Creating a Market for Ethanol - Challenges Faced in the Brazilian Experience

Agnes M. A. da Costa*, João Paulo Resende, Tiago de Barros Correia

Economic Advisors - Ministry of Mines and Energy – Federative Republic of Brazil

Abstract

Rising oil prices, greater concern with the effects of global warming and more stringent environmental protection regulation have been pushing countries toward finding alternative solutions to fossil fuels. In such context, the Brazilian experience with ethanol powered vehicles redraws the attention of worldwide energy experts and policy-makers. This paper reports on the latest developments of such experience and explains how it evolved from a government subsidized program into the world's largest market for flexible fuel vehicles.

Complete contact details for the lead author

1. Name: Agnes Maria de Aragão da Costa

2. Title: MSc., Economic Advisor

3. Organization: Ministry of Mines and Energy – Federative Republic of Brazil

4. Address: Esplanada dos Ministérios, Bloco "U", room 818

70.065-900 Brasília, DF - Brazil

5. Phone: 0055-61-3319-5303

Fax: 0055-61-3319-5068

Email: agnes.costa@mme.gov.br

1. Introduction

Since the first oil crisis in 1973 many countries have decided to embrace the challenge of reducing their dependence on fossil fuels. One alternative followed by some countries, including Brazil, was to develop alternative fuels as a way to reduce demand for oil derivatives. But developing alternative fuels means also creating markets for them, what might not constitute an easy task, since it depends on developing production as well as end use technologies, supply and demand as well as transportation and distribution infrastructures.

Counting on the country's former experience with sugarcane plantations the Brazilian government developed several interventionist policies which culminated in the launching of its Alcohol National Program (PRÓALCOOL) in 1975, aiming first at adding anhydrous ethanol to gasoline in order to reduce oil imports. But high oil prices induced some technological advances in end use technologies, leading to the development of 100% ethanol powered engines. Vehicles run exclusively on ethanol accounted for almost 90% of the cars sold in the late eighties in Brazil.

Nevertheless, the program was eventually abandoned a few years later in a context of market liberalizing policies. The scarcity of ethanol supply in the late eighties - due to higher sugar prices in the international market and to lower and more stable oil prices - might be considered one of the main causes of this relative failure.

This paper intends to address the contributions of the PRÓALCOOL experience to the creation of the Brazilian ethanol market and to present the recent development and behavior of the sugarcane industry in Brazil. This will then help to explain the significant revitalization of the ethanol industry by the beginning of this century.

This paper is composed by 5 sections, including this short introduction. Section 2 presents some facts and figures about the current structure of the sugarcane industry in Brazil, as well as addresses the role played by the sugar and the power markets in ethanol production. Section 3 summarizes the PRÓALCOOL experience and deals with the main reasons for its relative failure and its contributions to the creation of an ethanol market in Brazil. Section 4 covers recent developments in the Brazilian ethanol market, with special emphasis to the changes in the sugarcane industry's regulatory framework. Finally, section 5 draws some final considerations, including the role that Brazil can play not only as an international ethanol producer but as a technology exporter.

As to its methodology, the paper is mainly descriptive, addressing the above mentioned issues through a bibliographical revision of work done mostly by Brazilian ethanol experts. The objective is to understand and describe the main characteristics of a given phenomenon, that is, the development of the world's largest market for an alternative automobile fuel. Nevertheless, the research method adopted occasionally presents both explanatory and analytical remarks, e.g. the role played by the sugarcane industry and by deliberate public policies in the development of the Brazilian ethanol market.

2. The Sugarcane Industry in Brazil - Main Characteristics, Facts & Figures

Sugarcane crop growing is the oldest economic activity in Brazil. The plant was brought to the country in 1532 by Martim Afonso de Souza, a Portuguese colonial administrator. The first crops were initially established at the northeastern region of the country called "Zona da Mata"[1] and eventually spread to the southeastern region of Brazil, culminating at the domination of the agricultural area of São Paulo State. Nowadays, almost all Brazilian States produce sugarcane, but São Paulo concentrates about 60% of the national production.

According to the Ministry of Agriculture, Livestock and Food Supply[2], the ideal climate for sugarcane production is the one that offers two distinct seasons: one that is warm and humid, to enable sprouting, tillering and vegetative development; and another one that is dry and cold, to promote maturation and subsequent accumulation of sucrose.

The current characteristics of sugarcane crop growing in Brazil are summarized at the table bellow:

Table 1 – Crop Growing Characteristics

Growth cycle	5 years
Number of cuttings	5 cuttings
Sugarcane productivity	85 ton/ha (160 -65)
Sugar yield	138 kg/ton
Ethanol yield	82 l/ton

Source: Ministry of Agriculture, Livestock and Food Supply (2007)

Companhia Nacional de Abastecimento (CONAB)[3] released in May 2007[4] the first survey of the 2007/2008 sugarcane crop. A first estimate of the Brazilian sugarcane production in 2007/2008 crop is of 528 million tons, 11.2% superior to the former crop. From this total amount, 87.4% (462 million tons) are produced at the Center-South region of Brazil and 12.5% in the northern and northeastern regions.

The occupied culture area is 6.6 hectares wide (7.4% wider than at the former crop). Sugarcane has been growing mainly in previous grazing areas. CONAB expects the current crop's average productivity to be of about 79,754 kg/ha (3.5% greater than the former one).

