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ETHANOL:

Liquid Pork, Holy Water or Fields of Gold?

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Introduction

The United States' increasing dependence on foreign oil is widely recognized as one of the nation's biggest problem. Stories of our reliance dominate news reports in text, on television and in the movies. One possible solution, ethanol, is a form of biofuel. Ethanol is a high-octane fuel that burns clean and is produced from renewable sources. At its most basic, ethanol is grain alcohol, produced from crops of grain and corn. Ethanol helps reduce our dependence upon foreign imports because it can be domestically produced in the United States. Pure ethanol fuel is not used as a motor fuel; rather it is mixed with unleaded fuel. For example, E85 is 85% ethanol and 15% unleaded gasoline, whereas E10 is 10% ethanol and 90% unleaded gasoline. By mixing ethanol with gasoline it decreases the fuel's cost, increases the fuel's octane rating and decreases gasoline's harmful emission. However many are opposed to the use of ethanol due to its low energy input to output ratio. This case study focuses on corn and cellulosic ethanol while analyzing the efficiency, economic issues, environmental impacts (effects on agriculture, air pollution), production, the effect on car industry, the current affairs and future concerns of ethanol. We will also look at Brazil’s ethanol program which has been active longer than any other country’s.

Corn Based Ethanol

Background

Corn ethanol, through industrial fermentation, chemical processing and distillation, is produced from corn as a biomass. Primarily used in the United States it is an alternative to petroleum and gasoline. Corn based is the most common type of ethanol in the United States but is considered less efficient that other types of ethanol (cane, sugar, cellulosic etc.).

There are two corn-processing methods to produce ethanol, dry and wet corn milling. The difference between the two is the initial treatment of the grain. Dry milling has liquefied cornstarch produced by heating corn meal with water and enzymes. This starch is converted to sugars with a second enzyme and then fermented by yeast into ethanol and carbon dioxide. Wet milling separates the germ, fiber and protein from the starch before it is fermented into ethanol.

Benefits

The use of ethanol-blended fuel helps reduce the environmental impacts of gasoline consumption on our society. Fossil fuel-based gasoline is the largest source of man-made carcinogens and the number one source of toxic emissions, according to the

U.S. EPA. Ethanol is a renewable, environmentally friendly fuel that is inherently cleaner than gasoline. Ethanol reduces harmful tailpipe emissions of carbon monoxide, particulate matter, oxides of nitrogen, and other ozone-forming pollutants.

Economic Effect

An important issue that must be taken into account when making a choice between corn-based ethanol and standard fuel is what will happen to the economy. Various factors affect the issue of economy, such as land cost of the corn, the gas production trade, and the buyers of this ethanol. Growth in ethanol production has given the US an economic stimulus for agriculture due to the fact that most of the ethanol produced in the US is made of corn. The increase in ethanol demand has created a new market for corn, and agricultural policymakers. Ethanol can also be used as a biofuel and allows the US economy to decrease its dependency on imported oil.

Increasing the demand on ethanol creates a higher demand for the corn and thus raises the price of corn, which then results in reduced farm payments. Advances in technology over the last decade have greatly enhanced the energy efficiency of corn in ethanol. Though this is true, the efficiency or corn to ethanol is still rather low, and improvement is increasing slowly. The blender's tax credit is usually passed down to consumers in the form of more competitive prices at gas pumps. According to the Consumer Federation of America, consumers who purchase gasoline blended with 10 percent ethanol could be saving as much as 8 cents per gallon compared to straight gasoline.

With today's technology, one bushel of corn yields 2.8 gallons of ethanol. And that number is constantly increasing. Just a few years ago, that number was closer to 2.5 gallons per bushel of corn. In 2004, 1.26 billion bushels of corn went to ethanol production, which comes out to be 12% of the nation's total crop. That figure rose to 14% for the '05 corn crop, which is 1.6 billion bushels of an 11.1 billion bushel crop. As the nation's ethanol production climbs, some bushels from the export category will likely shift over into ethanol production. In 2005 the U.S. produced 4 billion gallons of ethanol, which equates to about 3% of the country's total gasoline consumption (140 billion gallons per year). This is a small percentage, but a critically important one.

Ethanol production/use can benefit U.S. agriculture. Because it is made primarily from corn and other agricultural products, ethanol increases demand for these crops, increases the prices farmers receive for these crops, and brings economic development opportunity to the rural areas where the ethanol is made. Farmers who invest $20,000 in a local ethanol plant receive an average 13.3% per year on their investment over ten years.

