Exemplary Team Prize: $5,000
Hunterdon Central Regional High School, Flemington, NJ

Coach: David Gelb
Team: Brandon Comella, Gawain Lau, Kelvin Mei, Nevin Raj, Yiwen Zhan

Ethanol:

The Future of America's Energy Independence?

TEAM #141

Summary

{AP NEWS FLASH}

9 Mar 2008

On Friday afternoon, crude oil futures reached another closing high of $105.50 per barrel. The national U.S. average price for a gallon of regular unleaded gasoline spiked to $3.20. OPEC, the world's leader producer of crude oil, has considered cutting production in response to lackluster seasonal demand.

Many economists have concluded that the U.S. has begun to enter a recession, blaming booming crude oil prices. This bleak picture of the vulnerability of the American economy has brought about a renewed push for energy independence. Ethanol, a corn and grain-based biofuel, has been tabbed as a viable energy alternate for the U.S. This fuel, indeed, possesses advantages and benefits. However, there are several obstacles that exist that prevent ethanol from being the cure for America's dependence on foreign sources of energy.

New research has shown that ethanol use in gasoline reduces carbon dioxide or CO_2 emissions, a greenhouse gas that has been attributed to global climate change. The study proposed that a gasoline mixture with 10% ethanol content will decrease CO_2 emissions by an average of over four percent.

Currently, because of this new technology, the cost of ethanol is not yet as cost-efficient as regular use of gasoline. However, future economic indicators along with further technological advancements will lead to greater efficiency of ethanol use. In addition, with due time, the amount of ethanol needed to supplant its energy difference with gasoline will decrease.

But obstacles exist, as ethanol is still derived from grains, corn, and wheat that are vital sources of food for national economies, especially the markets of developing nations. With greater demand for ethanol, demand for corn and grain will increase. Such demand does not arise from the agricultural and subsistent needs of the people but from private companies seeking to make profits.

However, the central issue of national energy independence cannot be fully addressed by ethanol, as it does not completely sever U.S. ties to foreign oil. For true energy independence, such renewable resources continue to be researched and tested for viability in a demanding American society. Hydropower, geothermal, solar, wind, and biomass are various sources of renewable sources that are all environmentally friendly while allowing full independence from foreign sources of energy.

Overview

Gasoline prices have skyrocketed over the past ten years from $1.10 per gallon to $3.40 per gallon, stimulating immense public concern. Amidst a period of political and economic changes, cultural revolution has been eminent due to the lack of viable alternate energy sources. The root of the problem has been identified as an increased demand of gasoline matched with a decreased supply.

However, the dilemma that the U.S. currently faces is being addressed through scientific speculation. Chemical engineers are starting to ponder the implementation of biofuels, such as ethanol, as possible energy alternatives. Plants primarily produce glucose via photosynthesis, but then they undergo fermentation to yield ethanol. The ethanol produced by plants can be distilled and sequestered to be utilized as fuel. Scientists have been interested in ethanol because they have identified it as an environmentally friendly, renewable energy source that has the ability to make the U.S. independent of foreign oil imports.

The following analysis seeks to produce a model to accurately characterize the quantifiable potential of corn-derived ethanol. The analysis will address an eclectic variety of aspects that are imperative in gauging the practical success of ethanol as a fuel source. The model will determine the amount of ethanol required to replace a certain percentage of U.S. gasoline, the effect of the substitution on carbon dioxide emissions, the cost efficiency of ethanol, the effect of the policy on grain prices in developing nations, and the comparison of ethanol to other alternate energy sources.

Assumptions

1. U.S. consumption of gasoline will continue to increase despite increasing gas prices. Americans have expressed a strong tendency to reform their spending habits to accommodate higher gas prices, as gasoline is viewed as a necessity for work and the supporting of their livelihood.

2. The U.S. economy will continue to achieve steady growth over the next five years. Amid worries of a recession, many economic indicators are still positive from the farming, services, and oil industries.

3. Unpredictable variables, such as technological advances, should been excluded, as it is unreliable and difficult to model these advances.

Part I: U.S. Consumption of Gasoline

It is key to understand that any sign of a recession must be addressed as an isolated factor and not one indicative of America's future gas consumption landscape. Charting the effects of a recession is not pertinent to the problem at hand: the feasibility of alternative fuel sources and America's need for energy independence. As a result, it is necessary to look at the general pattern of increase over the past several years to evaluate these issues.

Looking at the U.S. consumption of gasoline, it is important to recognize that a consistent rate of growth exists from year to year. The statistics on consumption from the Energy Information Administration illustrate an exponential, though seemingly linear, growth. Further analysis supports this observation. Consistent growth in the American economy helps consumers bear the burden of increasing gas prices and expands the market of gas consumption. Over the long term, gas consumption, coupled with economic growth, increases exponentially. Over the short term, it appears linear, but the exponential nature must be taken into account. As a result, consumption should be modeled upon the function for compound interest over a set period of time:

$$A(t) = A_0\left(1+\frac{r}{n}\right)^{n \cdot t}$$

where t = total time (in years), r = annual rate of change, and n = number of compounding periods per year. In this situation, $n = 1$, as the data was collected annually.

