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Three Decades of Ethanol: Has It Been Worth the Investment?

Part 1 of 3

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OCTOBER 3, 2011

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EXECUTIVE SUMMARY

Ethanol's boosters have cited three policy objectives in defense of ethanol's subsidies and import protections: Increasing the nation's energy security by reducing reliance on imported oil, reducing the environmental impact of petroleum use, and supporting U.S. farmers and rural economies.[1]

This Bloomberg Government Briefing evaluates academic and government research on ethanol's record in meeting the three goals—that is, the nation's return on its investment of almost $37 billion in subsidies since 1978 ($5.68 billion in 2010 alone). Based on a review of more than 30 government, academic and trade group studies and dozens of journal and news articles, the briefing concludes:

Energy Security — Corn-based ethanol, which represents virtually all U.S. ethanol production, can't free the nation from dependence on foreign oil. Corn is too inefficient to be more than a bit player in the nation's supplies of liquid transportation fuels. The gasoline displaced by corn ethanol in 2010 produced an "energy security" benefit of $3.36 billion. Cellulosic ethanol, derived from grasses and agricultural wastes, is more energy efficient but it has not met expectations to date because of its expensive and complex production process.

Environmental Impact — Corn-based ethanol offers modest environmental benefits compared with gasoline. Although its production and use create less greenhouse gas, it also contributes to water pollution and global deforestation and may increase smog.

Economic Impact — Ethanol contributes to increased global food prices, as higher corn demand pushes up costs throughout the food chain, from cereal makers to chicken farmers. Although the impact in the U.S. has been modest, the issue is a growing concern for developing countries dependent on grain imports.

THE GOALS OF ETHANOL POLICY

Energy Security

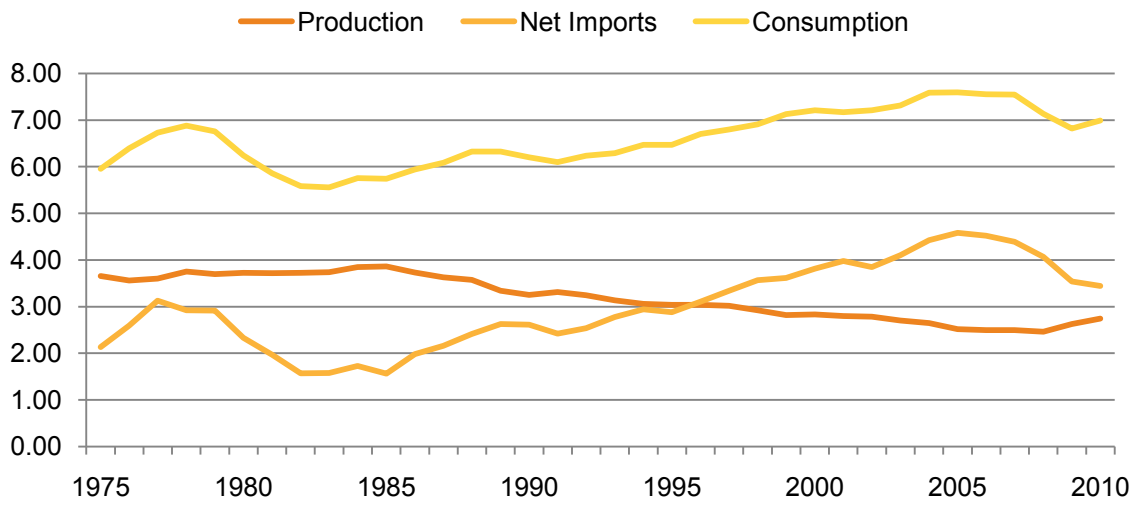
Reducing Reliance on Imported Oil

The primary argument for ethanol has always been its potential to reduce oil imports. The U.S. economy is vulnerable both to interruptions in supplies and to the pricing power of the OPEC cartel.[2] OPEC controls about 70 percent of global oil reserves, most of that in the volatile Middle East.[3] Ten of the 11 U.S. recessions since World War II have been preceded by sharp increases in oil prices, including the six downturns since 1970 (see Figure 1).[4]

Figure 1: Oil Prices and the Economy

The issue of energy security remains as salient today as it was in the 1970s. U.S. oil imports increased 61 percent between 1975 and 2010, as consumption increased 17 percent while domestic production declined by 25 percent. The U.S. imported 49 percent of its petroleum in 2010, down from a peak of 60 percent in 2005 (see Figure 2).[5]

Figure 2: U.S Petroleum Production, Consumption and Imports 1975-2010 (billions of barrels)



Despite its increasing production, corn-based ethanol has made only a limited contribution to energy independence due to its inefficiency as a fuel source. Because it takes about 1.5 gallons of ethanol to provide the 125,000 BTUs of energy in one gallon of gasoline,[6] the 13.2 billion gallons of ethanol produced in 2010 displaced about 9 billion gallons of gasoline, or 6.8 percent of U.S. gasoline consumption.[7]

Research suggests even modest reductions in U.S. demand for foreign oil can yield significant economic benefits. Research scientist Paul Leiby of Oak Ridge National Laboratory calculated that the U.S. saves about $16.63 in 2009 dollars ($16.90 in 2010 dollars) for every barrel of oil imports saved through reduced consumption or increased domestic production. About two-thirds of the benefit results from the "monopsony" component — the degree to which U.S. demand affects world crude prices. The remainder of the benefit was attributed to reducing the risk to the U.S. economy of oil price shocks and interruptions. The analysis did not attribute any savings to potential reductions in U.S. defense spending or costs of maintaining the Strategic Petroleum Reserve, because of the difficulty in ascertaining the extent to which those costs would vary with oil imports.[8] EPA has adopted Leiby's methodology in its impact analysis on the Renewable Fuels Standard, although it did didn't include the monopsony benefits in its calculation.[9] The Renewable Fuels Standard, enacted by Congress in 2005 and expanded in 2007, requires use of 15 billion gallons of renewable fuel in 2012, rising to 36 billion gallons in 2022.

