven demand increases, but rather are the result of two major factors—a sharp increase in energy prices which ripples through all phases of marketing and processing channels, and the strong increase in demand for agricultural products in the international marketplace from China and India (a product of their large populations and rapid economic growth).[43]

Feed Markets

Most corn grown in the United States is used for animal feed. From 1995 through 2005, domestic feed use accounted for 58% of U.S. corn use. As corn-based ethanol production increases, so do total corn demand and corn prices. As a result, sustained higher corn prices likely will have significant consequences for traditional feed markets and the livestock industries—hog, cattle, dairy, and poultry—that depend on those feed markets. Corn traditionally has represented about 57% of feed concentrates and processed feedstuffs fed to animals in the United States.[44] Persistent high feed costs will tighten profit margins and likely squeeze out marginal livestock producers. Because economies of scale tend to favor larger producers, persistently tighter profit margins suggest a potential for increased concentration in the livestock sector. The National Cattlemen's Beef Association (NCBA) has been one of the foremost critics of an expanded RFS. Instead, the NCBA argues for a phase out of current ethanol subsidies and a more market-based approach to renewable fuels policy.[45]

The price of corn also is 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 runup in the U.S. corn market has already spilled over into price increases in the markets for soybeans and soybean oil. Supply distortions also are likely to develop in protein-meal markets related to expanded production of the ethanol processing by-product, distiller's dried grains with solubles (DDGS), which averages about 30% protein content and can substitute in certain feed and meal markets.[46] Although DDGS use would substitute for

[42] For examples, see Food & Water Watch, "Retail Realities: Corn Prices Do Not Drive Grocery Inflation," Sept. 2007; and John M. Urbanchuk (Director, LECG LLC), "The Relative Impact of Corn and Energy Prices in the Grocery Aisle," white paper prepared for National Corn Growers Association, June, 14, 2007.

[43] For examples, see Jacque Diouf, Director General of the U.N. Food and Agriculture Organization, "Why Are Food Prices Rising?" in *Financial Times Online*, November 26, 2007; http://media.ft.com/cms/s/2/f5bd920c-975b-11dc-9e08-0000779fd2ac.html?from=textlink. See also Keith Collins, Chief Economist, USDA, Testimony before the House Committee on Agriculture, October 18, 2007.

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

[45] "NCBA on Renewable Fuel Policy," NCBA Issue Backgrounder-2007; available at http://www.beefusa.org/uDocs/NCBAonRenewableFuelPolicy-2007.pdf.

[46] 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, (continued...)

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 DDGS in their rations—dairy cattle appear to be best suited to expanding DDGS's share in feed rations; poultry and pork are much less able to adapt. Also, DDGS must be dried before it can be transported long distances, adding to feed costs and consuming more fuel. There may be some potential for large-scale livestock producers to relocate near new feed sources, but such relocation likely would have important regional economic effects.

Domestic Food Prices

Although corn primarily is used as a livestock feed or for ethanol production, it is also used widely as an ingredient (albeit minor) in many processed foods, for example, soft drinks, snack foods, and baked goods. Since corn prices are a relatively small share of the price of most retail food products, their price impact is concomitantly small. Higher corn prices have their largest impact on 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. A recent economic study estimated that a 30% increase in the price of corn, and associated increases in the prices of wheat and soybeans, would increase egg prices by 8.1%, poultry prices by 5.1%, pork prices by 4.5%, beef prices by 4.1%, and milk prices by 2.7%.[47] The effect was a 1.1% increase (0.9% on at-home food and 1.3% on away-from-home food consumption) in the all-food CPI. Thus, the price impact of higher corn prices is small but important for most livestock products, and probably much smaller for most other retail food products.

(...continued)

July 26, 2004.

[47] Simla Tokgoz and others, "Emerging Biofuels: Outlook of Effects on U.S. Grain, Oilseed, and Livestock Markets," Staff Report 07-SR 101, Center for Agricultural Research and Development (CARD), Iowa State University, May 2007.

