When Farmers Outperform Sheiks: Why Adding Ethanol to the U.S. Fuel Mix Makes Sense in a $50-Plus/Barrel Oil Market

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April 12, 2005

A survey of the ethanol literature reads like the arithmetic lessons of our childhood. Bushels, pounds, gallons, and barrels abound, but little effort has been made to pin down the actual costs associated with ethanol production and consumption. Even more crucial, the literature offers little guidance to when ethanol instead of gasoline becomes a cost effective alternative to importing crude oil. With the world's most populous countries ramping up their demand for oil, prices have entered a new phase, making hitherto unconventional energy sources attractive—ethanol first and foremost.

In the past, ethanol has depended largely on subsidies to be cost-competitive. But when the price of oil exceeds $44/barrel, ethanol becomes a significant competitor to oil imports – even *without* subsidies.

The Energy Information Administration's Annual Energy Outlook estimates that the U.S. petroleum balance today is 153.9 billion gallons.[3] The major use of petroleum, gasoline, accounts for 142.1 billion gallons. However, ethanol is already a small but increasing component of the fuel used in the U.S. automobile and light truck fleet – approximately 4.2 billion gallons in 2005. At current oil prices, ethanol can supply 10% of U.S. automobile and light truck fuel needs without engineering upgrades.

Leaving aside the economics of ethanol production for a moment, substituting ethanol for gasoline in the current pricing regime makes considerable sense. Ethanol does not require new technologies at either end of the supply chain: dry mill production technologies are efficient and cost effective, and many of today's car and truck models are designed to run on gasoline containing 10% ethanol. This 10% blend, established by the U.S. Environmental Protection

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[3] A good starting point is Table 11 in the Annual Energy Outlook 2005, EIA, February, 2005. All quantities are calculated in gallons in the following discussion. Although gasoline is refined from crude oil, not all of the hydrocarbons in a barrel of crude are appropriate for gasoline. Other hydrocarbons are refined into fuels of different grades.

Agency, has also been found to improve engine performance overall and reduce emissions.

Having examined current wholesale prices for gasoline and ethanol, we believe that U.S. gasoline blenders should voluntarily substitute 10% ethanol in their gasoline mixtures. At current prices, ethanol is now less expensive than import based gasoline.

Ethanol Production and Consumption

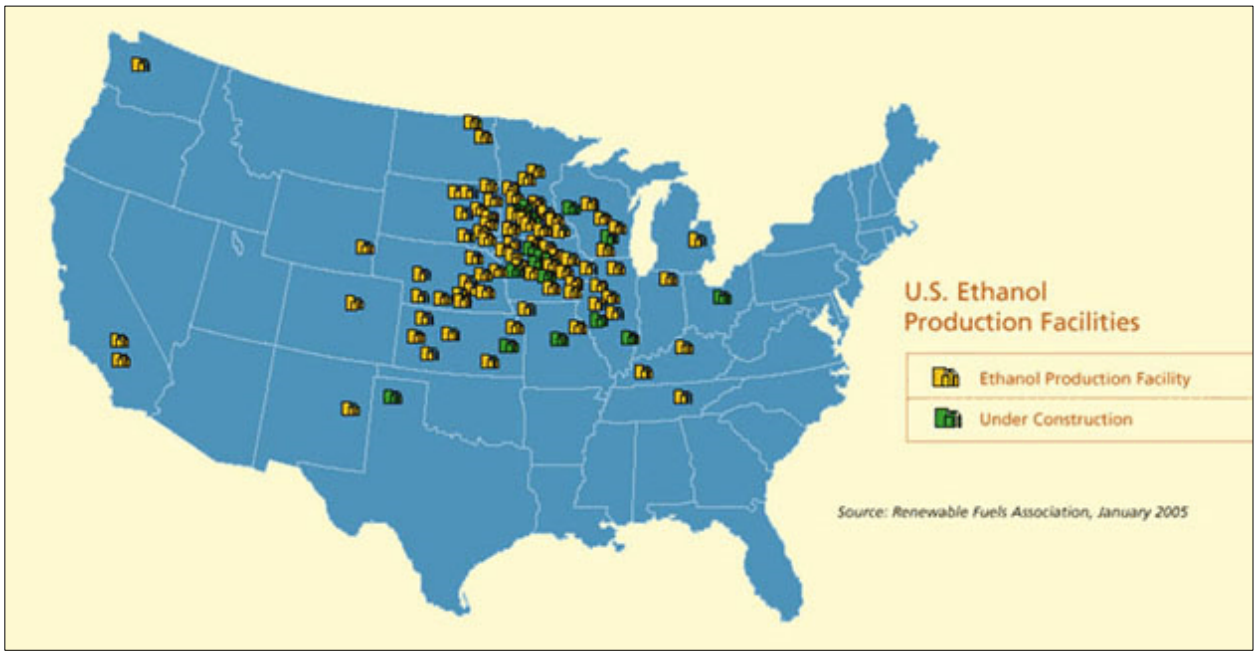
Ethanol, or white lightning in everyday language, is the product of a corn still – absent the gun-toting moonshiner of Prohibition times. Ethanol has been a component of retail gasoline supplies in the U.S. for years, although usually as an additive. Ethanol is slightly superior to gasoline in several ways – less environmentally polluting, higher octane, and requiring less investment and infrastructure.[4] Unlike some renewable energy resources that are still getting off the ground, ethanol's technology and manufacturing infrastructure is widely available and inexpensive to install. Public policies, including subsidies and tax credits, have supported ethanol production; now rising gas prices have made ethanol cost-effective absent such policy assistance.