Using Leiby's methodology, Bloomberg Government calculates the security value of the 8.9 billion gasoline-equivalent gallons displaced by ethanol in 2010 at $3.36 billion (see Table 1).

Table 1: Energy Security Value of Gasoline Displaced by Ethanol (2010)

Header	Header
Energy security value/barrel per Leiby (2009 $)	16.63
GDP deflator (CPI)	x 1.016
Energy security value/barrel (2010 $)	$16.89
Number of gallons refined product/barrel	/ 45
Energy security value per gallon	$0.38
2010 U.S. ethanol production (billion gallons)	13.23
Number of gallons ethanol/1 gallon gasoline	/ 1.48
Equivalent gasoline (billion gallons)	8.94
Energy security value of gasoline displaced (billion $) (per gallon value x equivalent gallons)	**$3.36**

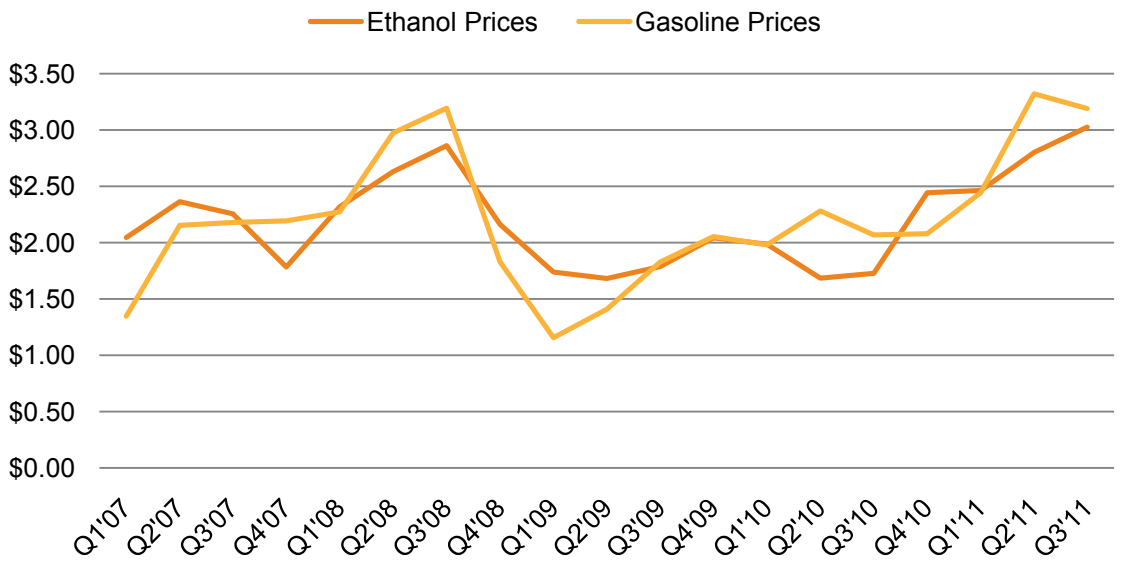
Source: Paul Leiby, Oak Ridge National Laboratory, Bloomberg Government.

Impact on Gasoline Prices

Ethanol has had a mixed record for consumers, at times reducing pump prices, sometimes increasing them, depending on the relative cost of crude oil and corn. Consumer savings at the pump, when they have occurred, have been uneven across regions.

As the congressional debate over ethanol subsidies neared its climax this summer, the Renewable Fuels Association, the industry's main trade group, ran ads claiming ethanol reduced gasoline prices by 89 cents per gallon in 2010, saving the average household more than $800 for the year.[10] The ads were based on an April 2011 RFA-funded study by economists from the University of Wisconsin and Iowa State University. The study concluded that the growth in ethanol production reduced wholesale gasoline prices by an average of 25 cents per gallon from January 2000 to December 2010. The impact was larger in 2010 because of increased ethanol production and high crude oil prices, according to the authors.[11]

Figure 3: Wholesale Ethanol and Gasoline Prices 2007-2011 (dollars per gallon)



Note: Not adjusted for mileage.

Source: Bloomberg.

A November 2008 study by McKinsey & Co. for the Department of Energy's National Renewable Energy Laboratory cast doubt on an earlier study by the RFA researchers. McKinsey reviewed the earlier Renewable Fuels Association study and four other reports, each of which found ethanol had reduced prices. McKinsey concluded that the previous studies failed to account for the reduced mileage produced by ethanol versus gasoline and improperly assumed that all savings in reduced production costs were passed on to consumers.[12] Consumers will pay more on a mileage-adjusted basis when ethanol exceeds 61.2 percent of the fossil gasoline price, the study calculated.[13]

The report concluded that mileage-adjusted retail gasoline prices were then about 17 cents a gallon lower than they would have been with no ethanol.[14] The savings result not only from the substitution effect — when the mileage-adjusted cost of ethanol is less than that of fossil gasoline — but also because ethanol's octane content allows refineries to increase the fossil gasoline yielded from a barrel of crude. The biggest cost advantage provided by ethanol is in the 22 states[15] that use cleaner-burning "reformulated" gas with a higher oxygen content. With the demise of MTBE,[16] ethanol is virtually the only oxygenate used and is about 51 cents a gallon cheaper than fossil alternatives. Because reformulated gas represents 30 percent of total U.S. consumption, the savings translate to 15 cents a gallon nationwide.

