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The Potential Viability of Biomass Ethanol as a Renewable Fuel Source: A Discussion

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Abstract

Much attention has been paid to alternative fuel sources of late. Ethanol has been a politically popular alternative fuel additive and has recently been pushed to the forefront as a leading replacement to MTBE as an oxygenate. This paper examines the potential markets for ethanol, including biomass ethanol, and discusses the strengths and weaknesses of different oxygenate products. We find that the market for ethanol is tenuous and dependent on government support at this time. Biomass ethanol is more expensive to produce, but does have the advantage of being able to be produced near petroleum refineries, thus reducing transport costs, compared to other sources of ethanol.

Keywords: ethanol, biomass, alternative fuels, markets

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Executive Summary

Ethanol demand has the potential to grow substantially in the near future due to the gradual phase out of its oxygenate counterpart methyl tertiary butyl ether (MTBE). With the growing environmental concerns in the United States, ethanol and other alternative fuels are receiving increased consideration. For example, biomass ethanol derived from agricultural residues, has garnered recent attention. The market for traditional corn based ethanol and biomass ethanol is the same, so understanding the market for ethanol, in general, will help to understand the market for biomass.

Currently most biomass energy systems are not economically competitive with their fossil fuel counterparts. Ethanol is a cleaner burning oxygenate and has less potential for ground water contamination, but it does have negative attributes. A key limitation for ethanol is that, it cannot be transported through pipelines, which makes transportation costs high relative to petroleum. For residents of the Midwest, the primary area for ethanol production, those transportation costs are low, but for residents of California where MTBE has been phased out, the cost may be prohibitive. This may a potential niche market for biomass ethanol because it can be produced locally with a variety of waste products, as opposed to relying solely on corn supplies.

The greatest threat to the future of ethanol is that biomass and starch-based ethanols currently depend on large government subsidies to be cost competitive with fossil fuels. In his 2003 State of The Union Address, President Bush touted the administration's liberal spending on the hydrogen fuel cell project. If these plans come to

fruition, biomass ethanol may have a limited time frame (10-12) years. The relatively high cost of ethanol may ultimately lead to increased attention on alternative fuels. While technological development and increased supply may lower ethanol prices, thereby increasing competitiveness, biomass ethanol is currently at a cost disadvantage to corn-based ethanol. Without significant cost reductions in biomass ethanol, it may not mature past being a residual supplier of ethanol to the market.

Ethanol Market

The market for ethanol was stimulated in the 1970's when oil supply disruptions adversely affected the U.S. economy and raised concerned by the government that oil dependency could jeopardize national security. Congress, prompted by the oil crisis, passed the National Energy Act of 1978, which gave a Federal tax exemption for gasoline containing 10% alcohol. The federal subsidy, now at $.52 per gallon, allows the price of ethanol to remain close to the price of gasoline. By 1980, 25 states had exempted ethanol from their gasoline excise taxes in order to promote its consumption (DiPardo).

From 1979 to 1980, ethanol production grew from 10 million to over 175 million gallons per year. The market rapidly expanded in the Midwest, but high transportation costs limited adoption in other parts of the country. Ethanol consumption in the United States grew about 12% per year from 1980 to 1998. About 1.2 billion gallons were consumed in 1998.

A major drawback of ethanol production is its extreme sensitivity to changes in corn prices. There was a substantial decrease in ethanol production in mid-1996, as shown in (Figure 1), when late planting due to wet conditions led to tight corn supplies and higher corn prices (DiPardo). The cost of producing of ethanol dropped from $1.40

in 1980 to less than $1.00 per gallon in 2001, due in large part to the economies of size (DiPardo). In 1990, ethanol production received support when the United States Congress passed the Clean Air Act Amendments. Policy now mandates that there is a minimum oxygenate level of 2.7 percent in some high pollution cities in the United States. This change in air quality standards opened new markets outside of the Midwest because the need to meet emission standards began to outweigh transportation costs.

To better understand the source of ethanol demand, the different types of gasoline and their use in the United States needs to be analyzed. Currently, three major types of gasoline are used, conventional gasoline (CG), reformulated gasoline (RFG), and oxygenated gasoline. CG is described as gasoline that is not RFG or oxygenated gasoline, but includes gasohol mixtures.

The Clean Air Act Amendments of 1990 mandated that RFG's must be used in areas with extreme summer ozone problems. A RFG is a gasoline that has been reformulated to achieve reductions in ozone-forming compounds and toxic air pollutants. In some states like California, with severe air pollution problems in some areas, the specifications are especially stringent. The Clean Air Act amendment also requires oxygenated fuels to be used in winter carbon-monoxide non-attainment areas (Anddress). Most oxygenate requirements today are being filled by MTBE or ethanol.

Oxygenates

Like ethanol, MTBE acts as an oxygenate in fuel. Oxygenates help fuels burn more completely, reducing some emissions. Both MTBE and ethanol have a higher octane rating than standard gasoline. The octane "boost" given by MTBE or ethanol allows petroleum refineries to produce at a lower octane level, which cuts refining costs.