The local price of corn increases by an average of 5-10 cents per bushel, adding significantly to farm income in the general area surrounding the plant. USDA projected that the increased demand for corn to support the additional ethanol production to replace MTBE will increase cash receipts for farmers by $2.3 billion between 2000 and 2004. USDA estimates that the renewable fuels standard would double the demand for corn for ethanol production to 2 billion bushels per year by 2012 and for this, ethanol is beneficial. Without it, there would be a need for 3% more gasoline.

On the other hand, the amount of land for crops is limited. Given that the US produces 11,807,217,000 Btu a year, and that the US uses 140 billion gallons of gas a year, it is apparent that the amount of corn needed is not enough for this amount of gasoline, including the amount towards food. The use of ethanol to replace gasoline can only be a temporary solution. Once natural recourses are depleted, humans must find a new source of energy that is more efficient. It takes about 35,000 Btu of energy to create a gallon of ethanol, and that gallon of ethanol contains at least 77,000 Btu of energy. Since the efficiency is less than half, other biofuels such as Butanol fuel could be a better investment of research and money. An argument can be made that the corn produced for ethanol can go to the cause of hunger, though the amount of corn taken away from this cause is near negligible.

Ethanol is used in reformulated gasoline (RFG) as set out in the Clean Air Act Amendments of 1990. This standard requires an oxygenate, like ethanol, to be added to gasoline to help it burn more completely. Reformulated gasoline is required in areas that violate carbon monoxide and/or ozone quality standards. Ethanol blends reduce carbon monoxide emissions in vehicles by between 10-30%, depending upon the combustion technology. In 2004, ethanol use in the U.S. reduced CO_2-equivalent greenhouse gas emissions by approximately 7 million tons, equal to removing the emissions of more than 1 million cars from the road. Research shows a 35-46% reduction in greenhouse gas emissions and a 50-60% reduction in fossil energy use due to the use of ethanol as a motor fuel. Ethanol contains 35% oxygen, making it burn more cleanly and completely than gasoline. Ethanol is highly biodegradable, making it safer for the environment. Though this is true, carbon dioxide is a co-product of dry mill ethanol production. Carbon dioxide is given off in great quantities during the fermentation stage of ethanol production. CO_2 is still given off, though the amount is much less than the amount of CO_2 given off by gasoline.

The production of corn-based ethanol has been increasing at a steady rate since the 70's and 80's, but over the last five years it has begun to grow at an exponential rate. The U.S. already has over 100 active ethanol plants capable of producing more than five billion gallons of ethanol per year. An additional 58 plants currently under construction or expansion will add nearly four billion more gallons of capacity, bringing total capacity to nearly nine billion gallons and surpassing the renewable fuels standard requirement of 7.5 billion gallons by 2012, far ahead of schedule. In addition, if all 150 currently proposed ethanol plants were to be built, U.S. ethanol capacity would surpass 19 billion gallons per year.

As good as this all sounds, it also brings up some concerning questions because too much of anything is never good. With the dramatic increase in the amount of ethanol being created in this country from our farmers' corn, we have to look at where all the corn used for this ethanol will be coming from. Corn exports are a big time business in this country, but with much of the country's corn being needed for its' ethanol plants, much of these corn exports may have to be rerouted. If only a quarter of the ethanol plants currently proposed in the Midwest do come on line, and if the corn needed to supply these ethanol plants and the plants currently under construction were to be diverted from exports, Midwest corn exports could be cut in half (Schoonover and Muller, 2006). What does this mean for us and our farmlands of the Midwest? First of all there will probably be a higher demand for corn and a resulting higher price for corn, which is not the most reliable crop due to the unpredictable weather of the Midwest that can result in extreme flooding or draughts. This higher price and demand for corn will most likely switch many farmers' main crop to corn. This in turn will directly affect the paralleled livestock industry. This increase in corn production for ethanol will decrease the amount of livestock farms as well as the amount of food available for the livestock because the livestock feed off of much of this corn growth as well. This is reiterated as one study suggests, the adjustments required to free corn for the U.S. ethanol industry are felt all over the world. For example, Argentinean corn producers adjust by growing more corn, whereas U.S. and Chinese consumers respond by buying less pork. Whether these effects will be beneficial, it is tough to tell right now, but either way the agricultural lands of the Midwest will be greatly changed for better or worse.