Considering 2005 figures, a comparison with other countries can be drawn as to offer a glance on Brazil's competitiveness regarding sugarcane production. Table 2 shows that

[1] In northeastern Brazil (Rio Grande do Norte, Paraíba,Pernambuco, and Bahia), the Zona da Mata (in Portuguese, "forest zone") refers to the narrow coastal plain between the Atlantic Ocean and the dry regions of the agreste and sertão.

[2] MINISTRY OF AGRICULTURE, LIVESTOCK AND FOOD SUPPLY (2007). *Balanço Nacional da Cana-de-Açúcar e Agroenergia – 2007.* Brasília: MAPA/SPAE.

[3] CONAB is a state owned company controlled by the Ministry of Agriculture Livestock and Food Supply in charge of government policy to ensure the production and supply of agricultural products.

[4] CONAB (2007). "*Acompanhamento da Safra Brasileira – Cana-de-Açúcar – Safra 2007/2008 – Primeiro Levantamento – Maio/2007"*.

Brazil was responsible for more than 30% of the sugarcane produced by the main producing countries in 2005.

Table 2: Main sugarcane producing countries – 2005

	Country	Sugarcane Production (thousend ton)	Crop area (thousend ha)	Productivity (ton/ha)
1	Brazil	422,926	5,794	72.99
2	India	232,300	3,602	64.49
3	China	87,768	1,361	64.49
4	Paquistan	47,244	967	48.86
5	Mexico	45,195	636	71.06
6	Thailand	43,665	1,097	39.80
7	Colombia	39,849	426	93.54
8	Australia	37,822	434	87.15
9	Indonesia	29,505	435	67.83
10	USA	25,308	373	67.85
11	South Africa	21,265	428	49.68
12	Philippines	20,795	369	56.36
13	Argentina	19,300	305	63.28
14	Guatemala	18,500	190	97.37
15	Egypt	17,091	135	126.60
16	Vietnam	14,731	266	55.38
17	Cuba	11,600	517	22.44
18	Venezuela	9,654	140	68.96
19	Sudan	7,186	70	102.66
20	Mianmar	6,937	401	17.30
21	Ecuador	6,834	94	72.70
22	Peru	6,765	62	109.11
23	Bangladesh	6,765	175	38.66
24	Honduras	5,625	76	74.01
25	Bolivia	5,112	108	47.33
26	Mauritius	4,984	68	73.29
27	Dominican Rep.	4,858	85	57.15
28	Kenya	4,801	57	84.23
29	Iran	4,723	55	85.87
30	El Salvador	4,405	54	81.57
31	Paraguai	3,820	74	51.62
32	Nicaragua	3,817	46	82.98
33	Costa Rica	3,616	48	75.33
34	Zimbabwe	3,290	43	76.51
35	Guiana	3,000	49	61.22
	Total	1,231,056	19,040	68.85 (average)

Source: Ministry of Agriculture, Livestock and Food Supply (2007)

Sugarcane is used as input to several industries, but mainly for sugar and ethanol production. CONAB indicates that 88.67% of the 2007/2008 sugarcane production will be designated to the sugar and ethanol industry – the remaining 11.33% (59.82 million tons) will be used for the production of "cachaça"[5]," animal food, seeds, "rapadura"[6], muscovado sugar and others.

From the 468 million tons of the 2007/2008 sugarcane crop that are being crushed in the sugar and ethanol industry, 49.47% will be used for sugar production and 50.53% for

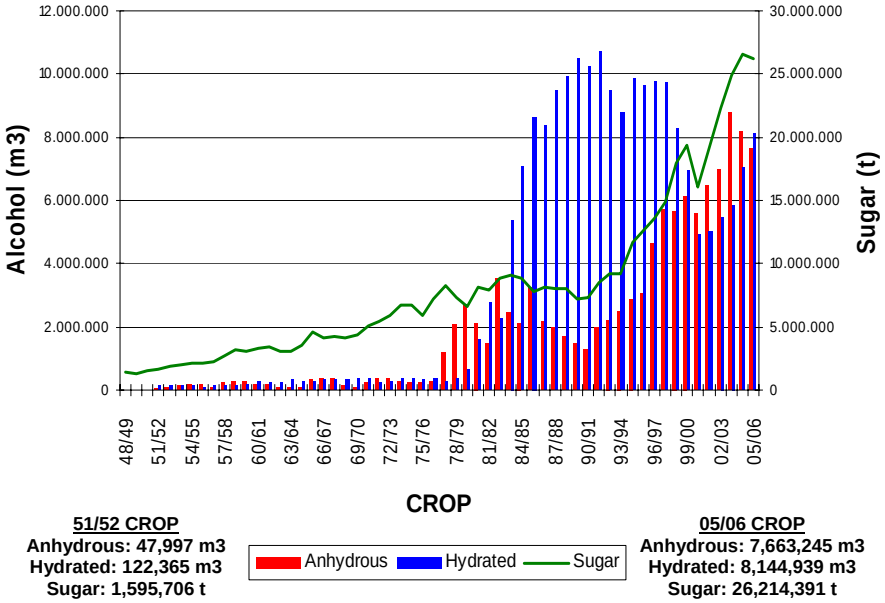
[5] "Cachaça" is the most popular distilled alcoholic beverage in Brazil.
[6] "Rapadura" is pure dried sugarcane juice, in the form of a brick.

ethanol production. The national sugar production is estimated to reach 31 million tons this year (3.6% greater than last year's) and ethanol production will be of 20 billion liters (14.54% greater than last year's). From the total production of ethanol, 46.73% will be of anhydrous alcohol and 53.11% of hydrated alcohol - both mainly used as fuels. According to UNICA (2007)[7], about 80% of the ethanol produced in Brazil is for fuel use, 5% for food, perfumery and chemical industries, and 15% for exports.

