# The Feasibility of Biofuels in the United States

Over the past few years interest in renewable, 'green' technology has exploded in conjunction with increased awareness of global warming. Such rising popularity, and the funds that go with it, have spurred both the use of biofuels and further research into them. Fuels such as biodiesel or ethanol are produced from renewable sources such as plant biomass (Encyclopedia Britannica, 2008). Biofuels, like conventional fuels such as gasoline, are derived from organic matter, either directly from plants or from an organism that depended on vegetation. Because plants produce their food with energy from the sun, it follows that all fuels are ultimately a form of solar power. It is also interesting to remind people that the first vehicular engines ran solely on ethanol for about the first forty-five years. Even after the proliferation of gasoline, ethanol was still used in concentration until gasoline prices dropped and its availability increased at the close of the Second World War (Energy Information Administration, EIA, 2005).

Today, with the resurfacing interest in biofuels, a discerning look ought to be taken to see whether the widespread use of biofuels is truly feasible in modern America, a country with over 200 million vehicles (Bureau of Transportation Statistics, 2005). In order to get a well-rounded understanding of biofuels in America at least three different points should be addressed: first, the current status of biofuels in America, to appreciate the underlying political sway and the existing infrastructure; second, an understanding of the difference between biodiesel and ethanol, as both are often discussed as potential alternatives but have dissimilar production requirements and outputs; and lastly, the amount of biofuel that would be needed to significantly displace the use of gasoline.

For the first one hundred years of motorized vehicles ethanol was used mixed with gasoline, and at first used on its own. The infrastructure for ethanol fuel production and distribution has existed in some form or other since the early 1900s (EIA, 2005). In part due to this, ethanol technology has been the most widely promoted biofuel in the United States. The government began research into ethanol fuel in 1974 after a thirty-three-year long gap in ethanol availability. The ease with which cars can be adapted or produced to run on ethanol, or E85, a high ratio of ethanol to gasoline, also makes ethanol attractive since it appears to have less economic and social impact than other renewable alternatives. As shown in Figure 1, both the production and consumption of ethanol have increased steadily since 1999.

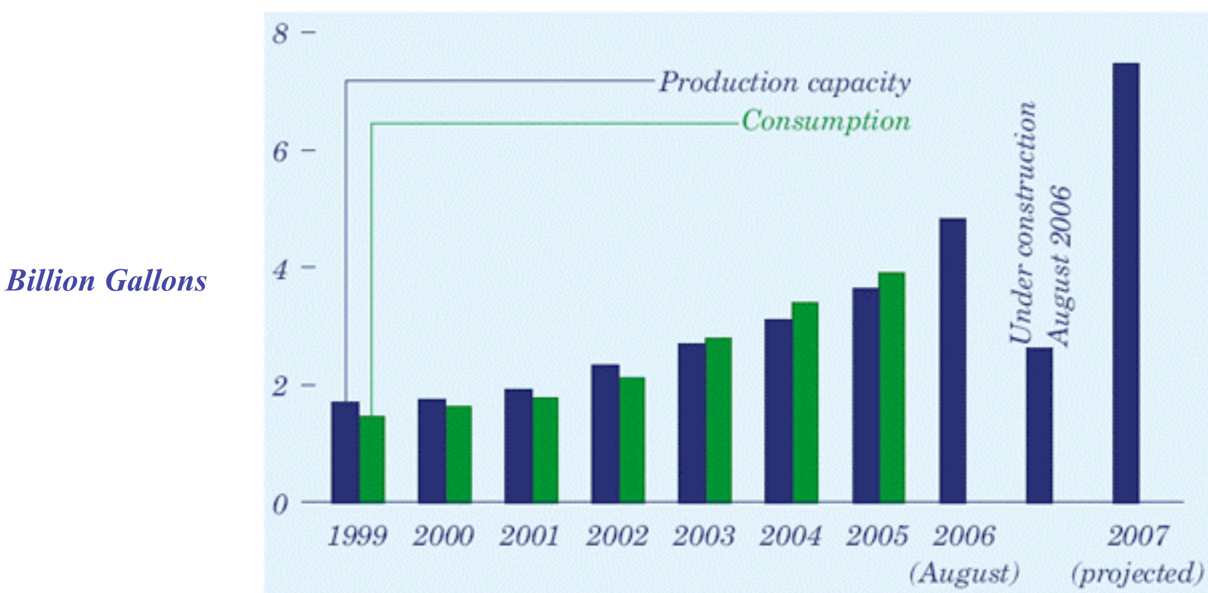


Figure 1. Amount of ethanol production and consumption between 1999 and 2007. The cause of such an increase is likely government funding and the new environmental awareness of America’s culture (EIA, 2007).