Consumers in markets where ethanol isn't widely accessible are unlikely to see any savings. Producers whose ethanol blending gives them lower production costs have no incentive to pass the savings on to consumers, the McKinsey study found, because the regional market price is set by the highest-cost producer. The Renewable Fuels Association says that is less of a factor now, with more than 90 percent[17] of gasoline containing ethanol.

Environmental Impact

Greenhouse-Gas Emissions

Lifecycle calculations attempt to capture the net greenhouse gas emissions produced during all stages of fuel and feedstock production, distribution and use. Cellulosic ethanol has the potential to reduce lifecycle greenhouse gas emissions by half or more compared with gasoline.[18] Corn ethanol's impact on greenhouse gases is more modest and the subject of much debate.

Producing and distributing corn ethanol results in more greenhouse gas emissions than gasoline made exclusively from crude oil, because planting, fertilizing and harvesting corn uses more energy from fossil fuels than the drilling, refining and delivery process for gasoline.[19]

However, corn removes carbon dioxide from the atmosphere as it grows and corn ethanol and gasoline produce similar amounts of greenhouse gas emissions in combustion.[20] The net impact of biofuels on greenhouse gas emissions is affected by the fuel feedstock (e.g., corn), the process used to convert the feedstock, the source of energy used to run it, and land-use changes resulting from conversion of forests and grassland to farming.

The impact of land-use changes is the least settled of the components determining ethanol's greenhouse gas emissions. Early studies found corn ethanol increased greenhouse gas emissions versus gasoline over a 30-year lifespan,[21] while a 2011 study by Argonne National Laboratory found that, on average, corn ethanol production and use caused 24 percent less greenhouse gas emissions than gasoline.[22] EPA's current estimates are slightly more conservative. The agency's 2010 Regulatory Impact Analysis on the expanded Renewable Fuels Standard concludes that corn ethanol at new natural gas-fired facilities using advanced technologies will cut greenhouse gases versus gasoline by more than 20 percent.[23]

Economic Impact

The ethanol industry has boosted farm economies and food prices, though the significance is disputed.

Impact on Rural Economies

Ethanol production contributed $36 billion to household incomes in 2010, generating $8.6 billion in federal tax revenue, according to an analysis conducted for the Renewable Fuels Association by economist John Urbanchuk.[24] Urbanchuk calculated that the industry directly employs more than 70,000 people — including more than 45,000 agricultural workers and 8,600 refinery plant workers — and indirectly supports an additional 330,000 jobs. He acknowledged that his analysis doesn't capture the *net* benefit to the U.S. economy because it doesn't calculate the increased economic activity that would occur in other sectors such as crude oil refining without ethanol production.[25] Critics, including the environmental advocacy group the Natural Resources Defense Council, say the RFA's analysis exaggerates the industry's impact.[26]

Eight of the 10 states with the largest increase in cropland prices from 2007 through 2011 also ranked in the top 10 for ethanol production. Nebraska, Iowa and South Dakota, three of the top five ethanol-producing states, each saw cropland values increase by more than 50 percent during the period while cropland prices nationally increased 20 percent.[27]

Pepperdine University researchers who looked at county employment and wage data for Corn Belt states found "insignificant" increases in wages and employment levels in counties with high and medium levels of ethanol production capacity compared with counties that don't produce ethanol.[28]

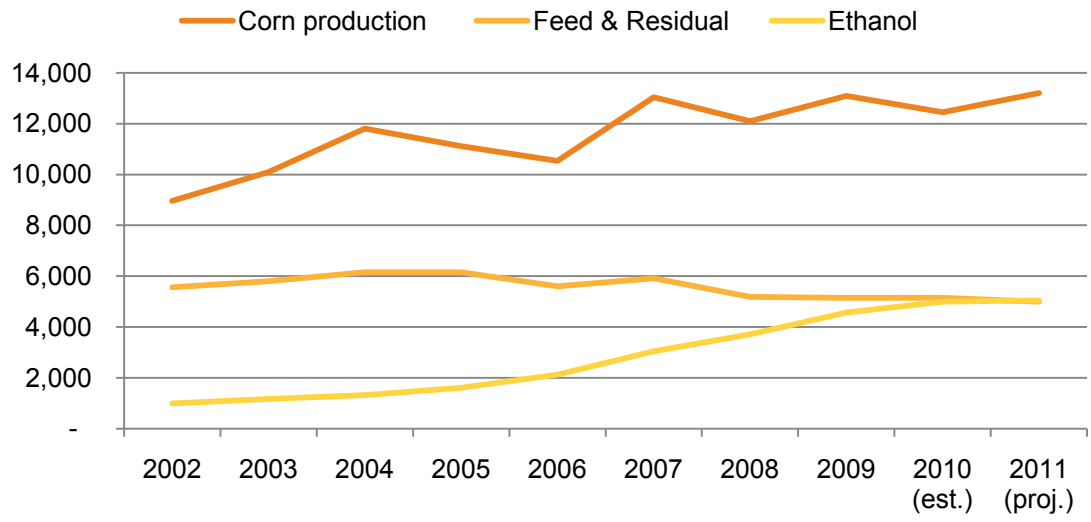
Impact on Food Prices

Ethanol now consumes about 40 percent of the U.S. corn crop, four times its share in 2002, a rise that has contributed to a debate about the impact of biofuels on food prices.[29] The "food vs. fuel" debate was crystallized in a 2007 Foreign Affairs article by two University of Minnesota economists, who asserted that filling up an SUV with pure ethanol would require "over 450 pounds of corn — which contains enough calories to feed one person for a year."[30]