MTBE has been used in the United States since the late 1970s as a replacement for lead as an octane booster. MTBE is a chemical compound that is manufactured by the chemical reaction of methanol and isobutylene. In 2001, the United States was producing over 200,000 barrels of MTBE per day (US EPA). Most oil refiners choose MTBE over other oxygenates due to its economic and blending characteristics. Unlike ethanol, MTBE can be shipped through pipelines, which makes transportation costs cheaper than ethanol. Since 1990 and the Clean Air Act, MTBE has been increasingly replaced by cleaner burning oxygenates such as ethanol.

One reason for the drop in demand for MTBE and the rise in demand for ethanol is the pollution attributes that MTBE possesses that ethanol does not. The U.S. Environmental Protection Agency currently classifies MTBE as a possible human carcinogen. A major concern with MTBE is its tendency to enter and pollute groundwater. It instills a bad taste and odor to water, even at extremely low concentrations. Some contamination of water sources has been reported. Leaching from underground storage tanks is the primary source of MTBE contamination in ground water. Unlike MTBE, ethanol is biodegradable; it normally degrades into harmless byproducts before the plume can reach any potential receptors. In 1996, the city of Santa Monica closed some of its major drinking water wells after discovering MTBE contamination. In addition, the U.S. Geological Survey recently reported MTBE to be the second most common contaminant in shallow urban aquifers (National Institute of Environmental Health Sciences).

In March 1999, Governor Gray Davis of California announced that MTBE may not be used in that state after 2002 (Anddress). According to the governor, MTBE possess an environmental and water quality threat to the people of California. On December 13, the city of Chicago became the first US city to ban MTBE when the city council unanimously voted to ban the petroleum-based oxygenate (Ethanol Climate Protection and Oil Reduction). Congress is now debating an amendment to the 2003 Energy Bill to completely eliminate MTBE from all gasoline in the United States. The amendment, which still must be part of the final Senate energy bill passed and signed by President Bush, would boost ethanol and bio-diesel use to 5 billion gallons by 2012 and ban domestic use of the petroleum-based MTBE (Abbott). If this bill comes to fruition by 2005, ethanol usage in the United States would be expanded to 2.7 billion gallons. The Senate version of the amendment phases in ethanol use more aggressively and reaches the minimum 5 billion gallons sooner than the House version. It seems clear that the short run growth or the potential growth for ethanol will be dependent on passage of federal law banning or restricting the use of MTBE.

While other oxygenates exist and are technically superior to ethanol, they are even more costly to produce. Ethyl tertiary butyl ether (ETBE) has a slightly higher-octane level and lower energy content. This combination results in a reduction in the evaporative emissions and is better for the environment than MTBE. Studies have shown, however, that ETBE does have trouble cold starting and overall drivability may not be as reliable (Canadian Renewable Fuels Association 2001). ETBE is produced by reacting ethanol with natural gas and petroleum derivatives to produce a new clean-burning fuel additive. Though ETBE is ethanol-derived, it is processed, in part, by the oil industry like MTBE. ETBE is less volatile than ethanol, which causes a lower gasoline vapor pressure. This property allows a lower evaporation rate than ethanol, which in the long run reduces smog in large urban areas. Even if ETBE becomes the oxygenate of choice it will still benefit the ethanol market because ETBE is produced using ethanol.

Many environmentalists claim that ethanol blends are the most financially feasible way to currently clean up the environment. Using a ten percent ethanol blend results in a twenty five to thirty percent reduction in carbon monoxide emissions by making combustion more complete in an engine. The same ten percent blend lowers carbon dioxide emissions by six to ten percent. A key point of the ten percent blend is that the carbon dioxide released by ethanol production activities and inputs, combined with its use, is less than is than the amount that the plants absorb used to produce ethanol and the soil organic matter (Canadian Renewable Fuels Association 2002).

There is no significant difference in the nitrogen oxide outputs between using MTBE and an ethanol blend. Biomass ethanol has a distinct advantage in nitrogen oxide emissions output over cellulose-based ethanol due to the fact that the amount of fertilizer needed to grow a sufficient amount of corn to supply the ethanol demand would increase the nitrous oxide rate. Ethanol as an octane enhancer can substitute for benzene, butadiene, and other hydrocarbons. By reducing the amount of benzene and butadiene, both carcinogens, the overall environment can potentially benefit.

Ethanol may have the greatest potential for success in the short run in Western and Northeastern urban cities' mass transit systems. Some cities have made the change from diesel to natural gas to reduce urban pollution and smog. Although diesel fuel regulations do not require the use of oxygenates, they can dramatically reduce the emissions from diesel engines. A more cost efficient option is to blend diesel with ethanol. If city buses begin switching to a blend of diesel and an oxygenate like ethanol, called biodiesel the smog rate could decrease (US DOE 2003). Table 1 shows how a blend of 20% ethanol (B20) and 100% ethanol B100 would affect the pollution rate. The fact that many cities are now mandating that their public transportation sector now implement some type of blending in their gasoline indicates some potential growth in ethanol demand.