Table 3. U.S. Farm Prices for Major Agricultural Commodities

		Farm Market Prices				USDA Program Prices[0]	
				Projections			
Commodity	Unit	Average 1997-2006	Actual 2006/2007	2007/2008[b]	2012/2013[c]	Loan Rate	Target Price
Wheat[d]	$/bu	3.24	4.26	6.48	4.29	2.75	3.92
Corn[d]	$/bu	2.15	3.04	4.25	3.25	1.95	2.63
Sorghum[d]	$/bu	2.04	3.29	4.15	3.02[e]	1.95	2.57
Barley[d]	$/bu	2.38	2.85	4.02	3.11[e]	1.85	2.44
Oats[d]	$/bu	1.54	1.87	2.63	1.90[e]	1.33	1.44
Rice[d]	$/cwt	7.17	9.96	12.60	9.64	6.50	10.50
Soybeans[d]	$/bu	5.72	6.43	10.15	7.72	5.00	5.80
Soybean oil[f]	¢/lb	21.4	31.0	53.0	36.8	—	—
Soybean meal[f]	$/st	187.7	205.4	335.0	202.0	—	—
Cotton, Upland	¢/lb	50.3	46.5	57.0[c]	59.9	52.0	72.4
Choice Steers[g]	$/cwt	73.5	85.4	91.8	86.4	—	—
Barrows/Gilts[g]	$/cwt	42.2	47.3	47.1	54.3	—	—
Broilers[g]	¢/lb	37.9	64.4	76.4	77.2	—	—
Eggs[g]	¢/doz	63.7	71.8	127.7	85.4[e]	—	—
Milk[g]	$/cwt	13.91	12.90	19.13	15.7	—	—

Source: Prepared by CRS using data from sources below.

a. For more information on U.S. commodity programs see CRS Report RL34594, *Farm Commodity Programs in the 2008 Farm Bill*, by Jim Monke.

b. Unless otherwise indicated: midpoint of price projection range from USDA, *World Agricultural Supply and Demand Estimates* (WASDE), November 10, 2008.

c. Unless otherwise indicated: FAPRI, *Baseline Update for U.S. Agricultural Markets*, August 2008.

d. Season average farm price from USDA, National Agricultural Statistical Service, *Agricultural Prices*. —= no loan rate.

e. FAPRI, *U.S. Baseline Briefing Book, March 2008*, FAPRI-UMC Report #03-08.

f. USDA, Agr. Marketing Service (AMS), Decatur, IL, cash price, simple average crude for soybean oil, and simple average 48% protein for soybean meal.

g. Calendar year data for the first year, e.g., 2000/2001 = 2000; USDA, AMS: choice steers—Nebraska, direct 1100-1300 lbs.; barrows/gilts—national base, live equivalent 51%-52% lean; broilers—wholesale, 12-city average; eggs—Grade A, New York, volume buyers; and milk—simple average of prices received by farmers for all milk.

The overall impact to consumers from higher food prices depends on the proportion of income that is spent on food. Since food costs represent a relatively small share of consumer spending for most U.S. households (about 10%), food price increases (from whatever source) are absorbed relatively easily in the short run. However, low-income consumers spend a much greater proportion of their income on food than do high-income consumers. Their larger share combined with less flexibility to adjust expenditures in other budget areas means that any increase in food prices potentially could cause hardship.[48] In addition, higher commodity prices combined with shrinking inventories mean that local school districts and the U.S. government will be forced to pay higher market prices for food for school lunch programs. The automatic food price escalators built into the food stamp program, renamed as Supplemental Nutrition Assistance Program (SNAP), mean rising expenditures as well.[49]

International Food Prices

Due to trade linkages, the increase in U.S. corn prices has become a concern for international markets as well. High commodity prices ripple through international markets where impacts vary widely based on grain import dependence and the ability to respond to higher commodity prices. Import-dependent developing country markets are put at greater food security risk due to the higher cost of imported commodities. In particular, lower-income households in many foreign markets where food imports are an important share of national consumption and where food expenses represent a larger portion of the household budget may be affected by higher food prices.[50] In China, where corn is an important food source, the government recently has 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.[51]

Exports

The United States is the world's leading exporter of corn. In the past decade (1997 to 2006), the United States has exported about 20% of its corn production, accounting for nearly 66% of world corn trade.[52] Increased use of corn for ethanol production could reduce the volume of U.S. corn production available for export. In 2006, the volume of corn used for ethanol equaled exports, with a 20% share of total use. By the 2009/10 marketing year (September-August), ethanol's share of U.S. corn production is expected to reach nearly 36%, while the export share falls to 14%.[53] FAPRI projections clearly suggest that higher corn prices will result in lost export sales. It is unclear what type of market adjustments will occur in global feed markets, since several different grains and feedstuffs are 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

48 Helen H. Jensen and Bruce A. Babcock, "Do Biofuels Mean Inexpensive Food is a Thing of the Past?" *Iowa Ag Review*, Spring 2007, Vol. 13, No. 2, pp. 1-3.