C = Consumption (liters)

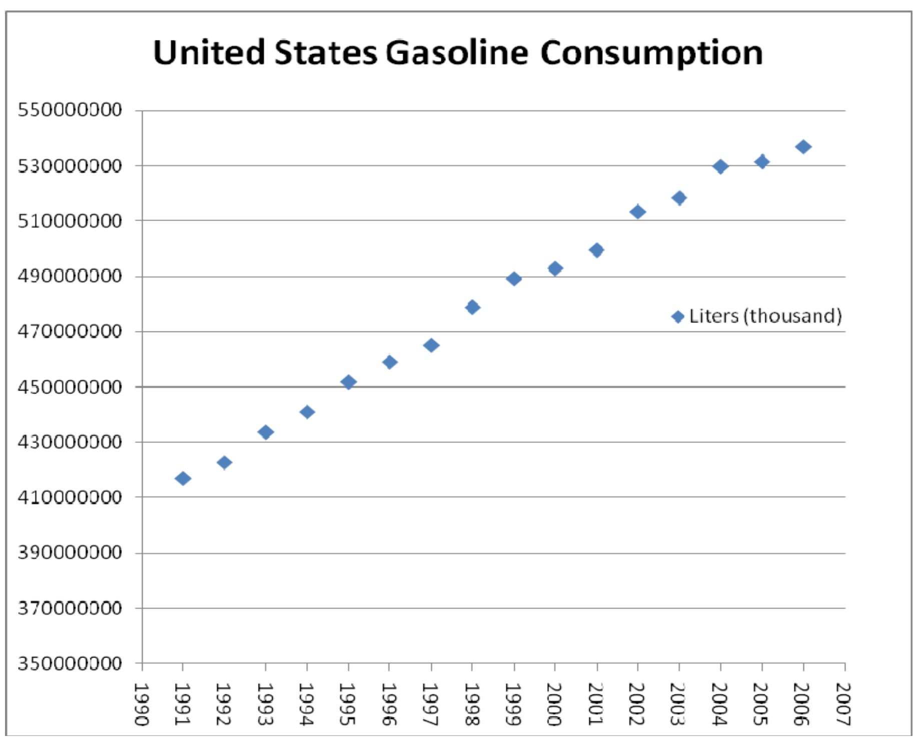
$C_0 = 4.170488927 \times 10^8$ liters (at t = 0) T = Years ***after*** 1991

1 gallon = 3.785 liters

$C(t) = C_0(1+r)^t$

At t = 1,
C = 4.228463696×10^8 liters.
So r = 0.014:

$C(t) = 4.228463696 \times 10^8 (1.014)^t$



YEAR	1991	1992	1993	1994	1995	1996	1997	1998
Liters (thousands)	4.1705×10^8	4.2285×10^8	4.3381×10^8	4.4106×10^8	4.5193×10^8	4.5910×10^8	4.6517×10^8	4.7890×10^8
YEAR	1999	2000	2001	2002	2003	2004	2005	2006
Liters (thousands)	4.8919×10^8	4.9293×10^8	4.9959×10^8	5.1339×10^8	5.1844×10^8	5.2978×10^8	5.3146×10^8	5.3687×10^8

3.785 liters → 124,000 BTU

Thus, it follows that one liter of gasoline yields 32,761 BTU. The quantity of energy, measured in British thermal units (BTU), used in gas consumption as a function of E, is

$E(t) = (32{,}761)[C(t)]$

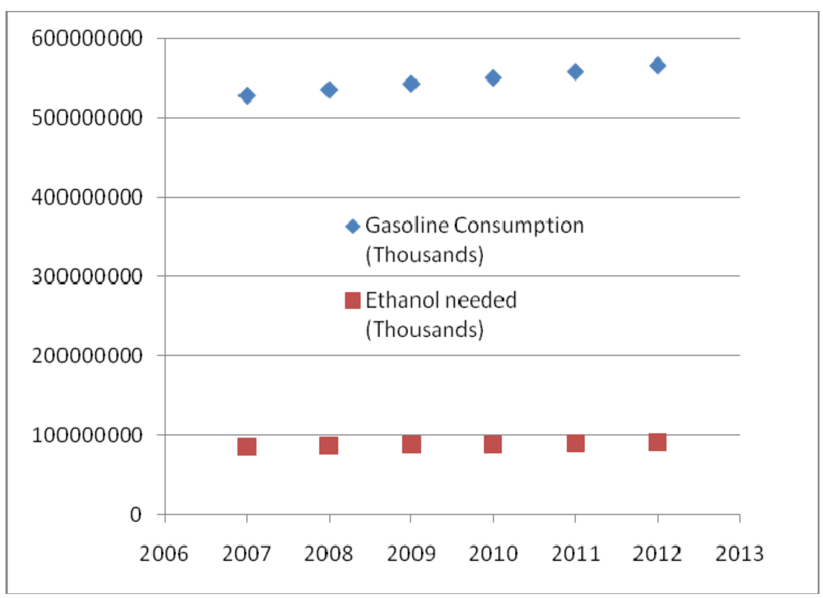
Thus, it follows that the combustion of ethanol must create (3276.1)[C(t)] BTU, as it needs to replace 10% of U.S. usage.

1 gallon of ethanol = 3.785 liters of ethanol → 77,000 BTU

As a result, 1 liter of ethanol → 20,343 BTU.

As a result, the U. S. needs (3276.1)[C(t)]/20343 or **.161*C(t)** thousands liters of ethanol or to make up 10% of American gas consumption.