While a number of technologies exist for turning the sugar in biomass into alcohol, the most common in the mainland U.S. is the use of dried corn as a feedstock, also known as dry mill technology. In dry mill production, a feedstock (usually corn or sugar cane) is ground, liquefied, and mixed with yeasts and enzymes. The feedstock is heated and the resulting alcohol is distilled, producing ethanol. In the U.S., where corn is the primary feedstock, the remaining co-product of ethanol production is suitable for sale as animal feed and reduces the cost of production by approximately 15%.

In 2004, eighty-three facilities located almost entirely in the Midwest produced 3.4 billion gallons of ethanol annually. Fifteen additional facilities under construction will soon increase production to almost 4.2 billion gallons annually.[5]

[4]Octane, one of the hydrocarbons present in crude oil, is used as an indication of energy content. The usage at the gas pump is misleading for consumers, since the octane rating represents the degree of compression to which the fuel is subjected before it spontaneously ignites. Because higher compression engines are more efficient, higher octane ratings represent higher energy content at the pump. Ethanol is less likely to cause engine "knocks", but it has lower energy content than standard gasoline; this is why blends of gasoline and ethanol are preferable to the unblended use of either fuel.

[5]Source: American Coalition for Ethanol. http://www.ethanol.org/productionlist.htm



Using one bushel of corn and 50¢ of natural gas, a modern dry mill produces 2.75 gallons of ethanol.[6] It takes fifteen bushels of corn to produce one barrel of ethanol – a fuel that is already refined and significantly less polluting than one barrel of gasoline.[7]

In 2004, one barrel of crude oil produced about twenty-three gallons of finished gasoline.[8] Filling the average car requires approximately two-thirds of a barrel of crude oil. A bushel of corn equals 2.75 gallons of fuel, and at $2.20/bushel, the corn feedstock in the ethanol costs less than a dollar (80¢ at current corn prices). At today's corn and energy retail prices, the average consumer can fill his or her tank with pure ethanol for $18.[9]

Transportation is the major use for crude oil, accounting for approximately 66% of total petroleum outputs.[10] In 2004, the U.S. consumed almost 134 billion gallons of gasoline. In 2004, the U.S. imported approximately 13 billion gallons of gasoline; year-end 2004 gasoline stocks were approximately 9 billion gallons.[11]

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[6]This report relies heavily the production coefficients derived in "Factors Associated with Success of Fuel Ethanol Producers" by Douglas G. Tiffany and Vernon R. Eidman, University of Minnesota Staff Paper PO3-7, August 2003.

[7]Ethanol as currently used is blended with gasoline to add oxygen to the mix, thus allowing the fuel to burn hotter and reduce the proportion of unburned hydrocarbons.

[8]Based on 2004 weekly crude oil inputs into U.S. refineries and 2004 weekly U.S. gasoline production.

[9]The average American car has a 14-gallon fuel tank. In May 2005, ethanol will cost $1.31/gallon, including a provision for an after-tax profit for the ethanol producer of 20%.

[10]Based on 2003 EIA data.