Corn prices have more than tripled since 2005, nearly doubling in the last year alone. Ethanol production is one of a combination of factors that has contributed to rising corn prices, including poor harvests overseas and the weakening of the U.S. dollar, which makes U.S. exports cheaper.[31]

Although the impact of rising corn prices on U.S. consumers to date has been modest, the increasing use of food crops for biofuels (including sugar cane, soybean oil and cassava) has generated international concern.[32] Biofuels can influence prices of other crops, such as wheat, because those crops can substitute for corn in consumption and compete with corn for land and other inputs.[33]

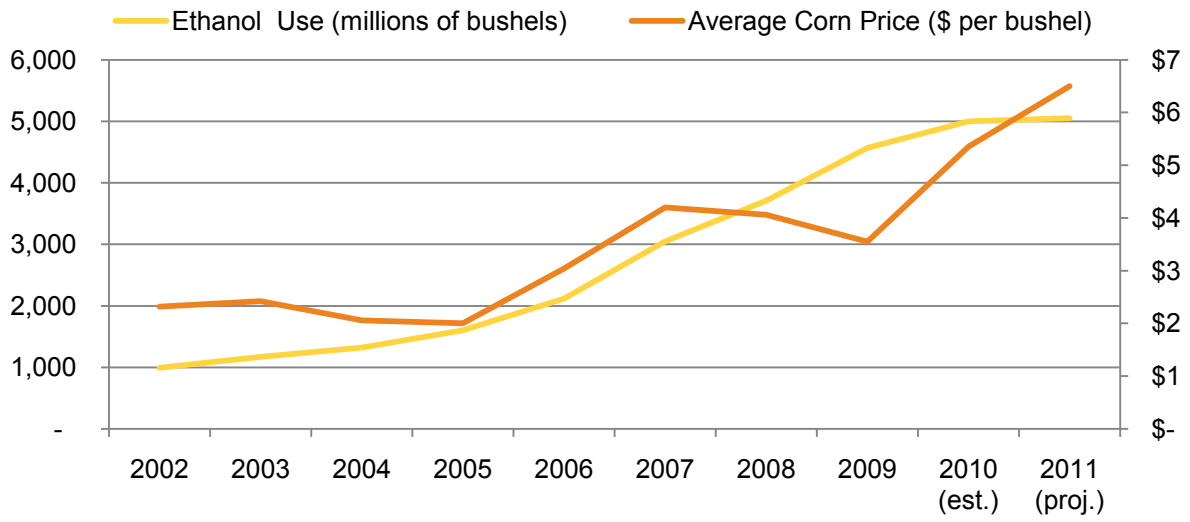
Figure 4: Ethanol's Growing Share of U.S. Corn Production (millions of bushels)



Note: Ethanol use in millions of bushels.

Source: USDA World Agricultural Supply and Demand Estimates.

Figure 5: Ethanol's Growing Share of U.S. Corn Production Accompanied a Tripling in Prices (millions of bushels)



Source: USDA World Agricultural Supply and Demand Estimates.

A June 2011 report to G-20 agriculture ministers from 10 major nongovernmental organizations, including the World Trade Organization, the World Bank and the United Nations World Food Program, concluded that mandates on biofuel production "aggravate the price inelasticity of demand that contributes to volatility in agricultural prices."[34] While food prices have long been influenced by the price of oil due to farmers' use of petroleum-based fuel and fertilizer, corn ethanol creates a more direct link between the prices of food and petroleum.[35]

A considerable body of research has concluded that corn ethanol and other biofuels have contributed, along with increasing international appetites, to rising food prices. The Congressional Budget Office estimates that the increased use of ethanol accounted for 10 percent to 16 percent of the rise in U.S. food prices between April 2007 and April 2008, requiring an increase of $675 million to $975 million in U.S. spending on federal domestic food aid programs.[36]

EPA estimates that the renewable fuels mandates will increase U.S. food costs by $10 per person per year by 2022 while cutting exports of corn and soybeans by up to 10 percent.[37] While the impact may be modest for Americans, who spend an average of 10 percent of disposable income on food,[38] even small increases can be devastating to the poor, particularly in developing countries, where food spending can consume as much as 70 percent of income.[39]

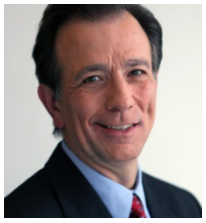
CONCLUSION

For more than three decades, proponents of ethanol have promised that the homegrown fuel would help free the U.S. from dependence on foreign oil, clean the air and revive farm economies. For as long, ethanol's critics have decried ethanol subsidies as wasteful corporate welfare that accomplished little but increased corn prices.

Ethanol's accomplishments are more modest than supporters have contended and more significant than its critics have acknowledged. Corn ethanol is now a mature technology and its limitations are clear: It's unlikely to displace more than 10 percent of U.S. gasoline consumption, providing the U.S. economy only small cushion against oil price shocks. Environmentally, it helps efforts to curb greenhouse gases but, as noted in the appendix (see page 12), it adds to fertilizer runoff and has a mixed record on ozone. Economically, it has primarily benefited farmland owners while contributing to higher grain and meat prices, a major concern to poor food-importing countries.

The final verdict on the nation's ethanol investment won't be rendered for another decade or more. Even its harshest critics may be forced to concede the wisdom of this investment if corn ethanol leads to economical second-generation biofuels, such as those produced from cellulosic feed stocks, that can displace more gasoline while not competing with food crops. As will be demonstrated in Part 3 of this series, second-generation ethanol is far from a sure thing.

