BPRO 29000: Energy & Energy Policy

Consequences of U.S. Ethanol Policy in Energy, Economics and Distribution of Wealth

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Abstract

The goal of this paper is to examine the efficacy of US ethanol policy. By focusing on a single alternative fuel policy it will be possible to analyze nuances that would not be viable to examine in a broader undertaking. This paper will seek to decipher the effectiveness of the United States government's ethanol policies by examining current policies, the history of these policies, how ethanol is currently produced in the United States, the unintended consequences levied by these policies, possible substitute alternative fuel policies that could be pursued, and the problems and technological challenges associated with ethanol production. It will then compare US ethanol policy to international ethanol policies and provide a prescription for the US government's stance on ethanol policies moving forward. This paper will do so using a variety of academic sources, interviews conducted with noted academics and government experts, and previously published research papers on this subject matter. This will be undertaken in the hope of bringing clarity to an often-controversial subject matter by providing an objective analysis of the merits and faults of the current policies enacted by the United States government surrounding ethanol. The results of this paper will demonstrate that –as it is currently structured— US ethanol policy developed largely outside of market forces, incentivizes subpar ethanol production methods, has a demonstrably negative affect on markets, has yet to tackle significant technological challenges, is environmentally destructive in many ways, compares poorly to ethanol policies in other nations, and can be claimed to be generally ineffective. For this reason, this paper will suggest the elimination of corn-based ethanol subsidies, pushing to incentivize cellulosic ethanol, and pushing for more E-85 stations throughout the nation.

Introduction

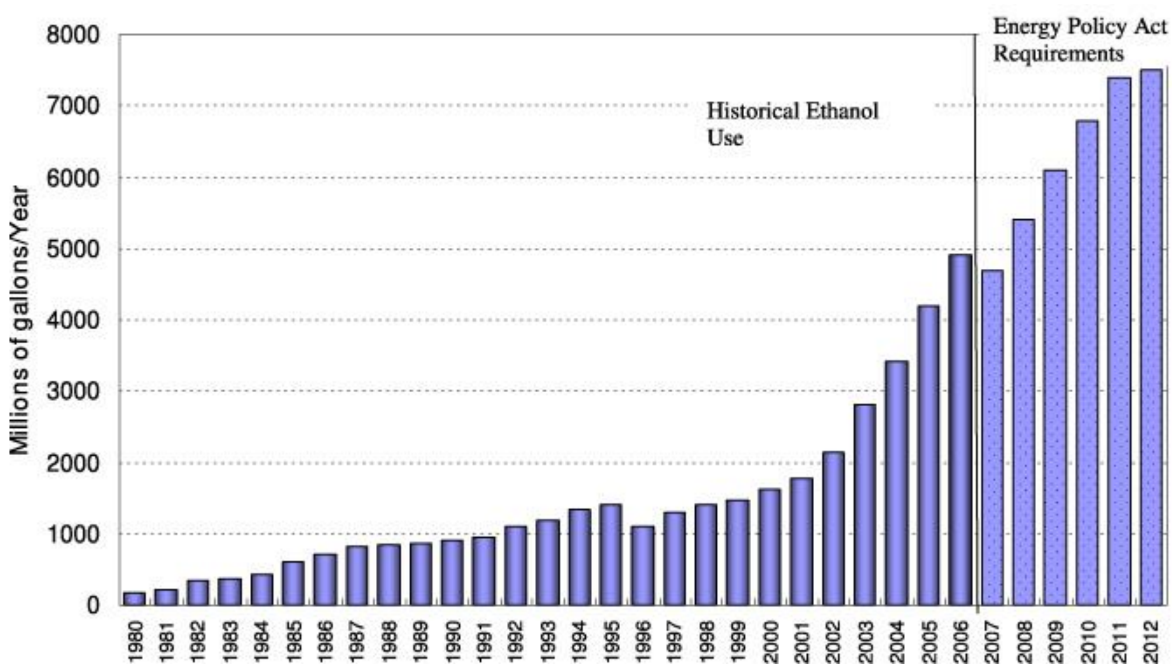
In this paper, we will be examining the United States ethanol policy and the negative effects that are created due to usage of corn as the main substance to produce ethanol. In order to gain a complete understanding of the ethanol industry in the United States, in addition to analyzing research papers, we also conducted interviews with some of the leading experts in the industry. We first look at the history of the United States ethanol legislation to see how we have arrived at the current policy. We then analyze the two main production processes of ethanol using corn as the primary source of production: dry milling and wet milling. This gives us the platform to understand ethanol policy and its negative effects on the price of corn as a commodity such as normal backwardation and contango among other consequences. Furthermore, there are technological challenges with the current methods of producing ethanol, which make it necessary to explore alternative options of production. Due to the negative effects that we find that ethanol policy has on corn, in addition to the technological challenges to producing it, we suggest alternative fuel-based substitutes and examine other international policies to look for improvements to be made to the United States ethanol policy.

History of United States Ethanol Policy

Events that Shaped Current Policies

Over the past 35-40 years in the United States, ethanol has been at the forefront of the alternative fuel source options in the United States. This increase in ethanol use as an alternative fuel source in the United States can be directly linked to environmental and economic legislation that has been passed since the 1970s. Below, we will provide a history of ethanol policy in the United States, showing the driving factors behind its boom in popularity as an alternative fuel source. We can divide the study of ethanol policy into 2 time periods: prior to the 21st century and during the 21st century. This is the best way to study ethanol policy, as the time period of 1970 – 2000 set the stage for the ethanol boom after the beginning of the 21st century. This shift in ethanol consumption in the United States can be seen in the graph below:

United States Ethanol Consumption



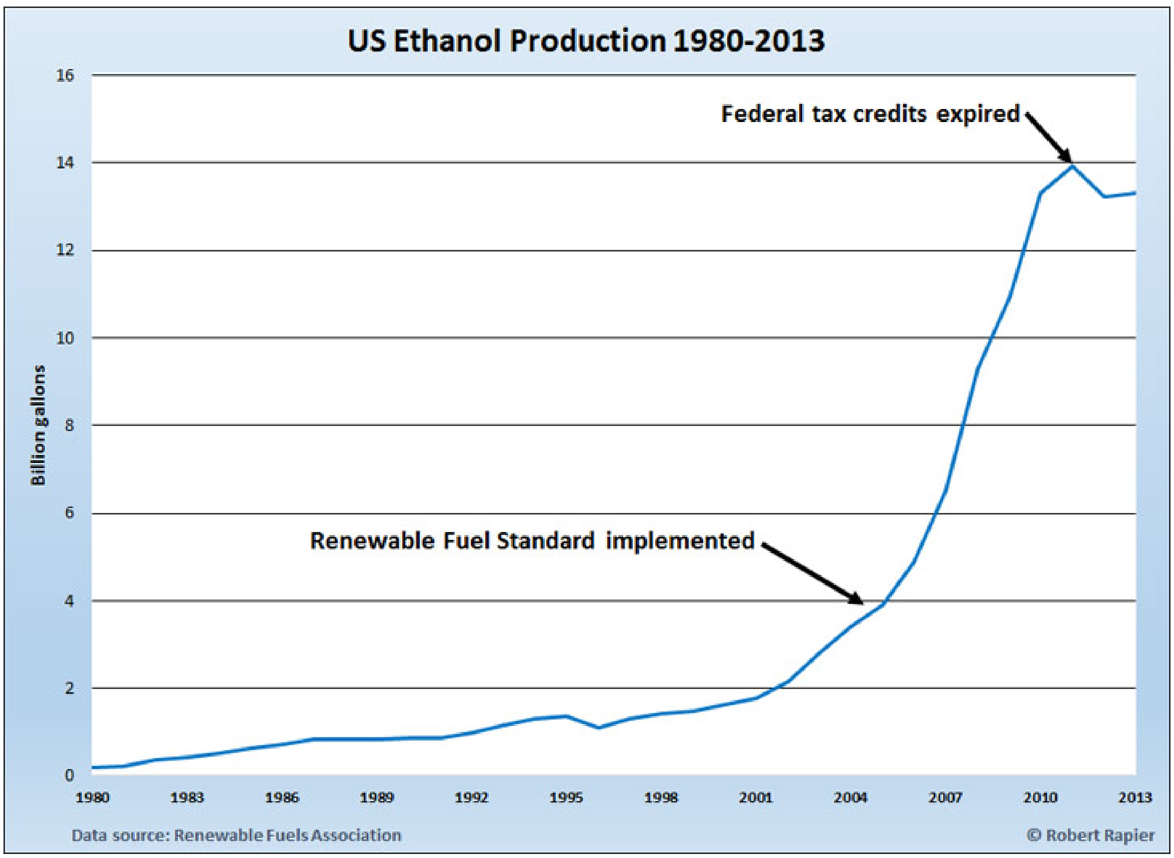
In the 1950s and 1960s, virtually no commercial fuel ethanol was sold to the general public in the United States. However, the prices of foreign crude oil began to rise and the United States began to look to alternative fuel sources. Additionally, in the 1970s, scientific studies began to raise concerns about the toxicity of lead additives in gasoline. This led the relatively newly formed Environmental Protection Agency (EPA) to announce regulations that would reduce lead content in gasoline beginning in 1974 (lead would be completely phased out of gasoline by 1986). It was at this point, that ethanol began to rise in popularity as a possible octane booster for gasoline and this was further evidenced by the Energy Tax Act of 1978 that created a $0.40 tax exemption on the $0.04 gasoline excise tax. Ethanol continued to experience growth throughout the early 1980s as well. The Energy Security Act of 1980 offered insured loans for small ethanol producers up to $1 million in loan guarantees for each project that could cover up to 90% of construction costs on an ethanol plant; price guarantees for biomass energy projects; and purchase agreements for biomass energy used by Federal agencies. Furthermore, the Crude Windfall Tax Act of 1980 extended the ethanol-gasoline blend tax credit and the ethanol subsidy was then increased to 50 cents per gallon through the Surface Transportation Assistance Act of 1982. In 1984, the number of ethanol plants peaked at 163 and the ethanol subsidy was increased yet again to 60 cents per gallon through The Tax Reform Act of 1984. However, in 1985 many ethanol producers went out of business despite the subsidies and only 74 of the 163 commercial ethanol plants (45%) remained operating by the end of 1985. This would however turn out to be only a small setback for ethanol as bigger possibilities were on the horizon. For example, in 1988, a big step was taken for the future of ethanol: it was used as an oxygenate in gasoline. Oxygenated fuels (fuels containing oxygen) were beginning to be used in the winter in order to control carbon monoxide emissions; once again an environmental factor was pushing for the increase of ethanol. Although oxygenated fuels represented a big step for increased ethanol, it did not happen immediately. Methyl Tertiary Butyl Ether (MTBE) dominated the market for oxygenates and would continue to do so until the inception of the 21st century (we will look at the fall of MTBE later in this paper). Ethanol policy continued to evolve throughout the 1990s as well. In 1990, the Omnibus Budget Reconciliation Act of 1990 decreased the ethanol subsidy to 54 cents per gallon of ethanol. In 1992, The Energy Policy Act provided for two additional gasoline blends (7.7% and 5.7% ethanol). The Act defined ethanol blends with at least 85% ethanol as alternative transportation fuels. It also required specified car fleets to begin purchasing alternative fuel vehicles, such as vehicles capable of operating on E-85 (a blend of 85% ethanol and 15% gasoline). The Energy Policy Act also provided tax deductions for purchasing (or converting) a vehicle capable of running on alternative fuel, such as E-85, and for installing equipment to dispense alternative fuels. The Clean Air Act Amendments mandated the wintertime use of oxygenated fuels in 39 major carbon monoxide nonattainment areas (areas where EPA emissions standards for carbon monoxide had not been met) and required year-round use of oxygenates in 9 severe ozone nonattainment areas in 1995. At this time, MTBE was still the primary oxygenate used in the United States. From the 1970s to the end of the 20th century, ethanol became relevant again in the fuel landscape largely due to environmental reasons and the United States government encouraged the production of ethanol through subsidies. The below chart gives a history of ethanol subsidy legislation up till the end of the 20th century:

History of Ethanol Subsidy Legislation (prior to 21st century)

1978	Energy Tax Act of 1978	$0.40 per gallon of ethanol tax exemption on the $0.04 gasoline excise tax
1980	Crude Oil Windfall Profit Tax Act and the Energy Security Act	Promoted energy conservation and domestic fuel development
1982	Surface Transportation Assistance Act	Increased tax exemption to $0.50 per gallon of ethanol and increased the gasoline excise tax to $0.09 per gallon
1984	Tax Reform Act	Increased tax exemption to $0.06 per gallon
1988	Alternative Motor Fuels Act	Created research and development programs and provided fuel economy credits to automakers
1990	Omnibus Budget Reconciliation Act	Ethanol tax incentive extended to 2000 but decreased to $0.54 per gallon of ethanol
1990	Clean Air Act amendments	Acknowledged contribution of motor fuels to air pollution
1992	Energy Policy Act	Tax deductions allowed on vehicles that could run on E85
1998	Transportation Efficiency Act of the 21st Century	Ethanol subsidies extended through 2007 but reduced to $0.51 per gallon of ethanol by 2005

However, although ethanol was now relevant again in the alternative fuel world, the 21st century would bring rise to a whole new level of ethanol production again due to legislation that was environmentally and economically focused.