On an amusing note, humans' ability to produce ethanol from sugars existed long before the invention of automobiles, as similar technologies were employed to create alcoholic beverages. Ethanol received further promotion when it replaced MTBE (Methyl Tertiary Butyl Ether, a product of natural gas and petroleum) as an oxygenate in gasoline following the banning of MTBE when it was discovered to be contaminating the water supply (EIA, 2005). So ethanol biofuel receives the most promotion; but how does that translate in terms of land set aside for ethanol production?

According to the U.S. Agricultural Census of 2002, 434 million acres, or about 23% of the total land area of the lower 48 states, is appropriated to all agriculture, with 81 million acres, or 19% of agricultural land, for corn and 72 million acres, or 17% of agricultural land, for soybeans, the top two biofuel crops in the United States. If all the cropland from both soybeans and corn were dedicated to ethanol production, it might produce approximately 70.8 billion gallons of ethanol (*Annual Energy Outlook*, EIA, 2007). This number overstates the amount of ethanol that could be produced if current levels of corn and soybeans produced for consumption were maintained. Biofuel production needs to increase considerably if it is to have a serious effect on the consumption of traditional fossil fuels. But it is unlikely that more land will be dedicated to biofuels since the existing cropland is already feeling the pressures of population expansion and competing agricultural demands. There are currently three main areas of research into expanding biofuel production without aggravating this pressure on land use. Because per-acre corn and soybean yields are increasing, it is possible that corn production could increase by 29% and soybean production by a billion bushels by 2030 without requiring more acreage (*Annual Energy Outlook*, EIA, 2007). Bioengineering research is currently underway to attempt to increase the levels of starch in corn and oil in soybeans. The Conservation Reserve Program (CRP) is researching alternative energy crops, such as switch grass, to see if the energy produced would exceed that of corn and soybeans. Also, the CRP has been researching cellulosic biofuel, which would turn current plant waste, such as the unused stalks and leaves of corn plants, into fuel and thereby significantly increase net biofuel production.

The introduction of a new crop may not be accepted, however, as agriculture is highly dependent on the economic balance between farmers' needs and consumers' desires. Recent government plans have been legislated in the form of the national Renewable Fuel Standard (RFS) to give biofuels a chance on the market. EPACT 2005 promises a market of 7.5 billion gallons of ethanol per year by 2012. Blenders' tax credits have reduced the cost of refining biofuel, which in turn makes it more competitive. The RFS has also given funding to the research, development, and commercialization of cellulosic ethanol technology, though this product remains unavailable at this time (EIA, 2007).

The production processes of biodiesel and ethanol have different demands and outputs. To explain the procedure for ethanol production, I will use corn as an example as it is currently the leading feedstock for ethanol in the United States. Corn kernels are ground to create a fine powder called 'meal' before it is heated in water and mixed with enzymes to break the corn down into mash. Ethanol production (Figure 2) requires yeast, and so ammonia is added as a yeast nutrient and for pH management. Next, high temperature cooking prepares the mash for fermentation by reducing the bacteria levels.

Conversion of sugar into ethanol begins when more yeast is added to the cooled mash. The result of the fermentation is a substance similar to beer, which is then separated from the non-liquid ‘stillage’ by distillation. The ethanol is then dehydrated with a molecular sieve system from 190 proof to 200 proof. The ethanol then just needs a denaturant [5% gasoline, according to the source I consulted] before it is ready for distribution (Lincolnland Agri-Energy, 2008).

