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Ethanol & Flex-Fuel Vehicles

1. Introduction

The 21st Century has been referred to as the "Century of the Environment" by some scholars and thinkers. This term certainly seems relevant given the current state of the planet and the growing population of ever consuming humans. Eco-systems are deteriorating, fresh water is becoming scarce and pollution from the burning of fossil fuels continues to infiltrate the environment as it has since the start of the industrial revolution. The threat of dwindling supplies and growing demands for a finite amount of oil adds to the list of problems and has inspired a search for alternative options for our energy needs. The high demand for oil and the resultant pollution from the transportation sector makes it a popular target for alternative solutions to these problems. Options like hydrogen fuel cells, electric vehicles and shifts toward more public transportation uses offer hope but remain a difficult transition due to current infrastructure limitations. However, ethanol derived from grains and/or cellulose offers an option that can potentially replace a significant percentage of our oil use. This could be achieved over a relatively short timeframe all while maintaining the majority of the current infrastructure.

Nations like Brazil have taken the initiative and have produced there own ethanol through farming sugarcane. This has drastically reducing their oil demand. Automakers have contributed to the effort by creating, not only vehicles that can run on ethanol, but vehicles that can run on any mixture of gasoline and ethanol. These vehicles are called Flex-Fuel vehicles and they are becoming the dominant preference in the Brazilian automobile market due to the less expensive ethanol fuel at the pump and the choice of fuel they offer during times of fluctuating fuel prices. The United States has an opportunity to follow suit by producing domestic ethanol via corn, lessoning the demand on foreign oil and reducing air emissions. This paper discusses the current problems with oil, the option of ethanol as a fuel in Brazil/US, the environmental implications of ethanol and the implications of a US transition toward this technology.

2. The Problem with Oil

Oil in America has been viewed as a symbol of wealth and abundance since its first discovery. Finding oil on your property has been like winning the lottery. But this romantic view of this limited resource is coming to an end. The reality is that oil is a finite resource and that global supplies may be approaching their limits. The United States alone accounts for approximately one quarter of global demand for oil while only comprising less than one twentieth of the world population. But the US faces increasing competition for oil by developing nations like China and India whose populations dwarf that of the US. Because of this, global demand is expected to increase as much as 47% by 2020. In addition, most experts agree that the prospect of reaching "Peak Oil" is highly likely before the end of this decade (2010) (Figure 1). With known reserves being drawn

down at four times the rate of new discoveries, the result could mean skyrocketing oil prices unless more oil reserves are found or other alternatives to oil are utilized.

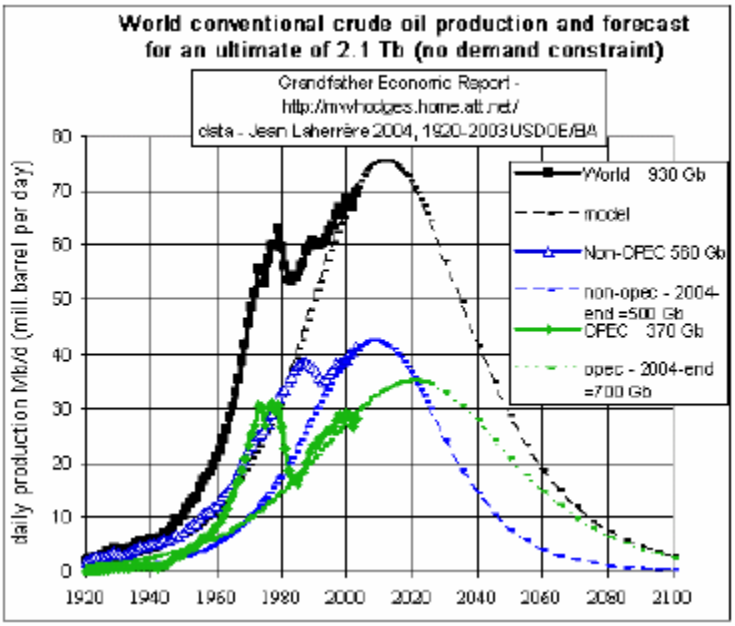

Figure 1

Transportation is the largest percentage of total world oil demand (68%) and it is growing according to the Energy Information Administration (EIA) (Figure 2). Also, the US depends on imports for 53% of its supply which will increase to 70% by 2025 according to the US Department of Energy (DOE). With increasing demand and competition for global oil supplies, it makes since that the US should focus its efforts on reducing the use of foreign oil through changing its transportation habits or at least changing the type of fuel used by that sector. Ethanol, derived from domestic corn, may be an alternative fuel source for passenger vehicles that can help alleviate the problems with foreign oil supplies.