49 Ibid.

50 Shahla Shapouri and Stacey Rosen, "Energy Price Implications for Food Security in Developing Countries," *Food Security Assessment, 2006*, GFA-18, Economic Research Service, USDA.

51 International Monetary Fund, *World Economic Outlook: Globalization and Inequality*. October 2007. Washington.

52 USDA, Production, Supply and Distribution Online (PSD database) available at http://www.fas.usda.gov/psdonline/psdHome.aspx.

53 FAPRI, Baseline Update for U.S. Agricultural Markets, August 2008.

U.S. agricultural sector if ethanol-induced higher corn prices led to a sustained reshaping of international grain trade.

Economic Impact

Several studies claim that increased biofuels production and use would produce enormous agricultural and rural economic benefits by raising farm and rural incomes and generating substantial rural employment opportunities.[54] One estimate suggested that the economic benefit from the ethanol industry to the U.S. economy for 2005 was $17.7 billion of GDP; the creation of over 150,000 jobs; $5.7 billion in spinoff economic activity; and more than $3.5 billion in government tax revenues.[55] However, a recent critical review of the standard input-output methodology used to generate such economic impact estimates suggests that the income and job growth attributable to biofuels production has been grossly overstated, perhaps by as much as a factor of four or five.[56] Yet, while the magnitude may be called into question, there appears to be no doubt about the potential positive value of biofuels production to rural economies. First, in addition to temporary construction work to build a new plant, several dozen permanent jobs also accompany a biofuels plant depending on the plant's operating capacity. Second, the new demand boosts the local prices received by farmers for corn and sorghum. Third, important secondary economic activity is associated with the operation of an ethanol plant. Fourth, given the high level of federal and state subsidies for the biofuels industry, any locality that is home to a biofuels plant can expect substantial net transfers of government funds into the area's economy.

The policy question of interest is not whether there are positive gains from growth in the ethanol industry, but whether the growth and its economic implications are sufficient to merit large government subsidies. A growing number of critics argue that the answer is no.[57] Others suggest that, at the very least, the issue deserves more study before continuing or expanding current government support levels.[58]

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[54] For example, see John M. Urbanchuk (Director, LECG LLC), *Contribution of the Ethanol Industry to the Economy of the United States*, white paper prepared for National Corn Growers Assoc., February 21, 2006; see also Urbanchuk, *Contribution of the Biofuels Industry To the Economy of Iowa*, white paper prepared for the Iowa Renewable Fuels Association, February 2007.

[55] Urbanchuk (2006).

[56] David Swenson, "Input-Outrageous: The Economic Impacts of Modern Biofuels Production," Department of Economics, Iowa State University (ISU), June 2006. Similar results are found in: David Swenson, "Understanding Biofuels Economic Impact Claims," Department of Economics, ISU, April 2007; Lisa Eathington and Dave Swenson, "Dude, Where's My Corn? Constraints on the Location of Ethanol Production in the Corn Belt," Department of Economics, ISU, paper presented at 46th Annual Meeting of the Southern Regional Science Assoc., Charleston, SC, March 29-31, 2007; Swenson and Eathington, "Determining the Regional Economic Values of Ethanol Production in Iowa Considering Different Levels of Local Investment," Department of Economics, ISU, July 2006.

[57] Examples include Robert Hahn and Caroline Cecot, "The Benefits and Costs of Ethanol," Working Paper 07-17, AEI-Brookings Joint Center for Regulatory Studies, November 2007; Richard Doornbosch and Ronald Steenblik, "Biofuels: Is the Cure Worse Than the Disease?" paper presented at an OECD Round Table on Sustainable Development, Paris, September 11-12, 2007; and Doug Koplow, *Biofuels at What Cost? Government Support for Ethanol and Biodiesel in the United States: 2007 Update*, report prepared for the Global Studies Initiative of the International Institute for Sustainable Development, Geneva, Switzerland, October 2007.

