The Brazilian Experience With Ethanol Fuel

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Abstract **-** The consumption of fossil fuels derived from petroleum presents a significant impact on environmental quality. Air pollution in big cities is, probably, the most visible impact resultant of petroleum derivatives combustion and credited almost all to the transport sector. This sector relies almost exclusively on liquid hydrocarbons leading to an emission of massive amounts of CO_2 with the associated greenhouse effect. Ethanol from sugarcane can contribute positively in the improvement of the environment with the reduction of the use of fossil fuels and of CO_2 emissions. The goal of this paper is to present the Brazilian experience with renewable energy, the contributions of Inmetro and the recent results of the Brazilian Ethanol Program, nominated PROALCOHOL, internationally known as the most successful alternative fuel program.

Keywords: biofuels, ethanol, renewable energy, measurements.

I. Introduction

Sustainability is concerned with reconciling the long-term development of human society with the finite limits of the planet. There are several definitions for sustainable development. In 1987 the World Commission on Environment and Development defined sustainable development as: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Ever since, questions as greenhouse gases reduction and the sustainability of a society based on finite fossil resources has been subject of ongoing scientific and political debate. One of the main subjects of this debate concerns the use of alternative sources of energy or renewable energy [1].

The term renewable energy refers to energy generated from natural resources such as sunlight, wind, rain, tides, geothermal, hydropower and various forms of biomass. These energy sources are considered renewable sources because they are continuously replenished, such as the sun and wind that theoretically never will be exhausted. They are also known as non-conventional sources of energy. The researches for alternative sources of energy have become very important and relevant to today's world because they cause less emission of toxic gases, reduce chemical radioactive and thermal pollution. Some climate change can always be attributed to natural cycles and disturbance in the climate system of Earth, but we cannot explain the general warming trend over the last decades without invoking human-induced effects. So, choosing, researching and using renewable energy we are doing something positive about the air we breathe, the environment we live in and the condition of the planet we leave to future generations.

Although the production of oil has had a vertiginous growth in the last decades, fossil fuels are limited and in a near future the world crude oil production will finish. Petroleum and other fossil energies have already started to disappear little by little. Today, the estimation of the conventional petroleum reserves is about 40 years to the current level of consumption [2]. On the other hand, the levels of gases from greenhouse effect continue to increase and in 2008 the global concentrations of carbon dioxide, methane and nitrous oxide, that are the main gases of the greenhouse effect in the atmosphere, reached the largest registered since pre-industrial times.

II. The Brazilian Ethanol Program

The Brazilian experience with the use of ethanol fuel as a gasoline additive dates back to the 1920s. However, it was only in 1931 that fuel produced from sugarcane began to be officially blended with gasoline, which at that time was imported. Despite of these early initiatives, it was only in 1975, with the launching of the National Ethanol Program (PROALCOHOL), that the Brazilian government created the necessary conditions for the sugar and ethanol industry to become, 35 years later, one of the most modern in the world, having achieved significant results from both environmental and economic perspectives.

The Brazilian Ethanol Program was created in November of 1975, two years after the Arab oil embargo, through the decree number 76.595 of General Ernesto Geisel, then-president of Brazil. The program was intended to reduce the need for oil imports and to provide an additional market for Brazilian sugar. As a first step, the federal government immediately began promoting the production of ethanol for blending into gasoline, to the maximum extent feasible in existing vehicles. In promoting ethanol, Geisel's government had many tools at its disposal. First, the government offered credit guarantees and low-interest loans for construction of new refineries. Second, a state trading enterprise began purchasing ethanol at favorable prices. Third, gasoline prices were set to give ethanol a competitive advantage. Fourth, a marketing program was launched. Finally, the state-owned oil company, ***Petrobrás***, began making investments for distribution of ethanol throughout the country. As result, between 1975 and 1979, the Brazilian ethanol production increased more than 500%. Figure 1 shows the production of ethanol in Brazil, since 1990, with significant growth in the last years.