As corn based ethanol becomes a more popular source for alternative fuel in our country, the car industry is forced to adjust accordingly. More than 5 million vehicles on U.S. roads today can run on ethanol. General Motors, Ford and DaimlerChrysler recently announced plans to double their annual production of so-called flex fuel vehicles to two million cars and trucks by 2010. It's the single largest commitment to renewable fuels in the history of the auto industry. This here shows us that we are moving in the right direction. Many have worried that it will be hard on the car industry to make this adjustment to renewable fuels, but this step by these companies shows us that they are committed and it is very possible. Other car companies should be sure to follow, as the transition is made easier with updated technology and shared ideas.

The most recent energy bill passed in congress that affects corn-based ethanol directly stated that by the year of 2012, less than 5 years away now, the U.S. must use at least 7.5 billion gallons of renewable fuels. This is great news for the ethanol companies and for the corn industry as it is leading the way in renewable fuels. One study suggests that the U.S. corn-based ethanol industry will continue to expand until the market price of corn reaches $4.05. This means better income for corn farmers and stockholders of ethanol companies. However these are only predictions because nature and its effects on crops are highly unpredictable. Other than the main goal as a country of reaching 7.5 billion gallons by 2012, there are many other state legislatures making changes as well, including the state of Minnesota changing the required amount of ethanol in all gasoline sold in the state from 10% to 20% by 2012, just recently.

As we work our way into this new century, renewable fuels will become more popular with every passing day, and an even more important part of our lives. Many of our agricultural lands that once provided food for our hungry mouths will be converted into great energy production lands. What this entails for your typical Midwest farmer or your corn loving consumers, only time will tell. One thing is for certain however, we will have to adapt to this change in agriculture. Our agricultural, transportation and trade policies will also need to shift to address this new reality and truly invest in the future of U.S. agriculture. Other concerns will continue to arise with the beginning of the renewable fuels era that we are beginning. People will have to get newer cars, as the old cars that are only powered by gasoline will be come obsolete. There will be environmental concerns with the new types of fuels, but we can only improve from the destruction of our earth that we have done with our carbon dioxide and monoxide emissions. All of this will be a slow and manageable transition though, as we have time to change over from gasoline into renewable fuels as long as we keep up the pace that we have already set for ourselves.

Problems

To build a crude oil refinery it costs $10+ billion whereas the cost to build a 100 million gallon ethanol plant is $140 million. On top of this, the cost of natural gas to operate these plants is estimated at $15-25 million per year. The amount of water required to produce ethanol is about 2 million gallons per day as corn is one of the most water intensive crops to grow.

The production of corn is very energy intensive and in practically every step of the crop cycle fossil fuels are used; transporting and planting seeds, operating farm machinery, creating and applying fertilizer, and even transporting corn to market. Fossil fuel fertilizers contaminate the soil and groundwater and cannot be replaced by natural fertilizer. There aren't enough animals to produce the fertilizer for all the corn needed to produce the grain based ethanol used to run American cars.

The sustainability question arises when considering the fact that ethanol from corn can't possible be grown forever. Growing corn depletes the soil, even if farming methods like crop rotation are used. Some researchers say that ethanol production from corn could result in soil being worn out in 30 years.

Ethanol cannot be shipped through gasoline pipeline systems that currently exist because ethanol is easily contaminated by water and will corrode the pipes. Currently there is no ethanol pipeline in the world. Presently ethanol is shipped by rail car or truck to fuel distributors who then mix it with gasoline and ship it to filling stations on subsequently more trucks. This thus leads to increased cost and higher overall CO2 emissions. To use ethanol on any large scale, transport vehicles need to be retrofitted or the government will be forced to build subsidized pipelines.

Massive Federal subsidies are required for ethanol to be economically viable. America's oil consumption, which is approximately 150 billion gallons annually, would barely be dented by the current biggest proposed ethanol support. This support is an increase in mandated ethanol consumption to 15 billion gallons a year from 7.5 billion which was called for in the bill Congress is debating as of last month.

Obviously there is no lack of disagreement on corn based ethanol. However, out of the argument it does appear as though corn based ethanol could be a viable short term solution to America's energy problem. Left is the question of a long term solution and enter cellulosic ethanol.

Cellulosic Ethanol

To meet President George Bush's ambitious goal which required to reducing the nation's dependency on foreign oil by producing 35 billion gallons a year of renewable and alternative fuels by 2017, cellulosic ethanol is an attractive alternative.