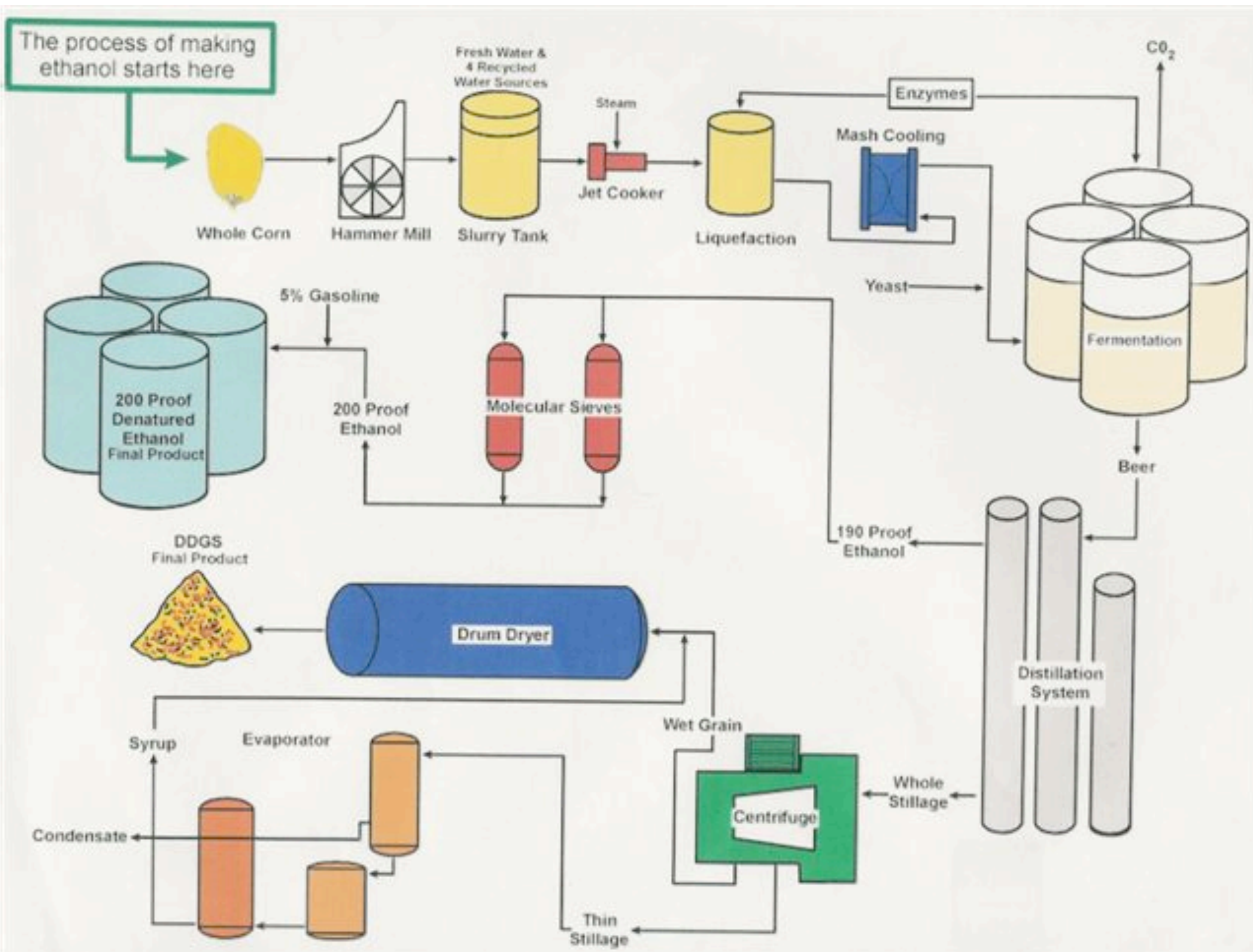


Figure 2. Depicts ethanol production and the treatment of the byproducts. Stillage, the byproduct, is separated into coarse grain and soluble fractions, the soluble fractions are turned into syrup then mixed with the coarse grain to produce a high protein animal feed. Interesting to compare

this to biodiesel production, which is more complex and both requires, and creates as a byproduct, toxic substances (Lincolnland Agri-Energy, 2008).

Biodiesel production (Figure 3) begins with a process called transesterification, in which oil feedstock, typically soybeans in the United States, is mixed with potassium hydroxide dissolved in methanol. The reaction of this mixture produces biodiesel and glycerin, which are separated into two distinct layers. The methanol must be removed or else the reaction may reverse, and it is then recycled back to be used again. Excess alcohol, potassium hydroxide, and soaps are next removed from the biodiesel by washing with clean water. The biodiesel can then either be stored for use or washed again to create a fuel with no sulfur (U.S. Department of Energy, 2008).