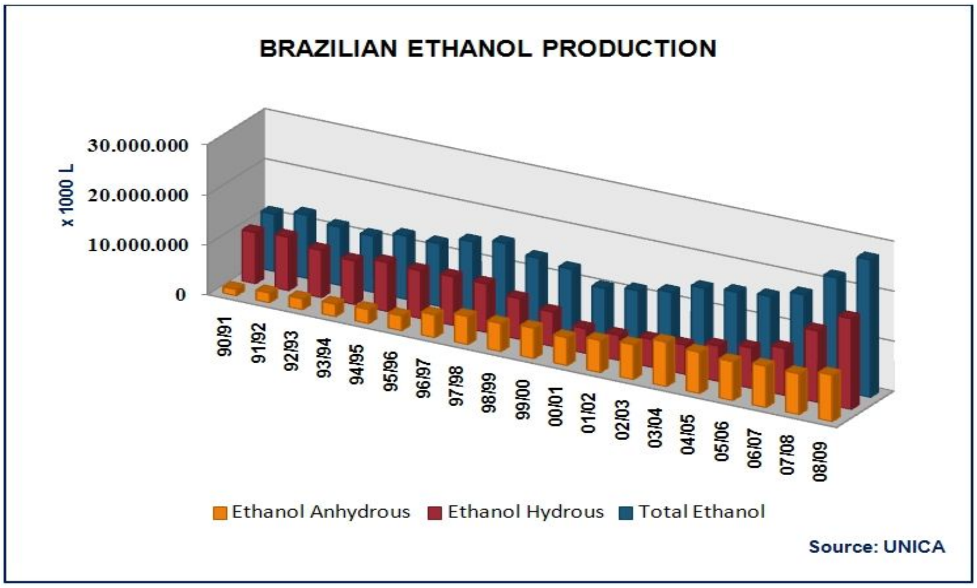

Figure 1. Brazilian production of ethanol since 1990.

A second stage of the program was launched in 1979, when the Brazilian government signed agreements with major car companies to install assembly lines for 100% ethanol cars. Participating companies – including Fiat, VW, Mercedes-Benz, GM and Toyota – agreed to produce 250,000 ethanol-only cars in 1980 and 350,000 in 1982. A government program provided taxi drivers with incentives to convert their cars to 100% ethanol. Several leading race car drivers made highly visible use of 100% ethanol cars.

During the early 1980's, the Brazilian ethanol program flourished. With the help of government pricing policies, which kept the cost of ethanol to consumers significantly cheaper than the cost of gasoline, ethanol production more than tripled between 1979 and 1985. A World Bank loan helped cover costs of the program. By the mid-1980's, ethanol made up roughly half of Brazil's liquid fuel supply.

The third stage of the program has started in 1985 when Brazil's ethanol program began to experience problems. World oil prices dropped sharply in 1985-86, Figure 2, reducing the immediate benefit of replacing oil imports with ethanol. At the same time, Brazil faced serious inflation problems and began a series of difficult economic reforms. As part of a broader cut back on subsidies, the price differential between ethanol and gasoline was eliminated, soft loans for the construction of new refineries were cut, and support for the ethanol program from state trading companies was slowed and then stopped. These changes had a significant impact on ethanol production, which stagnated. By the late 1980's ethanol production even began to decline slightly, as world sugar prices rose and export markets for refined sugar became more profitable [3].