Ethanol has the potential to compete with the petroleum markets in two different markets, the blend market and the neat market. The neat market is a blend characterized by a mixture of 85% ethanol by volume and gasoline. The blend market, which is a mixture of less than 10% of ethanol by volume and gasoline, has the highest probability of succeeding. While cars and light trucks are manufactured to handle a gas/ethanol blend today, most engines cannot handle the neat ratio. Modern gas station infrastructures are compatible with blended gasoline, while new equipment would be needed to compensate for the neat mixtures. Blends may hold more promise because they are viewed as an oxygenate while neat mixtures are viewed as direct alternatives to gasoline, and thus would directly compete with oil as a total fuel product. When viewed as an alternative to gasoline, neat fuels will have to compete on a mileage and energy content basis as well as cost. Neat fuels are at a disadvantage to petroleum when analyzed as a total fuel because a gallon of ethanol has only two-thirds the energy content of a gallon of gasoline (Hadder). Today, the only sector in which neat fuels are widely used is urban transit buses and in government fleet vehicles.

The future stability of ethanol prices may rely on the success of biomass ethanol, or ethanol made from grasses and agricultural waste. Unlike starch-based ethanol, biomass ethanol production is not directly linked to corn products and can be produced from a range of waste products.[1] Biomass contains energy that has been stored by living organisms through photosynthesis. Some of that energy is still present when those organisms have been processed for other goods. Wood and animal waste still contain a large amount of un-harvested energy. The key to accessing the energy content in biomass is converting the raw material feedstock into a usable form, which is accomplished through combustion, or biochemical or thermo chemical processes.

Biomass Ethanol

If the market for ethanol continues to grow, biomass has the potential to be the input of choice for several reasons. Biomass crops like switch grass and fast growing tree plantations use less fertilizer and require less energy to harvest than do traditional row crops such as corn. Biomass ethanol production also produces valuable by-products such as acetic acid, which can be used as a food addative, as a photographic chemical, and in the manufacture of plastics such as polyethylene terephthalate. The major deviation between biomass and starch-based ethanol are their energy efficiency ratios. Assuming an average efficiency corn farm and an average efficiency ethanol plant, the energy output –input ratio is 1.38:1. Given the same scenario, average efficiency biomass energy output-input ratios are 2.62:1 (Lorenz). This is due in part because the production of biomass ethanol consumes products that would not ordinarily be put to use. Biomass has the distinct advantage of being more energy efficient than its starch counterpart.

[1] A poor growing season in the Midwest can have severe consequences on ethanol supply and price. Another possible downside to cellulose based ethanol is that its main byproduct is gluten which is exported to the E.U. Gluten is classified as a processed product so it bypasses feed labeling laws in Europe for now, but that law may be revised in the future. This would mean that all cellulose-based ethanol produced would need to be GMO free. Production of biomass ethanol can facilitate several different materials for the final production. Although biomass materials are less expensive than corn, it is more costly to convert into a finished ethanol product due to the extensive processing that is required.

An efficient biomass ethanol production facility can handle both starch and hemicellulose materials in its conversion process. Many of the materials that can be used to produce ethanol from biomass include materials that are abundant and inexpensive. Farmers in the past tended to burn rice straw and wheat straw, a process which is coming under scrutiny due to the possible pollutants it may release. A biomass plant can now convert material, which had no monetary value and was discarded, into a small profit when sold to ethanol plants. Waste materials based from cellulose and hemicelluloses that have been dumped into a landfill now have the potential to be converted into ethanol. Unlike corn-based ethanol, which takes a primary source and uses its energy, biomass utilizes secondary energy sources making it more efficient. Another advantage of biomass is that unlike corn it may actually prevent some types of soil erosion. It is estimated that there are about nine tons of soil a year eroded by rain and wind in corn production areas (Pierce).

Biomass Categories

Biomass feedstock can be broken down into four different categories, monomeric sugars, starch, cellulose, and hemicellulose (DiPardo). Monomeric sugars require the least amount of processing to covert its inputs into ethanol. The most common form of monomeric sugars are found in sugar beets and sugar cane. Until the late 1930's, industrial grade ethanol was made using molasses from sugar beets and sugar canes. Today, however, the high cost of domestic sugar prohibits large-scale ethanol production from this source. Starch, the most prevalent input in ethanol production can be found in abundance in corn. Starch containing crops have a higher value as a food source because animals and humans can digest starch, but not cellulose. Moderate processing is needed to yield simple sugars that are in the form of biopolymers found in starch. Cellulose is also a biopolymer and is the most common form of carbon in biomass. More processing is needed to arrive at the final product due to the strong hydrogen bonds found in cellulose. Hemicellulose consists of short, highly branched chains of sugar, which has just recently been readily fermentable to alcohol. Both hemicellulose and cellulose show promise for the future, but for now, are too expensive to use on a mass scale.

One existing problem is the high cost of transforming biomass into ethanol. A promising new method is being developed called countercurrent hydrolysis. In the first stage, biomass feedstock is loaded into a co-current reactor via conveyor. Steam is pumped in and raises the overall temperature to 180° Celsius; eight to ten minutes later, when about sixty percent of the hemicellulose is hydrolyzed, the feed exits the reactor. During the second stage, a reactor is heated to 225° Celsius and very dilute sulfuric acid is added. By using the countercurrent hydrolysis method, DiPardo predicts that glucose yields may increase up to eighty four percent and the fermentation yield of ethanol up to ninety five percent (DiPardo). This alternative method has the potential for a production savings of up to $0.33 per gallon produced.