At the turn of the century, some states began to pass bans on MTBE use in motor gasoline because traces of it were showing up in drinking water sources, presumably from leaking gasoline storage tanks. Because ethanol and Ethyl Tertiary Butyl Ether (ETBE, made from ethanol and petroleum) are the main alternatives to MTBE as an oxygenate in gasoline, these bans increased the need for ethanol as they went into effect. This was the big event that caused ethanol to be used as the main oxygenate in gasoline and later in 2000, the EPA recommended that MTBE be phased out nationally. Things got even better for ethanol in 2002 as U.S. automakers continued to produce large numbers of E-85-capable vehicles to meet federal regulations that required a certain percentage of fleet vehicles capable of running on alternative fuels. The United States government then proved their commitment to renewable fuels and particularly ethanol through 2 acts: The Energy Policy Act of 2005 and The Energy Independence and Security Act of 2007. The Energy Policy Act of 2005 was responsible for regulations that ensured gasoline sold in the United States contained a minimum volume of renewable fuel, called the Renewable Fuels Standard (RFS). The regulations aimed to double, by 2012, the use of renewable fuel mainly ethanol made from corn. The Energy Independence and Security Act of 2007 expanded the Renewable Fuels Standard to require that 36 billion gallons of ethanol and other fuels be blended into gasoline, diesel, and jet fuel by 2022. For some reference on the magnitude on this increase in volume, in 2007, the United States consumed 6.8 billion gallons of ethanol and 0.5 billion gallons of biodiesel. In more recent years, The Obama Administration has set the goal of installing 10,000 blender pumps nationwide by 2015. These pumps can dispense multiple blends including E85, E50, E30 and E20 that can be used by E85 vehicles. The US Department of Agriculture (USDA) issued a rule in May 2011 to include flexible fuel pumps in the Rural Energy for America Program (REAP). This ruling provided financial assistance, via grants and loan guarantees, to fuel station owners to install E85 and blender pumps. In May 2011, the Open Fuel Standard Act (OFS) was introduced to Congress with bipartisan support. The bill required that 50 percent of automobiles made in 2014, 80 percent in 2016, and 95 percent in 2017, be manufactured and warrantied to operate on non-petroleum-based fuels. As can be seen by all the legislation described above, ethanol production has risen significantly in the United States and in fact the United States is now the world's leading producer of ethanol. The graph below shows the increase in ethanol production in the United States since 1980 and highlights the spike since the Renewable Fuel Standard was introduced:



As you can see, in the graph above, the production levelled off in 2010 due to the expiration of federal tax credits for ethanol production. However, this was not the only event that slowed down ethanol production and consumption. One of the most recent developments in the ethanol space occurred in November 2013 as the EPA moved to reduce the amount of ethanol required in the US gasoline supply as mandated by the Energy Independence and Security Act of 2007. The agency cited problems with increasing the blend of ethanol above 10%. This limit, known as the "blend wall," refers to the practical difficulty in incorporating increasing amounts of ethanol into the transportation fuel supply at volumes exceeding those achieved by the sale of nearly all gasoline as E10. Furthermore, experts in the industry such as Dr. Wallace Tyner (Department of Agricultural Economics at Purdue University) don't believe that ethanol production will continue to grow at the rate it has in the past. In our conversation with Dr. Tyner, he stated that "ethanol production will not exceed 15 billion gallons."

He also cited the uncertain future of the Renewable Fuel Standard (RFS) by stating "the future of the RFS is unclear. Ethanol production does not depend entirely on the RFS as the system now is geared to blending ethanol to achieve required octane levels at lowest cost. However, for this system to endure, ethanol must remain less expensive than gasoline. In recent weeks, the two wholesale prices are getting closer due to the drop in crude oil prices. If gasoline becomes less expensive than ethanol and if the RFS were weakened or eliminated, then under those two conditions, ethanol would face difficulty." We believe that this slowing of ethanol production and consumption would be a positive as the current ethanol policies in the United States create a large number of adverse effects.

In spite of recent events and possibilities for future reduction in ethanol, its production and usage has risen greatly in the United States since the 1970s. Naturally, this added demand for ethanol has brought people to seek the most efficient way to produce it. Below, we will talk about methods of ethanol production in the United States and highlight some of the negative effects of these methods.

Ethanol Production Process

Preliminary Overview

As legislation and economic policy concerning ethanol production has changed drastically throughout history, the production of ethanol from starch or sugar-based feedstock has remained one of the preliminary value-adding processes in America. The main cash crop for ethanol production in the United States is corn (less than 2% comes from other crops or sources). Overall, the basic steps have remained the same, but the process has been slowly refined in the past few years due to technological advancements leading to an efficient process. There are two main production processes: dry milling and wet milling; the only major difference between the two is the initial treatment of the grain.

Furthermore, many companies around the United States are focused and involved in technological innovations such as low heat fermentation, fractionation, methane capture, and biomass gasification (reduces the amount of fossil energy necessary to distill grains and produce ethanol). However, there has been a considerable amount of debate on the sustainability of corn-based fuel to replace fossil fuels since corn is the primary source of U.S. ethanol which requires electricity from many distilleries that come mostly from coal plants. The concerns and controversies stem from issues regarding pollution and water use due to ethanol production expansion, direct and indirect land use change effects, the large amount of arable land lost, and issues regarding carbon intensity and energy balance considering the full life cycle of ethanol production. Also, another factor for using ethanol is that burning ethanol emits fewer greenhouse gases than burning gasoline; however, scientist are beginning to worry about additional emissions associated with the increased pollution from fertilizer run-off, additional consumption of limited water for processing and irrigation, and land use changes.

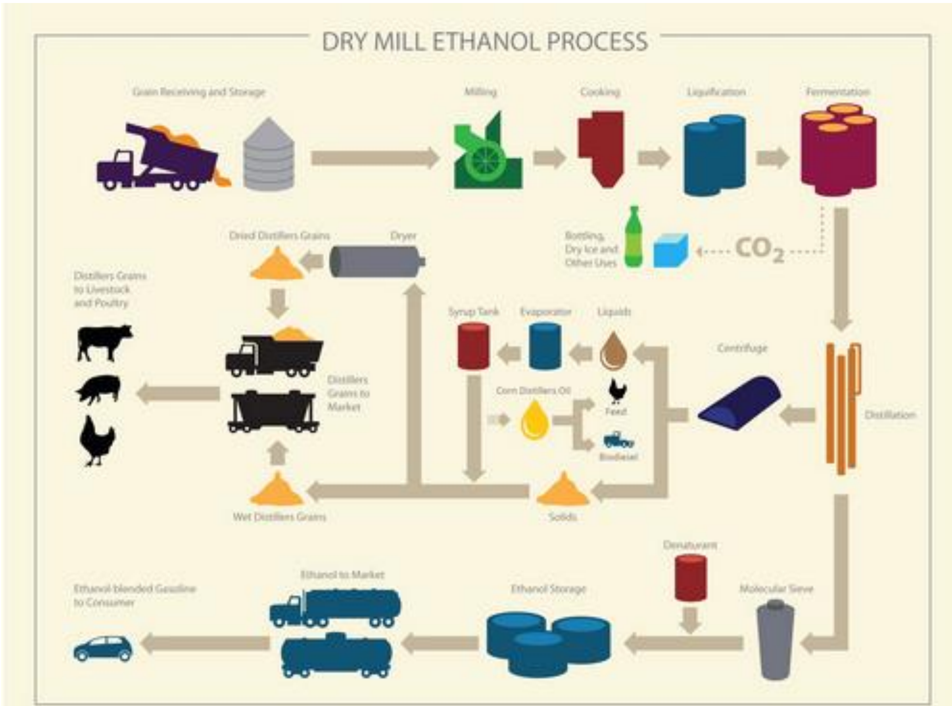
Dry Milling Process

The Dry Milling ethanol production process: during this process, the first step is to ground the entire corn kernel into flour (better known in the industry as 'meal') and is then processed without separating out the various parts of the grain. Next, water is added to the meal to create the next form: 'mash'. Enzymes are then added to convert the mash into a simple sugar known as dextrose and then ammonia is added to control and balance pH levels and to serve as a nutrient to the yeast.

Next, before fermentation, the mash is processed in a high-temperature cooker to reduce and eliminate the bacteria levels. After the mash has cooled, it is transferred to fermenters where yeast is added and the conversion of sugar to carbon dioxide and ethanol begins. Generally, the fermentation process lasts about forty-to-fifty hours – during the fermentation process the mash is kept cool and agitated to facilitate the activity of the yeast. Once the fermentation process is complete, the output (known as 'beer') is delivered to distillation columns where the ethanol is separated from everything else (known as 'stillage'). The production facilities aim to concentrate the ethanol to 190 proof using a conventional distillation system and it is then dehydrated at around 200 proof in a "molecular sieve system."

Moreover, the resulting anhydrous ethanol is blended with around 5% denaturant (essentially, this is just natural gasoline or a gasoline based product) to make it harmful and undrinkable for the human body – this avoids the producers having to pay beverage alcohol tax. It is then prepped and ready for shipment to retailers or gasoline terminals.

However, this is not the end – most producers and production facilities use the extra output in other ways. For example, the stillage is sent through a centrifuge the separates the coarse grain from the solubles. The solubles are then concentrated to around 30% solids by evaporation giving us a syrup type substance. The coarse grain and syrup are then dried together to create a very high quality and nutritious livestock feed. Finally, the remaining carbon dioxide from above is captured, controlled, and sold to different industries including usages in carbonating soft drinks and the makers of dry ice. The diagram below represents the dry milling process:

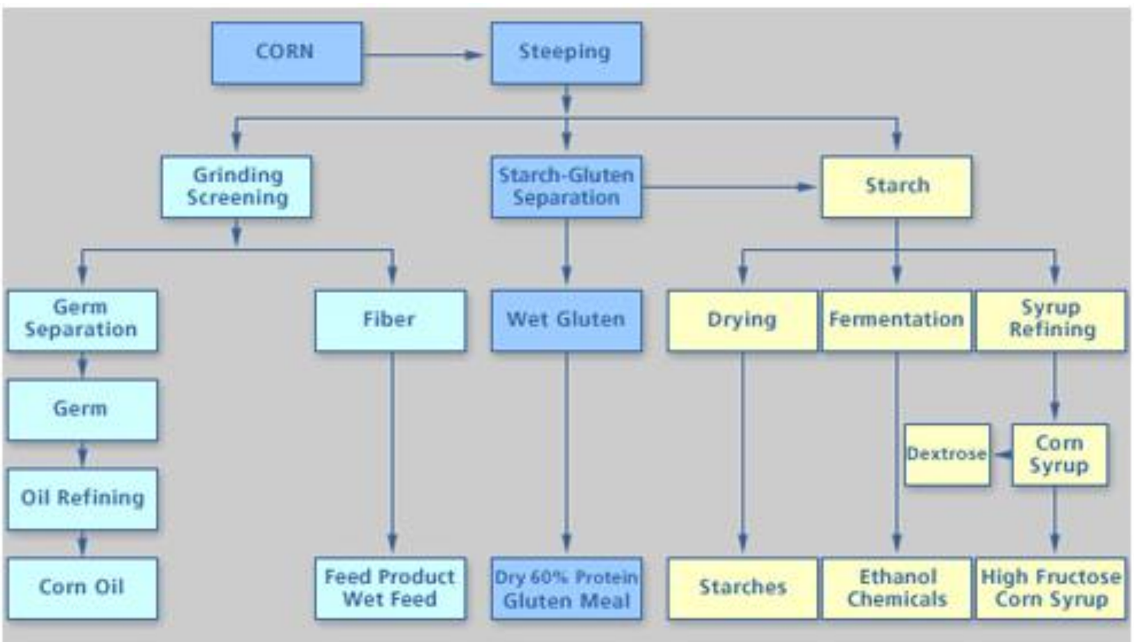


Wet Milling Process

The Wet Milling ethanol production process: during this process, the first step is to soak or 'steep' the grain in fresh water and dilute the sulfurous acid for about 24-to-48 hours depending on the quantity and quality of the grain received. This part of the process is known as the steeping section where it facilitates the separation of the grain into different segments. Once the steeping process is complete, the corn slurry is placed through a series of grinders to separate the corn germ from the extra output. Next, the production facilities extract corn oil from the germ or exports that job to a different facility. The remaining starch, fiber, and gluten segments are further separated using hydroclonic separators, centrifugal, and screen. Finally, the remaining water and starch from the mash can be processed using one of three different paths: processed into corn syrup, fermented into ethanol, and/or dried and sold as cornstarch. The fermentation process for ethanol is almost identical to the dry milling process described above.