What is cellulosic ethanol?

Unlike corn ethanol, which is only produced from sugars and starches, cellulosic ethanol can be produced from a wide variety of cellulosic biomass feedstock including agricultural plant wastes (corn stover, cereal straws, sugarcane bagasse), plant wastes from industrial processes (sawdust, paper pulp) and energy crops grown specifically for fuel production, such as switchgrass (Diane Greer, 2005).

How is cellulosic ethanol made?

The basic procedure to produce cellulosic ethanol is presented in Figure 1. Generally, there are four steps (Evan Ratliff, 2007). Step 1: Break down cell walls of the raw plant feedstock by thermochemical treatment and make the cellulose accessible; Step 2: Add enzymes to convert the cellulose and hemicellulose molecules into the simple sugars glucose and Xylose; Step 3: Convert the sugar into a mixture of ethanol and water by fermentation yeast; Step 4: Refine and purify the ethanol.

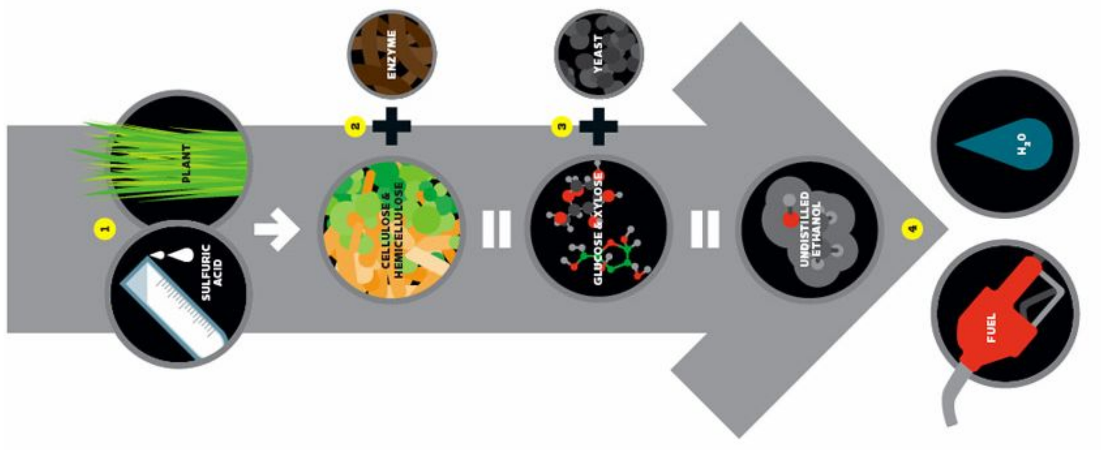

Figure 1: From Grass to Gas (Source: Evan Ratliff, 2007)

More detailed flowchart is shown in Figure 2 (Zfacts, 2004**)**. First the hemicellulose in the biomass is broken into Xylose sugar and Glucose with enzymes. Then the Xylose sugar and Glucose are fermented with yeast. Finally all the ethanol is distilled.

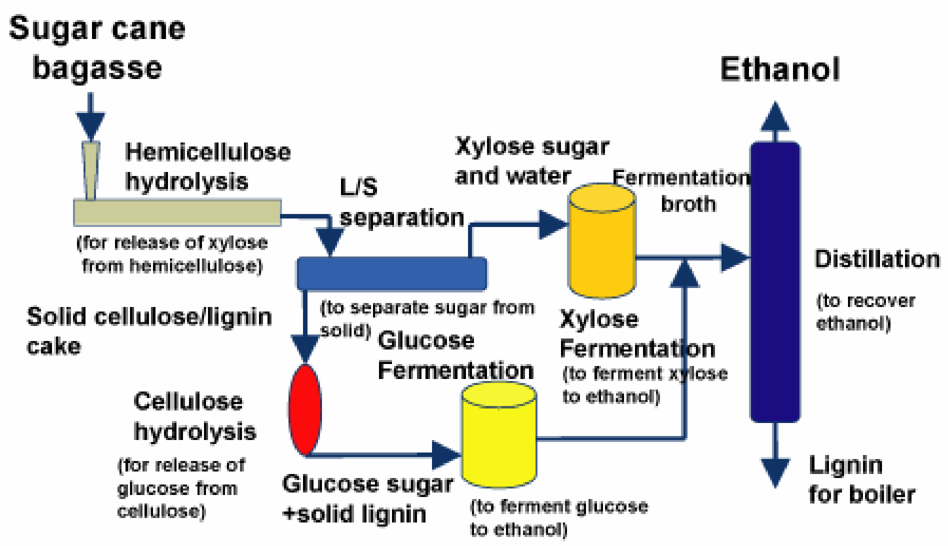

Figure 2: The Production of Ethanol from Cellulosic Biomass **(**Source: Zfacts, 2004**)**

What are the advantages of cellulosic ethanol?

