

**Ethanol Fuel and its Energy, Environmental and Economic Costs
to the United States**

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Increasing fuel and energy prices, global warming, national security concerns and the increasing dependency on foreign imports of oil have once again brought alternative fuel sources to the spotlight. Similar to the oil embargo in the 1970's the US has turned its focus to finding a fuel alternative. Ideally, this alternative will decrease the emissions of greenhouse gases, be produced by the US and be less expensive than gasoline. The main alternative that garners most of the attention is ethanol and biodiesel because the inputs into the alternatives are abundant in supply and are produced domestically.

As mentioned above, ethanol has been a hot topic of public policy back in the 1970's when OPEC placed on oil embargo on the US and others due to its ties with Israel. While the cost of oil was skyrocketing from \$14.00 per barrel to \$24.00, interests in ethanol as a fuel alternative were increasing. Ethanol's history in the US as a fuel alternative, however, does not begin in the 1970s. Rudolf Diesel and Henry Ford both began with the idea of using renewable resources to power their engines. Rudolf Diesel's original engine was designed to use peanut oil¹. Henry Ford originally designed the Model T to run on ethanol¹. Eventually gasoline was introduced as a cheaper alternative fuel source and both engine designs were altered to run on gasoline.

Now that the US is experiencing record levels of fuel prices and the ever-growing public concern of global warming, ethanol has found its way back into public policy. President George W. Bush made reference to ethanol in his 2006 State of the

Union Address saying, "We'll also fund additional research in cutting-edge methods of producing ethanol, not just from corn, but from wood chips and stalks, or switch grass. Our goal is to make this new kind of ethanol practical and competitive within six years."²

Due to the increased public attention on ethanol as a fuel alternative, there has been a lot of debate concerning the viability and impacts of switching to ethanol. The purpose of this paper is provide a cost and benefit analysis of ethanol and biodiesel. Additionally, this paper will discuss the environmental impacts of the use of ethanol and biodiesel and whether the impacts have an overall net benefit or cost. Third, the paper will touch on recent public policy concerning the production and use of ethanol as a fuel additive and alternative. Finally, the paper will briefly discuss other alternatives in both the production of fuel ethanol and also in place of ethanol.

Since ethanol has had a rich history in the US as a possible fuel source there is a wide array of research and literature available discussing the pros and cons of its use. In the past decade a lot of literature has come out detailing how ethanol may not be the great alternative that it has historically been portrayed. A major criticism to the previous papers on ethanol is that some of the energy inputs are not included in the total energy input and output breakdown.

One of the more complete energy balance calculations was provided by David Pimentel from the College of Agriculture and Life Sciences at Cornell

Inputs	kg	BTU	Dollars
Corn	10.2	40,221	\$0.69
Transport of corn	10.2	4,727	\$0.22
Water	601	1,353	\$0.08
Stainless steel	0.023	1,348	\$0.04
Steel	0.045	2,106	\$0.04
Cement	0.12	909	\$0.04
Coal	1.4	39,076	\$0.08
Electricity	.91 k Wh	9,379	\$0.60
Pollution control costs	-	-	\$0.23
TOTAL		99,119	\$1.48

University³. In his paper, Pimentel does an in-depth review of all the energy inputs into creating ethanol from corn feedstock and compares the energy balance in BTUs to gasoline. In order to breakdown the energy use and gain from ethanol, the process must work backwards, starting at the yield from a large ethanol plant to the cost of fermentation and distillation. A large plant, using typical industry standards for fermenting and distilling the corn feedstock yields approximately 2.5 gallons of ethanol per bushel of corn³. Thus a hectare of land (a hectare equals approximately 2.47 acres and is a typical measurement in agriculture) will produce roughly 842 gallons of ethanol³. According to Pimentel's calculations, the energy cost of producing the 842 gallons of ethanol is 33.9 million BTUs and is the gasoline equivalent of 293 gallons per hectare³.