However, with the wet milling process, there is more output than in the dry milling process that allows for different uses of the extra materials. For example, the excess steeping liquor can be concentrated in an evaporator and then the concentrated product is co-dried with the fiber component and is sold as corn gluten feed to the livestock industry. Also, the different gluten components can be filtered and dried to produce corn gluten meal co-product; this is a very sought after product in the poultry broiler operations industry. The diagram below represents the wet milling process:

Wet Milling Process



Comparing and contrasting the two different processes is straight forward: To begin, wet milling is very capital intensive with higher operating costs; however, it does produce a wider range of other products that can valuable in a volatile market. The wet milling process also results in slightly lower ethanol yields compared to traditional dry milling because some of the fermentable starch exits the process attached to the saleable co-products. That leads us into our interpretation of dry milling: it is less versatile, but also less capital extensive. Its main focus is on the production of grain ethanol rather than a variety of substances. Across the United States, dry milling is used vastly more than wet milling.

Production Locations

Ethanol production occurs all across the country; however, a majority of the 200+ plants are located in the Midwest – corn production is greatest in this area. See below a map explaining production and operating / under construction plants in the U.S. Blue dots represent operating plants while the yellow dots represent plants under construction. There are also 11 installed ethanol bio-refineries not shown bringing the total to 210 in 2014.

Because most of the operating plants reside in the Midwest, there are a lot of different risks that occur with such a high dependence on corn. For example, in 2012 there was a strong drought that negatively impacted the industry resulting in very high corn prices, oppressive ethanol stock, and an influx of Brazilian (ethanol) imports. We saw a strong rebound in 2013 as corn prices went down a three-year low; however, this goes to show how variable the industry is. Furthermore, we are seeing an increase in competition from oil companies and other renewable fuel source companies lobbying harder which puts a lot of pressure on the cost of corn. We will delve deeper into this point in the next section of the paper.

As stated earlier, there is more than one source (besides corn) that can be used to produce ethanol: sugarcanes and cellulose are the two other major possibilities. We will see in the penultimate section of our paper, Brazil's use of sugarcanes and its effectiveness / ineffectiveness versus the United States. Also, new technology allowing us to use cellulose is beginning to form – using cellulose helps eliminate a lot of the problems with corn listed above. It is seen as a purer 'green' fuel source; there is no competition for food sources and it is supposed to be able to reduce greenhouse emission by as much as 86% over gasoline.

Ethanol Policy and Its Effect on the Price of Corn as a Commodity

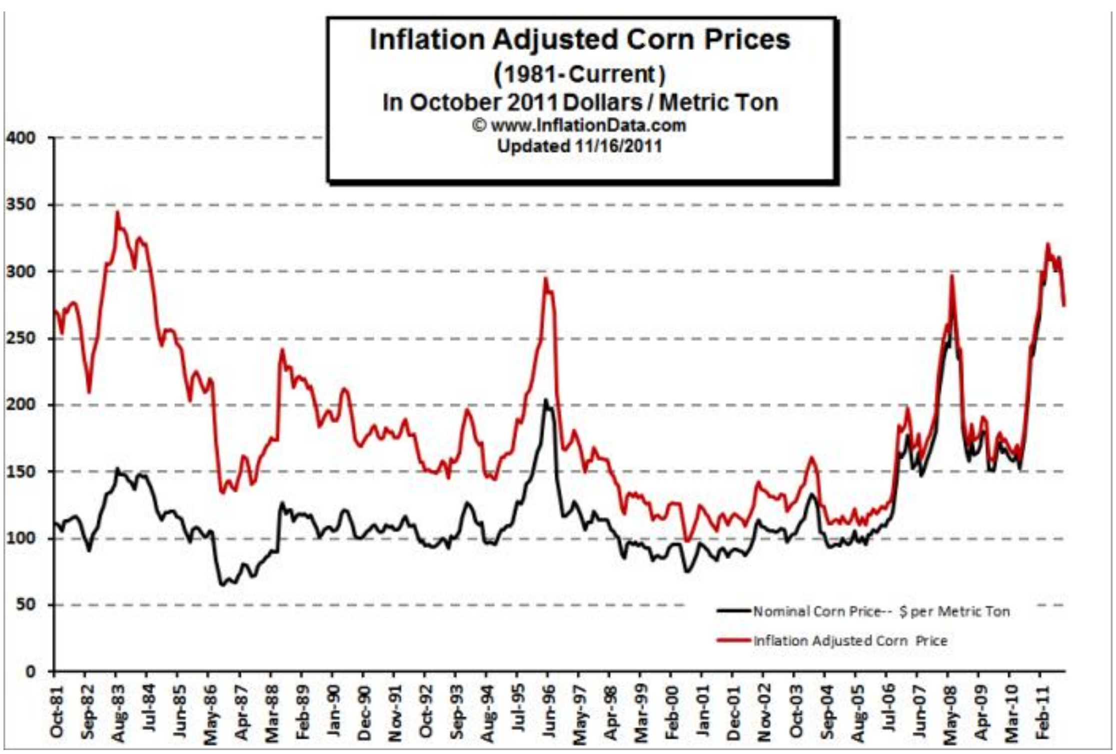
Introduction

The goal of this section is to examine the effects of ethanol policy on the global trade of corn as a financial commodity, specifically in terms of the price of corn and movements in the price of corn. Further, through analyses of market trends this section will demonstrate that ethanol policy affects the prices of corn independently of actual agricultural conditions–harvest conditions, precipitation levels, floods and droughts, and many others. That is, it seeks to demonstrate that ethanol policy has created a system in which the prices of corn move and are often derived independently of the actual value of the corn – but instead are driven by market forces, oil prices, and the market events that drive oil prices. In short, this section will attempt to examine how the commoditization of corn as an oil product – as a direct result of ethanol policy –has created an economic and financial reality wherein corn is priced independently of the true value of the corn and instead is traded as an energy investment.

This section will examine the four major movements in the price of corn that have occurred since the establishment of the modern commodities market surrounding corn. It will do so using the historical record and sources that examine it in conjunction with more recently published papers that touch on this subject. The aim of examining the first three movements in corn prices will be undertaken in order to establish an understanding of the fact that movements in the price of corn can be and are frequently shaped by Government policy, regulation, and market conditions. The fourth movement – the movement that occurred as a direct result of the implementation and continuance of ethanol policy – can then be properly examined in its historical context: as a movement in the price of corn driven by a policy prescription by the United States government. The final part of this section will attempt to delineate the effects of movements in corn prices and hone in on the wider effects of US ethanol policies.

Examining the Modern Commodities Markets of Corn

This subsection to delve into a few key events in recent history of the commodities market surrounding corn in order to discern the effects of trading corn as a global commodity. The following graph – inflation-adjusted to remove inflation as a possible confounding variable – illustrates four of the largest spikes in the prices of corn in the past 35 years.

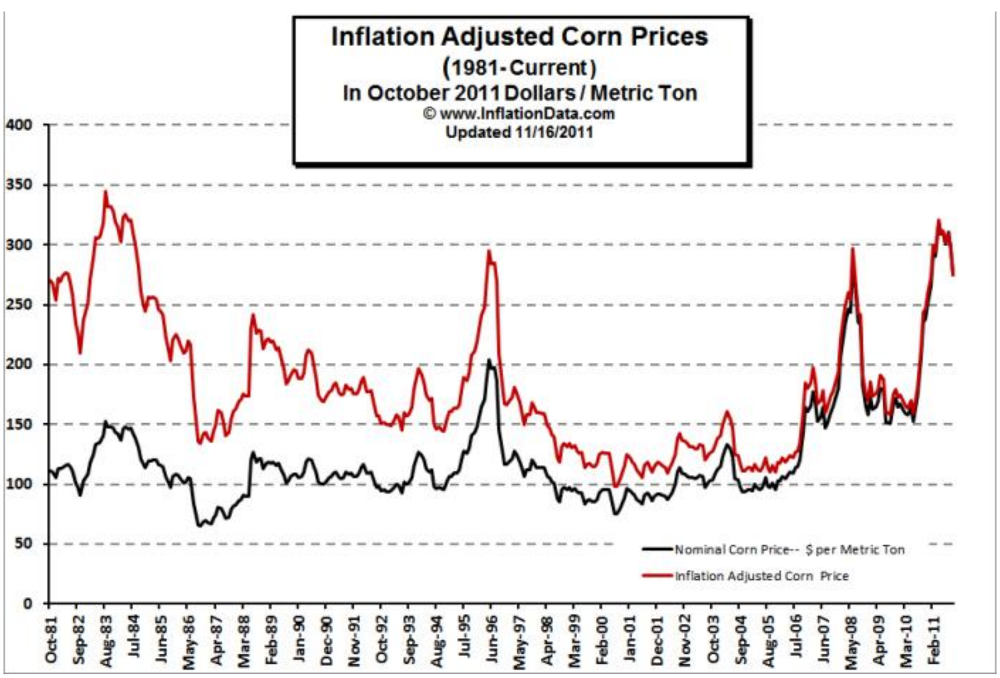


Payment in Kind

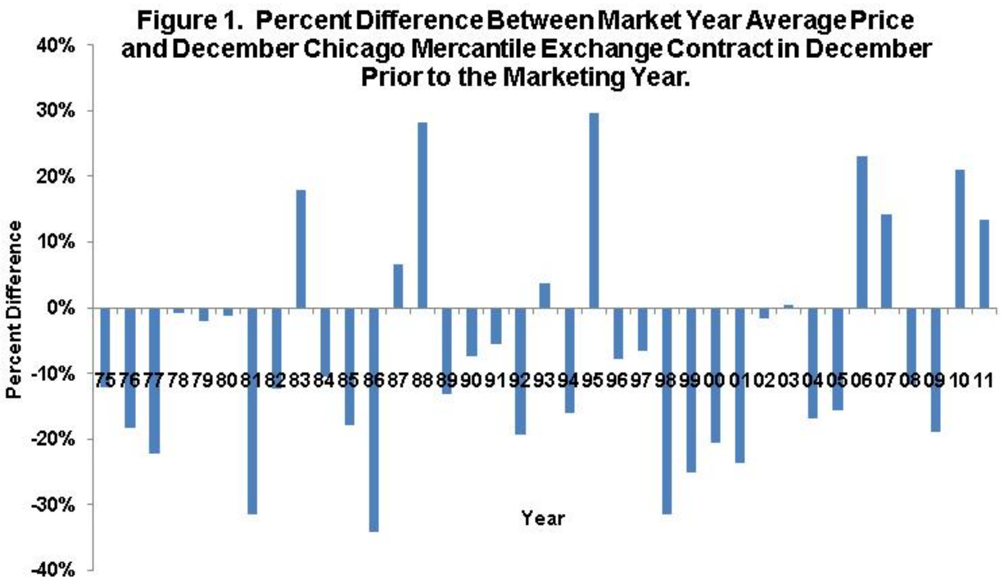
The first price spike, occurring in late 1982, is widely attributed to the institution of the Payment in Kind (PIK) program by the U.S. Federal government. The PIK program attempted to reduce government food stocks by paying farmers in crops from storage to reduce their planted acreage. The result of PIK was a 49% drop in production, resulting in an increase in price. After the program was abandoned, the price of corn plummeted over the course of the following three years before returning to pre-Payment in Kind levels. While interesting in its own right, the price fluctuations from 1982 through 1986 are widely attributed to the PIK program by scholars. Although, they demonstrate that US Government policy can affect global corn prices, a price spike driven by PIK is not directly applicable to ethanol policy's affect on global corn prices.