People concern that corn ethanol alone won't meet the president's goal to produce 35 billion gallons of alternative fuels in 10 years, because cultivating corn to use only its grain would take up too much land. According to the National Environmental Trust, producing 35 billion gallons of ethanol annually would require putting an additional 129,000 square miles of farmland area (ScienceDaily, 2007). However, cellulosic ethanol has no this limit because it use the feedstock such as wheat straw, grass, and wood chips, as the source which is cheap and abundant. Therefore, the greater productivity of cellulosic sources provides the possibility to reach the president's goal. According to a report by the National Resources Defense Council (NRDC), cellulosic ethanol can be produced as much as 150 billion gallons by 2050 (Kevin Bullis, 2007).

Except abundance, cellulosic ethanol is also expected to be less expensive and more energy-efficient than other ethanol because it can be made from low-cost feedstock. Table 1 (Zfacts, 2004) presents a comparison of cellulosic and corn based ethanol. Currently, the cost of cellulosic ethanol is expensive because a few companies are producing cellulosic ethanol leading excessive high price of enzymes as well as labor fee. But eventually the price will decrease and cheaper than gasoline.

	Corn Based	Cellulosic Today?-- *Illustrative*	Cellulosic 2010-12— *DOE target*
Feedstock	$1.17 @$3.22/bu 2.75g/bu	$1.00 @$60/dt 60g/dt	$0.33 @$30/dt 90g/dt
By-Product	-$0.38	-$0.10	-$0.09
Enzymes	$0.04	$0.40	$0.10
Other Costs**	$0.62	$0.80	$0.22
Capital Cost	$0.20	$0.55	$0.54
Total	$1.65	$2.65	$1.10

** (includes preprocessing, fermentation, labor)

Table 1: Cost (Data Source: Zfacts, 2004)

Table 2—Percentage Changes in World Prices of Feedstock Crops under Three Scenarios, Compared with Baseline				
Feedstock crop	Scenario 1: Aggressive biofuel growth without technology improvements		Scenario 2: Cellulosic biofuel	Scenario 3: Aggressive biofuel growth with productivity change and cellulosic conversion
	2010	2020	2020	2020
Cassava	33	135	89	54
Maize	20	41	29	23
Oilseeds	26	76	45	43
Sugar beet	7	25	14	10
Sugarcane	26	66	49	43
Wheat	11	30	21	16

Source: IFPRI IMPACT projections.

Table 2: Percentage changes in world prices of feedstock crops under three scenarios, compared with baseline (Data source: Rosegrant, M. W et al., 2006)

The third advantage of cellulosic biofuel is that it will soften impact to world food price. The research done by Rosegrant, M. W et al. (2006) confirmed this conclusion. In their research, they investigated three biofuel scenarios. The first is aggressive biofuel growth scenario with no productivity change. This scenario “assumes very rapid growth in demand for bioethanol across all regions and for biodiesel in Europe, together with continued high oil prices, and rapid breakthroughs in biofuel technology to support expansion of supply to meet the demand growth, but holds projected productivity increases for yields at baseline projection levels” (Rosegrant, M. W et al., 2006). The second scenario assumes that “second-generation cellulosic conversion technologies come on line for large-scale production by 2015” (Rosegrant, M. W et al., 006). And the third scenario assumes that “in addition to second-generation technologies, the effect of investments in crop technology that would lead to increased productivity over time, in order to better support the expansion of feedstock supply in response to growth in biofuel demand” (Rosegrant, M. W et al. ,006). Table 2 shows the impact to world food prices under three scenarios.