According to that calculation it is easy to see that the energy cost of the ethanol (in terms of gallons) is far greater than gasoline. Producing ethanol requires many energy inputs starting from the labor and machinery used in plant and harvesting to the conversion from corn feedstock to fuel ethanol. The costs of ethanol production equates to \$850/ha or 6.8 cents/kilogram of corn and is the energy

equivalent of 66% of gasoline³ for a plant that is producing 842 gallons of ethanol.

When all energy inputs are added into the production of ethanol at a large plant (Pimentel considers a large plant one that produces 65 to 70 million gallons of ethanol per year³) the total cost in BTUs is 99,119 BTUs. Table 1 below lists the energy inputs that were considered by Pimentel in his paper.

The table shows that the BTU cost of the production of ethanol is 99,119; however, ethanol has an output value of 77,000 BTUs³. According to Pimentel, there is a negative energy balance of 22,119 BTUs which is a 29% difference. The 29% figure considers neither the positive gains for ethanol by-product nor the useful distillation process by-product, called dry distillers grains (DDG). DDG are used to improve feedlots and are cost effective for farmers raising cattle. If you factor in the energy savings that DDG adds to the production of ethanol the 29% negative energy balance, the figure drops to 20%³ and is still a large negative energy balance.

David Pimentel's cost analysis is dated (being about 5-9 years old) and is also not the only energy cost/benefit analysis that has been completed. More

recent studies, such as David Tilman et al.'s paper, "*Environmental, Economic and Energetic Costs and Benefits of Biodiesel and Ethanol Biofuels*"⁴, have net energy balance calculations in which ethanol and gasoline share approximately the same energy balance.

Tilman et al. use estimates similar to Pimentel, starting from the farming and harvesting all the way to conversion from corn feedstock to fuel ethanol. The estimates are energy values the authors assigned to the inputs and outputs, including by-product outputs. Furthermore, the total yield is compared to the net energy balance from the production of gasoline. Tilman et al's results show that ethanol has a small but positive net energy balance. This means that ethanol produces approximately 25% more energy than it requires throughout its production process⁴. The positive energy balance; however, comes primarily from its by-product DDG and not from the use of fuel ethanol⁴.

The majority of the published energy cost/benefit analysis either agrees with Pimentel and Tilman et al or lies somewhere in-between a net energy loss or a small energy gain from ethanol. Biodiesel, however, does not have the high cost of energy inputs that ethanol requires. According to Tilman et al's calculation, biodiesel provides 93% more energy than its production uses⁴. Soybean biodiesel requires more farming inputs than fuel ethanol but it does not require the large factory energy costs that are associated with fuel ethanol⁴. This crucial difference accounts for the large energy gain in its use when compared to ethanol.

Since fuel ethanol has been shown by many to have little to no net energy gain, the argument for its continued and increased production fails when its environmental impacts are considered. According to the EPA, the use of ethanol as a fuel additive has helped reduce volatile organic compound emissions by 17% and toxic air pollutants by 30%⁵. These positive environmental impacts of fuel ethanol have been challenged by many authors including both Pimentel and Tilman et al who show that soybean biodiesel may have a negative environmental impact as well.

Both corn and soybean production requires large amounts of land and pesticides in order to grow. The pesticides often leach from the soil into rain runoff and ground water and eventually make its way into the public water supply and coastal waters. The impact on the plant and wildlife in these waters is very negative and long term⁴. Furthermore, corn production leaches nitrates from the soil. The nitrates could not only end up in the drinking water which can be very poisonous to humans but also take away from the future fertility of the soil. Plants require nitrogen to maintain life. The loss of these nitrates will require further fertilization of the soil and that would lead to further ground water pollution by leaching⁶.

According to Tilman et al, if the only greenhouse gas emissions from fuel ethanol and soybean biodiesel production were CO₂, then there is a gain in gas emissions. Ethanol emits 88% of the greenhouse gases as compared to gasoline; soybean emits 41% less greenhouse gases than diesel fuel⁴.