[11]Although consumption and imports are comparable on the margin, the actual engineering relationship is more

Ethanol becomes a significant competitor to oil imports when the price of oil exceeds $44/barrel. Given the forward prices for natural gas, gasoline, and corn, a dry mill ethanol plant in the Midwest could enjoy returns as high as 35% annually over the next three years.

Outgrowing the Need For Policy Help

The history of the energy policies that regulate ethanol production and consumption in the U.S. is a mixture of high subsidies, taxes, and political tradeoffs. Present high levels of federal government intervention are expected to last until 2010.[12] Although public policy distortions in U.S. petroleum markets are often similar, they do not generally unwind as dramatically as the pricing situation for ethanol that has now occurred.[13]

As of the end of March 2005, ethanol cost less to blenders than the comparable amount of gasoline – even assuming that no credits or subsidies were in place. The cost to blenders – including the $.51/gallon tax credit – was massively less than gasoline.

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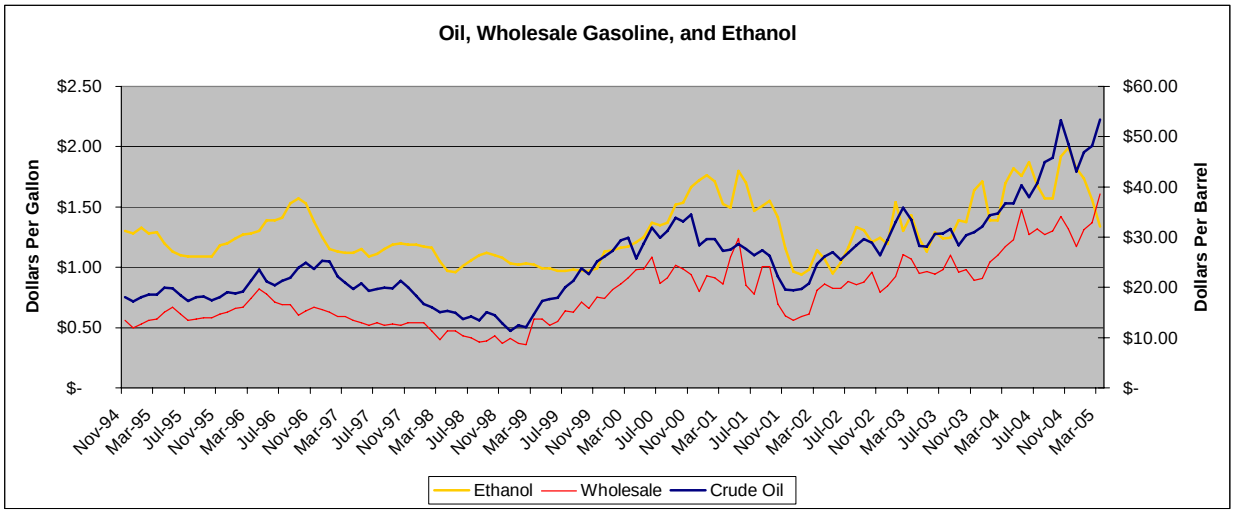
tenuous. The U.S. imports pre-processed crude. Each barrel contains a variety of hydrocarbons. The cracking process involves splitting the crude oil into final products ranging from home heating oil to jet fuel. If public policy dictated the total replacement of gasoline with ethanol, it would be impossible to produce only jet fuel for example, since the proportion of jet fuel is simply a fraction of the total. On the margin, it is possible to change the components of refinery output within limits

[12]The American Jobs Creation Act of 2004 (P.L. 108-357) provides for a tax credit of $.51/gallon for blenders who include ethanol, for example. Many states have also adopted measures to encourage ethanol. Ethanol's primary current use is as an additive to gasoline in urban non-attainment areas in winter months.