The forth advantage of cellulosic biofuel is that it reduces greenhouse gas emission compared to grain based ethanol. “The WTW model for cellulosic ethanol showed greenhouse gas emission reductions of about 80% [over gasoline]," said Wang, who has created a "Well to Wheel" (WTW) life cycle analysis model to calculate greenhouse gas emissions produced by fuels in internal combustion engines. "Corn ethanol showed 20 to 30% reductions.” The favorable profile of cellulosic ethanol stems from using lignin, a biomass by-product of the conversion operation, to fuel the process. “Lignin is a renewable fuel with no net greenhouse gas emissions," explains Wang. "Greenhouse gases produced by the combustion of biomass are offset by the CO2 absorbed by the biomass as it grows.” (Diane Greer, 2005)

In addition, the research done by Farrell A. E (2006) indicated that “GHG (greenhouse gas) emissions from ethanol made from conventionally grown corn can be slightly more or slightly less than from gasoline per unit of energy, but ethanol requires much less petroleum inputs. Ethanol produced from cellulosic material (switchgrass) reduces both GHGs and petroleum inputs substantially.” (See Figure 3)

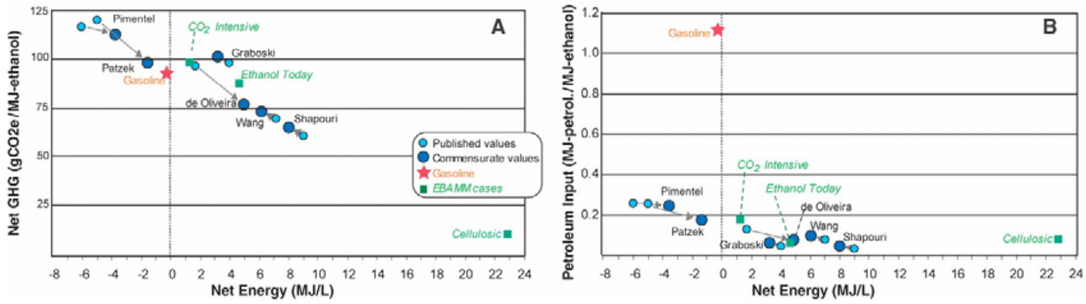

Figure 3 (A) Net energy and net greenhouse gases for gasoline, six studies, and three cases. (**B**) Net energy and petroleum inputs for the same. (Farrell A. E, et.al, 2006)

What are the problems of cellulosic ethanol?

Conceptually, it is easy to convert cellulose to ethanol. Scientists have long known how to turn trees into ethanol, but doing it profitably is another matter (Evan Ratliff, 2007).The problem is that cellulose is a tough molecule to break down. In nature, bacteria and other microorganisms use specialized enzymes to convert cellulosic to sugar. But for scientists, figuring out how to convert cellulose into a usable form on a budget driven by gas-pump prices has been neither elegant nor easy (Evan Ratliff, 2007). Actually, although people realize that Cellulosic ethanol, in theory, is a much better bet compared to other alternative energy sources, “No one has yet figured out how to generate energy from plant matter at a competitive price. The result is that no car on the road today uses a drop of cellulosic ethanol.” (Evan Ratliff, 2007).

The step that has perplexed scientists is the one involving enzymes which work everywhere in living cells by speeding up the chemical reactions that break down complex molecules. Scientists generally extract them from microorganisms that produce them naturally. But the trick is how to produce the enzymes cheaply enough at an industrial scale and speed (Evan Ratliff, 2007). To deal with this issue, there are three potential methods. One is advocated by Lee Lynd, who is trying “to create a bacterium that serves as an all-in-one fuel factory, instead of using enzymes to make sugar out of plant material and then using yeast to convert that sugar to ethanol” (Evan Ratliff, 2007). The second method is to reduce the cost of enzyme mixture by producing the new enzymes which can be much faster. The third potential method is to try to find the better enzymes. For example, Caltech microbiologist Jared Leadbetter and a group of Costa

Rican scientists, gathered termites from the rain forest floor and tried to find the organisms that naturally degrade and digest plant cell-wall material.

Case Study: Brazil

On October 16, 1973, due to Arab oil producing countries' opposition to Western support of Israel during the Yom Kippur War, the Organization of Petroleum Exporting Countries (OPEC) placed an embargo on shipments of crude oil to Western countries, with the United States as a main target. As a result of this embargo, oil prices rose dramatically, jumping from $3.11 to $3.65 per barrel overnight and up to almost $12.00 per barrel by 1974.

The oil crisis created in the United States and other Western countries is well documented, with lasting effects still felt today in the form of a national speed limit, the cabinet-level Department of Energy, Corporate Average Fuel Economy (CAFE) standards and the National Energy Act of 1978, among other things. In addition to significant legislation intended to conserve energy and reduce consumption of oil, interest was piqued in the field of alternative energy resources, such as solar power, wind power and nuclear power, which could be used as a substitute for power derived from oil.