Normal Backwardation and Contango

Before we examine the second increase in price, it is important to point out a distinction within commodities market. Modern commodities can be split into two segments: soft commodities – commodities that are grown and are perishable – and hard commodities – commodities that are mined. This section will focus on the subcategory of soft commodities, the subcategory containing corn.



With this distinction established, we can begin to analyze the second increase in price, which occurred in 1988 through 1989. In order to analyze this shift in price, we will first consider the graph below.



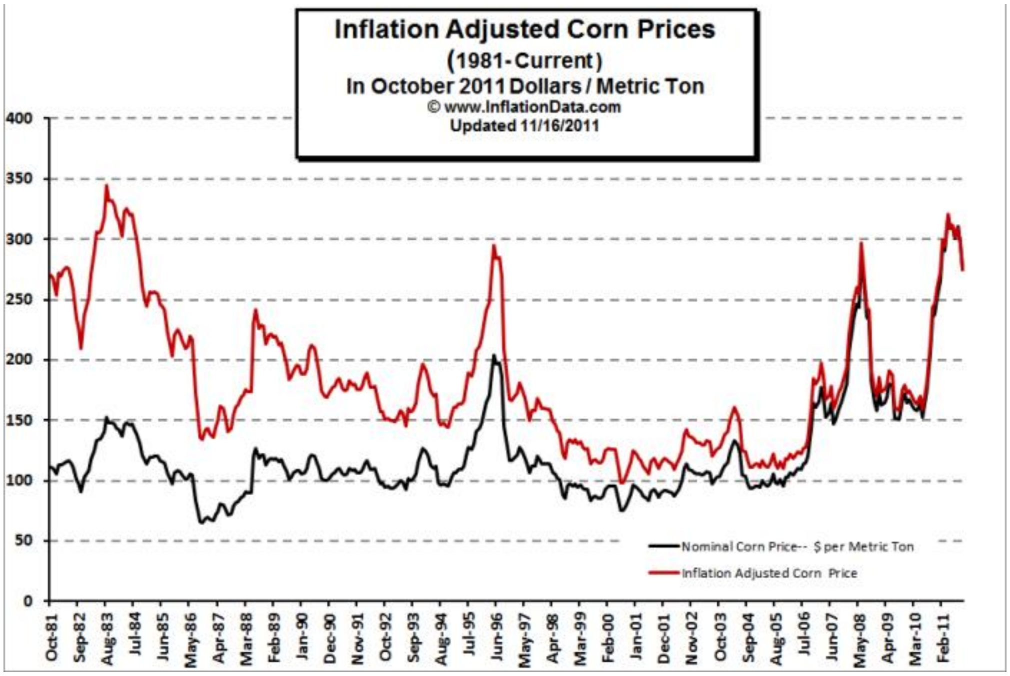
This graph compares the percent difference between the current market year average price of corn and the price of corn in a futures contract signed in December of the previous year to be delivered in December of the current year. When comparing this chart to the inflation adjusted corn prices, an interesting trend arises. In 1983 a government influenced increase in the price of corn caused prices to shoot past levels anticipated in previously signed futures contracts. However, this anomalous year aside, between 1975 and 1986 the cost of corn delivered through futures contracts was higher than the spot value – corn purchased and delivered immediately. This intuitively follows due to a trend known as normal backwardation. Backwardation occurs when the difference between the forward price (the price of the good in the futures contract) and spot price at maturation (the price of the good when the futures contract is realized) exceed the cost of carry (the costs inherent in a futures contract, insurance and storage of the commodity, and other incidental costs). That is, when the future price of the good minus the costs associated with the futures contract is less than the spot price of the good, the price of the futures contract will decrease because it is a poor investment.

Backwardation is an investment phenomenon that was traditionally associated with soft commodities from the inception of futures markets through 1987. However, after years of backwardation, rapidly falling prices in corn from late 1983 through the mid-1986 caused the price of futures contracts to plummet due to the expectation that corn prices would continue to fall. In mid-1986 prices of corn stabilized and, beginning in 1987, this trend of backwardation reversed. Contango, a trend found only in hard commodities until 1987, occurred.

Contango can be thought of as the opposite of backwardation. It occurs when there is a profit to be made on trading on the arbitrage between future and spot prices of a good. That is, if the forward price minus the cost of carry exceeds the spot price at the time of maturation of the futures contract, there is a profit to be made on buying futures now, holding them, and selling the goods as soon as the futures contract is settled. This tends to occur primarily with hard commodities because the storage of hard commodities – which are largely nonperishable – tends to be lower.

In 1987, this disparity between futures prices of corn and anticipated spot prices in the future leads to large amounts of the corn being purchased through futures before the corn is even harvested. Thus, it is not surprising to see that in 1988 the spot price of corn increase as the value of corn futures as an investment increases. It is also not surprising that other investors take advantage of this contango trend by investing in corn futures the following year, leading to another sharp increase in the price of corn from 1988 to 1989. However, in 1989 the market experienced a shock, halting the contango trend in its tracks. Investors, suddenly uncertain of the future of agricultural prices due to a litany of factors including Mikhail Gorbachev’s announcement of Soviet agricultural reforms, abandoned speculation and the cycle of contango abruptly came to a halt.

Opening Commodities Markets to Financial Institutions



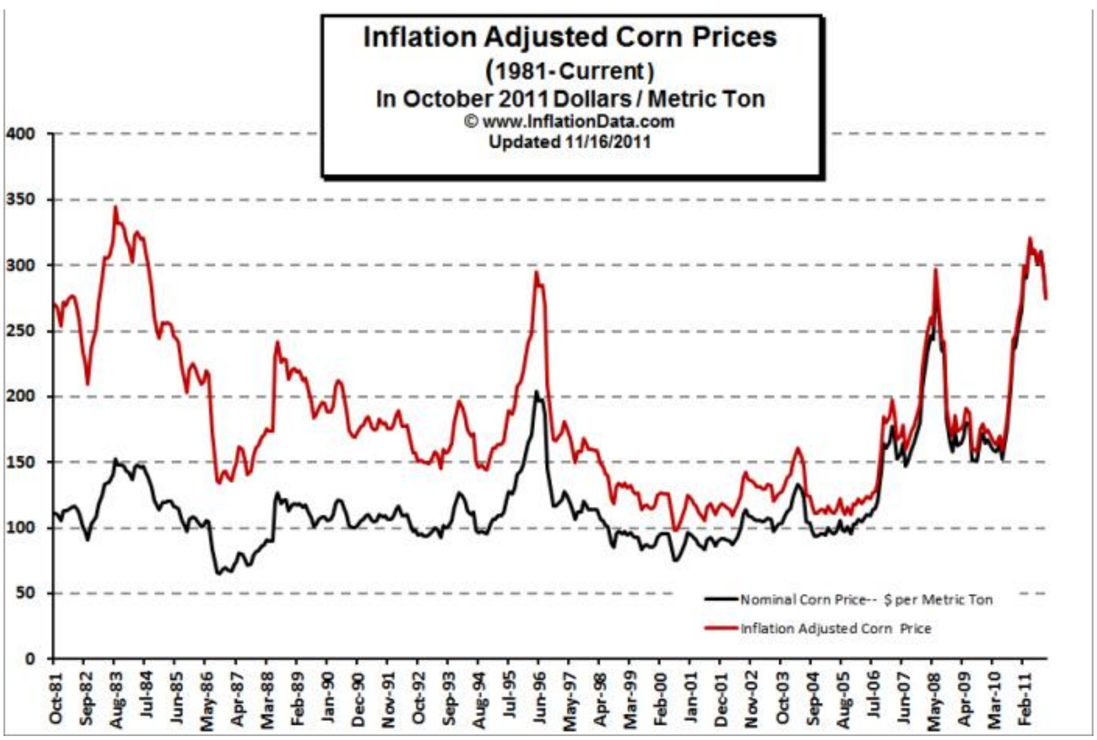
In 1991, the CFTC began granting exemptions to large financial entities that allowed them to begin trading in commodities markets to hedge bets on their assets. That is, the CFTC began allowing financial firms to begin hedging against assets they did not own. While speculation opens the door to huge profit margins for financial entities, it quickly became apparent that these practices could prove risky to the health of the economy as a whole.

As banks and large financial institutions began to look closely, they realized they could effectively begin to make informed wagers as to the future movements of the prices of commodities. Now, not only primary producers and producers of final goods but also financial institutions have a stake in the price of commodities. And the financial institutions have the clout to move the prices for their own benefit.

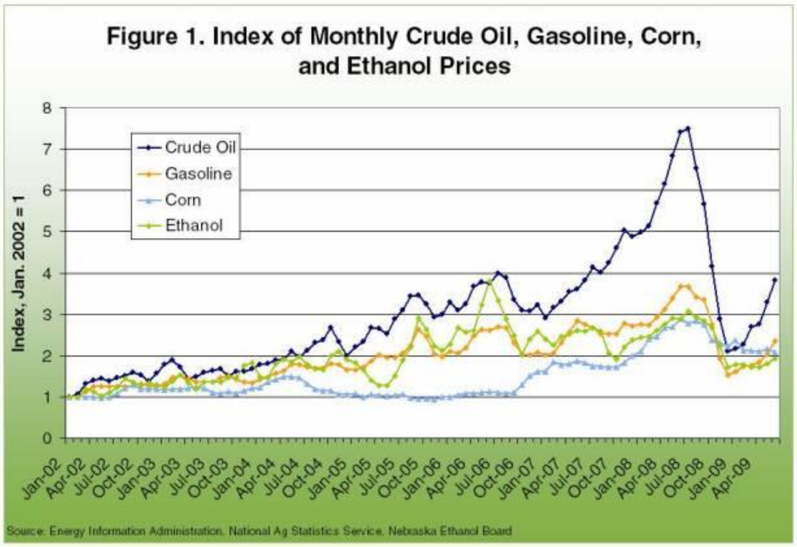
Further worsening the problem, in the mid 1990’s these financial institutions began heavily trading in commodities without any regulation whatsoever by trading them where the CFTC had no power, outside of exchanges through derivatives – assets that derive their value from the price of another asset. The inflation adjusted corn prices graph illustrates what happened within 5 years of financial institutions gaining the ability to speculatively trade futures of corn. Accordingly, we see a large spike in the price of corn in 1993 and a huge spike and 1996.

In 2003, the value of speculative activity in the commodities market shot up to $30 billion. By 2007, the value of these speculative activities exploded to over $300 billion. Many have attributed this runaway speculation with the food crises experienced in 2007 and 2008. After years of runaway corn prices, the CFTC was finally granted the authority to reign in speculation on commodities and we see corn prices begin to come under control.