Many in the industry believe that for biomass ethanol to compete on an economic level with its substitutes, enzyme hydrolysis must become the norm. The enzyme, cellulase, now being used in the textile industry to stone wash denim and in detergents, can replace the conventional sulfuric acid step currently used. Cellulase can be used at lower temperatures, reducing the sugar degradation. This process not only saves time, but also avoids the use and handling of certain acids that are costly to store and transport. In the short run, a change to cellulase is quite costly due to large up-front costs relative to output. In the long run, however, most believe that enzyme technology is expected to have the most promise for the large-scale production of biomass ethanol.

Table 2 describes the average gallons yielded per average ton of inputs using the enzyme technology (DOE Theoretical Ethanol Yield Calculator). While corn has the potential for yielding the most gallons of ethanol per ton of input, a corn byproduct, stover, which is typically left in the field, can be a very valuable resource when considering biomass production. In the Southeast, cotton gin trash, rice straw, mixed paper, and forest thinnings are possible energy sources.

Agricultural Waste

Agricultural waste is the main source of biomass feedstock in the United States. Corn stover is the dominant source nearly four times greater than the biomass accessible from wood waste and paper, the next largest category (US DOE Bio Fuels and the Environment). In 1999, there were more than 95 million tons of agricultural waste in the United States with the potential to be converted into ethanol. Of the different categories of biomass feedstock, agricultural waste appears attractive because it is simply a byproduct of other activities already in progress, adding a potential revenue source for farmers.

In the Midwest, corn stover is the most prevalent input for biomass ethanol production due to its abundance and its overall yield. Under today's production capabilities, corn stover is a close second in yield per ton at 113 gallons of ethanol, behind corn at 124 gallons per ton. Currently, stover is left in the field, burned, or plowed. Stover might also be the first large-scale biomass ethanol material due to its close proximity to the existing ethanol production plants and the fact that is already there for harvesting. It most be noted that all corn stover can not be used in the production of ethanol, a percentage must remain in the field for erosion prevention. Corn stover, with its ethanol yield capabilities, is the reason many believe that the Midwest with its large corn production, will be the home to not only cellulose-based ethanol, but to biomass ethanol as well.

In the Southeast, forestry waste could play a major role in ethanol production. Every year the U.S. produces from 100 to 280 million tons of forestry waste that could be used to produce ethanol (Bergman). Forestry waste is not simply forest thinnings, but includes logging residues, imperfect commercial trees, and non-commercial trees that need to be cleared for fire hazard reasons. Forestry waste, then, appears a prime source of feedstock, but its fluctuation in supply year to year suggests it must be supplemented with other feedstocks to ensure a stable input supply.

In the Northeast, the most potential for developing an ethanol industry could be in raising hybrid willows. The hybrid willow is the only natural feedstock that is carbon dioxide neutral. It is considered carbon dioxide neutral because it stores large amounts of carbon in its root system and restores the soil organic matter. Secondly, it will cut the usage of coal for electricity generation in the ethanol process. As with other biomass feedstocks, willows are more complex and costly, for ethanol production, as compared to corn. The Canadian government claims, based on a 25 ton/ha yield of hybrid willow, that 125 square miles of square hybrid willow could replace 10 CANDU reactors and all of Canada's gasoline requirements (Samson).[2]

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[2] The CANDU reactor is a pressurized-heavy-water, natural-uranium power reactor designed in the 1960's by a consortium of Canadian government and private industry. CANDU is a registered trademark and stands for "Canada Deuterium Uranium".

Potential energy crops include fast growing grasses, shrubs, and trees, such as switchgrass, willows, and hybrid poplars. What makes energy crops attractive is that they can be grown on marginal land, riverbanks, around lakeshores, and in any other open space. Production costs were estimated at $27.36-$49.27 a ton for switchgrass (Mann). Unlike corn for ethanol production, energy crops do not compete for prime agricultural land. Energy crops are specifically planted to harvest for use in the production of ethanol, but while growing they provide habitat for wildlife and renew soils. In 2000, the U.S. Department of Energy estimated that there would be about 100 million acres available for growing energy crops in the 21st century (US DOE, Biofuels and the Enviorment). Incentives for farmers to grow these energy crops include their heartiness, resistance to disease and pests, and they are relatively inexpensive to produce.

Transportation Problems

There are drawbacks to using ethanol as a major fuel source ranging from an increase of certain types of pollution to the expense and lack of infrastructure to transport ethanol. A distinct disadvantage of ethanol, as opposed to MTBE, is that ethanol cannot be shipped through pipelines. MTBE can be piped to a refinery, then blended with gasoline, and piped to pumping stations through out the United States. Pipelines are the cheapest and fastest way to move liquids. However, this mode of transportation is infeasible for ethanol for three reasons: ethanol absorbs water impurities found in pipes and then separates from the gas, logistical limitations of existing pipelines, and insufficient volumes of ethanol that need to be transported (Whims). Because ethanol cannot be sent through pipeline it must be "splash blended" where ethanol carried by tanker trucks is blended at the terminal instead of at the refinery. As a result, the oil industry must spend a projected $1 billion to modify its plants and build special tanks for ethanol in California.