Becoming the first country in the world to explore ethanol as an alternative to gasoline, the Brazilian government instituted the Programa Nacional do Álcool (National Alcohol Program), or Proálcool in 1975. The intent of Proálcool initially was to stimulate the production of ethyl alcohol (ethanol) as a way to decrease Brazil's dependence on foreign oil. The program intended to eventually phase out all automobile fuels derived from fossil fuels such as oil, and while gasoline is still used in Brazil today, it is estimated that 40% of all fuel consumed in Brazilian automobiles is ethanol.

Unlike in the United States today, where ethanol is derived from corn, Brazilian ethanol is resultant of sugarcane, as Brazil is the world's largest producer of sugarcane and sugarcane is the country's largest production of crop. Because most of the arable land in the United States resides in climates too far north of the equator to support sugarcane, it is unlikely sugarcane will ever replace corn as the source of ethanol production in the United States. High tariffs on imported sugar, as well as on ethanol itself, in an attempt to protect Midwestern farmers' corn interests, are liable to stunt the growth of sugarcane-based ethanol in the United States.

Ethanol produced from sugarcane has a large advantage over that produced from corn, not only in that sugarcane is cheaper to grow than corn, but because the starch in corn must first be converted to sugar before it can be fermented into ethanol, sugarcane also has the natural advantage of already being sugar, drastically lowering the production cost of sugarcane ethanol as well. As a result, it has become much more economically feasible for Brazil to replace its gasoline use with sugarcane ethanol than it currently appears to be for the United States to implement widespread use of corn ethanol.

One environmental concern that has surfaced in Brazil over sugarcane-based ethanol is the manner in which the cane fields are harvested. Just before harvest time, the cane fields are lit ablaze in order to kill pests, fertilize the soil and burn unwanted leaves, leaving just the stalks. Towns near sugarcane fields experienced a rash of respiratory ailments as a result of all the excess smoke and ash burned into the atmosphere. Laws have been enacted in Brazil banning the burning of sugarcane fields, but the practice still is used nonetheless. Concerns such as these appear minor, however, as they can be easily solved in the face of the dramatic reduction of pollutant emission as a result of burning ethanol instead of gasoline.

Currently, Brazil uses both a mixture of gasoline and ethanol, commonly referred to as gasohol, as well as high-ethanol content fuels such as E95 (95% ethanol content) and E100 (pure ethanol with up to a 4% water content). Different types of ethanol require different types to engines in order to run them. For instance, conventional engines are able to run both gasoline and gasohol, but for higher ethanol-content blends the compression ratio must be raised in order for the engine to run properly. So-called 'flex-fuel' engines can run anything from gasoline to E100 or any combination therein.

Brazil is scheduled to gain energy independence this year, meaning it will have the capacity to export as much oil as it imports. This is chiefly due to the proliferation of ethanol in the Brazilian market, replacing gasoline. Though gasoline is still used more widely than ethanol, it has been suggested that Brazil can be used as a model for other countries, primarily the United States, to become energy independent and no longer rely on foreign sources of oil for energy, which can fluctuate wildly in terms of price and supply.

Brazil's energy independence, however, would have some marked differences from possible American energy independence. Americans own a much greater number of automobiles than do Brazilians, as driving almost anywhere is much more prevalent in the United States. It is also much cheaper to produce sugarcane ethanol than corn ethanol, so Americans would either have to pay higher prices than Brazilians or have a smaller profit margin.

It has taken Brazil over thirty years to gain energy independence, in a much smaller market than exists in the United States. It will likely take a country as large as the United States a similar amount of time to proliferate ethanol into the market to the extent it has been in Brazil, due to market conditions as well as powerful American lobbies for oil, sugar and corn

Conclusion

Although it is clear in the United States that we cannot continue to live in the manner to which we have become accustomed with regards to fossil fuel consumption, it is as yet unclear what forms of alternative energy will be used predominantly in order to wean our dependence on foreign sources of oil. One of these alternatives is ethanol-based automobile fuel. However, given the tradeoffs with gasoline, mainly fuel efficiency and production cost versus output, it is unlikely that the United States will become independent of Middle Eastern oil as a result solely of corn ethanol. The future of alternative energy in the United States rather appears to be in cellulosic ethanol, so we must wait and see what that future holds.

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