For example, for the year 2007, when the consumption of gasoline totaled nearly 5.3 x 10^8 thousand liters, the amount of ethanol that was needed to replace 10% of the U.S. gas consumption was .161 $(4.22846 \times 10^8)(1.014)^{16} = 7.4 \times 10^7$ thousand liters.

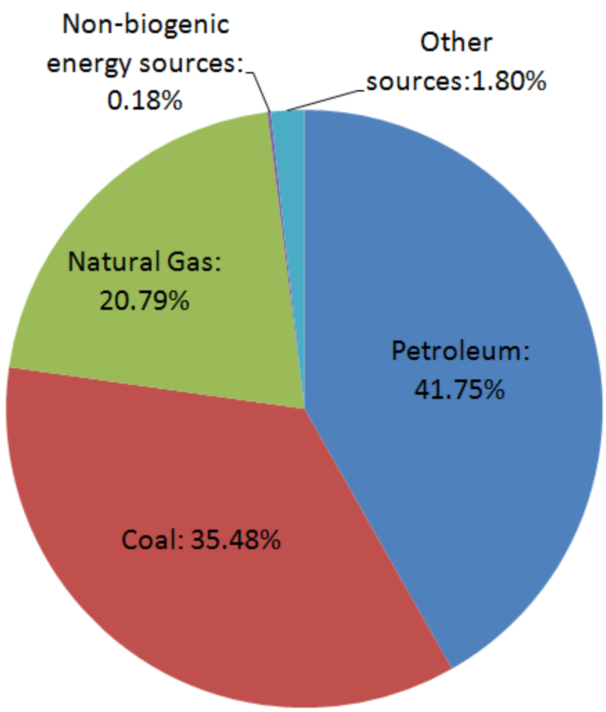


	2007	2008	2009	2010	2011	2012
Gasoline Consumption (thousands of liters)	5.2819×10^8	5.3558×10^8	5.4308×10^8	5.5069×10^8	5.5840×10^8	5.6621×10^8
Ethanol needed (thousands of liters)	8.5039×10^7	8.6230×10^7	8.7436×10^7	8.8660×10^7	8.9902×10^7	9.1160×10^7

Part II: Effect of Ethanol Fuel Production on CO_2 Emissions

Current CO_2 Emissions

Carbon dioxide emissions have been steadily increasing over the past century, which is harmful for both the environment and human society. Carbon dioxide emissions come from various sources, most of which come from energy related sources. Using a table that contained detailed carbon emissions data from 1991-2005, a pie chart was generated to display the main sources of CO_2 emissions.



Sources of CO_2 Emissions

The graph above shows that petroleum, coal, and natural gas account for approximately 99% of carbon dioxide emissions in the U.S. An analysis of the previously mentioned data table revealed that emissions steadily increased by a constant percent over the past two decades. In order to develop trendlines of CO_2 emissions, the following equation, which applies to data that increases annually at an exponential rate, was used:

$$A(t) = A_0 \left(1 + \frac{r}{n}\right)^{n \cdot t}$$

where t = total time (in years), r = annual rate of change, and n = number of compounding periods per year. In this situation, $n = 1$, as the data was collected annually. The rate of change per year was calculated for the following emissions: coal, oil, and natural gas, and it was found to be relatively constant over the years. Thus, the rates were averaged, and r was set as the annual rate of change. The three equations were derived for the three energy sources, as listed below:

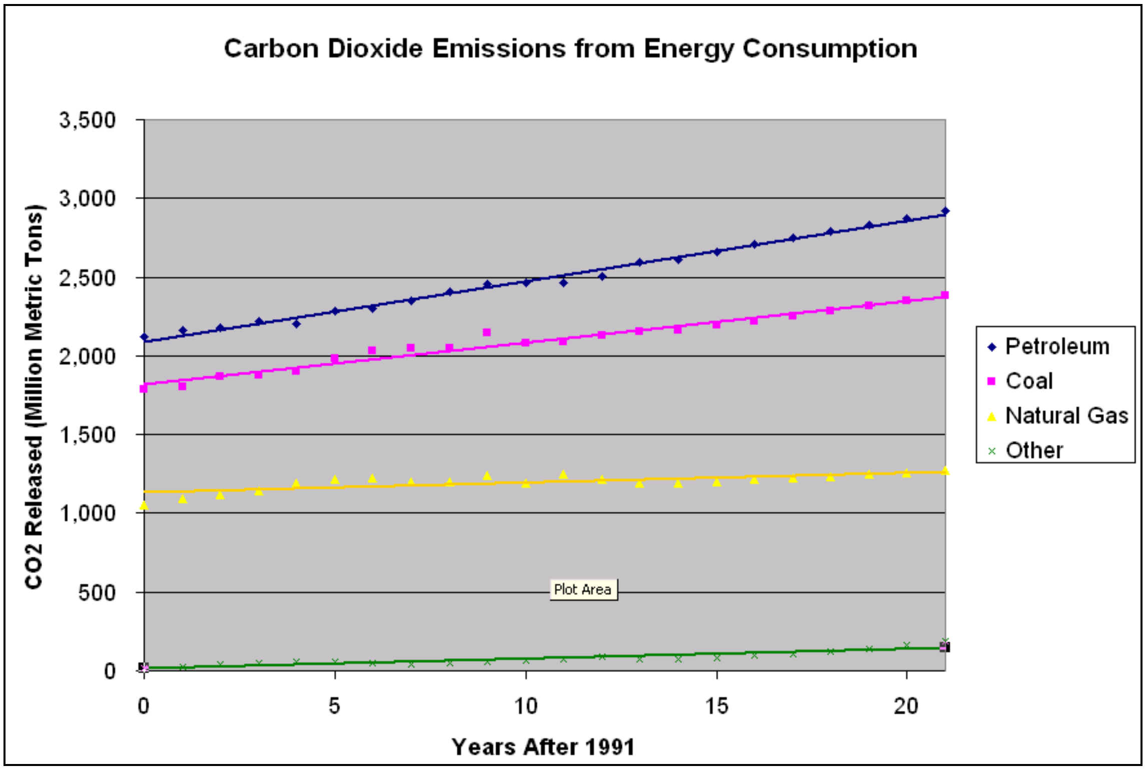
Coal: $A(t) = 1783.7(1.0138)^t, r = 1.38\%$