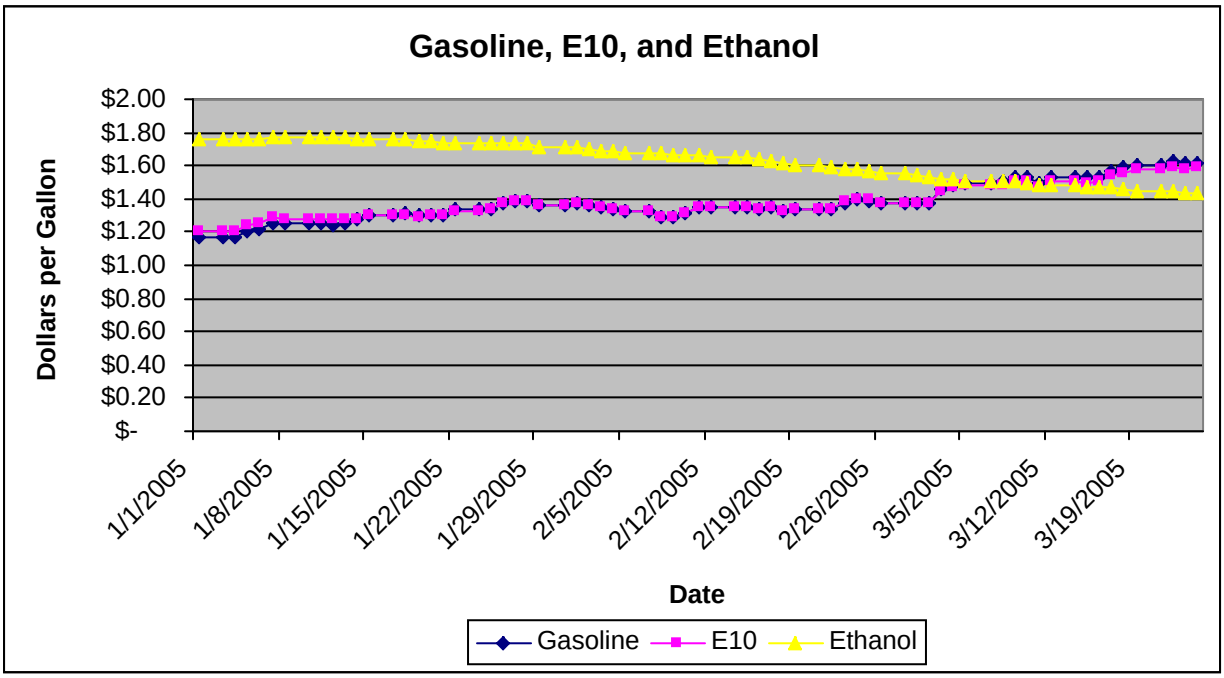
[13]Sources: Wholesale gasoline and ethanol prices are from http://www.neo.state.ne.us/statshtml/66.html. Oil prices are from the Energy Information Administration



Wholesale gasoline and crude oil prices are highly correlated. The relationship between ethanol prices and wholesale gasoline prices has traditionally reflected the tax credit provided to blenders purchasing the ethanol for delivery to consumers.[14] As is apparent in the graph above, the price relationship between ethanol prices and wholesale gasoline has always been significant. The far right side of the chart, however, shows that the price of ethanol has now dipped *below* the price of wholesale gasoline, without the tax credit.

Expanding the prices at the far right of the previous graph shows the rack price of ethanol actually below the rack price of gasoline.

[14]While the federal tax credit has been in place for many years, its actual amount and implementation change with each session of Congress.



The fall of ethanol prices below that of gasoline is an economic anomaly – especially since blenders receive the tax credit for blending ethanol as a reduction to the price paid ethanol producers. In economic terms, the price of ethanol fell below gasoline by an additional $.51/gallon in March.

Major Ethanol Markets

There are two major U.S. markets for ethanol. One is the mandated use of 10% ethanol blends in EPA non-attainment areas.[15] A 10% blend is called E10. Blends of up to 10% are covered under warranty for all major auto manufacturers, so the widespread adoption of 10% blends requires no new technology. Production levels that have now exceeded that market are one reason for the current collapse in ethanol's market price. When production is less than non-attainment requirements, ethanol prices have reflected the tax credit to blenders – approximately $.50/gallon above the price of wholesale gasoline. At this point, ethanol is a cost effective alternative to gasoline even without the tax credit. Simply stated, E10 is now less expensive than regular gasoline.