Anhydrous ethanol is used for gasoline "C" production – the only type of gasoline commercialized in the Brazilian national territory for automotive vehicles refueling. Fuel distribution companies acquire anhydrous ethanol at alcohol distillers and gasoline "A" (pure) at refineries, and mix both fuel in a proportion[8] that may vary between 20 and 25% of anhydrous alcohol.

Hydrated alcohol, on the other hand, is directly used in automotive vehicles refueling. This is the type of alcohol which may be bought by the consumers on the gas stations in Brazil. It may be used in ethanol-fired vehicles or in flex-fuel vehicles (these will be subject of further approach in this paper). Hydrated ethanol is available at almost all of the 29,000 service stations around the nation. The evolution of alcohol (anhydrous and hydrated) as well as of sugar production is represented in the following figure:

Figure 1: Evolution of alcohol and sugar production – by crop



Source: Ministry of Agriculture, Livestock and Food Supply (2007)

[7] ÚNICA (Sugarcane Industry Union) represents the sugar cane, sugar and alcohol business areas in the State of São Paulo.

[8] This is ruled by the Federal Law nº 8.723/1993 and by the Inter-ministerial Council for Sugar and Alcohol, established in 1997.

This production results from the operation of 320 industrial units, "*usinas*" [9], which differ significantly one from another considering their production capacity (from 0.60 to 6.0 Mt processed sugarcane a year). On the average, sugarcane is produced in the land owned by the *usina*, held by lease or through agricultural partnerships (ca. 70%); the remaining 30% is supplied by independent producers - about 45,000 - mainly through long term contracts (up to 10 years long).

Besides being bound to such contracts, the producer must also take other long term decisions: a sugarcane plantation has a useful life of about 5 to 7 years and, as mentioned in Table 1, a long growth cycle of 5 years. Thus, sugarcane production decisions must observe a long term planting plan.

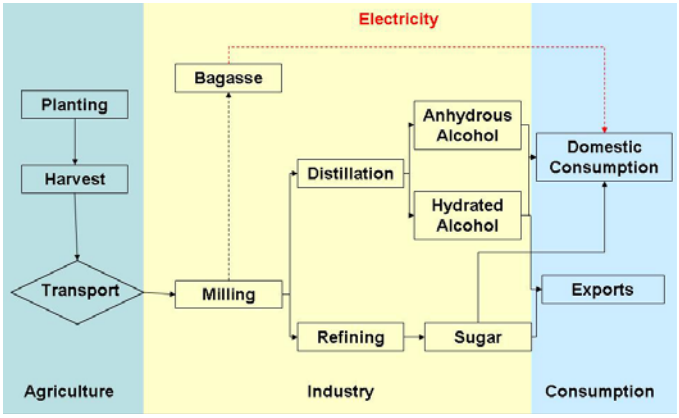
On the other hand, the producer must face issues typical of any agricultural activity, such as seasonality, unpredicted effects of climate changes, possible crop ruptures due to plagues or other factors and, depending on the product cultivated, exogenous market instability, given that a byproduct of the industry – sugar – is an internationally traded commodity.

Nevertheless, the producer must also cope with the flexibility of producing several goods with the same input: sugarcane (especially sugar, alcohol and electricity). Each year, the producer decides how much sugar and how much ethanol will be produced. The decision to supply sugar depends on its price (considering internal and external markets) and alcohol's as well as on sugar demand. Then again, the decision to supply ethanol depends both on the fuel market as well as on its relation to the sugarcane and sugar markets. The demand for hydrated ethanol, on the other hand, is a function of alcohol prices compared to gasoline, whose price in Brazil currently follows the international market. The availability of Flex Fuel Vehicles (FFV), which will be addressed later in this paper, turned consumers more price sensitive, as they may choose among any combination of both fuels (from 0% to 100% of each), which increases the influence of gasoline prices on the alcohol demand. The decision to produce anhydrous alcohol, on the other hand, is more stable as the mix of this fuel to gasoline in Brazil is determined by law. Last but not least, the producer must also decide how much of each type of alcohol he is willing to produce, and this decision must observe their relative prices and other variables like the vehicle fleet moved by each kind of fuel and fuel taxation policies.

Alcohol and sugar production system is represented in the following scheme:

[9] *Usina* is the name given to the industrial installation where transformation of sugarcane into products (mainly sugar and ethanol) and byproducts take place.

Figure 2: Alcohol and sugar production system



Source: JBIC (2006)

The scheme drawn by JBIC (2006) points out the recent role played by sugarcane bagasse. Bagasse is one of sugarcane's byproducts, as are also molasses, *vinhoto*[10], fusel oil, carbon dioxide, yeasts, filter tart, thermoplastic resins and energy cogeneration.