Currently, ethanol must be transported by barge, train, or truck to fueling stations. As shown in Figure 3, most ethanol must travel large distances to reach the heavily populated east and west coasts from the primary sources in the Midwest. These additional transportation costs make ethanol distribution to places like California expensive. About ninety percent of the nation's ethanol is produced in five states: Illinois, Indiana, Iowa, Minnesota, and Nebraska. Illustrated in Figure 2 are the costs of transporting each fuel. Ethanol shipping costs ($1.10-1.20/gal) are nearly double those of gasoline ($0.57-0.65/gal conventional; $0.60-0.68/gal reformulated), and significantly more than MTBE ($0.75- 0.85/gal). Existing federal tax subsidies of 5.4¢/gal, plus incentives in some states are sufficient to overcome the cost disadvantage in some but not all situations (Biomass Energy Research Association). This cost difference may be seasonal however; Ethanol is only three cents per gallon higher in Los Angeles than it is in Omaha (Ohio Corn Marketing Program). Those numbers showed ethanol at $1.39 in Omaha and $1.42 in Los Angeles. Currently, there are no biomass ethanol production facilities located in the Northeast, where the vast majority of the United States population resides and where there is a huge potential market for cleaner air (NESCAUM, 1999).

Pipeline location is another major obstacle for the efficient transportation of ethanol. The majority of the existing pipelines in the United States run from the Gulf Coast to the East or West Coast. For ethanol to but pumped through a pipeline it would first have to be barged down the Mississippi river or carried by train to staging areas around the Gulf of Mexico. Storage capacity would have to be built in both the Gulf and at the receiving market because ethanol cannot be mixed and stored with other fuels. Building a pipeline exclusively for ethanol from the Midwest to the Gulf and then to the East and West coast is so costly its construction is not likely in the near future. Finally, a pipeline would require sufficient volumes to justify the large construction cost. At present, projected volumes are insufficient to justify construction of dedicated pipelines.

These high transportation costs may provide the niche market for biomass ethanol to fill since it can made from local products located from coast to coast. Unlike corn-based ethanol, predominately produced in the Midwest and then shipped, biomass ethanol can be produced locally using waste products that are readily available. Thus, the Northeast and the West can produce at least a portion of the ethanol they need, and avoid shipping costs. Further, biomass ethanol can be produced using a variety of inputs, so each region of the United States and could use the waste or energy crop most suited for that area. The fact that biomass is not dependent on one crop (i.e., corn) makes it very appealing for those who live in regions far from the Corn Belt, this also provides a buffer against shocks in corn supply/price.

Another potential problem facing the ethanol industry is the fact that ethanol production is a highly concentrated industry. Archer Daniels Midland (ADM) controls 40% of all ethanol production in this country (Calgasoline, Ethanol Market Concentration). This market concentration will only increase if California switches to ethanol because ADM is better able than are other producers to alter their production to meet this large demand. As a result, Archer Daniels Midland could control about half of all the supply of an essential component of California's gasoline supply. If all 16 states where MTBE is now used were required by legislation to use ethanol, total demand for ethanol would more than double. ADM has given about $5 million in contributions to federal lawmakers since 1991. Many complain that it will be the agribusiness giants like ADM who will benefit from the banning of MTBE because of their relative market power. However, if profits from ethanol production grow, it will likely attract new entrants into the market, including smaller biomass ethanol providers.

Potential Environmental Concerns

One concern about ethanol is that pure ethanol contributes to the greenhouse effect more than pure gasoline, so many support burning pure gasoline until Federal Law changes the environmental regulations. According to the Energy Information Administration, ethanol produces less carbon dioxide and carbon monoxide than gasoline, but more nitrous oxide and methane.

Studies have shown that ethanol has been linked to a rise in volatile organic compound (VOC) emissions and will likely increase some toxic air emissions, compared to reformulated gasoline containing MTBE (NESCAUM). VOCs are directly related to gasoline vapor pressure, which is measured in Reid vapor pressure (RVP). The RVP of a gasoline is dependent on which fuels are mixed or blended with the gasoline. Ethanol has a RVP lower than that of gasoline; the RVP of ethanol blends (E10) is higher than that of pure gasoline. Currently, ethanol's high volatility limits its use in the hot summer months where evaporative emissions can contribute to ozone destruction. So, while certain areas of the United States such as Denver and Minneapolis, ethanol works well in the winter months to reduce carbon monoxide levels. Critics suggest that in cities such as Los Angles and San Diego ethanol use will raise smog rates in the hot summer months.

