Biomass the Smart Way to Reach Fuel Independence

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Abstract

Since the First World War the replacement of gasoline by sugarcane-derived ethanol was considered the preferred mechanism to resolve the chronic trade deficit problem in the Brazilian economy. The production of fuel was monopolized by the government and several short-term initiatives to mandate the blend of ethanol into gasoline had unsuccessful resulted, mainly due to the lack of quality of the gasohol produced and the inadequacy of engines designed to use gasoline only. Finally by 1975 the PROALCOOL program was launched. "PROALCOOL," which means "pro-alcohol," is considered to be the most successful biomass program worldwide. Crude oil price increases by OPEC worked as a powerful impetus in the push for fuel independence. When crude oil reached the level of $35.00 per barrel, the shift from gasoline to ethanol became economically justified. Part of the success of this breakthrough should be credited to society which financed the experimentation phases of the program's development. The study demonstrated why factors like social costs, biomass selection, climate, field productivity, past experience, and, above all, a serious political decision were key elements to reach crude oil independence, which can be used as benchmark to freedom other economies.

Keywords: Ethanol, Sugarcane, Biomass, Bioethanol, Renewable fuel

1. INTRODUCTION

At the beginning of the 20th century, Henry Ford considered ethanol the most efficient means to fuel his Otto engines (Kovarik, 2007). However, gasoline soon edged out ethanol as the top consumer choice for automotive fuel, mainly due to its abundance and lower cost. When crude oil started to be used as a political weapon with dramatic rises in costs, several economies dependent upon crude oil started to suffer with negative trade balances, and the old idea to use ethanol as a gasoline substitute reemerged as one possible solution to the recovery of the Brazilian economy. The idea of producing ethanol to replace oil imports is an old one; in 1931 the government created legislation that allowed blends of ethanol in gasoline (gasohol) of up to 40% (E-40) and encouraged the sugarcane industry to produce as much ethanol as it could.

By 1973, the Brazilian trade deficit was consuming about 50% of all national exports due to crude oil imports (Goldemberg, 2006) and worsened when the first oil crisis occurred with oil prices that increased from $2.70/barrel to $11.50/barrel (Leite et al., 2009), the sugarcane industry was reaching low levels of productivity with ethanol production costs at the level of $100/barrel (Goldemberg et al. 2004), and inflation was reaching triple digits. These causes combined to contribute to economic and social turbulence. The main problem Brazil faced was how to transform the old and poorly productive industrial base of the sugarcane industry, which traditionally used sugarcane to manufacture sugar and in which ethanol production was considered as a second option to fulfill the lack of market for sugar, into a competitive industry able to supply ethanol for transportation anywhere in the nation.

After years of unsuccessful ethanol programs, by 1975 one more program was created, the Brazilian Alcohol Program (PROALCOOL) which had the purpose of reducing oil imports by producing ethanol from sugarcane (Goldemberg et al., 2008). This program turned out to be the most commercially successful biomass fuel program worldwide (Matsuoka et al., 2009). It took nearly three decades to overcome all the program's road blocks before it was successful. The aim of this paper is to demonstrate that is possible to break free of foreign oil dependence by offering a renewable source of energy to suit society's needs. The following topics will be discussed: the political battle for fuel independence, social costs, why sugarcane is the best biomass to produce ethanol in Brazil, energy balance, productivity, and sustainability concerns**.**

2. POLITICAL BATTTLE

Political decisions to conquer fuel independence from imported crude oil were always recalled by Brazilian decision makers mainly at the times of oil scarcity or oil price increases. The idea of resolving this problem was consistently one utilizing ethanol from sugarcane as a gasoline substitute. The lack of a serious energy program designed to break the internal and external political interests of the sugarcane and fuel business sectors was the main reason for past unsuccessful results. At the time that oil imports were consuming about 50% of all national exports and crude oil prices increased by almost 300%, economic chaos was serious and these factors combined to push decision makers to create an energy program to resolve this chronic Brazilian problem.