Table 2. Wholesale Price of Pure Ethanol Relative to Gasoline⁵

	Relative Price By Volume (in ¢/ga.)	Relative Price on an Equivalent Energy Basis (in ¢/ga.)
Ethanol Wholesale Price	170 - 250	258 - 379
Alcohol Fuel Tax Incentive	51	77
Effective Price of Ethanol	119 - 199	181 - 302
Gasoline Wholesale Price	148 - 179	148 - 179
Wholesale Price Difference	(29) - 20	33 - 123

Pimentel considers the pesticides and greenhouse gas emission and draws a similar conclusion to Tilman et al. Additionally, he considers the amount of waste water used by ethanol plants as a negative environmental impact. Ethanol production uses 12 gallons of waste water in order to produce 1 gallon of ethanol from corn feedstock. The waste water has a biological oxygen demand (BOD) or 18,000 to 37,000 mg/liter³ but can vary depending on the type of ethanol plant. Moreover, the clean up of the waste water costs approximately 6 cents per gallon of ethanol³.

In addition to the energy and environmental costs of fuel ethanol production, it is important to consider the cost effectiveness of using ethanol as an alternative. Ethanol's cost inputs make the use of fuel not economically viable as an alternative. The cost for production of ethanol that is equivalent to a gallon of gas is \$2.24, the cost of producing a gallon of gasoline is \$0.63³. It costs two and a half times more to produce 1.5 gallons of ethanol (1.5 gallons of ethanol is the energy equivalent of 1 gallon of gasoline³) prior to taking into consideration any subsidy by the government. The energy equivalency of ethanol did improve, up to \$0.46 cost of production per energy equivalent liter of ethanol where gasoline cost was at \$0.44⁴ as estimated by Hill et al in 2005. Hill et

al's estimates; however, have already factored in any subsidy received by the ethanol producers.

In 1998, the ethanol industry was receiving a total of \$1.4 billion dollars in subsidies per year³. The subsidy payments were from both the federal and state level governments at \$0.60 and \$0.20 per gallon respectively³. After 2004, the subsidy was change to a \$0.51 per gallon of pure ethanol income tax credit⁵ and the subsidy helps to make ethanol more competitive with gasoline as seen on Table 2.

The subsidies enable ethanol to be cost competitive but without the subsidy, it would not be able to be competitive as a fuel alternative. The subsidies also face sharp criticism because the majority of the payments are not made to the farmers. Instead the subsidy payments are made to the large farming companies with very little trickle down to the actual farmers. A conservative estimate is that farmers receive \$0.02 per bushel of corn or \$2.80 per acre of corn³. Another criticism of the subsidy for fuel ethanol is that the tax incentive cause less money to be paid to the Highway Trust Fund. The tax loss is estimated at \$7.5 to \$11 billion in a 22 year period by the GAO⁵.

Another drawback to the use of ethanol as a fuel alternative to gasoline is a

supply concern. In 2007, 6.5 billion gallons of ethanol were produced in the US⁷. In 2005, 14.3% of the corn harvest for the US was used in the production of ethanol⁴. Approximately 14.8 billion liters of ethanol was produced from the total corn harvest w accounted for only 1.7% of the demand for gasoline on an energy-equivalent basis⁴. This means that if the entire corn harvest for the US in 2005 was used for the production of ethanol only 12%⁴ of the gasoline demand would be satisfied.

In order for the entire US demand for gasoline to be satisfied using fuel ethanol, it would require a significant amount of land in order to grow the corn. The gasoline demand for the US in 2005 was 140 billion gallons⁸. Since 1.5 gallons of ethanol produce the energy equivalency of a gallon of gasoline, the ethanol demand would be 210 billion gallons. The land requirement would be far above the amount of available farm land the US has available for such a purpose. The amount of fossil fuels required in the production of fuel ethanol would also have to be added into the cost of producing the volume of ethanol required to meet US demand.

Pimentel illustrates the lack of supply using figures from 2002. The US produced approximately 1.7 billion gallons of ethanol (1.1 billion gasoline equivalent gallons). This accounts for 0.9% of the gasoline used by automobiles for that year³. The production of the 1.7 billion gallons required 2.2 million hectares of land. If the US were to increase ethanol production to 10% of the gasoline demand of automobiles then 22 million hectares of land will be required³.