Natural Gas: $A(t) = 1054.3(1.0088)^t, r = 0.88\%$

Petroleum: $A(t) = 2118.8(1.0151)^t, r = 1.51\%$

Other Fuel Sources: $A(t) = 2118.8(1.1365)^t, r = 13.65\%$

Using these equations, predictions of CO_2 emissions for the next 5 years were calculated. The results are graphed:



The equations and graph above reveal that petroleum emits carbon dioxide at a steadily increasing rate and releases the most CO_2 emissions overall.

Total CO_2 Emissions (over the last 21 years, measured in metric tons)				
1991: 4,969.4	**1992:** 5,078.7	**1993:** 5,203.0	**1994:** 5,288.3	**1995:** 5,343.4
1996: 5,531.0	**1997:** 5,606.7	**1998:** 5,632.5	**1999:** 5,703.1	**2000:** 5,890.5
2001: 5,806.3	**2002:** 5,875.9	**2003:** 5,940.4	**2004:** 6,019.9	**2005:** 6,045.0
2006: 6144.7	**2007:** 6238.3	**2008:** 6334.6	**2009:** 6433.9	**2010:** 6536.5
2011: 6642.5	**2012:** 6752.5			

Analysis of the data above reveals that **currently, CO_2 emissions are increasing at a rate of 1.01416% annually**.

Because it is assumed that CO_2 emissions are directly proportional to the amount of petroleum consumed, a decrease in gasoline usage can decrease carbon emissions. If 10% of U.S. gasoline usage were replaced with ethanol, carbon dioxide emissions are expected to decrease. If gasoline usage is decreased by 10%, the carbon dioxide emitted from gasoline would decrease proportionally. However, we need to take into consideration the carbon dioxide emitted from the production of ethanol fuel.

CO_2 Emissions for Ethanol

In the process of producing ethanol, fossil fuels are used to create ethanol. The factors that must be considered while modeling the carbon dioxide emissions from the production of ethanol include the carbon dioxide production from (1) fermentation, (2) combustion, (3) industrial processes.

(1) $6CO_2 + 6H_2O + \text{Solar radiation} \rightarrow C_6H_{12}O_6 + 6O_2 + \text{Heat}$

(2) $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2 + \text{Heat}$

(3) $2C_2H_5OH + 6O_2 \rightarrow 4CO_2 + 6H_2O + \text{Heat}$

As derived from the above chemical equations, the biomolecular production and consumption of ethanol yields a net three moles of carbon dioxide per mole of ethanol. One dry ton of corn produces approximately 67 gallons of ethanol. Since there are 6.59lbs of ethanol per gallon, one dry ton of corn yields 441.53lbs of ethanol. This is equivalent to 200274.6391 grams, since 1 pound is equal to 453.59237 grams. Therefore, one dry ton of corn produces 200274.6391g / (46.06844 g/mol) = 4347.33 mol of ethanol. This produces 4347.33 * 3 = 13041.99 moles of carbon dioxide.

However, the carbon dioxide produced from corn itself can be assumed to be zero, because naturally emitted carbon dioxide is reabsorbed into plants through the carbon cycle. If it is assumed that the corn production rates each year are constant or increasing, the CO_2 emitted from the corn is directly taken back into the environment, resulting in no net gain of emissions.

However, ethanol production requires the use of fossil fuels, so the emissions from fossil fuel consumption need to be included in the total CO_2 emissions for ethanol. In the process of ethanol production, fossil fuels are used in the farming of corn, the ethanol production plant, and the BOD treatment. The farming of corn requires machinery, herbicides, release of nitrogen, and other factors that release carbon dioxide. The industrial processes of ethanol production include grinding, cooking, fermenting, sieving, and storage. Transportation is also an integral part of the distribution of ethanol to consumer markets. These functions require fossil fuels for energy, and fossil fuels release an abundant supply of carbon dioxide as well.