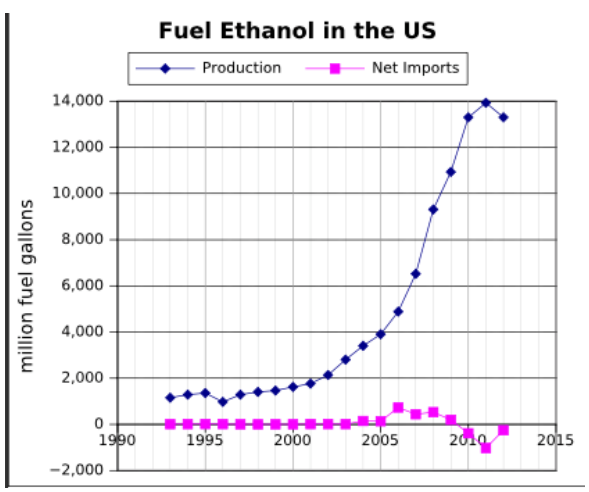
The Unforeseen Consequences of Ethanol Subsidies



In 2007 and early 2008, the prices of corn rose by over 100% before sharply falling back to prior levels by late 2008. However, in order to understand this trend we must also examine the relationship between crude oil, gasoline, corn, and ethanol prices, a relationship displayed in the graph below:



From 2002 through late 2006, corn prices are largely independent of crude oil, gasoline, and ethanol prices. However, beginning in 2007 – the first year with high enough oil prices that US Ethanol subsidies were in effect for – we begin to notice ethanol prices follow prices of crude oil and, albeit to a lesser degree, gasoline. After years of steadily increasing production, ethanol production skyrockets beginning in 2007 as the U.S. imposes new ethanol consumption mandates and further incentivizes ethanol production through subsidies, pulling corn prices up.



Further confounding this situation is the evidence presented by Lagi *et all.* in their paper, *The Food Crises: A Quantitative Model of Food Prices Including Speculators and Ethanol Conversion*. They point out ethanol used “only a small fraction of the production of corn before 2000” but “consumed a remarkable 40% of US corn crops by 2011”. While the ethanol policies of the U.S. were certainly not exclusively to blame for the increase in corn prices, they certainly did not help an already challenging situation. In addition to globally trending increases in expected corn prices, “ethanol conversion is sometimes considered the primary cause of price increase overall” in food prices, according to Lagi *et all*. However, Lagi *et all* are also quick to point out that “ethanol conversion itself cannot itself describe the dynamics of prices […] because it cannot explain the sharp decline of prices in 2008”.

The Effects of Rising Corn Prices on Global Food Prices

Food Crises: A Quantitative Model of Food Prices Including Speculators and Ethanol Conversion provides a very compelling argument that “a parsimonious explanation that accounts for food price change dynamics over the past seven years can be based upon only two factors: speculation and corn to ethanol conversion.” While the pricing of food was not entirely stable from year-to-year prior to these recent developments, this speculation, increase in U.S. ethanol production at the expense of U.S. corn used as food – which accounts for 4.3% of the world’s total grain production – and rapid increase in world food stores by 140 million metric tons – the amount of food consumed by 440 million individuals a year – driven by this global food price explosion have led to a global food market that seems to derive its prices independently of the true value of the food itself. This outcome has resulted not only in a devastating humanitarian crisis, but also a wildly inefficient global food market that serves investors, not the individuals most affected by these increasing food prices.

In *Do Economists Make Markets*, MacKenzie states “At the origin of markets there are never rootless and detached individuals." And in the case of commodities markets, this holds true. The initial participants in soft commodities markets tended to be farmers and those who took charge of their goods. However, as commodities markets evolved, either largely unregulated or poorly regulated for nearly a century, these markets began to be heavily influenced and arguably run by "rootless and detached individuals" with no real interest in anything but profit. Worse yet, once these markets were finally successfully regulated, the global trade of food as a commodity was allowed to move off regulated commodities markets and into derivatives and other investment vehicles that circumvent these rules. Unfortunately, these findings apply far beyond the prices of corn. As one of the staple foods of the modern world, an increase in the price of corn leads to an increase in demand for other foods, which serve as substitute goods, shooting their prices up.

Benefits of Ethanol Subsidies

However, this is not to say that there are no benefits to ethanol subsidies and alternative biofuel policy in general; they are especially helpful to farmers. According to *The Effect of Biofuel on the International Oil Market*, written by Hochman et. al, recent shifts in energy composition "not only reduces total fossil fuel production, but also reduce domestic gasoline prices". They continue, pointing out that during fiscal years 2007 and 2008 farm income was $88.7 billion and $89.2 billion, respectively, both setting records and beating the 10 year average by over 50%. They continued, establishing that "average farm household income is estimated at $89,434, nearly 20% above the five-year average from 2001-2006.

However, these benefits aside, it is beginning to become clear that other alternative fuel policies should be investigated; the benefits achieved by a few farmers do not outweigh the drastic economic and social consequences of driving up food prices in order to provide a substitute fuel that is considered by many to be inadequate environmentally to be a solution to US Energy needs and inadequate to be an eventual successor to fossil fuels.

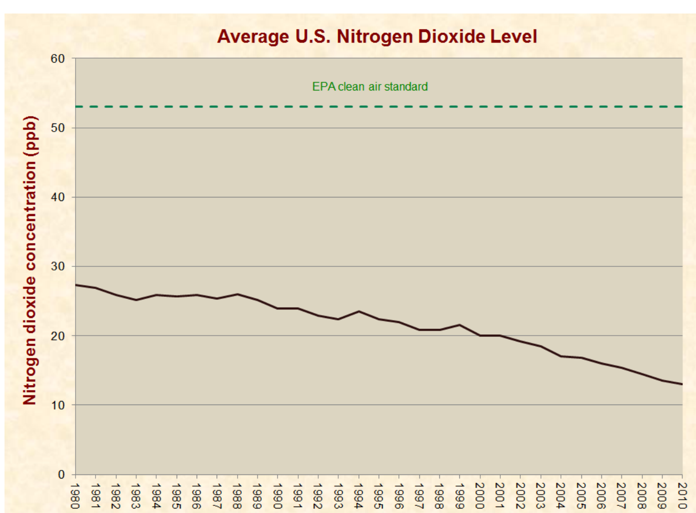
Fuel-Based Substitutes to Ethanol

Defining the Environmental Efficiency of Corn-Based Ethanol

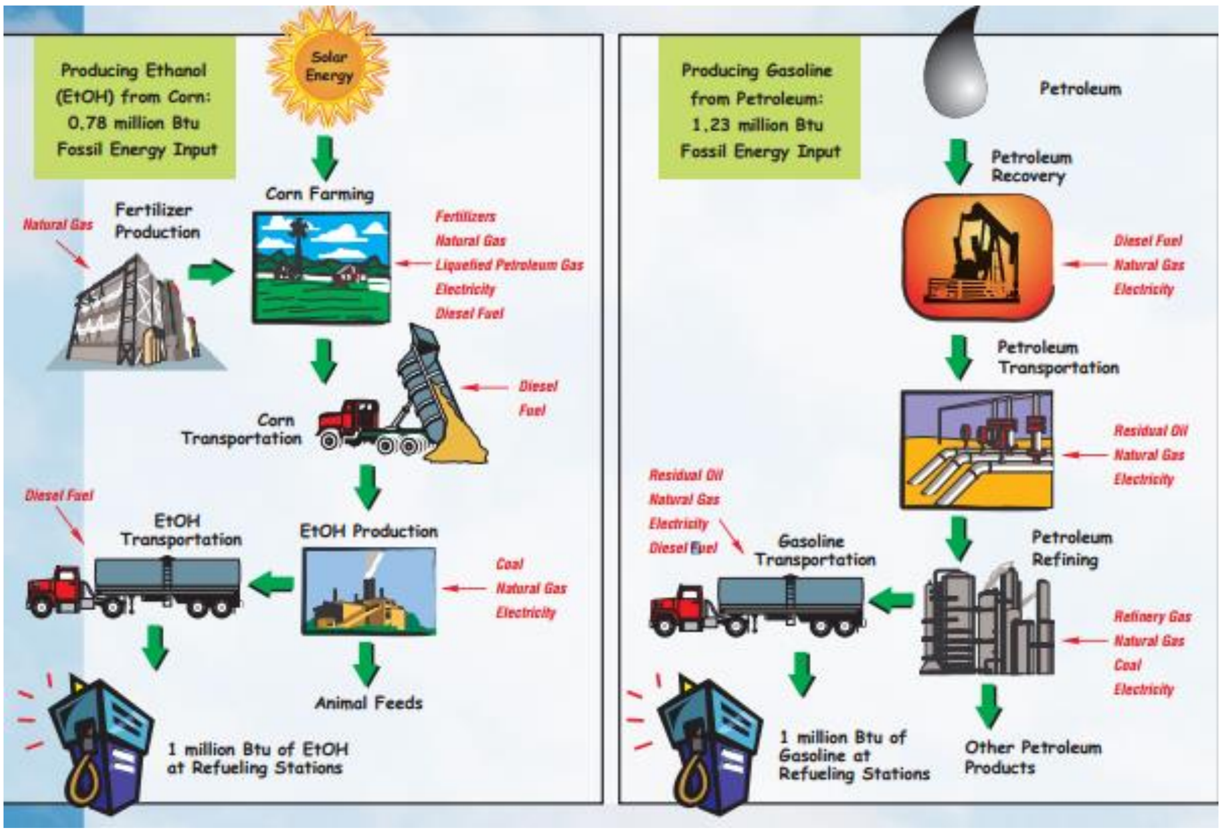
As can be imagined, it is difficult to understand the effectiveness of U.S. ethanol policy without fully appreciating how ethanol as a fuel compares to other fundamental fuel-based substitutes. There are multiple studies that compare and contrast the carbon intensity (the metric defining such intensity can vary) and ability to substantially reduce greenhouse gas emissions of corn-based ethanol vis-à-vis sugarcane biomass and cellulosic biomass.

It is important when examining such studies to consider the efficiency of corn-based ethanol and the substitutes it is being evaluated against on a life cycle level. Analysis of the efficiency at all aspects of its life cycle (including a thorough assessment of how the fuel is extracted as a raw material, its respective processing and manufacturing stage, actual utilization stage and finally the end stages of disposal and/or recycling) will ensure that the fuels are being compared on an equal and fair grading rubric.

Such a grading matrix might include metrics of success such as the emissions of carbon dioxide, methane and nitrous oxide being reduced. In addition, these metrics may also consider the consumption of total energy as well as emission of other pollutants such as carbon monoxide, nitrogen oxides and volatile organic compounds in comparing the efficiency of fuel based substitutes like corn–based ethanol.



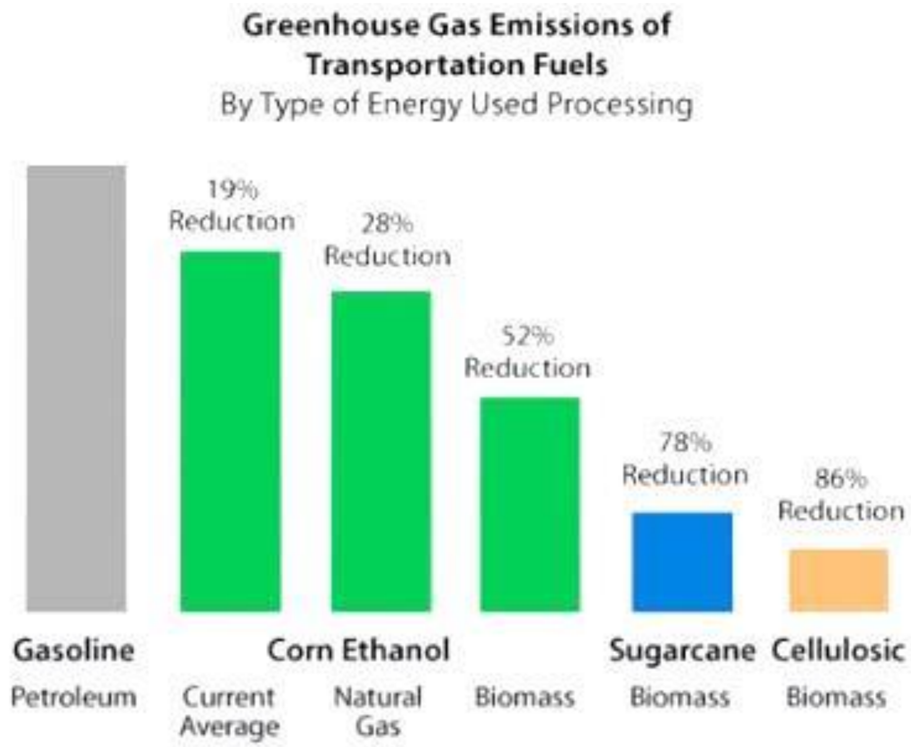
An example of a complete life cycle analysis (in this case the Greenhouse gases, Regulated Emissions and Energy use in Transportation (GREET) system being deployed by the Center for transportation Research, Argonne National Laboratory in conjunction with the U.S. Department of Energy's Office of Energy Efficiency & Renewable Energy) being deployed in analyzing alternative fuel solutions is evident in the chart below:



Notably, corn-based ethanol has a spectrum of different efficiency levels based on what type of energy is used for processing (e.g. biomass vs. natural gas vs. current average). While the corn-based ethanol utilization is ultimately be lower than gasoline as well as other transportation fuels in terms of greenhouse gas emission, it is still worthwhile to consider the shortcomings of such production relative to their respective magnitude of opportunity costs provided by sugarcane and cellulosic biomass (e.g. wood chips). This section will examine studies and primary due diligence efforts from the Argonne National Laboratory, U.S. Department of

Energy's Office of Energy Efficiency & Renewable Energy and Institute for Lifecycle Environmental Assessment in addressing the question of efficiency surrounding U.S. corn-based ethanol relative to its viable economic and environmental substitutes.