According to UNICA, the products and byproducts of the sugarcane industry are playing a more important role as sources of energy in Brazil. In 2006, ethanol accounted for 40% of the fuel burnt in automotive engines (Otto cycle) in Brazil. The Brazilian sugarcane industry generated as much as 11,3 TWh of electric and mechanic energy, mainly for self-consumption.

This characteristic of the sugarcane industry was emphasized by Macedo (2005), who points out that the production system has a big advantage in saving fossil energy. He summarized the system's global energy balance for ethanol[11] production in the following table:

[10] Byproduct used as fertilizer.
[11] According to the author, sugar production spends the same amount of energy but does not produce ethanol (energy) an output.

Table 3: System's global energy balance

	Average values (kcal/ t sugarcane)	
Sugarcane production (total)	**48,208**	
Agricultural processes	9,097	
Transport	10,261	
Fertilizers, inputs, seedlings, equipments	28,850	
Processing for ethanol production	**11,800**	
Electricity (bought)	0	
Chemical products, lubricants	1,520	
Buildings and facilities; equipments	10,280	
External Flows of Energy	Inputs	Production
Agriculture	48,208	0
Industry	11,800	0
Produced ethanol	0	459,100
Exceeding bagasse	0	40,300
Total	**60,008**	**499,400**
Renewable energy production/ Fossil inputs	8,3	

Source: Macedo (2005)

The sugarcane industry has a strong potential of energy supply growth, especially through the generation of electric energy. Excluding sucrose, the energy contained in one metric ton of sugarcane (straw added) is equivalent to 2/3 of the energy contained in one barrel of oil. This volume of biomass may be recovered for aprox. US$ 1/GJ[12]. Electricity production in this industry often results from cogeneration processes: sugarcane bagasse and straw are burned, producing heat and steam (in high pressure boilers). The steam than moves generators, producing electricity.

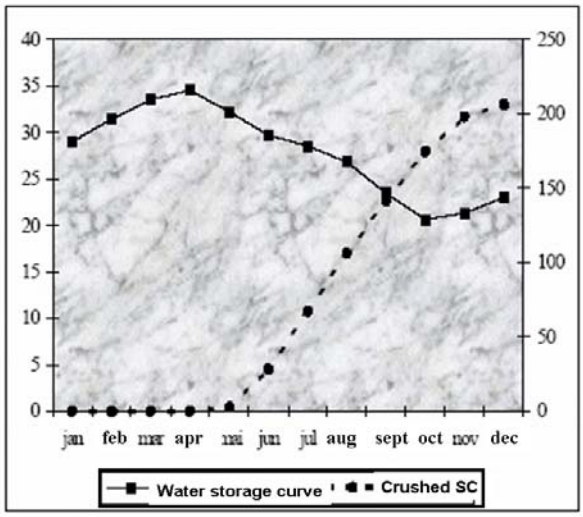
In fact, the electricity generated by the sugarcane industry in Brazil has not only been enough to cover the consumption of its industrial processes, but has also been sold to the grid. It is important to mention that electricity generation by the sugarcane industry has a special characteristic that fits very well to the functioning of the Brazilian Electricity Supply Industry (ESI): the seasonality of the sugarcane production. As reported by Souza (2002), sugarcane bagasse cannot be stored for long periods as it deteriorates because of the fermentation of organic matter and of residual sugars. In addition, there is a higher need of electricity to be supplied for the operation of the *usina* during the crop season. Therefore electricity generation by the sugarcane industry is limited to the crop season – which means for the Center-South region of Brazil the months from May to December.

On the other hand, this is the best timing for this energy to flow into the grid. Almost 85% of the Brazilian electricity supply is generated by hydropower plants which are located throughout the country and which depend on the storage capacity of large water reservoirs and on the rainy seasons (which vary, depending on the region). In the Center-South

[12] MACEDO, I. C. (2005). "Competitividade da agro-indústria brasileira da cana-de-açúcar" in *A Energia da Cana-de-Açúcar – Doze estudos sobre a agroindústria da cana-de-açúcar no Brasil e a sua sustentabilidade*. São Paulo: Berlendis & Vertecchia: ÚNICA – União da Agroindústria Canavieira do Estado de São Paulo.

region, the crop season coincides with the period of lower storage capacity at the Southeast / Center-West submarket[13], as may be seen in the following figure:

Figure 3: Storage Curve at the Southeast / Center-West Submarket (%) x Crushed Sugarcane in the Center-South Region (thousand tones, monthly average, 2001)



Source: Souza (2002)

Considering that the generation of electricity by the sugarcane industry reduces the expansion needs of the ESI, the government has recognized the relevance of this industry for the system and launched many initiatives in order to encourage the industry to invest in electricity generation.

The first initiative was the launching of PROINFA – an incentive program for renewable sources of power generation. Its creation was aimed at diversifying the generation matrix and guaranteeing the security of supply. PROINFA's goal was to promote the construction of 3,300 MW of installed capacity of small hydro plants, biomass-fired thermal plants and wind turbines by 2008. Investors benefited by the program were granted with long term power purchase agreements (PPAs) and, consequently, a predictable cash-flow. From the 144 projects granted with the PPAs, 30 have already started operation (809 MW).