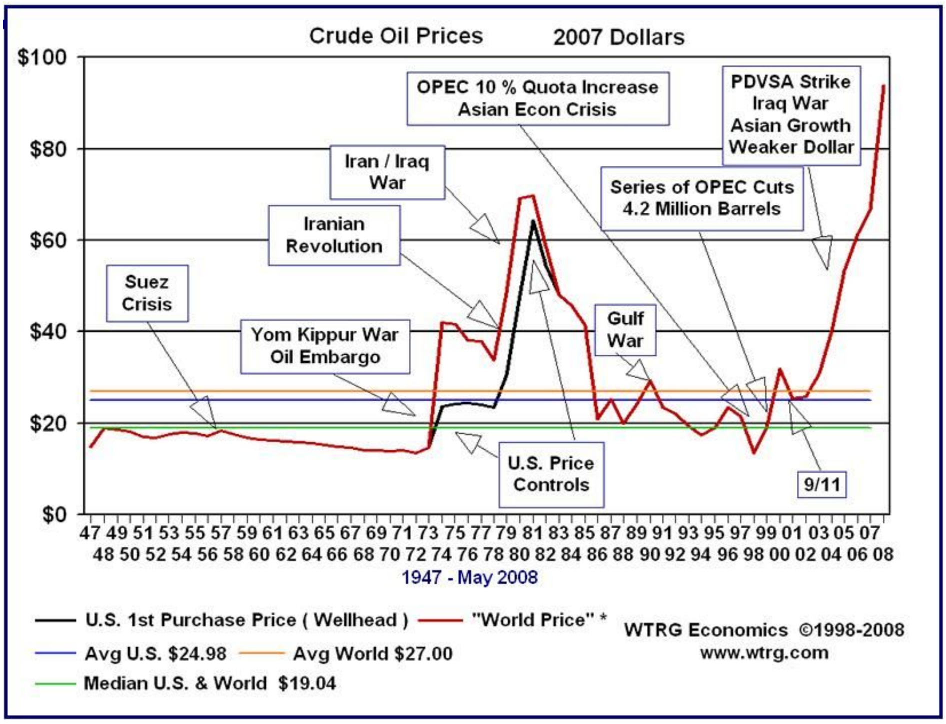

Figure 2. World oil prices evolution.

Finally, the fourth stage, since 2000, began with the revitalization of ethanol fuel and was marked by the liberalization of price for the products in this industry in 2002, by the introduction of flex-fuel vehicles in 2003, which run on any mixture of hydrated ethanol and gasoline, by opportunities for increases in ethanol exports, and by high oil prices in world markets. The figure 3 shows the Brazilian production of automotive vehicles, with prominence for production of Flex-fuel vehicles, which in 2006 overstepped the production of gasoline vehicles. During this stage, the dynamics of the sugar and ethanol industry began to depend much more on market mechanisms, particularly in the international market, than on government incentives. The industry made investments, expanded its production, underwent technological modernizations, and today sugar-cane ethanol is efficiently produced in Brazil at prices that are internationally competitive [4].

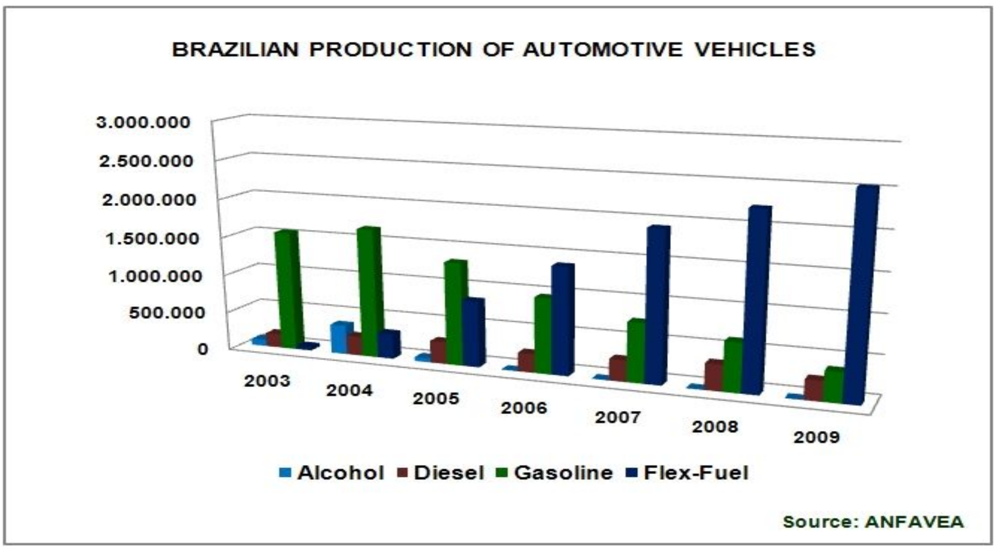

Figure 3. Brazilian production of automotive vehicles by year since the introduction of flex-fuel vehicles.