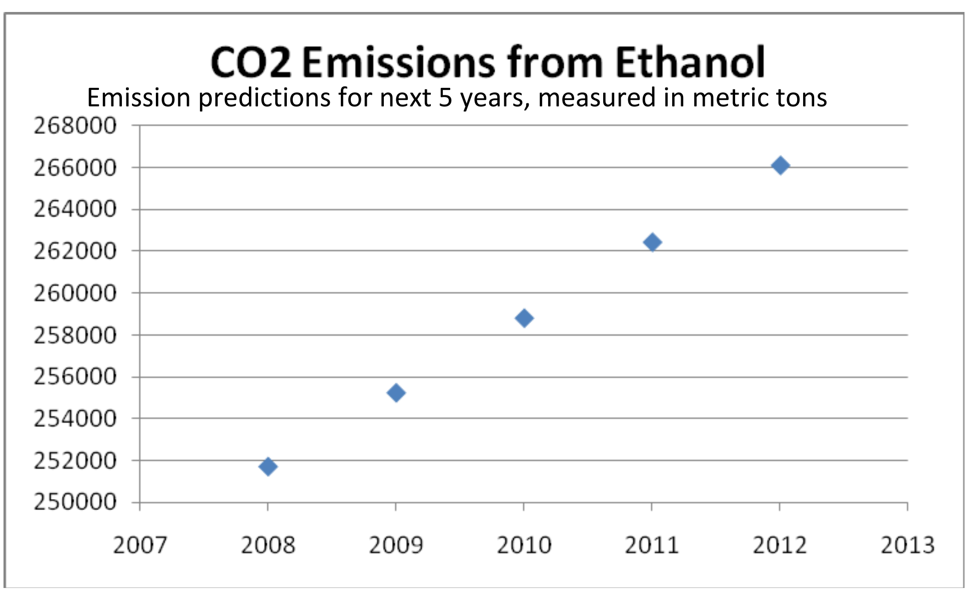
1 hectare of industrial corn-for-ethanol generates 8955 kg of equivalent CO2 from the fossil fuel inputs and humus oxidation (the natural release of CO_2 is not included in this calculation). After conversions, it appears that 1 ha of corn produces 214.14 liters of ethanol. From this, it can be concluded that 1 liter of ethanol generates 41.818 kg of equivalent CO2.

1 ha * 2.4711 acres / ha * 328 gallons ethanol / acre * 3.785 L / gallon = 3067.82 L

1 ha = 3067.82 L ethanol = 8955 kg CO2 generated, therefore:

1 L generates 2.919 kg CO_2

By using the ethanol production curve produced in Part I, CO_2 emissions of ethanol can be determined, as shown in the graph below:



If 10% of the annual U.S. gasoline usage is replaced with ethanol, the emissions from petroleum should be decreased by 10%, while the CO_2 emissions from ethanol should be added to the previous estimations. The changes in CO_2 emissions are listed:

Changes in CO2 Emissions due to increase in Ethanol Fuel Use (in million metric tons)					
Previously Estimated Total	6334.625	6433.933	6536.471	6642.536	6752.463
Petroleum Subtraction	274.6273	278.8498	283.1373	287.4907	291.911
Ethanol Addition	0.2517	0.2552	0.2588	0.2624	0.2661
New Estimated Total	6060.249	6155.338	6253.592	6355.307	6460.818
Decrease in Emissions (%)	4.33%	4.33%	4.33%	4.32%	4.33%

The data reveals that **if 10% of U.S. gasoline usage is replaced with ethanol, CO_2 emissions will decrease by an average of 4.33%.**

Part 3: Cost Efficiency

To determine cost-efficiency, the equation is

$$(O-I)/C$$

This equation takes into account three variables: (O) the output, which is the amount of energy released by the fuel per unit of measure; (I) the input, which is the amount of energy required to create the fuel per unit of measure from its basic resources; and (C) the cost, which is the production cost of the fuel per unit of measure.

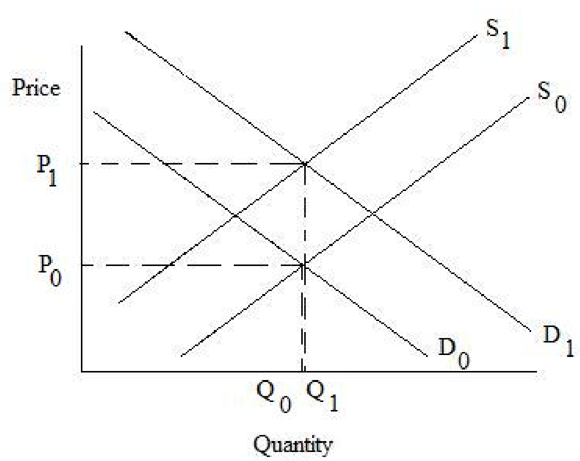
In the analysis, unpredictable variables, such as technological advances, have been excluded. While the input and output energies do largely depend on technology, the chances for a technological breakthrough in ethanol or gasoline production within the near future is limited at best. There has been a drop in ethanol prices due to technological advances in the early 2000s, but there is no reason to believe that this trend will continue due to lack of new technological innovation.

According to a statistical study done by the Department of Agriculture, the output energy value of ethanol, which is the combination of the net energy value and the total energy used, is 20164.25 BTU/L. The input value, which consists solely of the total energy used, is approximately 12099.61 BTU/L. This gives a net gain of energy of 8064.64 BTU/L. Furthermore the price of ethanol as of January 2007 is $.66 per liter. Therefore, the cost-efficiency value is 8064.64/.66 or 12219.15 BTU per dollar.