The second initiative was the restructuring of the contracting framework set in place by the 2004 reform of the ESI. This reform is discussed in length at Araújo et al (2007), but the outputs related to the contracting of the electricity generated by the sugarcane industry may be summarized as follows:

The owner of a biomass-fired thermal plant must obtain an authorization at the Brazilian Electricity Regulatory Agency (ANEEL) in order to operate as a self-producer or as an independent power producer (PIE). As a self-producer, he may only produce electricity for self-consumption. As a PIE, on the other hand, he may produce electricity which can be

[13] The Brazilian interconnected system is divided into four submarkets (Southeast / Center-West; South; Northeast; and North), because of transmission restrictions that still exist among them. The great majority of the *usinas* of sugarcane at the Center-South region are connected to the grid at the Southeast / Center-West submarket.

partially or totally commercialized. The commercialization may occur in two different contracting environments[14]:

- In the regulated bi-lateral market (ACR): According to the recent Brazilian regulatory framework established by Law 10,848 of 15 March 2004, distribution utilities (DISCOS) must ensure that their market demand has full contract coverage by purchasing electric energy through public auctions conducted within ACR. DISCOS inform the government their contracting needs 5, 3 or 1 year prior to the energy delivery. The government organizes energy contracting auctions to contract the demand informed by the DISCOS - these form a pool which functions as a single buyer. The auctions are won by those generators (which include the PIE), which accept the lowest prices for long term PPAs.

- In the free-bilateral market (ACL) agents are free to make bilateral contracts, defining prices, quantities, durations and hedge clauses. Besides PIEs, ACL may comprise concession holding generators, free consumers, power traders and power importers.

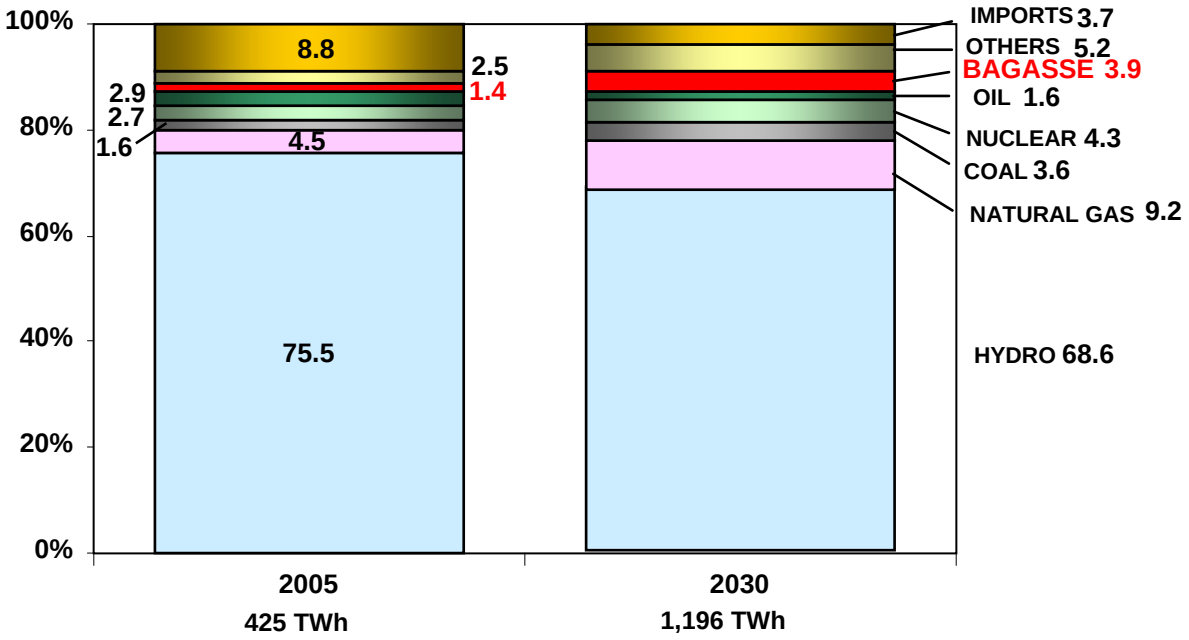
The third initiative refers to distributed generation[15]. In order to alleviate the requirement for transmission investments, distribution companies are allowed to contract energy from distributed generation plants. This must be done through public bidding directly promoted by the distribution utility, and may not exceed ten per cent of its load. As many bagasse-fired thermal plants are connected directly to the DISCOS' grids, many of them contract with DISCOS as distributed generators.

As a result of these measures, the importance of the sugarcane industry to the Brazilian power system is expected to grow in the next years, as shown in the following figure.

[14] More details can be obtained in COSTA, A. M., J. L. ARAÚJO, T. B. CORREIA and E. MELO (2007) Energy Contracting in Brazil. In *30th Conference of the International Association for Energy Economist*, Wellington, New Zealand.

[15] Article 14 of Decree 5163/2004 qualifies as distributed generation in Brazil the production of electric power from generation plants directed connected to the buyer's distribution system, except that from (I) hydropower plants with nameplate capacity above 30 MW; or (II) thermal power plants, including co-generation, with energy efficiency below 75%.