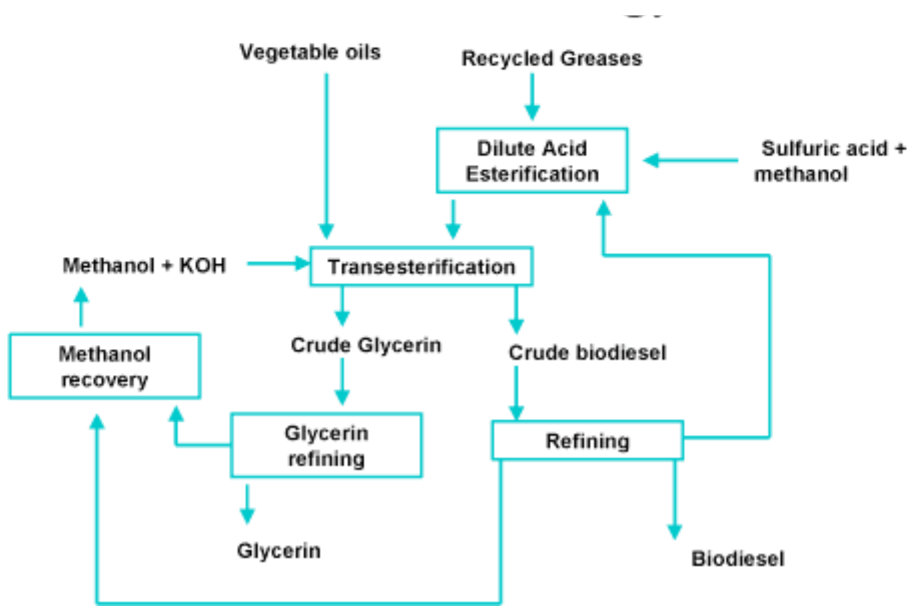


Figure 3. Shows the process of biodiesel production and the treatment of byproducts. Soaps and unreacted potassium hydroxide are neutralized with acid and the water and alcohol are removed to create 50%-80% crude glycerin, which can then be further purified to 99% for sale for pharmaceutical or cosmetic uses. Other remaining contaminates include unreacted fats and oils (U.S. Department of Energy, 2008).

Both diesel and gasoline engines work through the process of internal combustion. Gasoline engines (Figure 4), which can run on ethanol, begin with an open intake valve through which a mixture of air and gasoline is drawn down by the downward motion of the piston. This is called the intake stroke. The piston moves up to compress the mixture, making the explosion more powerful. The explosion occurs when a spark plug ignites the gasoline, driving the piston down and thereby turning the crankshaft and wheels. Once the piston hits the bottom of this stroke, the exhaust valve opens and the exhaust is pushed out as the piston is driven up from the previous explosion (HowStuffWorks, 2008).

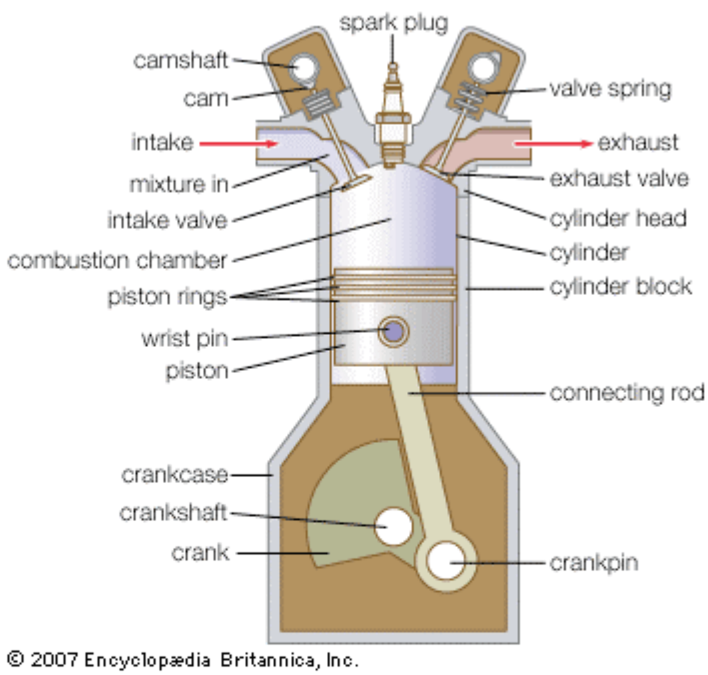


Figure 4. This diagram depicts a piston, the main driving component of a gasoline engine. It has a similar shape to a diesel engine piston, but a diesel engine does not require a spark plug (HowStuffWorks, 2008, Encyclopedia Britannica, 2007).

The internal combustion of a diesel engine (Figure 5), which can run on biodiesel, begins when the piston is at the top of the combustion chamber. At this time diesel fuel is sprayed into the chamber by an injector. The high pressure and heat inside the chamber cause the diesel to immediately ignite. The explosion drives the piston down, an action known as the power stroke. The exhaust valve opens as the piston nears the bottom of the stroke and the exhaust is pushed out by pressure. When the piston hits the bottom it uncovers the air intake ports so air will rush into the chamber. As the piston drives upwards once more it compresses the air. This is known as the compression stroke (HowStuffWorks, 2008).