The second market for ethanol is for gasoline with blends of upwards of 85% ethanol. This fuel

[15] EPA non-attainment areas are listed at http://www.epa.gov/oar/oaqps/greenbk/. Non-attainment areas require special measures including changes in the fuel mix during certain months of the year.

is called E85. These blends require the adoption of new but readily available automotive technology. Flex-fuel vehicles, or FFVs, are cars and trucks that can run on a wide range of fuel blends. FFVs have been produced by most major U.S. auto manufacturers since 2000. Although there are many FFVs on the road today, their proportion is only a small share of the total fleet.[16]

U.S. car manufacturers have been producing engines engineered for the E85 standard for some years. It is surprising how many models are being offered. It is also surprising that many owners of FFVs are currently unaware that they have the capability of running their vehicles on less expensive fuels. For example, Ford offers FFV models of both its popular Taurus and Explorer vehicles. The website, http://www.fueleconomy.gov/feg/byfueltype.htm, lists the models that can run on ethanol. Many of the vehicles on this site are unexpected, including large, low gas mileage models like Chevrolet's Suburban.

The Economic Cost of Ethanol

Detailed dry mill economics of ethanol have been studied in any number of contexts, and spreadsheets designed for plant evaluation are available from a number of sources.[17] Curiously, we have not been able to find a study that actually compares the economic cost of ethanol to the price of oil.

At current prices for corn, energy, and other inputs, the economic cost of a standard dry mill facility is $1.31/gallon of ethanol.

[16]According to the National Ethanol Vehicle Coalition, there are 3.5 million flexible-fuel vehicles that can run on 85% ethanol on the road in 2004.

[17] The following discussion depends on the production coefficients derived in "Factors Associated with Success of Fuel Ethanol Producers" by Douglas G. Tiffany and Vernon R. Eidman, University of Minnesota Staff Paper PO3-7, August 2003. Department of Applied Economics, University of Minnesota, August 2003. The authors of this study have also developed a spreadsheet, Bugal.xls, containing their analysis. A second interesting source is the analysis cited in the Iowa Ethanol Plant Pre-Feasibility Study, Bryan and Bryan, January 2000.

The cost breakdown is:

Cost Categories	Cost/Gallon
Corn Feedstock Costs	$0.76
Chemical Costs	$0.14
Energy Costs	$0.32
Capital Costs	$0.24
Other Costs	$0.09
Total Costs	$1.54
Byproduct Revenues	$0.24
Net Costs After Byproducts	**$1.31**

The individual variable cost categories follow the analysis by Tiffany and Eidman, with costs updated to forward prices for corn as of May 1, 2005.[18] We have updated the capital costs to reflect a levelized real cost stream reflecting an 80/20 debt/equity capital structure and a 20% real return on equity after taxes.

As discussed below, the primary cost of ethanol is the cost of the feedstock. Corn prices have remained low for many years in spite of an increasing use of corn for ethanol. In part, this has been due to rapid productivity increases in the productivity of corn. We will address the probable impact of increasing ethanol impact on corn prices in the next section.

The relationship between crude oil prices and the wholesale price of gasoline is relatively stable:

$$\text{Wholesale Gasoline Price per Gallon} = (\$.036 + .029) \times (\text{Crude Oil per Barrel})$$[19]

Working back from the calculation above, ethanol is competitive on economic grounds when oil is at $43.29/barrel. In simpler words, ethanol – absent subsidies and tax credits – is a prudent economic choice whenever the price of oil exceeds $44/barrel.