Figure 4: Electricity Supply – by source



Source: Ministry of Mines and Energy – Brazil

Last but not least, an important characteristic of the sugarcane industry is that it is based on an environmentally sound agricultural activity. As mentioned by the Brazilian Presidency Nucleus for Strategic Affairs (NAE)[16] , from the environmental point of view, this agricultural activity presents many benefits compared to others: the culture does not depend on irrigation; all industrial effluents, as well as vinasse, tart and ashes are recycled; biological control of plagues are used in large scale; and the use of mineral fertilizers and defensives has been reduced in the last decades. Programs for the reduction of sugarcane burnings are being implemented in production intensive regions,,and the same is expected to happen to spring water protection and water welling for industrial use. Experiments with transgenic seeds are also limited by law. Finally, it is important to mention that, according to the Brazilian Ministry of Agriculture, Livestock and Food Supply (2006), the Brazilian sugarcane industry shows a comparative advantage to other countries': new land may be incorporated to its activity without having to compete with food agriculture. For the moment, in Brazil, the area that still may be incorporated without having to displace food agriculture and without deforestation is of about 200 million hectares.

3. The PRÓALCOOL Experience

Focusing now on the purpose of this paper – the creation of a market for alcohol fuel – it is important to address the main promotion strategies for this fuel. The presentation of the sugarcane industry was necessary to enlighten the background of ethanol production, as

[16] BRAZILIAN PRESIDENCY NUCLEUS FOR STRATEGIC AFFAIRS – NAE (2005). *Cadernos NAE* – nº 2 (jan. 2005) - Brasília, DF.

the birth of the ethanol market cannot be separated from the development of the sugarcane industry, nor from interventionist policies implemented by several Brazilian governments in this industry until the late eighties.

Public interventionism in the industry was institutionalized after the overproduction crisis at the 1929/30 crop and the simultaneous great depression, which caused the ruin of many sugarcane producers and industrialists. Considering the relevance of this industry for the economic activity in Brazil, the government designed policies to maintain its organization and profitability. Facing the excess of sugar production compared to national consumption needs and the inevitable tendency of reduced world sugar production (and demand), the production of ethanol started to be considered as a viable alternative to the sugar industry.

In 1931 the government established the obligatory addition of 5% of anhydrous alcohol to gasoline. Most importantly, in 1933 the Sugar and Alcohol Institute (IAA) was created. Through the IAA the government controlled production and regulated exports (and imports) of both products, becoming responsible for the production cycle and commercialization, settling prices and quotas for production, exports and imports.

According to JBIC (2006), during the seventies the IAA launched three programs to promote the development of the sugarcane agro-industry: the Sugar Industry Rationalization Program; the Sugar Industry Support Program and the Sugar Industry Improvement Program. They emphasized the relevance of research and test for variety improvements, plague control, advances in cultivation techniques and in production plants. Brazil still benefits from the policies implemented back then: nowadays the industry counts on more than 500 varieties of sugarcane, which are simultaneously cultivated throughout the country.

But the major event that shaped the Brazilian ethanol market was the launching of the Alcohol National Program (PRÓALCOOL) in November 1975, as a response to the first oil crisis and to the consequent deterioration of the Brazilian trade balance. At first, PRÓALCOOL aimed at granting incentives to ethanol production of any kind: from sugarcane, cassava or any other raw material. The government wanted to stimulate the expansion of raw material supply - giving special emphasis to the growth of agricultural production, the extension and modernization of existing distillery plants and the installations of new producing units (connected to the existing *usinas* or autonomous ones) and of storage facilities.

PRÓALCOOL was divided into two phases (UNICA, 2007). In the first one, the government defined the localization criteria that should be observed for the installation of new distillery units and new storage facilities, established the annual program for each type of ethanol, specifying their use, and; decided about the framework system for proposals or projects of modernization, expansion or installation of new distillery units considering the program's goals. At that time, it was also decided that investments related to the program should be financed by the banking system - with lower interest rates than offered elsewhere in the market.

The government created also a pricing regulation scheme, in which it guaranteed a selling price to ethanol producers; these prices were subject to premiums or discounts according to technical specifications. And the government took also the leading role in guaranteeing the commercialization of fuel ethanol, as it draw up delivery programs to oil distribution

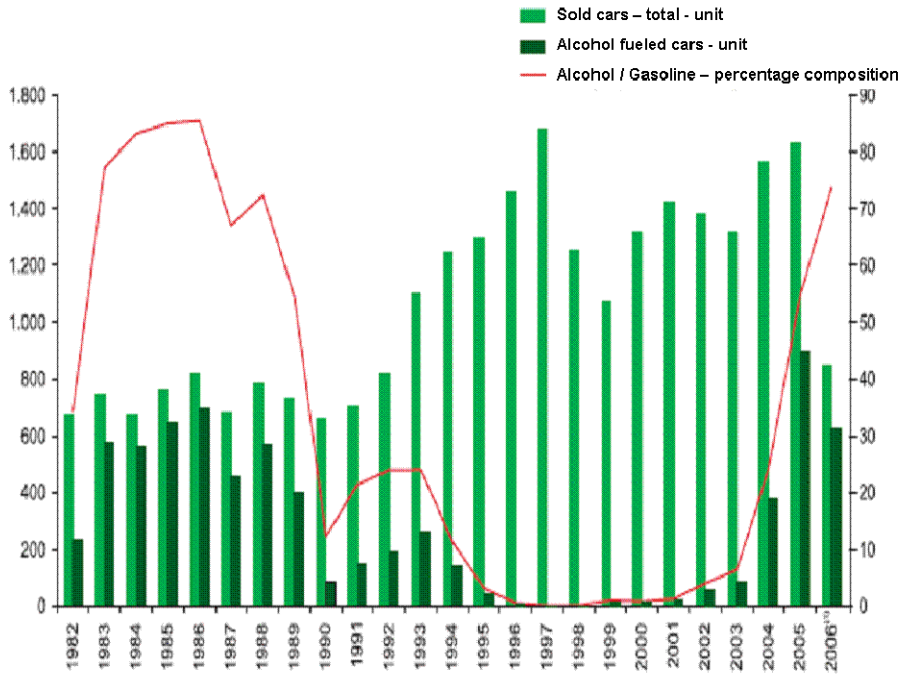
companies and/or consuming industries, which bought the product for yet another fixed price.