Historically, the economic break-even point that justified replacing gasoline for sugarcane ethanol was calculated as the point when crude oil costs reached the level of $33-35 a barrel (Pereira, 2006 & Rothkopf, 2007), and by 1980 OPEC provided the economic opportunity to replace gasoline for ethanol by increasing the crude oil barrel price to $36.00/bll. Crude price increases above this break-even point provided an opportunity to implement sugarcane ethanol production to replace gasoline. Another justification was that ethanol is a renewable fuel that can be offered at lower costs than gasoline and is better for the environment, which accelerated the ethanol shifting process away from gasoline.

From the perspective of a population experiencing years of frustration with the government's monopoly of fuel management, continuous increases in fuel prices and a lack of a strong political desire to seriously implement an alternative fuel program, any internal/external drives with the power to change the status quo were welcomed. In that sense, one needs to thank OPEC for all the crude oil price increases, as they worked as positive drives to force Brazilian decision makers to reengineer fuel policies for the country.

3. SOCIAL COSTS

At the beginning of the program, the sense of urgency to produce ethanol from sugarcane supplanted quality control enforcement of the ethanol produced. The quality of gasohol could not be enforced at all supply terminals which allowed an increase in predatory trade practices offering low quality gasohol to customers, who actually received an adulterated fuel mixed with low cost chemicals and water. The lack of uniformity in the quality of the gasohol increased the malfunctioning of car engines fed with gasohol, leaving car owners with additional expenditures to fix their cars after refueling them. A feeling of unfairness led car owners to point fingers at the government, ethanol producers, gasohol blenders, and car manufacturers for not offering fuel or cars suitable for gasohol. Unfortunately, due to the lack of specific laws to protect the consumer, the population of gasohol users was punished economically so their interest in gasohol declined.

Car manufacturers, in agreement with the government, designed a plan to offer a new generation of cars designed to use 100% ethanol with very attractive monetary incentives. However, the issue of low quality fuel persisted with the appearance of a new problem: the premature collapse of engine parts in contact with ethanol due to corrosion. Ethanol car owners felt that they were punished twice – once for buying a car designed to use only ethanol and second for using a fuel which was continuously outside of specifications. The additional costs necessary to overcome the problems listed above were totally absorbed by the first generation of ethanol car owners. This problem was finally resolved with the advent of flex-fuel technology and the creation and enforcement of national quality standards for ethanol.

4. SUGARCANE AS BIOMASS

There is an abundance of crops, vegetables and grasses which have the ability to synthesize sucrose in the photosynthesis process; however not all vegetation offers a sucrose level per hectare high enough to justify the sucrose extraction costs to produce ethanol. Sugarcane sucrose is measured in POL (percent of apparent sucrose content), and, according to Lima and Marcondes (2002), the sugarcane in Brazil has a POL average range between 13% and 18% POL. A 12% POL is the maximum achieved in other parts of the world. This is one of the main reasons why sugarcane is the most suitable biomass raw material for Brazil.

A comprehensive analysis must be performed to evaluate specific crops, climate conditions, and land sustainability to determine the best local resource available for producing alternative fuel sources. Ethanol produced from biomass can be processed from different plant sources.

Brazil selected sugarcane as a biomass raw material to produce ethanol mainly because of the country's 500-year tradition of working with sugarcane and the favorable climate conditions to cultivate this species. China produces ethanol from rice, corn and wheat, while Thailand generates ethanol from raw sugar and yucca. The United States uses corn as biomass to produce ethanol but is currently experimenting with algae and switch grass which, according to Chisti (2010), is more efficient than corn and does not adversely affect food prices.

According to Rothkopf (2007), sugarcane ethanol has consistently been considered the most cost-efficient first generation ethanol, at $0.21/liter compared to the respective $0.27 and $0.76 costs of corn and sugar beet ethanol. Sugar cane requires a climate that will provide the appropriate temperature, balance of sun exposure and high humidity levels combined with specific soil characteristics to maximize its sucrose production. The climate that meets these specifications is the tropical or sub-tropical climate predominantly found in Brazil.

There are many tangible benefits associated with biomass fuel technology, including its sustainability and economic advantages; however, beyond all tangible advantages the most important is the intangible one: Ethanol from sugarcane is a perpetual source of energy that will be available as long we have sunlight, which is not the case of crude oil.