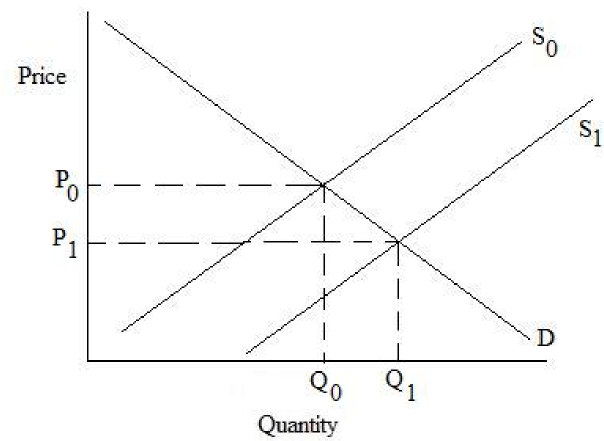
For comparison, the cost-efficiency of gasoline has been calculated. The output energy is 33050.4 BTU/L, while the input energy is approximately 8006.96 BTU/L, considering the percent efficiency of gasoline. The average price of gasoline according to a recent 2005 study is $.494 per liter. Therefore, the net gain of energy is 25043.44 BTU/L, and the cost efficiency of gasoline is 50695.22 BTU per dollar.

As can be seen from the above two values, the cost efficiency of gasoline is greater than the cost efficiency of ethanol. Therefore, ethanol is less cost-efficient than gasoline and not a very valuable source of fuel if the value is based strictly on cost efficiency.

Gasoline Supply and Demand Curves



Ethanol Supply and Demand Curves



Although the preceding analysis concludes that gasoline has a greater cost efficiency than ethanol, the supply and demand curves predict a shift in this equilibrium. The increasing demand for gasoline as a fuel source will cause demand to increase, thus shifting the demand curve from D0 to D1. In conjunction with the increase in demand, the depletion of crude oil reserves will cause the supply to decrease, shifting the supply curve to from S0 to S1. The shift in the supply and demand curves then cause the equilibrium price of gasoline to increase from P0 to P1.

In contrast, the demand for corn is currently constant. Therefore, the demand curve remains unaltered at DO. Technological advances and an increase in corn fermentation act as determinants to shift the supply curve from S0 to S1. The new equilibrium price of ethanol consequently decreases from P0 to P1.

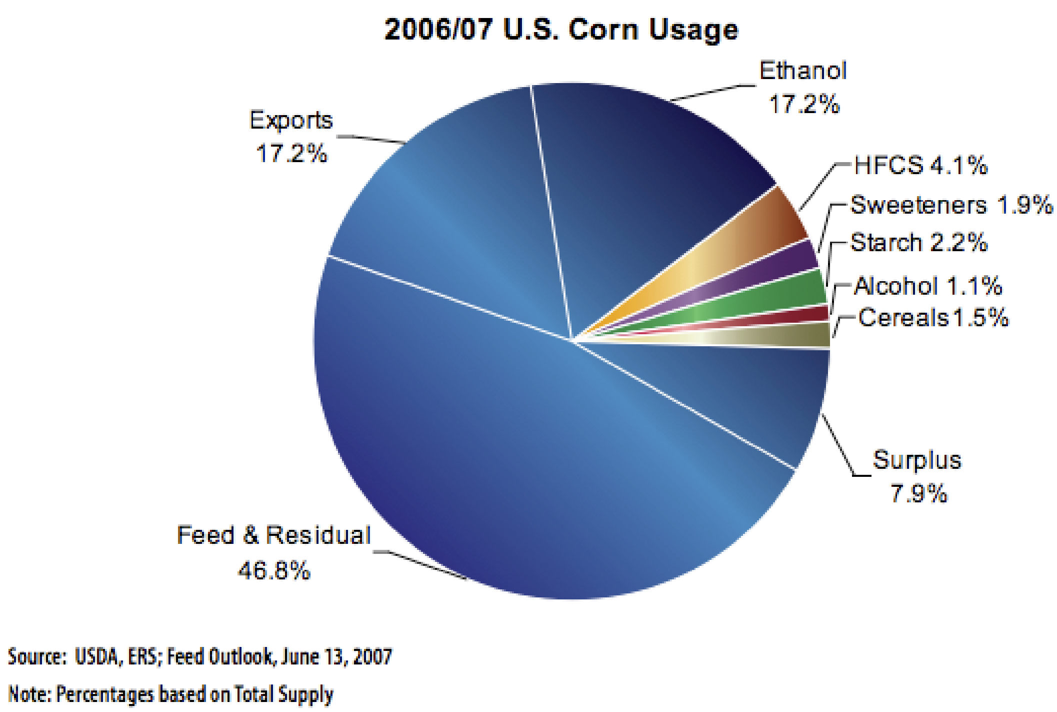
Economic circumstances are signaling an increase in the cost of gasoline and decrease in the cost of ethanol. These will change the cost efficiencies of both fuels in the near future. Because the aforesaid formula for cost efficiency is (output - input)/cost, the cost efficiency of gasoline will decrease and the cost efficiency of ethanol will increase. Although technological advances have the potential to increase the mechanical energy yields from ethanol and gasoline, the trend in prices will cause a relative distinction in cost efficiencies. It is therefore important to acknowledge that the conclusion reached by the analysis holds true only for the current market and may change in the near future.