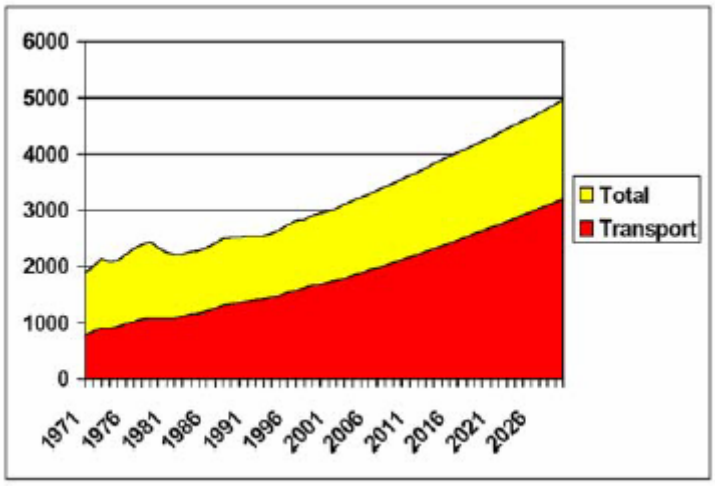

Figure 2: Transport and Total World Oil Demand (1971-2030)

3. Ethanol & Flex-Fuel Vehicles

Ethanol is alcohol that is derived from crops such as corn, soy and sugarcane. It is a technologically capable alternative fuel for use in internal combustion engines. In fact, corn-based ethanol was used in internal combustion engines in the US as early as 1826. Henry Ford's Model-T in 1903 was capable of running on any combination of gasoline or ethanol, since the standard fuel of choice for automobiles had not yet been established. Once oil was discovered to be in relative abundance, it seemed to be the less risky investment. So, it became the fuel of choice in the US and around the world as other nations adopted the technologies. However, ethanol can and is used in today's oil-based internal combustion engines. Ethanol is already blended with gasoline up to an average of 7% in approximately one third of all US fuel stations. This is done for the purpose of achieving clean air standards and for reducing the price of a gallon of fuel since ethanol is less expensive than oil. Actually, all passenger vehicles in the US are capable of utilizing a blend of up to 10% ethanol in their engines.

In the 1980's, Ford Motor Company created the first modern internal combustion engine utilizing Flex-Fuel technology which, like the Model-T, was capable of running on any mixture of gasoline and ethanol (Appendix 1). But, with a lack of ethanol refineries and government funding for the production and transportation of ethanol, the market for Flex-Fuel vehicles in the US has been limited to isolated areas in the Midwest near the source of ethanol production. But other nations, like Brazil, have chosen to invest in the infrastructure and have worked toward a transition to higher ethanol blends in their engines.

3.1 Brazil History as a Case Study

During the oil crisis in the early to mid 1970's, the Brazilian government decided to reduce their dependence on foreign oil. They felt that the best way to achieve this goal would be to change the type of fuel that they used in their automobile engines. So the

government created a program to produce more sugarcane ethanol for fuel use. By 1979, they had produced an engine capable of a 20-25% blend of ethanol with gasoline. By the early 1980's, an engine capable of 100% ethanol was devised (Appendix 2). A combination of favorable government subsidies and relatively high oil prices drove the vehicle market in Brazil to a point, in 1984, when 94% of all vehicles sold were those capable of using 100% ethanol. Then, in 1986, oil prices dropped. This was followed by an ethanol shortage in 1989, causing the market for ethanol vehicles in Brazil to almost completely disappear during the 1990's. In 1999, however, oil prices tripled in Brazil so ethanol became approximately 20-25% less expensive than gasoline. Then, in 2003, Flex-Fuel vehicles were introduced into the Brazilian automobile market and then 27% of the vehicles sold in June 2004 were made with this technology. General Motors expects that 60% of the vehicles sold in Brazil in 2007 will be Flex-Fuel vehicles (Figure 3). Consumers in Brazil prefer Flex-Fuel vehicles because it allows them to choose the type of fuel that they use. This can potentially protect them during fuel price fluctuations in the market.