5. ENERGY BALANCE

It is well established in literature that the energy balance to produce ethanol from sugarcane is positive. Coelho (2005) points out that "all energy needs in sugarcane mills are provided without external source". Goldemberg (2006) quantifies the efficiency of the energy balance stating that there are "up to 10 outputs for each input unit." Lima and Marcondes (2002) state that bagasse (fiber left after sugarcane is crushed), which today is used as fuel, can supply 1.65 million BTUs per ton of sugarcane processed, providing enough energy to process all sugarcane required to produce ethanol plus a surplus that can be redirected to the electrical grid. However, this can be altered in the future as necessary. Soon new technological breakthroughs, with the aim of using bagasse as a raw material to produce ethanol, will be achieved. This use of cellulosic feedstock to produce ethanol is known as second generation ethanol (2010, Schaffell and Rovere).

6. PRODUCTIVITY

Sugarcane productivity in the field is expressed in tons of sugarcane per hectare. In a period of 33 years this productivity increased from 46.8 to 77.52 tons of sugarcane per hectare. Recently, with new soil management techniques, some areas reach up to 120 tons/hectare, increasing the Brazilian average of sugarcane productivity to 85 tons of sugarcane/hectare (MAPA, 2006). While quantity is important, quality is a major consideration, and quality in this business is determined by the amount of sucrose obtained per ton of sugarcane produced. For this reason it is important to maximize sucrose content in order to increase the production of ethanol.

Theoretically, one ton (2200 pounds) of sucrose can be converted into 511 kilograms (1124.2 pounds) of ethanol and further processed into 640 liters (168 gallons) of ethanol. However, the practical yield (also known as Pasteur yield) indicates that it is possible to achieve up to 95% of the theoretical yield via fermentation which will result in a maximum of 608 liters (160 gallons) of ethanol produced for each ton (2200 pounds) of fermented sucrose.

Proper care and management of sugarcane growth, maturation and harvest is strategically related to the sucrose content for each ton of sugarcane produced; sucrose content may range from 12% to 18% of sucrose per ton of sugarcane produced. When successfully maximized, the results can yield 180 kilograms (396 pounds) of sucrose per ton of sugarcane produced and, ultimately, 109.4 liters (28.7 gallons) of ethanol. With this quality level of sucrose productivity in the sugarcane and the field quantity productivity of 85 tons (187,000 pounds) of sugarcane/hectare, the total volume of ethanol produced will be 9,302.4 liters (2,455.8 gallons) per hectare. According to Schaffel & Rovere (2010) Brazil is reaching a field productivity of 8,000 liters (2,112 gallons) of ethanol per hectare, which confirms that field productivity is reaching desired levels.

7. SUSTAINABILITY CONCERNS

There are three major concerns raised internationally about the sustainability of Brazil's ethanol production: land use, pollution and labor issues. The land use concern is that sugarcane farmers will use the Amazon forest as a base to expand their business; however this concern was dispelled by the fact that the Amazon forest climate and the soil are inadequate for the harvest of sugarcane (Goldemberg, 2008).

The second main concern is that the practice of burning sugarcane in the field will increase pollution and cause health problems for laborers. Industry is committed to eliminating the practice of burning in mechanized and non-mechanized fields by 2021 and 2031, respectively, according to existing law. In fact industry is promising a voluntary compliance by 2014 and 2017, respectively (Rothkopf, 2008). According to Jank (2009) the displacement of gasoline by ethanol improved the quality of the air by reducing 600 million tons of CO2 emissions from 1975 to 2008. It is estimated that if ethanol from sugarcane were to replace 10% of the gasoline consumed in the world, carbon emissions would be reduced by 66 million tons per year (Goldemberg, 2006). The EPA (2010) demonstrated that sugarcane ethanol from Brazil reduces GHG emissions by 61% as compared to gasoline.

The third concern is about labor exploitation. Harvesting sugarcane, traditionally done by hand, is one such opportunity provided by the sugarcane industry for workers who lack the qualifications necessary to obtain mainstream employment. In the past, there were reported occurrences of inadequate wages and poor working conditions; however, the modernization of the industry coupled with new regulations at the state and federal levels have had positive results. Modern ethanol facilities have incorporated the use of machinery, and modified plantation field designs have also served to enhance efficiency. According to Rodrigues and Nagami (2006), 35% of sugarcane production is mechanized, indicating a trend to increase this level to improve productivity in the field. The government is enforcing labor laws in the field to ensure fair working conditions and has established minimum wage regulations. These advancements have led to more positive perceptions and the public's financial support of the industry.