Small quantities of ethanol are capable of significantly increasing the volatility of gasoline creating increased evaporative VOC emissions (NESCAUM). The use of ethanol in RFG directly increases emissions of acetaldehyde, a toxic combustion by-product of ethanol, and will likely increase some toxic air emissions of reformulated gasoline when compared to MTBE by diluting lesser quantities of toxic compounds found in gasoline. Ethanol may release less carbon dioxide than MTBE when used in a combustion engine, but that maybe secondary because many plants used in ethanol production burn coal for energy to support the fermentation process.

Other environmental concerns need to be addressed when looking at the production stage of both biomass and corn based ethanol such as the fertilizer usage in corn production and the amount of wastewater by-product leftover after biomass production. For each gallon of corn ethanol produced, about 160 gallons of wastewater are produced (Pimentel). If the cost of processing this wastewater sewage is included in the pollution cost of an average production facility of ethanol, the total pollution costs per gallon of corn based ethanol would be $.42 (Pimentel).

Many studies have shown that there might be a net loss of energy during ethanol production. Pimentel (1998) has shown that it takes 131,000 BTU's, on average, to produce one gallon of corn-based ethanol, while that gallon only provides 77,000 BTU's of energy. Thus, there is a net loss of 54,000 BTUs, a 41% energy loss. Lorenz and Morris counter this finding. They claim that ethanol possesses a positive net energy balance. Lorenz and Morris took information based on the current energy efficiency of corn farming and ethanol production and found that the net energy ratio is 1.38:1. The key to their study is that they took the average of, all farmers, including those who used various types of irrigation, wet milling, dry milling, fertilizer amount, drying equipment and tractor usage. They also shows that, if one assumes corn raised by the least energy efficient farmers, (those who use continuous corn planting and irrigation) then being processed by ethanol plants that do not use cogeneration and other energy efficient processes, ethanol production would not have a positive energy value. In this scenario, they state that ethanol production could have a negative energy balance of about .07:1. According to Lorenz and Morris, only about 5% of ethanol is produced in this manner, and while the remainder might not be at the net energy high of 1.38:1, the majority is a positive net energy gain.

The dilemma of space and logistics also becomes critical when considering mass implementation of ethanol requirements. If E85 (a blend of 85% ethanol and 15% gasoline) were to become prevalent in the United States, a vast majority of American farmland would have to be put aside for ethanol production. Pimentel (2002) argues that for ethanol to be a substitute for gasoline, and fuel all the cars in the United States, 97 percent of U.S. land would have to be planted with corn.

Conclusions

The key unknown in both biomass and corn-based ethanol is how long the subsides will last. Without subsidies, ethanol would not be competitive with crude oil at current prices. Currently there is a 53-cent per gallon tax break to keep ethanol prices competitive with gasoline prices, but what would happen if those subsidies were stopped? Essentially, ethanol, ethanol producers, ethanol plants, and some corn farmers are almost completely dependent on current subsidies. As state budgets become tighter, subsidies are convenient targets for budget reductions. For example, in January of 2003, Minnesota

Governor Tim Pawlenty proposed elimination of $26.8 million in subsidies for 13 ethanol plants. Pawlenty's plan to erase a $356 million deficit projected through June calls for $77 million in cuts to state agency grants and programs. Ethanol subsidies account for more than a third of the total cuts in the state of Minnesota. Whether this trend will extend to other states remains to be seen.

Some politicians are starting to view subsidizing that ethanol as pork barrel politics. For example, John McCain had this to say in 1999 during a stop in Iowa while attempting to earn the GOP nomination for President:

> "I'm here to tell you that I want to tell you the things that you don't want to hear as well as the things you want to hear. And one of those is ethanol. Ethanol is not worth it. It does not help the consumer. And those ethanol subsidies should be phased out and everybody here on this stage, if it wasn't for the fact that Iowa is the first caucus state, would share my view that we don't need ethanol subsidies. It doesn't help anybody (Des Moines Iowa GOP Debate Dec 13, 1999)."

Ethanol subsidies cost taxpayers some $770 million a year, according to the Cato Institute. Ethanol cannot be considered economically efficient at present because its existence is based on heavy subsidies. Mandated increased use, due to the banning of MTBE, would mean additional production costs, transportation costs, infrastructure costs, and environmental costs. However, current subsidies may also be viewed as an investment to ensure that technology and infrastructure are developed that will provide an alternative fuel source in the future.

Ethanol looks to have a chance to succeed within the oxygenate market by overtaking MTBE as the preferred octane booster. However, as a complete fuel, ethanol cannot directly compete with petroleum on a cost or performance level. This fact needs to be considered when analyzing the prospects for future ethanol expansion. There are two distinctly different markets in which that ethanol is competing: fuels and oxygenates. There looks to be a ten to twelve year window in which the ethanol industry looks to expand, before other alternatives such as hydrogen fuel cells become commercially viable. The question with hydrogen fuel cells is not when they will be available, but when they will be the standard. Ethanol as an oxygenate can fill the niche of the of being a cleaner burning fuel while the scientific community tries to develop an alternative to petroleum as our main fuel source. Biomass ethanol, although currently more expensive to produce, may have the potential to lower the overall price per gallon by cutting transportation costs. If produced locally, costs of shipping liquid ethanol from the Midwest to the refineries in the West and Gulf is eliminated. The question that remains with biomass ethanol is will the reduction in transportation costs offset the higher production costs. If so, there will be a market for biomass ethanol in those regions. If not, then, as in the Midwest, starch based ethanol will prevail.