As a result of this first phase, fuel ethanol production was increased from 555 thousand cubic meters to 2,490 thousand cubic meters between 1975/76 and 1978/79 – most of it being used as addition to gasoline (2,095.9 thousand cubic meters of anhydrous ethanol).

Production expansion due to hydrated alcohol happened only after the second oil crisis - in the program's second phase, characterized by the commercialization of 100% ethanol-fired vehicles, which was the end product of a partnership created between the government and the automobile industry to favor the technological development of vehicles fired exclusively on ethanol.

In 1980 the federal government determined that alcohol should be sold at 60% of the gasoline price – establishing an advantageous price / calorific value parity. As a result, 90% of the new vehicles commercialized in Brazil from 1983 to 1988 were ethanol fueled (figure 5).

Figure 5: Light Cars: Turnover of Sold Cars - Fueled with Alcohol and with Gasoline C



Source: Morceli (2006)

Consequently, PRÓALCOOL became the major renewable energy program in the world, as it developed the ethanol market by congregating multiple incentives to the growth of installed capacity in agriculture, industry, infrastructure and storage facilities. On the demand side, lower prices for ethanol were guaranteed (comparing to its substitute - gasoline C price), an end use technology was developed and improved along the years,

and there were no bottlenecks in distribution of this fuel to its consumers as ethanol used the same distribution network as fossil fuels did.

The supply of ethanol to consumers at service stations also resulted from several interventionist policies along the supply chain. As mentioned by UNICA (2007), each year, considering the sugarcane production at that crop, the government decided how much of the alcohol production should be designated to the chemical industry as well as to fuel use (considering the demand for hydrated and anhydrous alcohol). Fuel ethanol was then sold to fuel distribution companies as well as to Petrobras (the Brazilian state owned oil company which also possessed a distribution company and a great number of service stations). Petrobras was also responsible for acquiring ethanol in order to form strategic safety stocks, which should be as great as the lowest levels of foreseen consumption volumes of anhydrous and hydrated alcohol for two months.

The financial resources required to cover operational costs, losses, storage, transport cost, financial immobilization costs of fuel ethanol stocks, including administration costs amounted to 2% of the product's acquisition price, and were granted to Petrobras through the Specific Price Portion (PPE) - a sort of tax levied on ethanol prices and, sometimes, on fossil fuel prices.

The policies related to PRÓALCOOL led to a quick implementation of new producing units and to a vertiginous growth in ethanol production - without meaning any harm to sugar production. Between 1980 and 1985, technological and learning processes were deepened. Productivity gains in agriculture and in the handling of sugarcane enabled a sensitive reduction of ethanol production costs. According to Goldemberg et all (2004, p. 302):

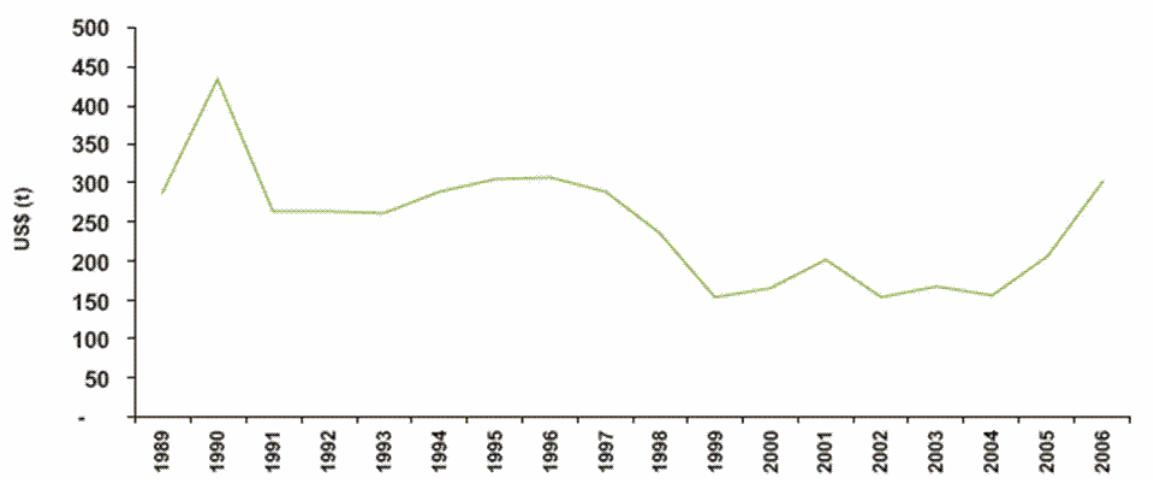
> "*During the initial phase, prices fell slowly reflecting the gains in agroindustrial yield and economies of scale captured by producers, and transferred to consumers through the pricing regulation scheme. After 1985, however, prices were set at levels below the average costs of production, while the federal government tried to curb inflation by controlling public prices, inclusive fuels. Due to this factor, together with economies of scales, the price fell much more rapidly (…) However, in the medium and long term, the high competition in the ethanol activity has caused the prices to move towards production costs."*