The use of fuel ethanol as an alternative to gasoline has yet another underlying problem; producing fuel ethanol displaces corn feedstock production. The use of corn feedstock has two major

impacts on the average consumer. The first impact is that the production of fuel ethanol means there is less corn crop dedicated as a food source and cattle feedstock. The reduction of supply will invariably lead to an increase in the price of corn. The price increases will be widespread because corn is not only used as an animal feed, but also as but also as an additive to many directly consumed products through ingredients like high fructose corn syrup. Some estimates state that the use of ethanol has increased the price of the production of beef by \$1 billion annually³.

The use of corn for fuel ethanol doesn't only affect food prices domestically but it has dramatic global implications. In a world with a population currently over 6 and a half billion people where almost half of the population is malnourished, more expensive food would be disastrous³. Additionally, staples such as corn make up a substantial amount of the developing nations food source. For instance, cereal grains account for up to 90% of the food for people worldwide³. Using corn feedstock as a fuel source ends up not only being an economic decision but a moral one as well. As the US continues to devote more of its corn harvest to fuel ethanol production, the global supply of corn will decrease causing a price increase of products using corn. This makes it more difficult for already malnourished people to afford food; people who live on only a fraction of the per capita income enjoyed by the US.

Even when faced with numerous facts and figures as above, the US government is continually engaging in policy that is ethanol production friendly. On August 8th 2005 President Bush signed the Energy Policy Act of 2005⁵. The Energy Policy Act of 2005 set a renewable fuel standard (RFS), which required the use of a

set amount of renewable fuels starting in 2006 and increasing until it reaches a maximum required amount in 2012⁵. In 2006 4.0 billion gallons of renewable fuel were required to be available and the level is set to increase 7 billion each year up to 7.5 billion gallons in 2012⁵.

In addition to setting a required amount of renewable fuel use, RFS made another important change. RFS began to reduce the amount of methyl tertiary butyl ether (MTBE) used as a fuel additive alternative because it is believed to be a carcinogen⁵. Limiting the use of MTBE has an effect on fuel ethanol because it is a chief competitor to ethanol⁵.

Also, In 2004, President Bush passed the American Jobs Creation Act, in which was a provision that created the Volumetric Ethanol Excise Tax Credit (VEETC)⁷. VEETC replaced the federal ethanol excise tax credit that was discussed earlier and provides \$0.51 per gallon of pure ethanol which is the same amount of credit but the credit was changed in order to not draw funds from the Highway Trust Fund⁷.

President Bush gave a speech at the International Renewable Energy Conference on March 5th, 2008 and continued to illustrate the government's ethanol friendly policy. At the conference, President Bush stated that since 2000 ethanol production has quadrupled and that the fact that ethanol is made from corn is good because corn is a domestic product⁸.

It is clear that the current path of the US is to continue to pursue fuel ethanol as

a gasoline alternative that supposedly provides national security, lower prices and reduced international dependence on imports as the motivators for the policy. This is despite the fact that intellectuals and experts have shown that fuel ethanol fails to meet any of these goals. It is important that the US continue to search for alternatives because oil is a limited natural resource.

One alternative to corn feedstock ethanol is cellulosic feedstocks. Cellulosic feedstocks are comprised of mainly waste products like recycled paper and rice husks⁵. The use of cellulosic feedstocks will help keep the price of food from rising since it uses waste products; however, it has a price barrier in its production. Currently it adds approximately 70% to the production costs because cellulosic feedstock is mainly plant matter and cannot be directly fermented⁵. Adding more resources to finding a more efficient fermentation method to cellulosic feedstock could help make fuel ethanol more cost competitive with gasoline and not carry the same moral issue as corn feedstock.

Other alternatives are to reduce the amount of gasoline consumption by the US. A reduction in consumption can be obtained by adding higher taxes to gasoline, by mandating more fuel efficient vehicles such as hybrids, or both. But it is clear that ethanol is not the fuel alternative that can efficiently and effectively replace gasoline due to its low or negative net energy gain, the high cost of production and its negative environmental impacts.

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