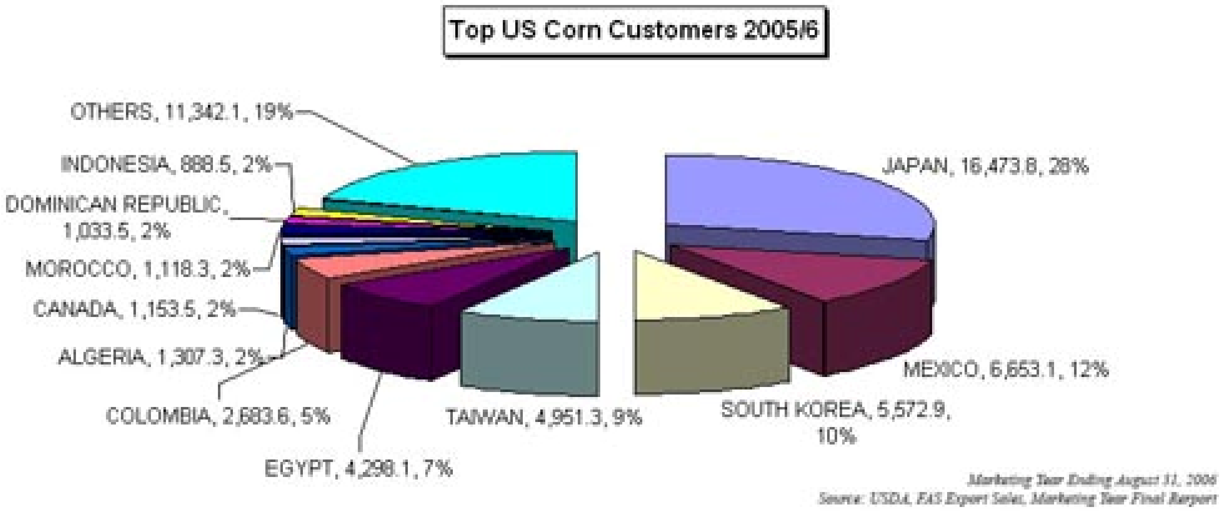
Part IV: Impact of Ethanol on Grain Prices and Developing Nations

To maintain this policy, a greater percentage of the corn will have to be converted into ethanol. The U.S. uses about 146 billion gallons of ethanol a year, 14.6 billion of which will need to be made up of ethanol. Since a bushel of ethanol yields about 2.8 gallons of ethanol, we find that you will need 5.21 x 10^9 bushels of ethanol. This represents 39% of the 13.3 billion bushel annual harvest. Subtracting the 17% of the crop that is currently used for ethanol and the 8% surplus we are left with 14% of our corn we need to convert to ethanol. This can be easily shifted from the 60% that is used for feed domestically and abroad, especially since ethanol can be extracted from corn and still leave it suitable to use for feed.

With demand for ethanol exceeding the available supply, prices will increase. If the price of corn were to increase to $4 a bushel, it would only result in a 6 cent increase in the price of a bottle of soda. At the same price, a box of corn flakes would only contain 5 cents worth of corn. The price of a bushel of corn increased 54% from April 2006 to April 2007, while the consumer price of food has only increased 3%. Corn makes up a greater percentage of the cost of meat and dairy products, but it is still a relatively small amount, and an increase from $3 to $4 per bushel of corn would result in a 6.5 cent increase in the cost of a pound of pork. The same $1 increase in the price of a bushel of corn increases food prices just 0.3%, while an equal energy price increase would impact consumer prices 2 or 3 times more. The cost of food inputs, such as grain, makes up 19% of the retail cost of food, while transportation and energy costs make up 24% of the retail cost. Considering that virtually all food products are affected by transportation costs, while only a fraction of the food market is made up of corn-based products, food prices will be affected far more by petroleum costs than corn prices. Federal subsidiaries for corn farmers in 2007 will drop by 76%, saving $6.7 billion in government funds. To cope with the increased demand, farmers are planting record breaking amounts of corn as well as developing ways to increase the average yield.

Because ethanol is mainly produced from corn that is consumed by livestock, and not humans, increased ethanol production in the U.S. has very little effect upon the food markets of developing countries. Over 32% of dry mill ethanol is used to make high-protein feed for livestock. Ethanol biorefineries produced 12 million metric tons of distillers grains, 1.25 million metric tons of which went to foreign markets. Increased U.S. ethanol production would benefit developing nations by providing them with highly valued feed for livestock and poultry. Every year since 2004-2007 has yielded record crops. As a consequence of rising demand, greater numbers of crops are planted, which will result in an expected 700 million bushel surplus. The efficiency of crop yield has been rising by 3.5 bushels/acre each year since 1995. We know that to maintain this policy, we need an additional 14%. Because about 80% of exported corn is used for feed, and because ethanol can be extracted from the corn while leaving the feed portion untouched, we can use about 13.75% of our exports for ethanol. The remaining 0.25% of the corn needed can be taken from the 46.8% used for domestic feed, or the U.S. can reduce exports to developed nations, who make up approximately half of the importers. This will leave the developing nations secure and not threaten their food and feed grain supply. Therefore, to maintain this policy will be feasible, and future increases in yield per acre in addition to greater acreage of crops planted will allow domestic as well as foreign corn demand to be met without any compromising having to be made in other sectors of the corn market.





Part X: Alternative Paths to National Energy Independence

Gasoline Independence

In order to develop energy independence, the U.S. must relinquish dependence on energy sources imported from other nations. Due to the increasing automobile activity in the country, the U.S. is heavily dependent on gasoline today. If the U.S. is to achieve energy independence, it must first focus on growing independent from gasoline imports.