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Table 1. Reductions in Pollutants when using 100% ethanol (B100) and an ethanol blend of 20% (B20)

Emission	B100	B20
Carbon Monoxide	-47%	-12%
Hydrocarbons	-67%	-20%
Particulates	-48%	-12%
Nitrogen oxides	(+) 10%	(+) 2%
Air Toxics	-75%	-15%
Mutagenicity	-85%	-20%

** Figure ES-A Environmental Protection Agency Draft Technical Report EPA420-P-02-001 "A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions"*

Table 2. Yield of ethanol in gallons per dry ton of various Biomass feedstocks

Feedstock	Theoretical yield in gallons per dry ton of feedstock
Corn Grain	124.4
Corn Stover	113
Rice Straw	109.9
Cotton Gin Trash	56.8
Forest Thinnings	81.5
Hardwood Sawdust	100.8
Bagasse	111.5
Mixed Paper	116.2

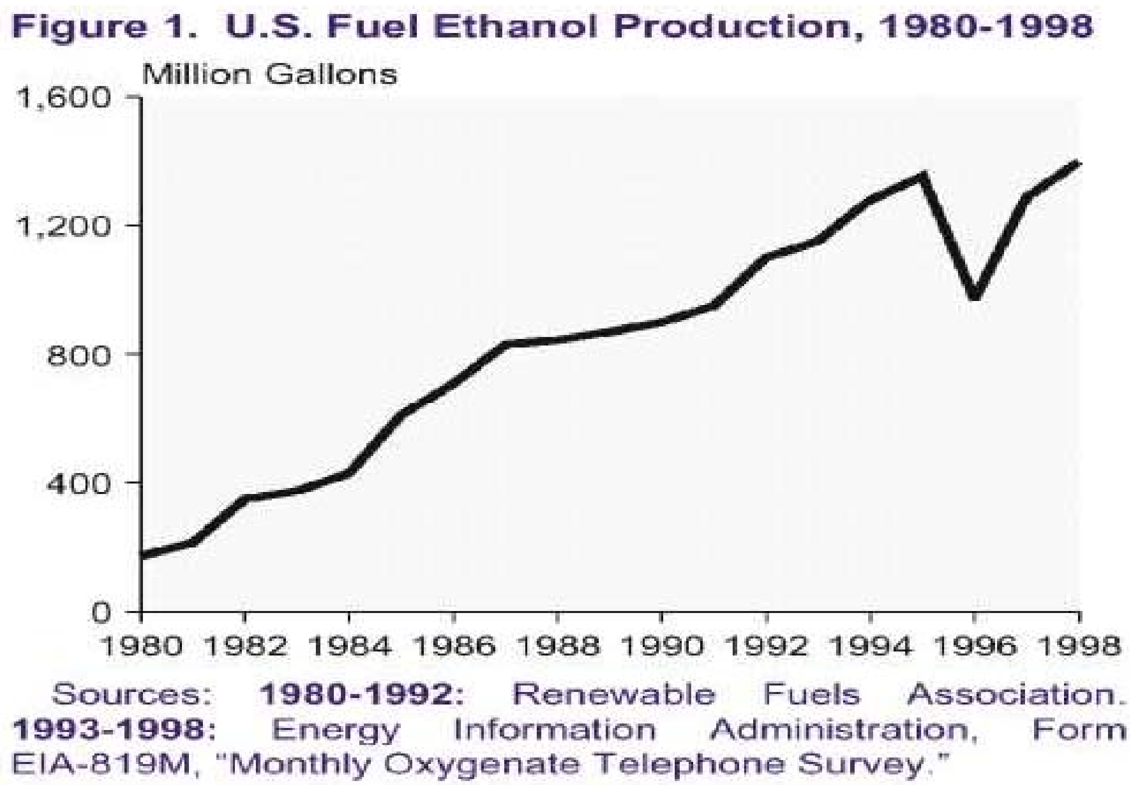

Figure 1. U.S. Fuel Ethanol Production from 1980-1998

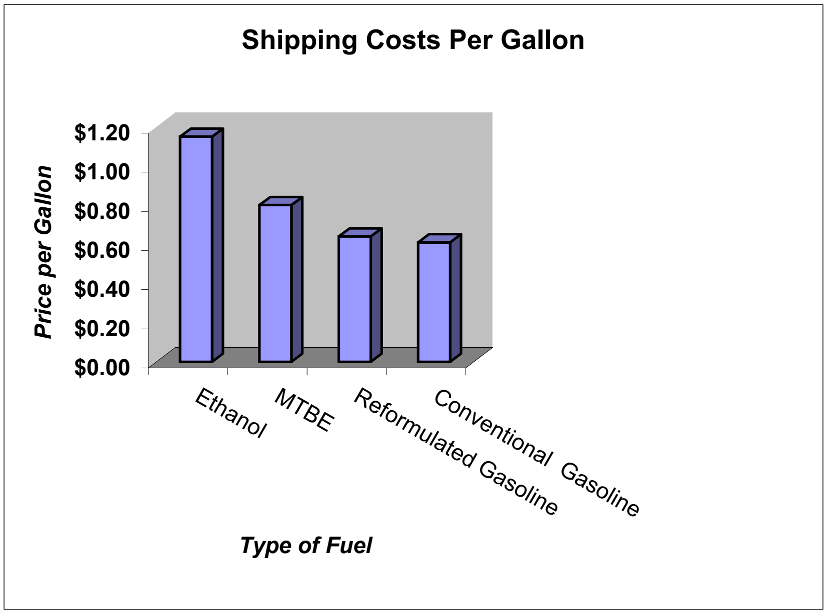

Figure 2. Shipping Cost per Gallon of Fuel

Figure 3. Regional Ethanol Consumption 1990 and 1996

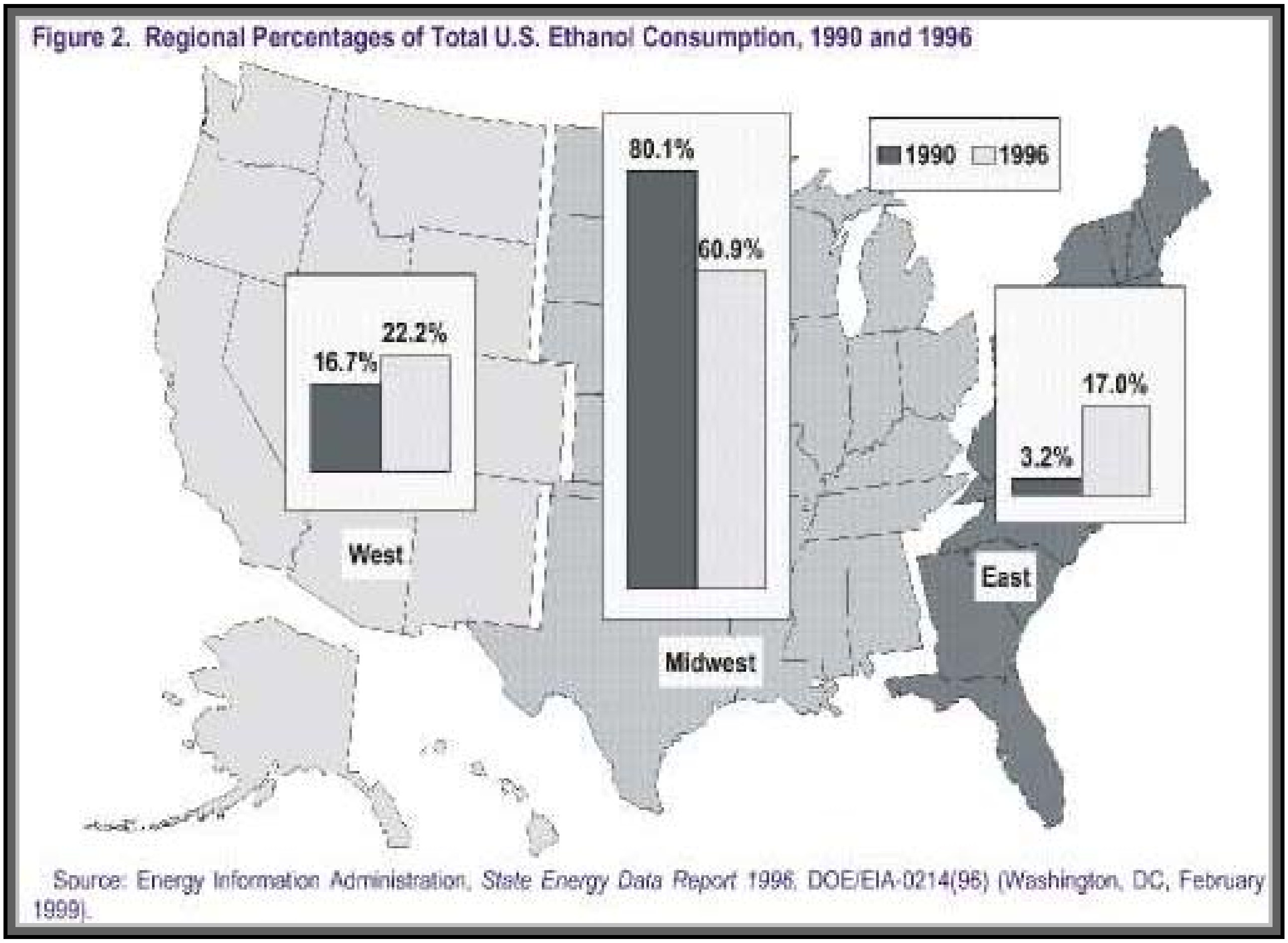

Figure 2. Regional Percentages of Total U.S. Ethanol Consumption, 1990 and 1996

Source: Energy Information Administration, *State Energy Data Report 1996*, DOE/EIA-0214(96) (Washington, DC, February 1999).