»ABOUT THE ANALYST



Rich Heidorn Jr., leader of the Bloomberg Government energy analysts team, has been writing about ethanol and other energy issues for more than 25 years. He worked for 17 years as a reporter and editor for *The Philadelphia Inquirer*, where he won several state and national awards for investigative and business reporting, including the National Press Foundation's 1998 energy reporting award. After earning an MBA, he served as general manager of an Internet startup providing news and market data for electric and natural gas traders. He worked as an investigator and analyst for the Federal Energy Regulatory Commission from 2002 through 2010.

APPENDIX: ETHANOL'S UNINTENDED CONSEQUENCES

Environmental

Smog

Although EPA has touted ethanol since 1990 as a weapon against urban smog from auto pollution,[40] the agency now says increased ethanol use will increase ground-level ozone, an air pollutant harmful to breathe and a main ingredient of smog.[41]

Ground-level ozone is produced when nitrogen oxides (NOx), volatile organic compounds (VOCs), and carbon monoxide (CO) react with sunlight. The 1990 amendments to the Clean Air Act mandated use of oxygenates such as ethanol to reduce emissions of ozone precursors in regions that failed to meet air-quality standards.[42]

While the Renewable Fuels Association asserts that ethanol reduces smog pollution,[43] research since 1990 has raised questions about those benefits.[44] A 1999 study by the National Research Council, part of the National Academies, found ethanol had little impact on reducing smog and might worsen the problem in some regions.[45] The study found ethanol appeared to increase emissions of nitrogen oxides, a more important cause of smog in some regions than volatile organic compounds are, while producing only small decreases in emissions of volatile organic compounds and carbon monoxide as well as their reactivity. The study also found ozone models used by regulators were based on limited data and ignored other influences on emissions.[46]

EPA's 2010 Regulatory Impact Statement on the Renewable Fuels Standard predicts increased biofuels use will "adversely impact ozone air quality over much of the U.S., especially in the Midwest, Northeast and Southeast." EPA says expanded ethanol use will help some populous areas with poor air quality by reducing tailpipe emissions of VOCs while increasing NOx emissions at production facilities in areas where that pollutant is a bigger contributor to ozone.[47]

Like oil refineries, ethanol production facilities can release air pollutants that contribute to smog. Through fiscal year 2006, EPA reached settlements with 27 ethanol producers and grain processors to reduce more than 100,000 tons a year of pollutants at a cost of more than $384 million.[48]

The agency also predicts increased biofuels use will result in more particulate-matter pollution. It estimates an additional 69 to 245 premature deaths a year by 2022 from ozone and particulate exposure related to increased biofuels use.[49]

Fertilizer Runoff, Recultivation

Biofuel production can harm ground and surface water quality because of erosion and fertilizer runoff from cornfields. More than a quarter of the nitrogen applied to corn fields typically ends up in water supplies. EPA has blamed fertilizer runoff as a contributor to the so-called dead zone in the Gulf of Mexico, an area in which oxygen concentrations fall below the level needed to sustain most animal life.[50] The agency predicts nitrogen and

phosphorus levels in the Mississippi River will increase about 1 percent by 2022 as a result of increased biofuels use.[51]

In addition, ethanol production threatens to undercut the USDA's Conservation Reserve Program, which pays farmers to set aside a portion of their cropland for buffer zones to conserve wildlife habitats, reduce erosion and protect water quality. One study cited by EPA estimated that high corn prices resulting from corn ethanol production could lead to the cultivation of up to 70 percent of the expiring acreage enrolled in the program in Iowa.[52]

Economic

Reduced Revenue for the Highway Trust Fund

Until 2004, the ethanol subsidy was funded by a partial exemption from the motor fuel excise tax, which is also the funding source for the Highway Trust Fund. The tax exemption resulted in a $14 billion less revenue for the Highway Trust Fund from 1980 through 2004 ($20 billion in 2010 dollars),[53] enough to construct 4,200 miles of new four-lane highways.[54]

A 2004 study comparing state highway fund apportionments concluded that all but six states[55] lost highway apportionments as a result of the ethanol subsidy from 1981 through 1996, with 10 states[56] losing more than $100 million each (in 1996 dollars) during that period.

After 2004, the subsidies were deducted from the general fund.

Automakers Exploit Fuel-Economy Act

About 10 million cars and light trucks are built to run on 85-percent ethanol blends (E85).[57] Due to ethanol's cost and E85's limited availability, however, only about five percent of those vehicles, mostly fleet vehicles, are currently running on the high-ethanol blend.[58]

Automakers have continued to produce these "flexible fuel vehicles" primarily to avoid fines for failing to meet federal fuel-economy standards, according to a recently published paper. Corporate average fuel economy (CAFE) standards require automakers to achieve a minimum average mileage across their entire vehicle production. The Alternative Motor Fuels Act modified CAFE regulations beginning in 1993, allowing manufacturers to improve their mileage ratings by adding flexible fuel capacity at a cost of $100 to $200 for each vehicle. The provision was intended to induce automakers to make flexible-fuel vehicles in the hope that an ethanol fueling infrastructure would be built.

The paper by researchers from the University of Chicago and Michigan State University found that Chrysler would have fallen short of the mileage standard for light trucks every year from 1999-2002 if not for the flexible-fuel provision, while Ford would have missed the light-truck standard every year from 1999-2005, except 2001.[59]

[1] Congressional Budget Office, *Using Biofuel Tax Credits to Achieve Energy and Environmental Policy Goals*, July 2010, page1, http://cbo.gov/ftpdocs/114xx/doc11477/07-14-Biofuels.pdf, retrieved Sept. 28, 2011.