III. Alternative-Fuel Vehicles

Ethanol produced through an enzymatic process can derived from plant sugarcane, from corn starch as in the United States, from wheat or sugar beet as in the European Countries or from others vegetables or plant fibers, mainly cellulose, in new generation process. Ethanol makes excellent fuel for cars with spark ignition engines. Developments are also being made to use ethanol as a pure fuel or blended with diesel in buses and trucks with compression ignition engines. In fact, ethanol is also used in the sophisticated engines of racing cars. It burns very cleanly, and delivers more power than gasoline [5]. In Brazil most of the gas stations sell pure ethanol (hydrated ethanol) and fuels that contain a blend of gasoline and ethanol anhydrous (**Gasohol**). Actually, gasohol refers to a gasoline that contains an ethanol percentage by volume in the range of 20% - 25%. Methanol derived from fossil sources also can be use as a fuel. Its use however is limited due to the high toxicity being deadly poisons, especially in the amounts used to make transportation fuels.. Even small amounts breathed in as fumes or accidentally swallowed can cause blindness, severe liver damage, and death.

Alternative-fuel vehicles are designed to operate with fuels other than gasoline or diesel. Alternative fuels are substantially non-petroleum and yield energy security and environmental benefits. Besides ethanol and methanol are used as alternative fuels: hydrogen, biogas derived from biological materials, and electricity (including solar and wind energy). In Brazil an outstanding change happened in the production and sale of automotive vehicles by the introduction of **Flex-Fuel Vehicles** in 2003. A **flexible-fuel vehicle (FFV)** or **dual-fuel vehicle** (colloquially called a **flex-fuel vehicle**) is an alternative fuel vehicle with an internal combustion engine designed to run on more than one fuel, usually gasoline blended with ethanol fuel, and both fuels are mixed and stored in the same common tank. Flex-fuel engines are capable of burning any proportion of the resulting blend in the combustion chamber as fuel injection and spark timing are adjusted automatically according to the actual blend detected by electronic sensors (lambda sensor). Flex-fuel vehicles are distinguished from bi-fuel vehicles, where two fuels are stored in separate tanks and the engine runs on one fuel at a time as with gasoline and natural gas.

Under Brazilian regulations two types of fuel ethanol are produced (table 1). A) Anhydrous, that is the ethanol blended with automotive gasoline producing the gasohol. B) Hydrated, that is used as a neat fuel in vehicles or blended with gasohol by the consumer in Flex-Fuel Vehicles (FFV). In 2008 Brazil produced 24.5 billion liters of ethanol (6.47 billion U.S. liquid gallons), which represents 37.3% of the world's total ethanol used as fuel.

Table 1. Brazilian types of fuel ethanol

FUEL ETHANOL TYPES	ALCOHOL CONTENT ^{o}GL (at 20 ^{o}C)
Anhydrous	99.58 minimum
Hydrous	95.13 - 95.98

IV. The Brazilian Production of Sugarcane and Ethanol

The sugar and ethanol production is one of the most important economical activities in Brazil, mainly due its high efficiency and competitiveness. Brazilian sugarcane has three major uses. It is used to produce refined sugar, to produce ethanol (anhydrous and hydrated) and to produce heat and electricity by burning the bagasse. Anhydrous ethanol is used to blend with gasoline as mandated by the Brazilian government, and hydrated ethanol was used as fuel for vehicles powered 100 percent by alcohol and now is used in the modern Flex-fuel vehicles. For this reason hydrated-ethanol production has increased strongly since 2003 (figure 1).

The majority of Brazilian sugarcane is produced in the Center-South region and the North-Northeast region (figure 4). The Brazilian Union of the Industry of Sugarcane (UNICA) recently published a forecast of the crop of 2009/2010. The forecast for the crop 2009/10 is about 550 million tons of sugarcane in the area center-south, against 505 million tons in the crop 2008/09. In the case of ethanol, the expectation of the UNICA is an increase of 4,7% in relation to 2008/09. Brazil exported 3,4 billion liters of ethanol in 2006, 3,5 billion liters in 2007 and 5,2 billion liters of ethanol in 2008. The main countries importers of ethanol from Brazil are shown in the table 2.