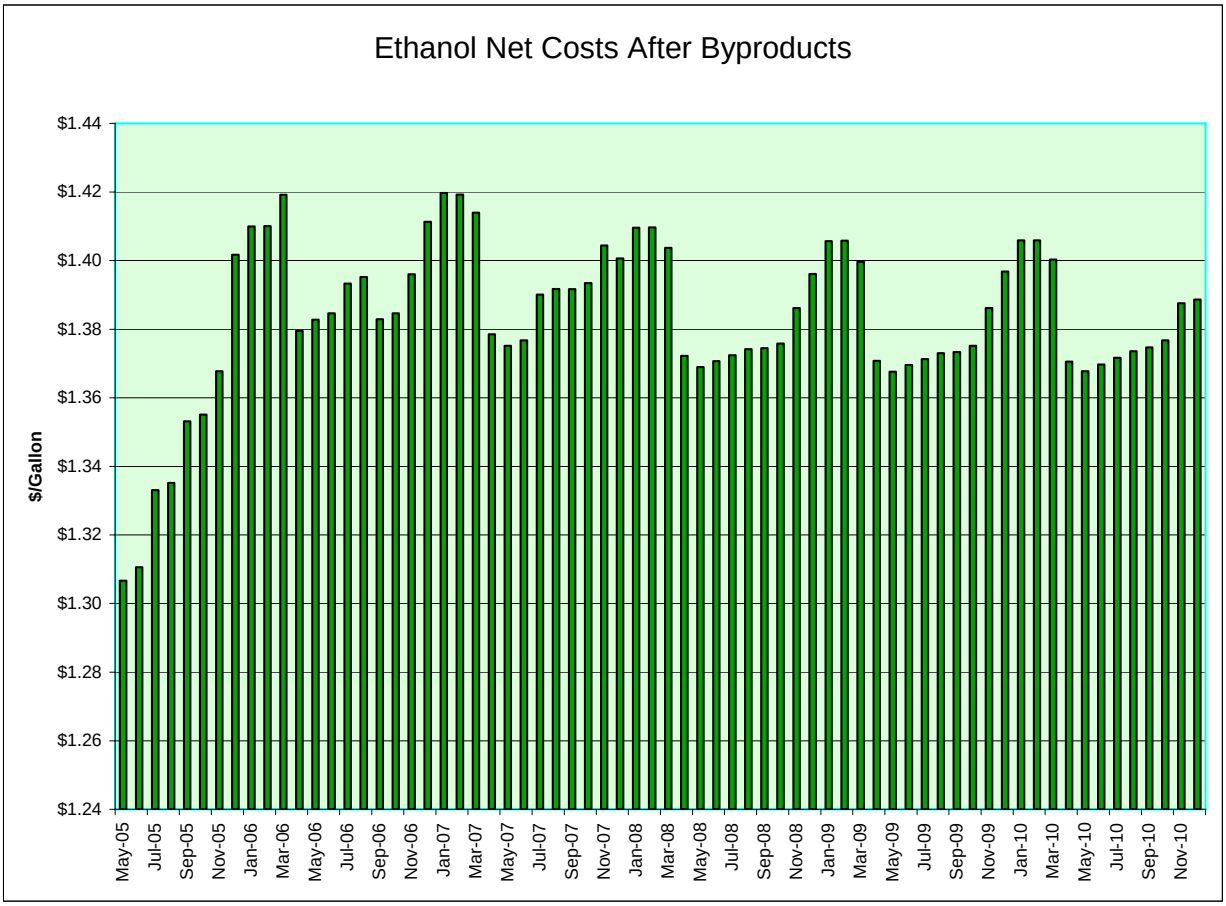
Ethanol currently enjoys a major tax credit equal to $.51/gallon. When this is added into the

[18]This analysis uses values available on March 18, 2005.

[19]This is the simple regression of monthly average wholesale gas prices against monthly average crude oil prices for the past decade. The relationship between wholesale gasoline prices and crude oil prices is highly significant. The intercept term is not significant at any level, but has been retained for simplicity.

calculations, production of ethanol is viable whenever oil exceeds $26/barrel.[20]

The true economic cost of ethanol can be calculated for the next five years using forward prices for corn and natural gas. When forward prices are not available, the costs have been forecasted at the last available forward prices and then increased by inflation.



The chart above indicates that an ethanol facility will be running above a 20% rate of return for the entire period of forward gasoline prices.

The major determinant of ethanol economics is the forward price of corn. Rising corn prices will increase the price at which ethanol is economically competitive absent subsidies and tax credits

[20]This calculation is straightforward. For every gallon of ethanol blended into gasoline, the blender receives a $.51/gallon tax credit. This effectively makes ethanol economic at $.80/gallon – $1.31/gallon of true economic cost less the tax credit.

to $46.80/barrel by February 2008 – considerably below current and forward oil prices.[21]

Feed Stocks

The primary feed stock for ethanol is corn. The most recent data from the U.S. Department of Agriculture (USDA) shows the corn supply was 12.8 billion bushels in 2004-2005.[22] At current ethanol production levels of 4.2 billion gallons, this implies that over 15% of the current harvest is used as feedstock for ethanol. This is a large commitment. For ethanol production to meet the 10% blend with regular gasoline, the number of bushels used for ethanol production would have to increase to 4.7 billion, 39% of the current crop. Even for the U.S. agricultural industry, this would be a major shift in production and consumption.