[2] Paul N. Leiby, *Estimating the Energy Security Benefits of Reduced U.S. Oil Imports - Final Report,* Oak Ridge National Laboratory, page 4, Feb. 28, 2007, www.epa.gov/oms/renewablefuels/ornl-tm-2007-028.pdf, retrieved Sept. 28, 2011.

[3] International Energy Statistics, Energy Information Administration, www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=5&pid=57&aid=6, retrieved Sept. 27, 2011.

[4] Stephen P.A. Brown and Hillard G. Huntington, *Reassessing the Oil Security Premium,* Resources for the Future Discussion Paper 10-05, Feb. 2010, www.rff.org/RFF/Documents/RFF-DP-10-05.pdf, retrieved Sept. 28, 2011.

[5] Energy Information Administration, Annual Energy Review 2009, Table 5.1, Monthly Energy Review, July 2011, www.eia.gov/totalenergy/data/annual/pdf/sec5_5.pdf, Table 3.1, www.eia.gov/totalenergy/data/monthly/pdf/sec3_3.pdf, retrieved Sept. 28, 2011).

[6] Congressional Budget Office, *Using Biofuel Tax Credits to Achieve Energy and Environmental Policy Goals*, July 2010, page 3, http://cbo.gov/ftpdocs/114xx/doc11477/07-14-Biofuels.pdf, retrieved Sept. 28, 2011.

[7] Energy Information Administration, Table 10.3 Fuel Ethanol Overview, Table 5.11 Petroleum Products Supplied by Type, 1949-2009, www.eia.gov/totalenergy/data/annual/index.cfm#petroleum; Table 10.3 Fuel Ethanol Overview, www.eia.gov/totalenergy/data/monthly/#renewable; Table 3.7c. Petroleum Consumption: Transportation and Electric Power Sectors, www.eia.gov/totalenergy/data/monthly/#petroleum, retrieved Sept. 28, 2011.

[8] Paul N. Leiby, *Estimating the Energy Security Benefits of Reduced U.S. Oil Imports - Final Report,* Oak Ridge National Laboratory, page 5, Feb. 28, 2007, www.epa.gov/oms/renewablefuels/ornl-tm-2007-028.pdf, retrieved Sept. 28, 2011. The $16.63 represents the mid-point of a range of $8.82 to $26.22.

[9] Environmental Protection Agency, *Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis,* EPA-420-R-10-006, February 2010, page 6, www.epa.gov/otaq/renewablefuels/420r10006.pdf, retrieved Sept. 28, 2011.

[10] Renewable Fuels Association, *University Report: Ethanol Reduced Gas Prices $0.89 in 2010,* www.ethanolrfa.org/news/entry/university-report-ethanol-reduced-gas-prices-0.89-in-2010, retrieved Sept. 28, 2011. The $800 savings assumed consumption of 900 gallons of gasoline at a cost of $2,470; according to the RFA study, the cost would have been about $3,270 without ethanol.

[11] Xiaodong Du and Dermot J. Hayes, *The Impact of Ethanol Production on US and Regional Gasoline Markets: An Update to May 2009*, April 2011,

www.card.iastate.edu/publications/dbs/pdffiles/11wp523.pdf, retrieved Sept. 28, 2011.

[12] National Renewable Energy Laboratory, *The Impact of Ethanol Blending on U.S. Gasoline Prices,* November 2008, page 3, www.nrel.gov/analysis/pdfs/44517.pdf, retrieved Sept. 28, 2011.

[13] Ibid, National Renewable Energy Laboratory, page 9.

[14] Ibid, National Renewable Energy Laboratory, pages 4-5.

[15] Environmental Protection Agency, *RFG Areas*, www.epa.gov/otaq/fuels/gasolinefuels/rfg/areas.htm, retrieved Sept, 19, 2011.

[16] MTBE (methyl tertiary butyl ether) has been identified as a potential human carcinogen. Concerns over MTBE leaking into water supplies led at least 25 states to ban MTBE use between 2000 and 2005.

[17] Renewable Fuels Association. *2011 Ethanol Industry Outlook: Building Bridges to a More Sustainable Future*, pages 2, 10-11, www.ethanolrfa.org/page/-/2011%20RFA%20Ethanol%20Industry%20Outlook.pdf?nocdn=1, retrieved Sept. 28, 2011.

[18] Congressional Budget Office, *The Impact of Ethanol Use on Food Prices and Greenhouse-Gas Emissions,* April, 2009, www.cbo.gov/ftpdocs/100xx/doc10057/04-08-Ethanol.pdf, retrieved Sept. 28, 2011.

[19] Michael Q. Wang, Jeongwoo Han, Zia Haq, Wallace E. Tyner, May Wu, Amgad Elgowainy,

Energy and Greenhouse Gas Emission Effects of Corn and Cellulosic Ethanol with Technology Improvements and Land Use Changes, Biomass and Bioenergy, Volume 35, Issue 5, May 2011, pages 1885-1896, www.sciencedirect.com/science/article/pii/S0961953411000298, retrieved Sept. 28, 2011.

[20] Congressional Budget Office, *Using Biofuel Tax Credits to Achieve Energy and Environmental Policy Goals*, July 2010, page 12, http://cbo.gov/ftpdocs/114xx/doc11477/07-14-Biofuels.pdf, retrieved Sept. 28, 2011.