First and foremost, a 2007 study by the Argonne National Laboratory discovered that in the context of entire fuel life cycles, the utilization of corn-based ethanol in lieu of gasoline and petroleum is able to generate environmental benefits in the form of reductions in life cycle GHG emissions ranging from ~20% to ~50% (as seen in the diagram below):



Such a spectrum is notably contingent on blend levels (e.g. using a higher level blend of ethanol such as E85 will result in enhanced efficiency), the vehicle type as well as its respective energy calibration. Interestingly, lower level of ethanol blends tends to have higher ratings of octane when compared vis-à-vis unleaded petroleum gasoline. Furthermore, ethanol has been scientifically proven to be beneficial over its petroleum based counter-part at the life cycle stage given that greenhouse gas emission (particularly carbon dioxide) from corn-based ethanol fuel can be mitigated by the ability of the ethanol-producing crops to absorb a portion of the greenhouse gas. Such would be a positive feature of corn-based ethanol over the traditional forms of fuel used in vehicular combustion.

Conversely, as quite clearly depicted in the above chart that compares the ability of corn-based ethanol against gasoline petroleum and sugarcane and cellulosic (produced from non-food-based feedstock) biomass, other forms of ethanol are even more effective in reducing greenhouse gas emissions. Indeed, sugarcane biomass and cellulosic biomass have the manifestation of greenhouse by up to 78% and 86%, respectively (again, such levels of comparison are contingent on particular assumptions being involved and integrated within the life cycle analysis). Thus, as was concluded by the Argonne study comparing and contrasting nine different plant types of corn ethanol "researchers need to closely examine and differentiate among the types of plants used to produce corn ethanol so that corn ethanol production would move towards a more sustainable path".

Upon translating the findings above that cellulosic ethanol is more efficient than corn based ethanol into a U.S. policy level discussion, it is also important to examine the energy return on investment as another yardstick. The term return on energy policy is defined to be the return ratio of ethanol energy divided by the non-renewable forms of energy that were required to manufacture the respective corn-based ethanol. This is an impact based metric associated with the Institute for Lifecycle Environmental Assessment in understanding and evaluating the level of dependence ethanol technology has on nonrenewable (natural gas, coal, oil and nuclear energy) inputs.

The following table below summarizes how the energy return on investment of corn-based ethanol would stack up based on different forms steps to production (e.g. wet vs. mixed vs. dry milling technology, fuel & electricity vs. upstream energy). The range of values from different studies illustrates a return varying from 0.84x to 1.65x based on the implied differences in manufacturing processes.

TABLE 1. Results of Corn Ethanol Studies, Grouped by Common Process Steps and Normalized to HHV (Sums May Not Match Totals Due to Rounding Error)

	Marland & Turhollow 1991	Lorenz & Morris 1995	Graboski 2002	Shapouri et al. 2002	Pimentel & Patzek 2005	Kim & Dale 2005
milling technology:	wet	mixed	mixed	dry	dry	dry
	all values in MJ per liter ethanol unless otherwise noted					
	fuel and electricity					
agriculture						
fuel	2.0	0.7	2.2	2.7	2.0	0.8
electricity	0.2	2.0	0.5	0.6	0.5	0.1
feedstock transport		0.4	0.5	0.6	1.5	0.5
industrial process						
fuel	10.5	10.9	11.8	10.0	11.7	12.5
electricity	3.5	3.2	2.9	3.6	5.3	2.2
ethanol distribution			0.4	0.4		0.6
total fuel and electricity	16.1	17.1	18.4	17.9	21.0	16.8
	upstream energy					
agriculture						
fertilizer	4.2	3.6	2.6	2.3	4.7	2.0
biocides	0.3	0.3	0.2	0.4	1.3	0.4
other		0.9	0.3	0.1	3.1	0.1
other nonagriculture					0.1	
total upstream energy	4.5	4.9	3.2	2.8	9.2	2.5
	calculation of r_E					
gross energy input	20.6	22.0	21.6	20.7	30.1	19.3
coproduct energy input	(2.3)	(7.7)	(4.5)	(3.7)	(2.0)	(4.8)
net energy input	18.3	14.3	17.1	17.1	28.1	14.5
allocation factor (%)	89%	65%	79%	82%	93%	75%
r_E (unitless)	**1.29**	**1.65**	**1.38**	**1.38**	**0.84**	**1.62**
	reference data					
upstream fuel included?	yes	no	yes	yes	yes	yes
electricity heat rate	3.0	2.4	3.0	2.7	3.3	3.2–3.4
corn yield (Mg/ha)	7.5	7.5	8.8	7.7	8.7	9.0
ethanol yield (L/kg)	0.37	0.38	0.39	0.39	0.37	0.39
oil reduction (%)			94%	84%		
projected r_E (unitless)	1.67	2.51	1.40			1.91

The following table also calculates the energy return on investment but instead for cellulosic ethanol (a direct substitute to corn-based ethanol as previously mentioned). These return ratios again are evaluated on different types of manufacturing processes and techniques.

TABLE 2. Results of Cellulosic Ethanol Studies, Grouped by Common Process Steps and Normalized to HHV (Sums May Not Match Totals Due to Rounding Error)

	Tyson et al. 1993	Lynd & Wang 2004	Sheehan et al. 2004	Pimentel & Patzek 2005
fuel:	various	poplar	corn stover	switchgrass
	all values in MJ/L unless otherwise noted			
	fuel and electricity			
agriculture				
fuel	0.8	1.1	0.8	1.1
electricity				
feedstock transport	0.4	1.3	0.5	1.4
industrial process				
fuel	0.2	2.9		20.1
electricity	0.1		0.3	8.9
ethanol distribution	1.4			
total fuel and electricity	2.9	5.4	1.5	31.5
	upstream energy			
agriculture				
fertilizer	1.1	0.1	4.0	0.9
biocides		0.0		0.3
other				0.8
other nonagriculture	0.5	0.4	0.3	0.5
total upstream energy	1.5	0.5	4.3	2.5
	calculation of r_E			
gross energy input	4.4	5.9	5.8	34.0
surplus electricity	5.4	3.3	1.9	
gross energy output	29.0	26.9	25.5	23.6
r_E (unitless)	**6.61**	**4.55**	**4.40**	**0.69**
	reference data			
upstream fuel included?	yes	?	yes	yes
nominal electric multiplier	3.3	2.7	3.0	3.3
feedstock yield (Mg/ha-yr)	11.2–33.6		8.2	10.0
ethanol yield (L/kg)	0.37–0.41	0.34	0.34	0.40
oil reduction (%)			95%	

On the policy level, it is thus evident that comparing and contrasting the energy return on investment for cellulosic ethanol vs. corn-based ethanol would yield a favoring for cellulosic ethanol. This is because the values of return ratios calculated from various studies indicate that cellulosic efficiency is **materially** higher than that of corn based ethanol.

Problems and Technological Challenges

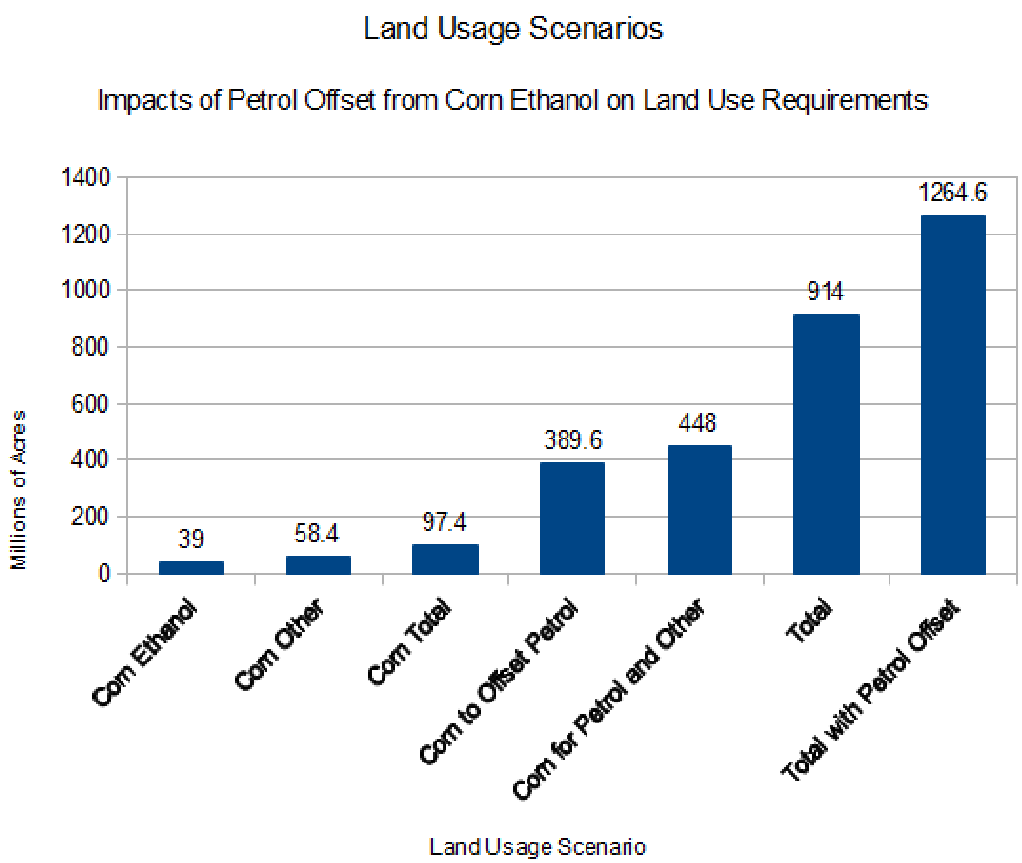
Introduction

While the technologies to develop ethanol certainly exist at a substantial scale, many technological barriers prevent ethanol from replacing fossil fuels. As with any technologies, many of these barriers may be overcome with appropriate investment, however, at present ethanol suffers in viability due to it's high costs in terms of arable land, usage and contamination of irrigation water, fuel and fertilizer usage associated with modern industrialized agricultural practices, lack of existing wet and/or dry milling facilities, electricity usage for milling, and chemical inputs such as denaturants and chemicals to control pH for milling.

Arable Land

Ethanol derived from plant sources, especially in the case of United States corn ethanol, requires large amounts of land to grow sufficient crops. However only 17.0% of United States land area and 9.3% of global land area meet Food and Agriculture Organization specifications for land capable of growing crops. In the United States, 97.4 of the 914.0 million acres devoted to agriculture are used for corn already, with that share likely to grow in the future if ethanol policy is continued.