[58] For example, see Bruce A. Babcock, "High Crop Prices, Ethanol Mandates, and the Public Good: Do They Coexist?" *Iowa Ag Review*, vol. 13, no. 2, Spring 2007.

Ethanol Infrastructure and Distribution Issues

In addition to the above concerns about raw material supply for ethanol production (both feedstock and energy), there are issues involving ethanol distribution and infrastructure. Expanding ethanol production likely will strain the existing supply infrastructure. Further, expansion of ethanol use beyond the current 10% blend will require investment in entirely new infrastructure that would be necessary to handle a higher and higher percentage of ethanol in gasoline. If biomass-based diesel substitutes are produced in much larger quantities, some of these infrastructure issues may be mitigated.

Distribution Issues

Ethanol-blended gasoline tends to separate in pipelines due to the presence of water in the lines. Further, ethanol is corrosive and may damage existing pipelines and storage tanks. 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.[59]

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 prices higher than for 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, although final data is not yet available.[60] 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 likely will be expensive, and could further increase ethanol transportation costs.

As non-corn biofuels play a larger role, as required in EISA, some of the supply infrastructure concerns may be alleviated. Cellulosic biofuels potentially can be produced from a variety of feedstocks, and may not be as dependent on a single crop from one region of the country. For example, municipal solid waste is ubiquitous across the United States, and could serve as a ready feedstock for biofuels production if the technology were developed to convert it economically to fuel. Further, increased imports of biofuels from other countries could allow for greater use of

[59] 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.

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

biofuels, especially along the coasts. Moreover, some biofuels, especially some diesel substitutes, may be able to be mixed with petroleum fuels at the refinery and placed directly into the pipeline.

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). This 10% currently is an upper bound (sometimes referred to as the “blend wall”) to the amount of ethanol that can be introduced into the gasoline pool. If most or all gasoline in the country contained 10% ethanol, this would allow only for roughly 15 billion gallons, far less than the amount of biofuels mandated in EISA.

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 storage tanks, pumps, etc. In addition, EPA would need to certify that the fuel will not lead to increased air quality problems.

There is also interest in expanding the use of E85 (85% ethanol, 15% gasoline). Current E85 consumption represents only about 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,[61] as compared to approximately 230 million gasoline- and diesel-fueled vehicles.[62] 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, ethanol has a lower per gallon energy content than gasoline. 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. Owners of a large majority of the FFVs on U.S. roads choose to fuel them exclusively with gasoline, largely due to higher per-mile fuel cost and lower availability of E85.

E85 capacity is expanding rapidly, with the number of E85 stations nearly tripling between January 2006 and January 2008. But those stations still represent less than 1% of U.S. gasoline retailers. Further expansion will require significant investments, especially at the retail level. Installation of a new E85 pump and underground tank can cost as much as $100,000 to $200,000.[63] However, if existing equipment can be used with little modification, the cost could be less than $10,000.

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

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

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

Vehicle Infrastructure Issues

As was stated above, if a large portion of any increased RFS is met using ethanol, then the United States likely does not have the vehicles to consume the fuel. The 10% blend wall on ethanol in gasoline for conventional vehicles poses a significant barrier to expanding ethanol consumption beyond 15 billion gallons per year.[64] To allow more ethanol use, vehicles will need to be certified and warranted for higher-level ethanol blends, or the number of ethanol FFVs will need to increase. Turnover of the U.S. automobile fleet is likely to slow during the recession, making it more difficult to integrate FFVs into the fleet.

Conclusion

There is continuing interest in expanding the U.S. biofuels industry as a strategy for promoting energy security and achieving environmental goals. However, it is possible that increased biofuel production may place desired policy objectives in conflict with one another. There are limits to the amount of biofuels that can be produced from current feedstocks and questions about the net energy and environmental benefits they might provide. Further, rapid expansion of biofuels production may have many unintended and undesirable consequences for agricultural commodity costs, fossil energy use, and environmental degradation. Owing to these concerns, alternative strategies for energy conservation and alternative energy production are widely seen as warranting consideration.

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[64] Note that 15 billion gallons is the corn starch ethanol limit for the expanded RFS in the EISA.