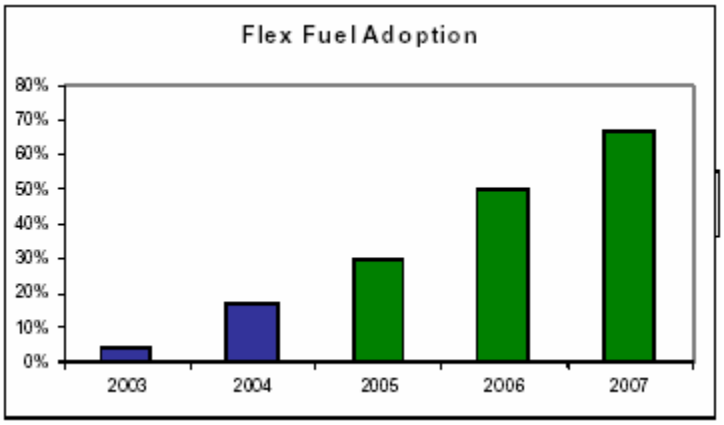

Figure 3: Brazil

4. Is Ethanol More Sustainable Than Oil?

In terms of environmental benefit, higher percentages of ethanol blend lead to lower emissions of air pollutants and greenhouse gases. As air pollution regulations have increased over the last few decades in the US, oil companies have been forced to add oxygenates to the gasoline to help the fuel burn more completely, thereby reducing air emissions. MBTE and ethanol are the only two real viable options for oxygenates. Originally, MBTE was the oxygenate chosen most by the oil companies. But when environmental advocates began revealing the impacts of MBTE in rivers and streambeds, it lead to more regulation and it forced the oil companies to switch to ethanol. This is why the average fuel mix in one third of US fuel stations is around 7% ethanol. It is interesting to note that the oil companies also produce MTBE but have no ownership of the farms producing ethanol in the US. So it makes sense that they would prefer to use MTBE instead of ethanol.

According to a study by the Argonne National Laboratory in 1998, fuel that is blended with 10% ethanol can reduce tailpipe emissions of fine particulate matter by 50%, carbon monoxide by 30%, greenhouse gases by ~40% and can reduce emissions of precursors to smog like nitrogen oxide and hydrocarbons. This is when compared to a 0% ethanol blend. It is interesting that oil companies don't take advantage of the ability for current engines to handle ethanol blends of up to 10%. A strategy of blending all fuel with 10% ethanol could be used as a marketing tool to show how they are cleaning up emissions and making fuel less expensive. But, apparently the costs to purchase ethanol from American farmers is not worth the publicity. When asked about ethanol production as a fuel source, most oil companies refer to studies that suggest that it takes more energy to create a gallon of ethanol than you receive from that same gallon of ethanol. In other words, they claim that the net energy balance is negative in the case of ethanol production. However, the US Department of Agriculture completed a study in 2004 which showed that the net energy balance for the production of ethanol is positive and each gallon produces 34% more energy than it took to create it.

In terms of greenhouse gases, ethanol can reduce tailpipe emissions. But since the process of using ethanol instead of fossil fuels is just recycling carbon between the atmosphere and the corn that grows to produce the ethanol, it is considered carbon neutral. That is, no new carbon is being added to the atmosphere through the use of ethanol. This effect is lessoned however in places like Brazil where rain forests are removed in order to grow sugarcane to produce ethanol. In these cases, carbon is being left in the atmosphere that would have been sequestered by the rain forest creating a net gain of carbon in the atmosphere.

In terms of costs, ethanol fuel is generally less expensive than gasoline. Also, raw sugar prices in Brazil have fluctuated significantly during the last 40 yrs and have recently dropped to below oil, in general, since 2000 (Figure 4). According to a study in Brazil using fuel prices from May 2004, ethanol performed less efficiently than gasoline on a miles per gallon basis. However, since the price of ethanol is significantly lower than the price of gasoline, ethanol yields more miles per dollar than gasoline. So ethanol can give the consumer a further distance for the same price (Appendix 3). In terms of savings using ethanol blends, studies suggest that prices are generally ~$0.05 cheaper per gallon for blends of 10% and ~$0.50 cheaper per gallon for blends of 85%. Blends of 85% are available in localized places in the Midwest but adjustments are necessary in a vehicle's engine to handle the higher concentration of ethanol. Conversion to this type of engine costs approximately $200 per vehicle. In addition, sugarcane ethanol in Brazil costs 2/3 of corn based ethanol in the US.