In order to lessen dependency on foreign gasoline, the U.S. must take two initiatives: first, dig into petroleum sources within the nation, and second, focus on the transition to automobiles with engines that run off alternative fuels.

Currently, OPEC (Organization of Petroleum Exporting Countries) controls a majority of the world's oil supply. Rather than depending on OPEC imports, the U.S. should dig into its own supply of oil. Currently, the country's most abundant oil reserve lies in Alaska; there are also suspected reservoirs in the Gulf of Mexico. The retrieval of oil from these reserves, if done carefully, will do minimal damage to the environment, while providing oil independence for the country.

However, petroleum resources are limited, so the U.S. will need to switch to an alternative fuel source in the future. Although ethanol is a renewable resource, the use of ethanol to power engines depends on the availability of gasoline (as the two must be mixed) – therefore, ethanol production is not an efficient solution for energy independence.

The U.S. should also focus on building engines that are either hybrid or run off another fuel completely. Hybrid cars have two engines – one that is electrically charged and one that runs off gas; these cars heavily decrease gasoline usage, as the cars are often running from the electrically charged battery.

In addition to petroleum, natural gas and coal are the other fuel sources the U.S. is dependent upon. Currently, the U.S. imports coal from China, Japan, and Canada, while it imports natural gas from Canada, Denmark, and the Netherlands. In order to eliminate dependence on these fuels, the U.S. must look into its own country for fuel resources. Currently, coal and nuclear plants fuel a lot of the country, but it is important to note that both sources are nonrenewable – both sources will eventually run out, leaving the U.S. dependent on energy once more. In order to avoid this pitfall, the U.S. should focus on developing renewable energy resources, because they will always be available.

Analysis of Renewable Energy Sources

The top five renewable energy sources are geothermal, biomass, photovoltaic, hydropower, and wind power. All five resources are relatively abundant in the U.S., and all can provide energy with little environmental damage. Because these energy sources are dependent upon time and location, there is always a chance that one source will be unavailable. Therefore, it is essential that the U.S. implement all five sources, in order to ensure that energy will always be abundant within the nation. A quantitative analysis, based on three factors, is provided below, in order to provide a guideline for which resources should be emphasized more.

Quantitative Comparison of Renewable Energy Sources

(Data pertains to facilities that produce 1 billion kWh of electricity per year)

	Land (hectares)	Energy (Input/Output Ratio)	Cost per kWh ($)
Hydropower	75000	1:24	0.02
Biomass	200000	1:7	0.058
Wind	13700	1:5	0.07
Photovoltaic Cells	2800	1:7	0.16
Geothermal	30	1:48	0.064

Using these values, a quantitative analysis was completed. For each of the three factors, the five sources were each given a score from 1 to 10, with 10 being the best score and 1 being the worst. For the three factors, the following equations were used to determine the scores:

Land Use: $(1 - h/200000) * 10$; h = hectares of land

Energy: $(o/50) \times 10$; o = units of output (per 1 unit input)

Cost: $(1 - c/0.2) * 10$; c = cost per kWh

The availability of these resources was also assessed, in addition to the factors listed above. Because quantitative data regarding resource availability could not be determined, a subjective score was given. The five sources were given a rank from 1 to 5, with 1 being the least abundant and 5 being the least abundant, and this score was multiplied by 2.

Below is a table of the resulting scores:

Analytical Scores for Energy Sources

	Land Use	Efficiency	Cost	Availability	Total Score
Hydropower	6.25	4.8	9	8	28.05
Biomass	0	1.4	7.1	6	14.5
Wind	9.315	1	6.5	4	20.815
Photovoltaic Cells	9.86	1.4	2	10	23.26
Geothermal	9.9985	9.6	6.8	2	28.3985

The individual scores are then added to determine the total assessment score. The total scores reveal that geothermal energy and hydropower, which have the highest score (approximately 28), are the most efficient resources to use in the U.S. Solar energy and wind power, with scores of 23 and 20, respectively, should also be looked into as potential sources of energy. Biomass, however, is proven to be inefficient compared to the rest, so less emphasis should be placed on that resource.

Testing the Model

The model can be tested by observing future trends and applying future data to the system. This will determine whether the model is accurate amidst the array of lurking variables, such as technological advances, cultural changes, and economic shifts. Other aspects of the model, including the mechanical energy gained from ethanol and comparative carbon dioxide emissions, can be tested through proportional small scale laboratory systems.

Conclusion

From the data collected, it can be concluded that ethanol is an inefficient source of energy. It does not help the U.S. achieve energy independence, as the use of ethanol fuel in automobile engines is dependent on the availability of gasoline. Also, the cost efficiency of gasoline is substantially higher, so it is not economically beneficial to produce ethanol as an alternate fuel source. Lastly, developing countries with a high dependence on wheat will have a negative impact on their food availability.

While the use of ethanol can reduce CO_2 emissions, this benefit is not substantial enough to warrant the use of ethanol as the U.S.'s alternative fuel source. Other renewable resources, such as hydropower, geothermal energy, wind power, photovoltaic cells, and biomass all generate little to no CO_2 as well – these resources also do not carry the negative impacts that ethanol production does. As a result, these renewable resources are better ways for the U.S. to attain national energy independence.

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