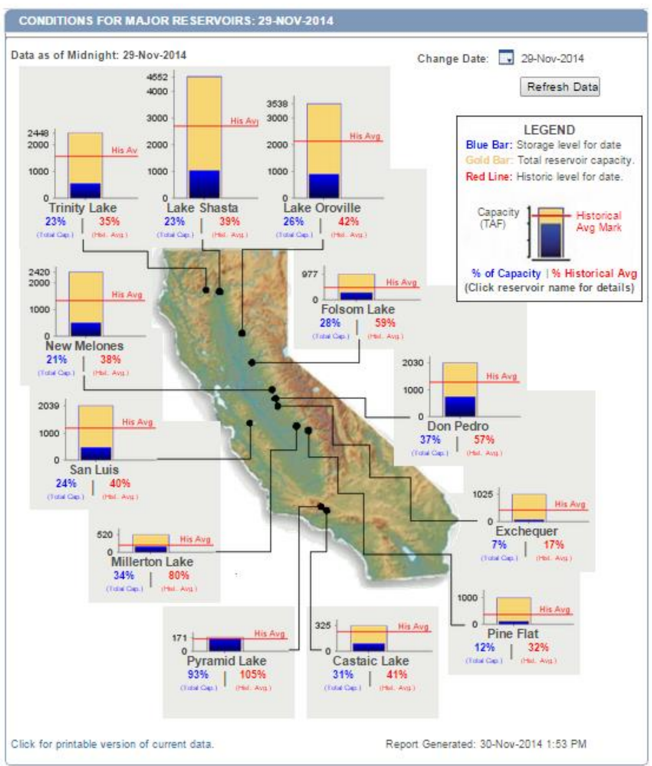
To offset petrol completely would require 389.6 million acres of corn grown for the sole purpose of producing ethanol, with a further 58.4 acres needed to meet existing demand for food, beverages, and livestock feed. While agricultural practices continue to produce higher and higher yields per acre, it is unlikely that incremental improvements will be able to offset the 38.3% uptick in arable land demand that would be generated from offsetting petrol with corn ethanol in the near future. The figure below shows that using corn ethanol as an alternative to fossil fuels would severely strain arable land resources:



While this land pressure could be alleviated by reducing other demands (through lower population) or somehow introducing new arable land, from 1959 to 2002, arable land in the United States declined by 5.3% while population (and associated demand) increased by 63.3%. While ethanol policy could be used to increase corn's share of arable land, at present, the large amount of additional land required to make a more significant contribution to petroleum independence represents are relatively large problem with ethanol as a viable alternative.

Irrigation Water

Of the approximately 410 billion gallons per day of water used in the United States, 128 billion are used for irrigation, the second highest usage after thermoelectric power, and accounts for 62% of freshwater usage excluding thermoelectric usage. From 1950 to 2005, irrigated acreage in the United States increased by more than 140% as record setting settings droughts began to return for the first time since the dust bowl, leading to questions about resource allocation in the face of mandatory conservation measures taking place in many cities in the American West such as Denver, San Francisco, and Los Angeles. In Colorado, for example, scarcity of water and the difficulties in maintaining agricultural business model lead to development of an increased tax burden through continuation of the antiquated business personal property tax, despite these taxes having relatively low degrees of allocative efficiency and promoting other, potentially more environmentally harmful activities such as mineral or oil and gas extraction rather than agriculture.



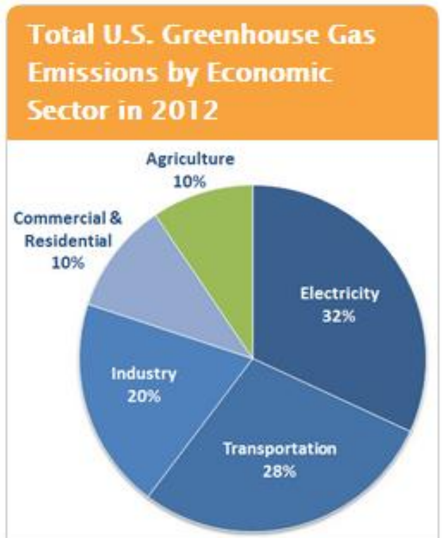
As corn for ethanol already makes up 40% of corn produced in the United States, an industry projected to consume up to 72 trillion gallons of water in 2014, meaning ethanol currently requires approximately 28.8 trillion gallons with up to 288 trillion gallons needed to offset petroleum usage, which, much like land usage, is substantially higher than currently available stores and would severely strain other irrigated crops, electricity generation, municipal use, and other forms of water usage, especially with reservoir levels far below historical averages across the western United States as, of course, population continues to grow.

In addition to straining water availability, water usage for irrigation often deteriorates water quality through fertilizer run-off. Increased fertilizer use to grow corn for ethanol has been linked to a seasonal dead zone forming in the Gulf of Mexico as a result of nitrogen and phosphorous pollution in the Mississippi water shed and associated algae blooms.

The figure below shows a dead zone has begun forming seasonal after ethanol's share of corn production grew from 5% to 40% from 2002 to 2012.

Emissions from Agriculture

One major argument for ethanol is that it reduces emissions, and while ethanol has been regarded as burning cleaner than gasoline by most metrics, emissions from agriculture may lead to worse emissions footprints than petrol. Ethanol can theoretically produce up to 90% reduction in emissions compared to fossil fuels, but in practice is often significantly worse than gasoline (Union of Concerned Scientists). Particularly, in an observational case study of São Paulo, when motorists returned to using gasoline from ethanol due to price fluctuations, nitric oxide and carbon emissions increased significantly. In it's present state, it is highly unlikely that ethanol produces fewer greenhouse gases than gasoline. In the United States, agriculture is already responsible for 10% of greenhouse gas emissions. The figure below shows that agriculture makes up 10% of United States' Greenhouse Gas emissions and Transportation and further 28%.



Milling (Wet and Dry)

The United States currently only has the milling capacity to produce about 14.9 billion gallons of ethanol fuel per year, of which 13.8 billion is currently in use (Nebraska Energy Office). The United States currently uses 217.2 billion gallons of petrol per year (United States Energy Information Administration) meaning that milling capacities would need to be substantially expanded to convert to ethanol.

Currently, with corn ethanol, the only 1.3 units of ethanol energy are produced per 1.0 unit input (National Geographic). With approximately 67% of United States energy being produced from fossil fuel sources (United States Energy Information Administration), on average, 87.1% of the energy from ethanol fuel combustion will be from fossil fuels, assuming complete carbon neutrality prior to milling.

Ethanol fuel often contains gasoline as a denaturant during the milling process as well. Even E85, named for being 85% ethanol, tends to be only about 51% to 83% ethanol due to the addition of gasoline in the milling process.

United States vs. International Ethanol Policy

Comparing United States' Ethanol Policy to Brazil

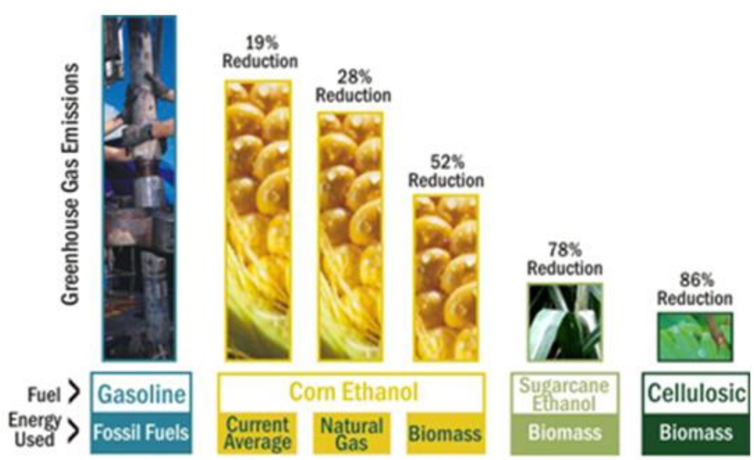
From the previous paragraphs, we saw various problems with the way the United States produces ethanol and alternative methods that could improve production and be more beneficial to the environment. There are specifics within the US ethanol policy that can be improved on just by looking at other ethanol policies around the world. For example, Brazil's ethanol policy is considered to be the best in the world because of how energy efficient and effective their program is. The biggest reason being Brazil uses sugarcane to produce their ethanol, while the United States uses corn. However, it is not just the crop that Brazil uses that the United States should learn from; the US should look at Brazil's whole ethanol policy and in particular focus on their Flex Fuel program in order to improve its own ethanol policy.

Comparison between corn ethanol production in the USA and sugarcane ethanol in Brazil

Parameter	Units	Sugarcane	Corn
Production[§]	million t	386,5	282,0
Yield	t/ha	90,0	8,1
Energy Needed	kcal x1000 1000	10.509	8.115
Energy input:output	kcal	1: 4,60	1: 3,84
Alcohol Production	liters/ha	8.100	3.000
Alcohol Production	liters/ t	90	371
Conversion Rate	kg/ 1000L	11.110	2.690
Total Energy Used	kcal/ 1000L	1.518.000	6.597.000
Present Total Production	billion (L)	15,8	17,2
Energy Balance[#]	kcal input: output	1:3,24	1:1,29
Production Cost	US$/L	0,28	0,45
Sale Price	US$/ L	0,42	0,92
Number of Plants[a]	unit	140	101
Subsidie	US$ billion/year	_	$4,1

We can see from the above table just how much more effective sugarcane is compared to corn. Brazil's sugarcane-based ethanol has a net energy balance of 8.3 – 10.2, while US's corn-based ethanol only has a net energy balance of about 1.3. Net energy balance refers to the difference between the energy needed to turn the crop into ethanol and the amount of energy that is released from its consumption. This means that on average Brazil's ethanol produces a net energy balance 6.4 – 7.8 times greater than the United States. Sugarcane uses 4 times less energy than corn in terms of the amount of total fossil energy to produce the sugars into ethanol. This shows that sugarcane is more energy efficient than corn because of an additional step needed to convert corn into ethanol that is not needed in sugarcane-based ethanol production. Only 50% of the starch from the corn can be converted into ethanol and then the starch must be converted into sugar before being distilled into ethanol. This step is not needed with sugarcane and, as a result, it costs $80 less to produce a cubic meter of ethanol in Brazil compared to the US. Not only is sugarcane more energy efficient, but it also yields, on average, 62 more gallons of ethanol/acre. Sugarcane is also much better for the environment as it reduces the amount of greenhouse gases emitted as seen in the image below. Since it takes less energy for sugarcane to produce ethanol than corn and that it produces less greenhouse gases in the ethanol production process, it is the best source, both economically and environmentally, in the production of ethanol.

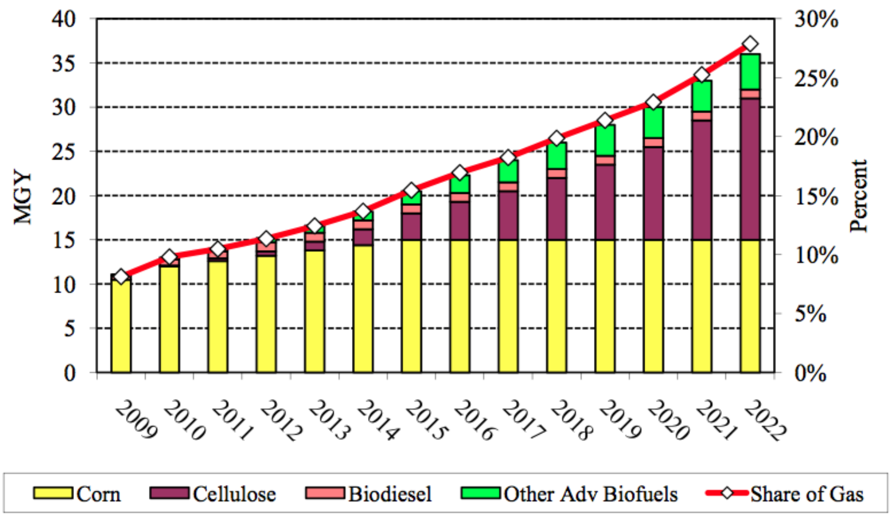
Comparison of Reductions in Greenhouse Gas Emissions



The reason sugarcane is not used in ethanol production in the US is because there is an extremely small supply of it, as it is only grown in 4 states. However, there is definitely a better alternative to corn, which are cellulosic plants such as switch grass and stover corn. Switch grass has a net energy balance of 4, which is about 3.1 times greater than corn. Also, switch grass can yield about 1,000 - 1,500 gallons of ethanol/acre, which is higher than both corn and sugarcane. Unlike corn, switch grass is not used as food and will not drive any sources of food an increase in price.