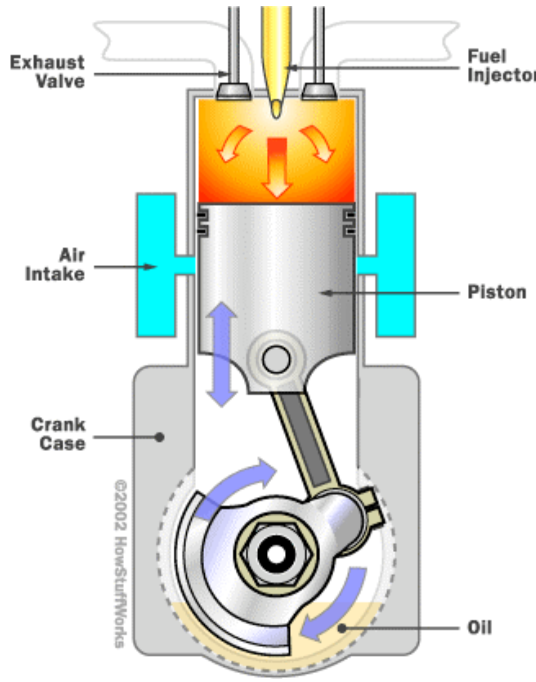


Figure 5. Shows the main components of a diesel engine piston. This figure is specifically of a two-stroke piston. It is important to note that diesel pistons only compress air as opposed to gasoline pistons, which compress a mixture of gas and air (HowStuffWorks, 2008).

The main difference between a diesel engine and a gasoline engine is that a diesel engine does not require a spark plug because the fuel is injected into a pre-compressed chamber which, along with the heat, causes the diesel to explode. Diesel fuel has a higher energy density than gasoline; likewise biodiesel has more fuel density than ethanol fuel, which translates into the fact that diesel/biodiesel engines get better gas mileage (Figure 6).

| Fuel | Btu per gallon (low heating value) | Btu per gallon (high heating value) | Gallons of gasoline equivalent (high heating value) |
|---|---|---|---|
| *Conventional gasoline* | *115,500* | *125,071* | *1.00* |
| *Fuel ethanol (E100)* | *76,000* | *84,262* | *0.67* |
| *E85 (74% blend on average)* | — | *94,872* | *0.76* |
| *Distillate fuel oil (diesel)* | *128,500* | *138,690* | *1.11* |
| *Biodiesel (B100)* | *118,296* | *128,520* | *1.03* |

Figure 6. This shows the numerical discrepancy between gasoline and diesel as well as ethanol and biodiesel. In both cases, the green alternative has significantly less energy output than the conventional equivalent. The energy loss between gasoline and ethanol is approximately 33%, whereas the energy loss between diesel and biodiesel is closer to 7%. More physical fuel would be required to satisfy consumers in a replacement scenario, and it would likely prove difficult to balance an increase in fuel substance with the low price necessary to make an economic incentive (EIA, 2007).

To get a rough estimate of the plausibility of biofuel implementation in the United States, it is necessary to estimate the amount of conventional fuel that is typically consumed and the acreage that would be required to grow that fuel. The amount of gasoline used in the United States in 2007 was approximately 142 billion gallons (EIA, 2005). If all 81 million acres of corn currently grown were dedicated to ethanol production, roughly 37.5 billion gallons of ethanol fuel could be produced, or only enough to meet one third of the demand. Soybeans could foreseeably produce 130 million gallons (Campbell, 2000) from its 72 million acres of crop, which falls considerably short of the 43 billion gallons of diesel consumed in 2005 (EIA, 2005). According to this rough analysis, a complete replacement of conventional fuel with renewable fuel is not possible.

Both biodiesel and ethanol are forms of solar power, as previously mentioned. However, energy is lost along the process from sun to plant to fuel. To demonstrate this I will compare the energy yield per acre, over one year, of ethanol with the amount of solar energy that hits one acre over one year. Approximately 463 gallons of ethanol can be produced in one acre per year (Solving the Climate Problem, 2004), and approximately 2,649,900 kilowatt-hours of solar energy hits one acre over the course of one year

(American Energy Independence, 2008). After converting both figures to Btu, it can be seen that more solar energy hits one acre than can be derived from that acre in the form of ethanol, 9,041,833,708 Btu of solar energy as opposed to 57,821,467 Btu of ethanol energy. The first of three reasons for this discrepancy is that the plants use a large portion of their solar energy to develop their main structures, such as roots, stems, and leaves, the energy in which, as of yet, is lost during ethanol production. Secondly, not all the solar energy that hits an acre is absorbed by the vegetation on that land. Some of it falls on bare soil or rock. Lastly, solar energy also heats whatever it touches, so energy that could eventually be turned into ethanol instead raises temperatures. In this sense biofuels, and all fuels for that matter, are an inherently inefficient iteration of solar energy.

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