8. CONCLUSION

1 - The social cost of the implementation of the Brazilian renewable fuel program cannot be quantified. However, ethanol fuel users financed the program heavily by buying vehicles dedicated to using ethanol during all phases of the program, absorbing all costs generated by the experimental phase of the program, and supporting it until it became successful. For this reason, a great part of the success must be credited to the population of bioethanol users.

2 - Crude oil import prices and their use as political weapons devastated the Brazilian trade balance. However they worked as positive drives towards a firm political decision to create a renewable fuel program to replace gasoline with sugarcane ethanol.

3 - The selection of sugarcane as a biomass to produce ethanol fuel in Brazil was shown to be the right choice due to the climatic conditions, the quality of the earth, and the technology developed in the cultivation and processing of the sugarcane to produce ethanol. The levels of productivity reached in the field are providing a competitive advantage that is benefiting internal and external markets in need of fuel ethanol.

4 - Today, Brazil has the infrastructure, technology, and capacity to maintain its foreign fuel independence. It is in a position to cooperate at worldwide levels with technology as well as supplying ethanol from sugarcane to better serve the environment and economies that are dependent on foreign crude oil.

5 - After the consolidation of the ethanol program, the Brazilian economy is growing, the economic downturn caused by the trade deficit due to oil imports disappeared, a positive trade balance is a reality that promotes more public investments and consequently Brazil is demonstrating historically one of its best economic momentums.

9. REFERENCES

Chisti, Y. (2010). Fuels from microalgae *Biofuels* 1 (2), 233-235

Coelho, S. (2005, December). Brazilian Sugarcane Ethanol: Lessons learned *CENBIO-The Brazilian Reference Center on Biomass, December 2005.* Retrieved July 2011 from http://www.bioenergytrade.org/downloads/coelhonovdec05.pdf

Goldemberg, J. et al. (2008) Energy Policy, Energy *Policy Journal* 36(2008) 2086-2097

Goldemberg, J. (2006). The Ethanol Program in Brazil, *Envronm. Res. Lett.* 1 (2006) 014008 (5pp)

Goldemberg, J. et al. (2004). Ethanol learning curve-the Brazilian experience *Biomass and Bioenergy* 26 (2004) 301-304

Jank, M.S. (2009). Etanol, beneficion, riscos e desafios, O Estado de Sao Paulo, edicao November 6, 2009. Retrieved June 10, 2011, from http://www.estadao.com.br/estadaodehoje/20091106/not_imp462047,0.php

Kovarik, W. (2007). Biofuels: back to the Fuel of the Future *4th annual Life Sciences and Society Symposium*, University of Missouri

Leite, R.C. et al. (2009). Can Brazil replace 5% of the gasoline world demand with ethanol? *Energy* 34(2009) 655-661.

Lima, L. & Marcondes, A. (2002). *Alcool Carburante uma Estrategia Brasileira* Editora UFPR, Curitiba, Parana, Brazil

MAPA (2006). *Ministerio da Agricultura, Pecuaria e Abastecimento, Plano de Agroenergia* 2006-2011, Brasilia, DF, 2005 URL Retrieve June 15,2011from http://www.21.sede.embrapa.br

Matsuoka, S. et al. (2009). The Brazilian experience of sugarcane ethanol industry *In Vitro Cell.Dev. Biol Plant* (2009) 45:372-381

Pereira, R. (2006). Assessment of the National Potential of Crop Residues Generation for Ethanol Production, *M.Sc. Dissertation* Technology of Chemical and Biochemical Process FURJ, Brazil

Rodriges, A. & Nagami, H. (2006). A morte por tras do Ethanol, *Isto E*, March 28, 2006

Rothkopf, G. (2007). A Blueprint for Green Energy in the Americas – *The Global Biofuels Outlook 2007, Strategic Analysis of Opportunities for Brazil and the Hemisphere*- prepared for the Inter-American Development Bank

Schaffel & Rovere, (2010). The quest for eco-social efficiency in biofuels production in Brazil, *Journal of Cleaner Production 18 (2010)1663-1670*