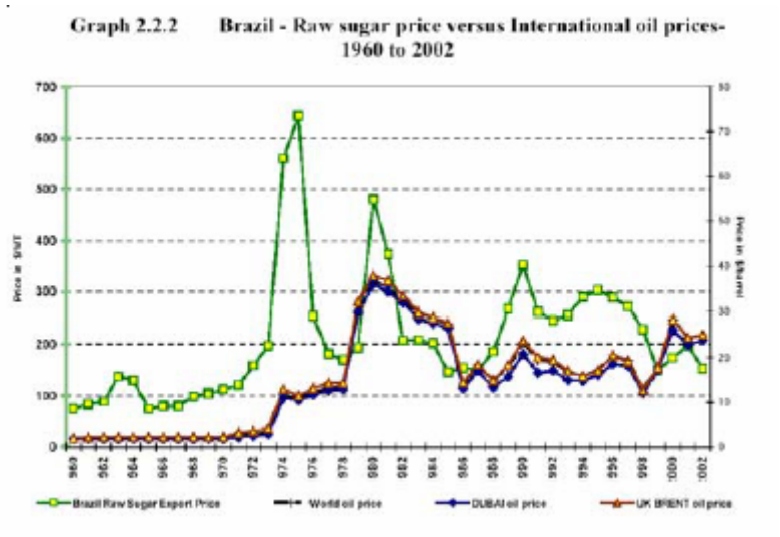

Figure 4

In terms of social equity, ethanol production has traditionally been highly labor intensive relative to the production of gasoline. But improvements in efficiency technologies recently have reduced most of the potential labor impacts associated with ethanol production.

5. Ethanol & Flex-Fuel Vehicles in the US?

The US already produces corn-based ethanol. In fact, 33% of the global supply of ethanol is produced in the US. This is second only to Brazil which produces 37% of global supply. With current technology and agricultural land available for ethanol producing crops, the US can feasibly replace 30-40% of its fuel use with ethanol. This number could be 25% higher with technologically improved yields expected by 2020. If 24% of US fuel was replaced by ethanol, there would be no need for foreign oil. This could be a worthy goal to reach.

The biggest barrier to ethanol use in the US is a lack of refineries and other infrastructure that is required. Also, subsidies for ethanol production pale in comparison to those for oil-based processes. In Brazil, subsidies for government programs were a major reason for the success of ethanol. Currently the US has the capacity to produce four billion gallons of ethanol per year but would need to produce fifty billion gallons per year to replace 30-40% of fuel needs. Government incentives and stricter emissions could help boost the production of ethanol toward these levels. Improvements in efficiency, yields and engineering can also reduce the cost and increase the production of ethanol in the US.

Cellulosic Ethanol made from straw and other plant wastes (corn stover, cereal straws, sugarcane bagasse, saw dust, paper pulp, switchgrass) is identical to corn or soy based ethanol. However, it contains three times the net energy content of corn or soy based ethanol. Though, this technology is not likely to be economically viable until 2012. When it becomes viable it can lead to an 80% reduction in GHG emissions from automobiles

over gasoline compared to a ~40% reduction with other grain based (corn or soy) ethanol. In fact, properly grown feedstocks of switchgrass can net sequester carbon dioxide overtime and actually reduce levels in the atmosphere rather than just neutralizing levels. Investing in refineries that can handle both grain-based ethanol and cellulosic ethanol may help with the transition as this technology becomes a more viable option.

Considering the existing reality with oil, it would make sense for the US to move in the direction of an alternative fuel source like ethanol. Perhaps the US can start by simply increasing production of ethanol enough to require all fuel pumps in the US to have a 10% ethanol blend since this would not incur any change in current fueling infrastructure. This would reduce dependency on foreign oil, lower gas prices, and return dollars into the pockets of Americans. From there, pumps with 85% ethanol blend can be added gradually as consumers become aware of the payout for a simple $200 dollar investment to alter their automobiles for higher blends of ethanol. Automakers could also respond to the demand by offering Flex-Fuel vehicles as is done in Brazil. With government incentives and improvements in technology, efficiency and engineering, ethanol and Flex-Fuel vehicles could become a viable option for the US.