Little detailed research has been done in this area, absent a 1997 paper by Michael Evans of Northwestern University.[23] Evans' results indicated that a $1 increase in corn prices would yield an 8.5 million increase in the number of acres dedicated to corn.[24] While the statistical evidence is significant, it is not clear that the use of time series for an industry whose technology has changed so dramatically is defensible. During the series Evans used, corn yields per acre increased from 62.4 bushels/acre to 113.5.[25] More current data from the USDA puts yields at 160.4 bushels/acre.[26]

If Evans' research is correct, the price of corn will have to increase by $1.83/bushel – effectively doubling from current levels in order to bring enough acreage into production to meet the 10% ethanol blend standard.[27] Obviously, such a large price increase would add significantly to the economic cost of ethanol – $.97/gallon – and the breakeven economic cost of oil would increase to $64.82/barrel before subsidies and credits are considered. However, if the current tax credit is added into the calculation, the breakeven oil price is $47.58/barrel – less than today's price.

[21]Forward prices are taken from the Chicago Board of Trade and NYMEX as of March 18, 2005. As always, such estimates are highly volatile and should be taken with a substantial degree of caution. The analysis is only offered here to show how current estimates change over time. A substantial increase in oil prices will increase ethanol production and the prices of corn and natural gas above current forward prices.
[22]Source: AOTAB15[1].xls, USDA.
[23]"The Economic Impact of the Demand for Ethanol", February 1997.
[24]Ibid. Page 8.
[25]USDA Historical Track Records, April 2004, pages 19-20.
[26]Source: AOTAB15[1].xls, USDA.
[27]At current yields, it would require an additional 15.6 million acres of corn to support production of 14 billion gallons of ethanol. At a $1 required increase in corn prices to shift 8.5 million acres to corn, this would increase corn prices by $1.83/bushel.

What Happens When the Price of Oil Reaches $100/Barrel?

Recently, an analyst at Goldman Sachs has hypothesized an increase of oil prices to $100/barrel.[28] It is relatively easy to predict the ethanol production response to crude oil at $100/barrel. The wholesale price of gasoline would increase to $2.97/gallon. At this level, U.S. ethanol production would increase to 18.7 billion gallons per annum. The reduction in U.S. oil imports due to ethanol would be 14.5 billion gallons of crude oil – approximately 10% of current imports. If the tax credit was maintained in the face of the oil price increase, ethanol production would increase by 19.7 billion gallons and U.S. imports would be reduced by 14%.

Obviously, such calculations simplify a major change in agricultural output as well as a relatively large investment in dry mill infrastructure. At the $100/barrel level, U.S. ethanol consumption would also stretch the limitations of the current fleet of automobiles and light trucks at the E10 level. In this scenario, corn production would increase by 37% and ethanol's share of the U.S. corn crop would increase to 46%.[29]

Conclusions

There are currently no institutional, technological, or economic obstacles preventing the replacement of at least 10% of U.S. gasoline with ethanol. The price of ethanol is currently competitive with gasoline and will remain so as long as oil exceeds $44/barrel. Rising oil prices, the continuation of subsidies and supporting alternative fuel policies, and increased ethanol production capacity make ethanol a sensible alternative to foreign oil. Leaving aside the potential environmental benefits of ethanol as an alternative fuel, the economics of making this shift seem clear.

At higher ethanol blends and greater production demands, the economics become slightly more complex, and technological and institutional barriers start to appear. Even though the automotive technology for higher ethanol blends is already spreading to light car and truck fleets, fueling stations and production facilities are concentrated in the Midwest and the ethanol transportation infrastructure will need to expand. At extremely high oil prices, ethanol demand will exceed current feedstock and fuel production capacity. Even with these obstacles, however, ethanol's viability as an alternative fuel is apparent.

[28]Goldman Sachs: Oil Could Spike to $105, Reuters, March 31, 2005.

[29]These changes could not possibly take place in a given year. The analysis conservatively assumes no shift of consumption from corn to competitive feeds, but glosses over the massive structural changes required to shift crops by this large degree.

Information is the missing piece to facilitate change:

- American policymakers still lack relevant economic research about ethanol production.
- Retailers need to know that before any direct subsidies, ethanol, the renewable fuel, is now cheaper than conventional gasoline products – whose prices continue to rise.
- Consumers need to know they can take advantage of the E10 fuel. Owners of cars and light trucks that already meet the E85 standard could be saving more than 10% on their fuel costs, but most do not even know that their vehicles are already engineered for them to do so.

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