[21] T. Searchinger, R. Heimlich, R.A. Houghton, F. Dong, A. Elobeid, J. Fabiosa, et al., *Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land use change*, Science 2008;319:1238e40. Available at www.princeton.edu/~tsearchi/writings/Searchinger_et_al-ScienceExpress.pdf retrieved Sept. 28, 2011.

[22] Ibid, Wang, 2011, page 1894.

[23] Environmental Protection Agency, *Biofuels and the Environment: First Triennial Report to Congress*, External Review Draft, January 2011, EPA/600/R-10/183A, page 4-8. http://oaspub.epa.gov/eims/eimscomm.getfile?p_download_id=500584, retrieved Sept. 27, 2011.The 2007 Energy Independence and Security Act requires corn-based fuel from newly constructed refineries to reduce greenhouse gas emissions by at least 20 percent compared with gasoline to be counted toward the renewable fuels mandates.

[24] John Urbanchuk, *Contribution of the Ethanol Industry to the Economy of the United States*, February 2011, http://ethanolrfa.org/page/-/Ethanol%20Economic%20Contribution%202010%20Final%20Revised%20010411.pdf?nocdn=1, retrieved Sept. 28, 2011.

[25] Ibid, Urbanchuk.

[26] Nathaneal Greene, "Big Ethanol is Using Bad Jobs Numbers to Push Bad Tax Credit," National Resources Defense Council Staff Blog, http://switchboard.nrdc.org/blogs/ngreene/big_ethanol_is_using_bad_jobs.html, retrieved Sept. 28, 2011.

[27] U.S. Department of Agriculture, National Agricultural Statistics Service, *Land Values 2011 Summary*, August 2011, http://usda.mannlib.cornell.edu/usda/current/AgriLandVa/AgriLandVa-08-04-2011.pdf, retrieved Sept. 28, 2011.

[28] Luisa Blanco, Michelle Isenhouera, "Powering America: The Impact of Ethanol Production in the Corn Belt States," Energy Economics, Volume 32, Issue 6, November 2010, pages 1228-1234. The researchers noted that neither corn cultivation nor ethanol production are labor intensive and concluded "we cannot justify the movement towards increasing consumption of biofuels as a way to create jobs and increase wages all across the board." The study looked at data for 2005 and 2006, at the beginning of the share increase in ethanol production created by the Renewable Fuels Standard.

[29] U.S. Department of Agriculture, *World Agricultural Supply and Demand Estimates*, WASDE-495-12, June 2011, page 12, http://usda.mannlib.cornell.edu/usda/waob/wasde//2010s/2011/wasde-06-09-2011.pdf , retrieved Sept. 28, 2011.

[30] C. Ford Runge, Benjamin Senauer, "How Biofuels Could Starve the Poor," Foreign Affairs, May 2007 - June 2007, www.foreignaffairs.com/articles/62609/c-ford-runge-and-benjamin-senauer/how-biofuels-could-starve-the-poor, retrieved Sept. 28, 2011.

[31] Tyner, Wallace et al., "Comparison of Fixed Versus Variable Biofuels Incentives," Energy Policy, Volume 38, Issue 10, October 2010, www.agecon.purdue.edu/papers/biofuels/Energy_Policy_final_Oct_2010.pdf, retrieved Sept. 28, 2011. See also, Purdue University, "Ethanol mandate means corn demand less responsive to price," June 28, 2011, www.purdue.edu/newsroom/outreach/2011/110628TynerEthanol.html, retrieved Sept. 28, 2011.

[32] Elizabeth Rosenthal, "Rush to Use Crops as Fuel Raises Foods Prices and Hunger Fears," New York Times, April 6, 2011, www.nytimes.com/2011/04/07/science/earth/07cassava.html?_r=1, retrieved Sept. 28, 2011.

[33] International Centre for Trade and Sustainable Development, *Price Volatility in Food and Agricultural Markets: Policy Responses*, Policy Report including contributions by FAO, IFAD, IMF,OECD, UNCTAD, WFP, the World Bank, the WTO, IFPRI and the UN HLTF, June 2, 2011, http://ictsd.org/i/agriculture/106203/, retrieved Sept. 28, 2011.

[34] Ibid, International Centre for Trade and Sustainable Development.

[35] Benjamin Senauer, "Food Market Effects of a Global Resource Shift toward Bioenergy," American Journal of Agricultural Economics, Vol. 90, No. 5, Proceedings Issue, December 2008, pages 1226-1232, http://econpapers.repec.org/RePEc:bla:ajagec:v:90:y:2008:i:5:p:1226-1232, retrieved Sept. 28, 2011.

[36] Congressional Budget Office, *The Impact of Ethanol Use on Food Prices and Greenhouse-Gas Emissions,* April, 2009, page VII-VIII, www.cbo.gov/ftpdocs/100xx/doc10057/04-08-Ethanol.pdf, retrieved Sept. 28, 2011. CBO estimated costs of $600 to $900 million for the Supplemental Nutrition Assistance Program (SNAP, formerly the Food Stamp program) and $75 million for the Women, Infants and Children program.

[37] Environmental Protection Agency, "EPA Proposes New Regulations for the National Renewable Fuel Standard Program for 2010 and Beyond," EPA Regulatory Announcement, May 2009, www.epa.gov/OMS/renewablefuels/420f09023.pdf, retrieved Sept. 28, 2011.

[38] Environmental Protection Agency, *Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis*, EPA-420-R-10-006, February 2010, page 890, www.epa.gov/otaq/renewablefuels/420r10006.pdf, retrieved Sept. 28, 2011.

[39] Food and Agriculture Organization of the United Nations, *Price Volatility in Agricultural Markets,* December 2010 policy brief, www.fao.org/docrep/013/am053e/am053e00.pdf, retrieved Sept. 28, 2011.