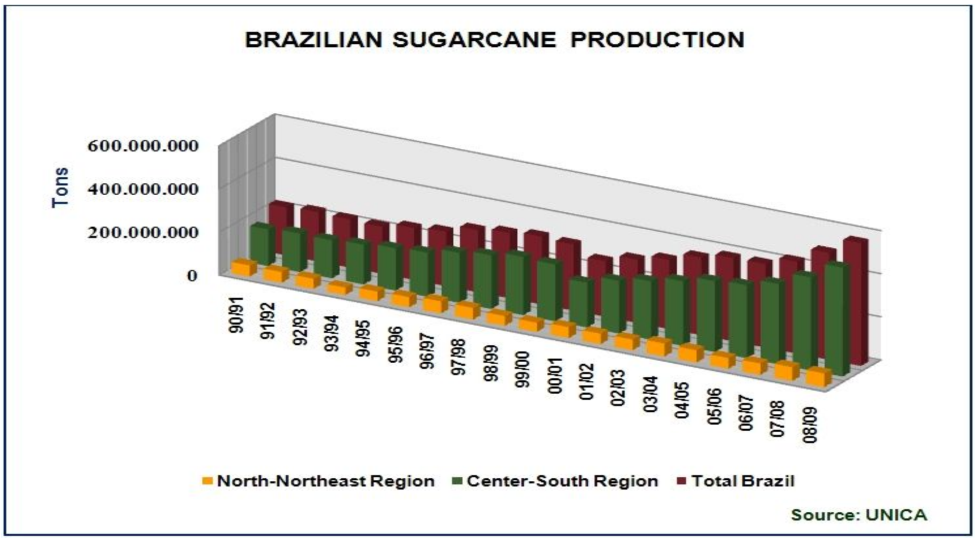

Figure 4. Brazilian production of sugarcane since 1990.

Table 2. The main countries importers of ethanol from Brazil

COUNTRY	VOLUME (million of liters)		
	2006	2007	2008
United States	1.749,2	849,7	1.519,4
Netherlands	344,5	800,9	1.331,4
Jamaica	133,0	312,1	436,1
El Salvador	182,7	226,8	355,9
Japan	227,7	367,2	263,2
Trinidad and Tobago	72,3	160,5	224,3
South Korea	93,4	67,4	186,6
Costa Rica	92,2	172,2	109,4
Nigeria	43,1	124,2	97,8
United Kingdom	26,7	47,1	69,6

V. Inmetro and Biofuels

The global demand for renewable fuels has been increasing, and Brazil is today the exporter leader as it has the potential to keep the leadership as exporter of ethanol fuel in the world. With this initiative Brazil is strongly contributing for the Green House Gas (GHG) emissions reduction, responsible for the global warming. To maintain the exporting leadership it is necessary that the ethanol become an international commodity. To achieve this quality, the requirements should be harmonized on the market.

In 2007, a tripartite Working Group formed by Brazil, United States and European Union started a study for harmonization of the specification of bioethanol and biodiesel including definition of quality parameters, measurement units, values limits and standards analytical methods. The National Institute of Metrology, Standardization and Industrial Quality (Inmetro), together with others Institutes and Organizations, had an important role in this first harmonization attempt. As a result of the work, in 2008 was published a document called “White Paper on Internationally Compatible Biofuel Standards” [6] as a base document to transform the biofuels – bioethanol and biodiesel – in an international trade commodity.

Besides the efforts in the tripartite work, Inmetro has been involved since 2005 in several initiatives concerning biofuels. Among them is the organization of Biofuels Panels involving the main decision makers from the government sector and civil society, organization of International Conferences on harmonization of standards, with NIST and European Commission as partners.

Inmetro has the function to assist the needs of the Brazilian government, as well as of the society in general, not only in Metrology but also in the development of conformity assessment programs for Biofuels. Thus, Inmetro, which plays a key role in research on biofuels is involved in an important program in this area encompassing critical researches with specific objectives helping to understand the performance of biofuels in engines and to know the physico-chemical properties that can impact in its quality. Some of the research are:

A) To provide improved methodology for the characterization of physical and chemical parameters in biofuels. These parameters are defined and discussed in the "White Paper on Internationally Compatible Biofuel Standards";

B) Development and production of Certified Reference Materials (CRMs) for Bioethanol and Biodiesel. Developed in cooperation with NIST, four CRM were produced: bioethanol anhydrous and hydrated and biodiesel soya oil based and animal fat based. The certified parameters and measurements units included in the bioethanol CRM are those defined in the “White Paper”. The analytical methods used are also those discussed in the “White Paper” [7]. The parameters and analytical methods are:

Quality Parameter	**Unit**	**Analytical Method**
Water Content	vol. %	Karl Fischer Coulometric Titration;
Electrical conductivity	µS/m	Conductivity meter; establishment of Primary Method;
Density at 20°C	kg/m³	Digital Density meter;
Acidity	mass %	Potentiometric Titration (gravimetric preparation) Ethanol Content: vol. % GC-FID (Gas Chromatography Flame Ionization Detector) and DSC (Differential Scanning Calorimetry);
Copper	mg/kg	Atomic Absorption Spectrometry and Isotope Dilution Inductively Coupled Plasma Mass Spectrometry;
Iron	mg/kg	Atomic Absorption Spectrometry and Isotopic Dilution Inductively Coupled Plasma Mass Spectrometry;
Sodium	mg/kg	Atomic Absorption Spectrometry;
Sulfate	mg/kg	Ion Chromatography or Potentiometric Titration;
Chloride	mg/kg	Ion Chromatography or Potentiometric Titration;
pHe:	pHe	pH meter;
pH:	pH	pH meter.

Besides the development of bioethanol CRM for both anhydrous and hydrated, Inmetro is involved in many R & D projects in Energy comprising bioethanol, biodiesel and biomass. The researches involve from identification of sources and physicochemical characterization of biofuels to the study of its performance on engines. Among many researches under development we can point out some of them:

C) Water is one of the worst contaminants to any type of fuel. Two main reasons are identified: growing of microorganisms promoting the biodegradation and contaminants solubilization leading to a accelerated oxidation process. Evaluation of the rate of humidity absorption by bioethanol and biodiesel in atmospheres of different humidity degrees and temperatures can help the producers and distributors in the design of transport and storage;

D) Evaluation of the biofuels aggressiveness in metallic and polymeric materials;

E) Determination of the calorific power of different biodiesel mainly related to the chemical composition, building a bank data;

F) Development of high quality metrology references suitable for biofuels. Requirement of very precise measurements of physical parameters such as volume, viscosity and energy content, data in a wide temperature range for an optimized control of injection into an engine;

G) Assessment of methods for the characterization of biofuel’s quality indicators. Faster, cheaper and more flexible assessment of the quality of biofuels, for relevant parameters, such as corrosion potential and inorganic contamination;

H) Traceability for origin discrimination of biofuels. Feasibility study to clearly state whether it will be possible to discriminate between biofuels produced from fossil or biologic origins;

I) Identification of natural markers, specific organic compounds for each source of biofuel;

J) Analytical method development to identify the geographic origin of the biofuel, acting as a government tool to reduce the arising of technical barriers;

K) Clarify and facilitate what measurement methods, standards and reference materials are needed to support efficient production and use of high-quality second generation liquid biofuels.

VI. Conclusion

Renewable energy is one of the most efficient ways to achieve sustainable development. Increasing its share in the world matrix will help to prolong the existence of fossil fuel reserves, to address the threats posed by climate change, and enable better security of the energy supply on a global scale. Brazil has a great deal to contribute to this discussion, since it has accumulated important know-how in the biofuels area, particularly regarding the use of ethanol as an automotive fuel. Brazilian energy matrix is one of the cleanest in the world and currently more than 45 percent of all energy consumed in Brazil comes from renewable sources, whereas the average share of renewable sources in the energy mix of all developed countries is about 10 percent. This constitutes a clear advantage in terms of where Brazil stands in the current situation, in which concerns over energy security and the environment have led various countries to seek alternatives to fossil fuels while making efforts to implement initiatives to reduce their greenhouse gas emissions.

Nowadays there is a consensus that a sustainable energy future depends on an increased share of renewable energy, both in developed and in developing countries. One of the best ways to achieve such a goal is by replicating the large Brazilian program of sugarcane ethanol [8], started in the 1970s. Many developing countries have suitable conditions to expand and replicate the Brazilian sugarcane program, supplying the world's gasoline motor vehicles with a renewable, relatively cheap and efficient fuel.

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