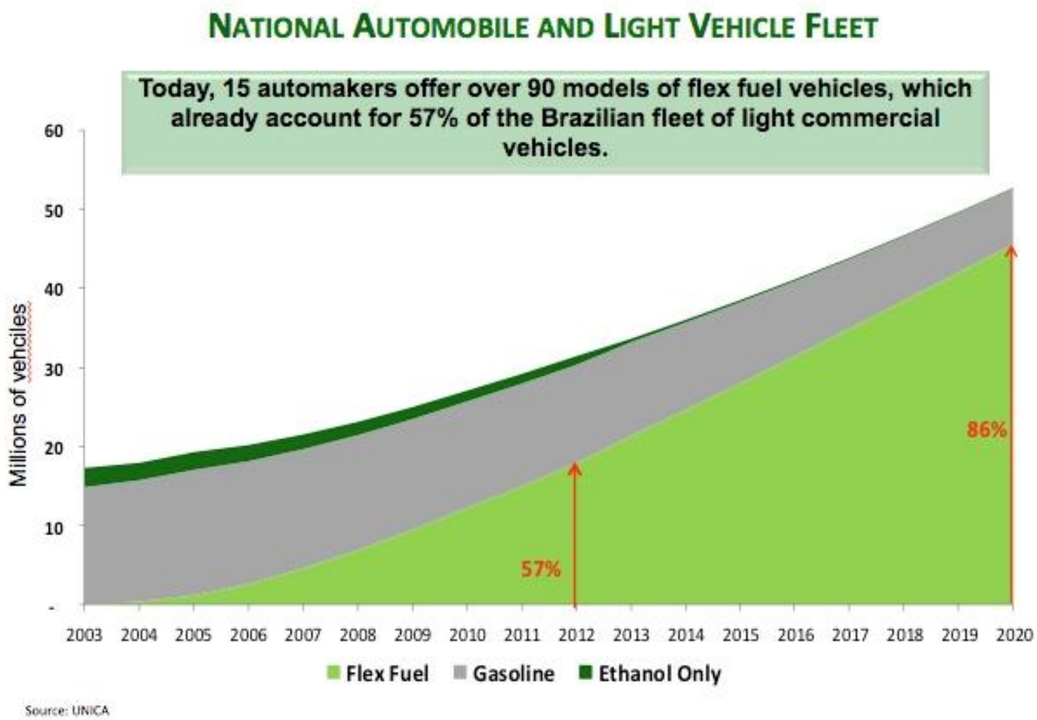
Looking at Brazil's whole ethanol history, the main lesson that the United States can learn is the diversification of feedstock used to produce ethanol. After speaking with Jon Urbanchuk, the Technical Director at Cardno Entrix who has written many reports for the US Department of Energy, it was clear that the United States could learn a lot just by analyzing "Brazil's ethanol production history of 83 years". Through a mix of political influence, changes in the market, and government incentives and mandates, Brazil was able to come to a conclusion that sugarcane was the crop they should use and further enforce to produce their ethanol. In the beginning of their ethanol policy, Brazil used both the manioc root and sugarcane in their ethanol production but over time they realized that sugarcane was the most effective and efficient source. So far the United States has mostly been dependent on corn, as shown in diagram below, even though it is not the most energy efficient and is not as environmentally friendly as other sources. Instead of using sugarcane the United States can definitely use switch grass as their source of ethanol production as mentioned in the previous paragraph. Not only does it have a higher net energy balance and yield more gallons of ethanol, but also the land used to grow switch grass would not affect food production like corn does. Switch grass is also much more beneficial to the environment as it aids in cleaning runoff water and provides a home for wildlife. There are obviously many alternatives sources in producing ethanol but the main point to draw from Brazil's ethanol policy is to analyze their ethanol history deeply and see how they concluded on sugarcane to be their main source in ethanol production. This led to Brazil's efficient ethanol program and can lead the United States to improve its own policy.

Comparison of Sources used in Ethanol Production in the US

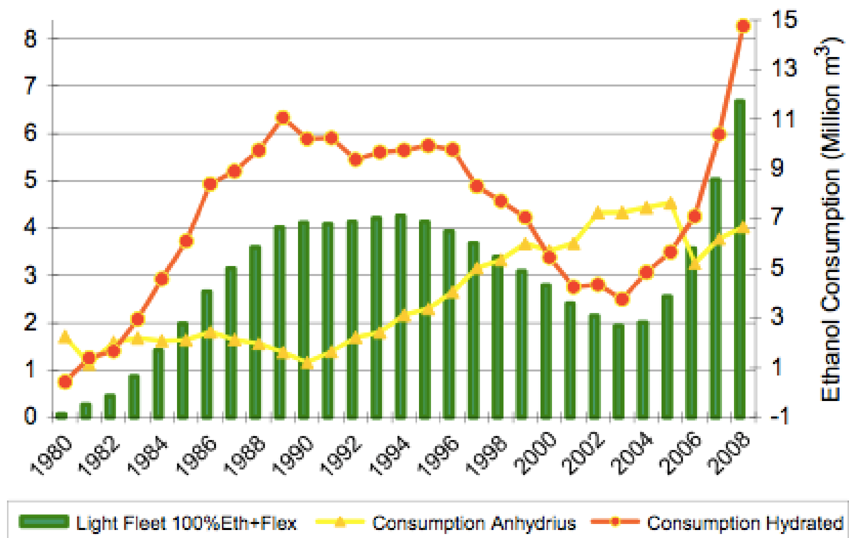


As a result of Brazil's successful ethanol program, currently more than 90% of cars sold in Brazil are flex fuel, which is a vehicle where the internal engine can run on more than one fuel. Cars in Brazil can run on pure ethanol, a mixture of gasoline and ethanol, or pure gasoline. Brazil began using ethanol in their cars in the late 1920's but it was not until 2003 when the Flex Fuel program was introduced where ethanol fuel gained popularity. Brazil has sold 16.3 million flex fuel cars compared to the United States 10 million sold. The reason behind this is because of the decades of support for ethanol usage by the Brazilian government. In the figure on the next page, it shows that flex fuel vehicles already account for 57% of the Brazilian fleet of light commercial vehicles and by 2020 it will account for 86% of this market. As a result of this support, all fueling stations contain E100 as a source of fuel, compared to only 1% of all gas stations in the United States have E85. Today, most citizens in Brazil even choose gasoline as their last pick because of the harm it causes to the environment and the higher cost that comes with it.

Percentage of Cars run on Flex Fuel in Brazil



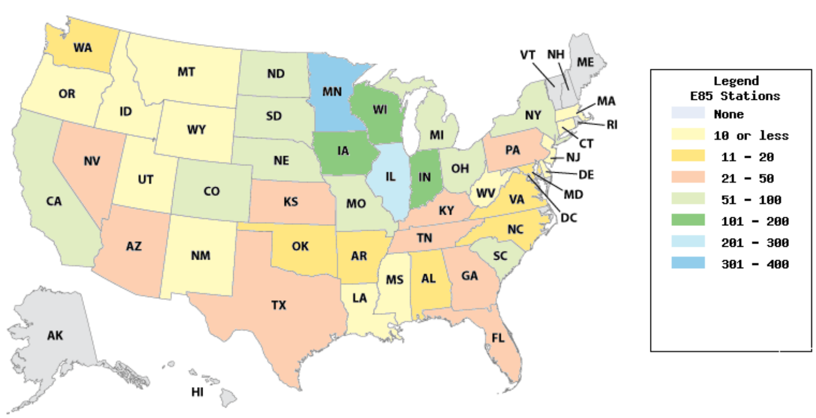
Amount of Ethanol Consumption in Brazil



From the graph on the previous page, it is evident that the amount of people choosing to use pure ethanol to fuel their vehicles has increased dramatically since 2003. This is due to the increase in number of flex fuel vehicles on the road and increased support and advertisement for ethanol usage. The amount of ethanol usage and production has been such a success that Brazil has reached energy independence and is no longer dependent on oil.

Brazil does not only use more flex fuel cars and consume more ethanol, but the percentage of ethanol in the blend with gasoline is also significantly higher. Today, Brazil uses an ethanol blend between E20-E25, depending on the price of the sugarcane crop each year, while the United States uses a universal blend of E10-E15. There are only a limited amount of gas stations throughout the United States that even offer ethanol blends up to E85, so it can be very difficult for a consumer to use ethanol for their vehicles depending on where they live. Figure 6 shows where most E85 stations are located throughout the country. It is evident that most E85 stations are located in the Midwest, which makes sense as most corn ethanol production is done in this region. This is very different from Brazil as every gas station has E100. Most people in the United States do not even though that their vehicle is a flex fuel type, whereas everyone in Brazil is informed on what type of fuel their cars can use.

Number of E85 Stations by State



This demonstrates how successful the Brazilian government has implemented the Flex Fuel program in the past decade and how the United States has not reached Brazil's level of ethanol implementation.

Brazil continues to be a dominant force in the ethanol market by the influence of their government and has made improvements every year. They have progressed over the past several decades and have narrowed down to their main source of ethanol production, sugarcane. The United States has a lot to learn still and there is a lot it can take away from Brazil's ethanol policy. Although the United States does not have the weather and climate to sufficiently grow sugarcane, there are other options, besides corn, that they can use to successfully create ethanol and improve the economy and environment. As the United States' government continues to show the importance of ethanol to the people then this is where progress will be made, especially in the fuel industry.

Concluding Statements

In the past 40 years, the United States has made great strides to improve the environment and economy by moving away from petroleum and increasing ethanol production and consumption. We understand that corn-based ethanol fuel (Ex: E-85) is cheaper than premium gasoline per gallon; however when comparing it by energy per unit volume E-85 corn-based ethanol is more expensive. The economic feasibility of using ethanol could be put into question, but the positives and strengths of using ethanol as an alternative fuel outweigh the economic negatives. We believe that ethanol should be continued being produced and utilized in the US; however, as described in this paper, we believe that corn-based ethanol is not the right substance. Since the year 2000, ethanol consumption has increased significantly due to new acts and policies put in place, all to improve energy efficiency and help reduce the amount of pollution. Not only have policies been put in place to increase the amount of ethanol usage, but many have been put in action to refine the ethanol production process as well. This is to make sure that the production of ethanol is as efficient and cost productive as possible. However, as we have seen throughout this paper, corn-based ethanol has had many negative effects on the US economy and environment, outside of the positives it contributes, and there are several technological barriers preventing corn-based ethanol to replace petroleum. It has raised corn prices greatly and currently much of the corn supply is used to produce ethanol, instead of being used as a food source. To replace petroleum, corn ethanol would need an inadequate amount of arable land and irrigation water, and a much larger milling capacity. As a result, it is important to look at alternative sources of fuel such as sugarcane and cellulosic plants. Both of these alternatives are much more energy efficient, yield more gallons of ethanol/acre, and reduce greater amounts of Greenhouse Gas Emissions compared to corn. However, the United States' ethanol policy will not improve just by looking into alternative sources but it must look at international ethanol polices, such as Brazil's ethanol policy, which is considered to be the best in the world. It is the history of their whole policy and their Flex Fuel program that the US can learn from. After diving deeply into the United States' ethanol policy history and production, analyzing the implications of the policy onto the economy and technological barriers that come with it, and comparing it to alternative sources and international policy, we have come with several key recommendations to the policy. First, eliminate subsidies for corn-based ethanol and redirect them to cellulosic projects. Next, increase the number of gas stations that contain E-85 as a choice of fuel and spread them throughout the United States and not just the Midwest region, and continue to increase production of flex fuel vehicles. Lastly, use ethanol as the source of fuel, instead of gasoline, due to decreasing gasoline production and an increase in gasoline demand. We believe that these key recommendations can result in vast improvements to the US ethanol policy.

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