[40]Congressional Budget Office, *Using Biofuel Tax Credits to Achieve Energy and Environmental Policy Goals*, July 2010, page 5, http://cbo.gov/ftpdocs/114xx/doc11477/07-14-Biofuels.pdf, retrieved Sept. 27, 2011.

[41] Environmental Protection Agency, *Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis,* EPA-420-R-10-006, February 2010, page 924, www.epa.gov/otaq/renewablefuels/420r10006.pdf, retrieved Sept. 27, 2011.

[42] Environmental Protection Agency, Office of Mobile Sources, *Motor Vehicles and the 1990 Clean Air Act*, www.epa.gov/otaq/consumer/11-vehs.pdf, retrieved Sept. 27, 2011.

[43] Renewable Fuels Association, Ethanol Facts: Environment, www.ethanolrfa.org/pages/ethanol-facts-environment, retrieved Aug. 14, 2011.

[44] Seth Borenstein, "Ethanol may cause more smog, more deaths," Associated Press, April 18, 2007, www.msnbc.msn.com/id/18162493, retrieved Sept. 27, 2011.

[45] National Research Council, *Ozone-Forming Potential of Reformulated Gasoline,* 1999, www.nap.edu/catalog.php?record_id=9461, retrieved Sept. 27, 2011. The National Research Council is a private, nonprofit institution that is part of what is known as the National Academies, along with the National Academy of Sciences, National Academy of Engineering and Institute of Medicine. The Academies do not receive direct appropriations from the federal government, but many of their activities are funded by Congress and federal agencies.

[46] Ibid, National Research Council, pages 7, 9.

[47] Environmental Protection Agency, *Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis,* EPA-420-R-10-006, February 2010, page 924, www.epa.gov/otaq/renewablefuels/420r10006.pdf, retrieved Sept. 27, 2011.

[48] Environmental Protection Agency, *Compliance and Enforcement Annual Results: Enforcement Highlights, FY2006 Air Case Highlights*, www.epa.gov/compliance/resources/reports/endofyear/eoy2006/fy2006enforcementhighlights.pdf, retrieved May 23, 2011.

[49] Environmental Protection Agency, *Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis,* EPA-420-R-10-006, February 2010, pages 5, www.epa.gov/otaq/renewablefuels/420r10006.pdf, retrieved Sept. 27, 2011.

[50] The "dead" or "hypoxia zone" occurs when oxygen consumption exceeds oxygen production through photosynthesis and replenishment from the atmosphere. The presence of excess nutrients in water is thought to lead to reduced oxygen concentrations.

[51] Environmental Protection Agency, *Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis,* EPA-420-R-10-006, February 2010, page 5, www.epa.gov/otaq/renewablefuels/420r10006.pdf, retrieved Sept. 27, 2011.

See also, Renewable Fuels Association, *The Facts on Ethanol, Corn Production, and Hypoxia in the Gulf of Mexico,* http://ethanolrfa.org/page/-/Hypoxia%20Fact%20Sheet.pdf?nocdn=1, retrieved Sept. 27, 2011.

[52] Environmental Protection Agency, *Biofuels and the Environment: First Triennial Report to Congress*, External Review Draft, January 2011, EPA/600/R-10/183A, pages 3-4, http://oaspub.epa.gov/eims/eimscomm.getfile?p_download_id=500584, retrieved Sept. 27, 2011.

[53] Molly Sherlock, *Energy Tax Policy: Historical Perspectives on and Current Status of Energy Tax Expenditures*, Congressional Research Service, May 2, 2011, Table B-6. Alcohol Fuels Excise Tax Exemption: Estimated Revenue Losses, http://leahy.senate.gov/imo/media/doc/R41227EnergyLegReport.pdf, retrieved Sept. 27, 2011.

[54] Florida Department of Transportation, *Generic Cost Per Mile Models,* ftp://ftp.dot.state.fl.us/LTS/CO/Estimates/CPM/summary.pdf, retrieved Sept. 27, 2011. The Florida Department of Transportation estimates a construction cost of $4,837,011 a mile for a four-lane divided urban roadway with four-foot bike lanes.

[55] Kevin N. Rask, *Ethanol Subsidies and the Highway Trust Fund*, Journal of Transport Economics and Policy, Volume 38, Part 1, Jan. 2004, pages 29-44, http://ideas.repec.org/a/tpe/jtecpo/v38y2004i1p29-43.html, retrieved Sept. 28, 2011. The states are Vermont, North Dakota, Idaho, Rhode Island, South Dakota and New Hampshire.

[56] Ibid, Rask. The states are Maryland, Ohio, Georgia, Florida, Massachusetts, Illinois, New York, Pennsylvania, Texas and California.

[57] U.S. Department of Transportation, Federal Highway Administration, *State Motor-Vehicle Registrations - 2009*, www.fhwa.dot.gov/policyinformation/statistics/2009/mv1.cfm, retrieved Sept. 27, 2011.

[58] Energy Information Administration, *Alternatives to Traditional Transportation Fuels - 2009,* April 2011, table V1, page 8, www.eia.gov/renewable/alternative_transport_vehicles/pdf/afv-atf2009.pdf, retrieved Sept. 27, 2011.

[59] Soren Anderson and James Sallee, "Using Loopholes to Reveal the Marginal Cost of Regulation: The Case of Fuel-Economy Standards," American Economic Review, 101, June 2011, page 20, www.msu.edu/~sta/AndersonSallee_ffvcafe.pdf, retrieved Sept. 27, 2011.