Sources

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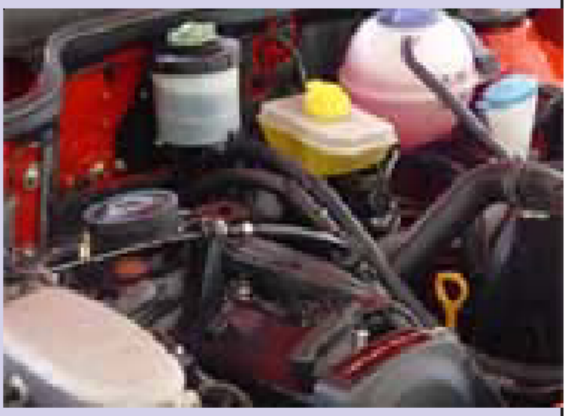
Appendix 1

The Flex-Fuel Technology – An Overview



The Flex-Fuel technology was created by Ford Motor Company in the 80's. The Flex-Fuel vehicle runs on gasoline and alcohol fuel in any mixture, using a single fuel tank, fuel system and engine. The engine and fuel system in flex-fuel vehicles has some differences as the system analyzes the fuel mixture and controls the fuel injection and timing for different fuel proportions. The materials used in the fuel system are also different, with additional protection for corrosion as alcohol is more corrosive than gasoline.

In 1994, the Brazilian subsidiary of Robert Bosch Group began the development of the Flex-Fuel engine in Brazil. They envisioned the Flex-Fuel engine as a substitute for the alcohol only engines, that were facing a decline in sales. The Flex-Fuel engine would provide additional security for customers, being able to use either gasoline or alcohol, and also would represent saving for the auto manufactures as they would not need to develop two different product lines (alcohol and gasoline vehicles). The development of the Flex-Fuel engine in Brazil used the alcohol engine as a base, and consequently was significantly different from the engine developed in the United Sates.

In 1999 another important supplier for the Auto Industry, Magneti Marelli, announced the development of the Flex-Fuel engine and invested R$ 3 million (approximately 1 million US dollars) to develop the software the system uses to identify and make the adjustments based on the proportion of fuel used.

According to João Leite, owner of the Autoinforme Web site focusing on Brazil's auto industry, Flex-fuel cars will grab an increasing share of the Brazilian auto market even if gas prices fall because buyers get a viable fuel choice they never had before.

"If gas and alcohol are the same price, I'm still going to go for the flex because you never know what will happen in a year or two," he said. "You can't lose with a flex car."

Appendix 2

The Alcohol Engine technology

The development of Alcohol-only cars began in Brazil after the 70's oil crisis. Government subsidies helped the design and manufacture of alcohol-only cars. The development of the alcohol engine was done at the Instituto Tecnológico da Aeronáutina – ITA (the Brazilian Air Force Institute of Technology) and was coordinated by the Prof. Urbano Ernesto Stumpf. Prof Stumpf presented the technology President Ernesto Geisel and convinced him to support the research and development of the alcohol engine. This project led to various patents related to the engine, including a new carburetor for alcohol engines. The first widespread test of the alcohol engine was also coordinated by Prof. Stumpf, when TELESP, the telecommunication company responsible for the state of São Paulo, converted its fleet to alcohol cars.

Some of the major issues they have faced when developing the alcohol engine was corrosion, carburetion and engine startup problems. As technology evolved, these problems were solved with the usage of new materials to protect the engine components against corrosion and the usage of electronic fuel injection.

Today the technology used in the alcohol engine is very mature, with almost three decades in widespread use in Brazil. Alcohol fueled cars have comparable performance than the gasoline equivalents, with better results in acceleration and maximum speed but with less autonomy (alcohol consumption is approximately 30% higher than gasoline). Even though the fuel consumption is higher, the economy provided to the consumers is significantly as the gasoline cost at gas stations in Brazil is more than 50% higher than alcohol, due to the high oil prices.

Appendix 3

Alcohol vs. Gasoline: Show me the money

Today there is no significant price difference between cars that use alcohol or gasoline in Brazil. The new Flex Fuel cars are approximately R$ 950 (approximately 320 US dollars) more expensive than their single-fuel counterparts. The Flex Fuel technology allows the customer to use whichever fuel provide more economy.

Using May 2004 average fuel prices in Brazil and the estimated consumption data for the Chevrolet Corsa 1.8 FlexPower we have calculated which fuel implies more savings for the final customer:

	Gasoline	Alcohol
Average Consumption (km/l)	13.65	9.3
Average Retail Price (R$/l)	2.020	1.153
Km/R$	6.76	8.07

In this example alcohol provided better savings for the customer. But one of the main advantages of the Flex Fuel technology is to provide an option for the customer: if the oil price increase pushing the gasoline price up, the customer has the option to use alcohol. On the other hand if the alcohol price raises due to increased demand of alcohol (or sugar, reducing the supply of alcohol), the customer has the option to use gasoline.