At the same time, there were also remarkable improvements in the ethanol fueled engines, raising the reliability of these new cars (Brazilian Ministry of Agriculture, Livestock and Food Supply, 2006). All of this resulted in, as highlighted by Morceli (2006), an ethanol peak production in the crop of 1991-1992: 228 million tons of sugarcane were produced, which meant an increment of 64.72% compared to the levels when ethanol production began (1979-80). Only 28.5% of the raw material was used for sugar production (8.7 million tons - meaning a 24.64% growth). As to alcohol production, anhydrous alcohol suffered from a 26.84% reduction while hydrated alcohol grew over 14 times - resulting in an increase of 248% in total alcohol production (cf. figure 1).

In 1986, however, oil prices started to fall abruptly, from an average greater that US$ 27.00/barrel in 1985 to less than US$ 14.00/barrel, making it no longer possible for the government to hold alcohol prices in such competitive levels. Nonetheless, hydrated alcohol consumption continued to grow until the early nineties, as mentioned before.

Furthermore, in 1990, international sugar price, unlike oil ones, reached unexpected high levels (figure 6), which contributed to shape the production decision of the *usineiros*[17] - raw material (sugarcane) were strongly reallocated to sugar production instead of ethanol (cf. figure 1) As a consequence fuel shortages service stations became usual in Brazil, deeming the consumers' confidence on the sugarcane industry and on ethanol as fuel. The response of the demand was quick: alcohol fueled car sales sank from 52.5% in 1989 to 11,55% (of total cars sold) in 1990 (cf. figure 5).

Figure 6: Average Export Price Evolution - Raw Sugar



Source: Ministry of Agriculture, Livestock and Food Supply (2007)

In order to avoid the collapse of the whole alcohol production structure, the government published a law raising the percentage of anhydrous ethanol added to gasoline to 22%. Ethanol sales continued to grow until 1997. From then on to 2000, however, the reduction in the hydrated alcohol production surpassed the growth of anhydrous alcohol consumption.

Nonetheless, as to the Brazilian trade balance, the developments in the sugarcane and automobile industries resulting from the PRÓALCOOL experience meant to the country savings of about US$ 43.5 billion in terms of reduction in oil imports.

4. The Recent Ethanol Market Development in Brazil

Since the promulgation of the Brazilian Federal Constitution in 1988, and coherently to liberalizing structural changes implemented throughout the world, the Brazilian Government has been reducing its interventionist role in the economy - and therefore also in the sugarcane industry. As reported by Costa (2003), among many liberalizing procedures in this industry the following should be highlighted:

- End of IAA: In May 1990, during the Administrative Reform led by President Collor's government, the IAA was extinguished. Some of its former assignments were at first allocated to other federal institutions but, finally,

[17] Owner of the *usinas.*

nowadays there is no such government body that plays the interventionist role played before by IAA. In 1997, however, the Inter-ministerial Sugar and Alcohol Council (CIMA) was created in order to analyze and propose policies related to the sugarcane industry. The Minister of Agriculture, Livestock and Food Supply is the president of the council, which also congregates representatives of other ministries (e.g. Mines and Energy; Environment; Economy; Science and Technology, among others) as well as sugarcane, ethanol and sugar producers. CIMA's currently most important decisions concern the changes of the proportion of anhydrous ethanol mixed into gasoline – to form gasoline C. Last change was done in June 2007, and settled the mixture at a 25% level. Concerning the regulation, supervision and inspection roles in the fuel market, these are played by the National Agency for Oil, Natural Gas and Biofuels (ANP). ANP is responsible for specifying the quality standard for fuel ethanol and regulating the activities of fuel distribution and reselling.

- End of the Annual Crop Planning: Since 1965, the federal government drew Annual Crop Plans, in which it fixed volumes for sugar and ethanol production and commercialization (including exportable surpluses and alcohol volumes designated to form safety stocks), product prices and taxation. In 1996, Law 9362/96 put an end to the requirement that economic agents must observe the amounts indicated by the Annual Crop Plan. The Plan's lack of purposed caused its 1997/98 edition to be the last one published.

- Liberalization of commercializing prices: To this point, it is important to mention that, since 1965, the IAA had been fixing the prices of sugarcane industry's products based on sugarcane and production costs. These costs were gathered by IAA's technicians all over the Brazilian territory and corroborated by an autonomous institute (Fundação Getúlio Vargas) to confer credibility to the research. These technical data collected by the IAA were then submitted to the Ministry of the Economy, which, however, constantly fixed the prices of sugarcane products below those calculated by the IAA, justified by an inflation control policy. Such practice resulted in a continuous flattening of the prices imposed to the industry and constituted the main reason for the large indebtedness carried by the industry against public and financial institutions. This situation changed when price liberalization of the sugarcane's products started in 1995 and ended in 1999; since then, producer may decide on their selling prices, which reflect their real production costs.

- Exports liberalization: Sugar and ethanol exports were strictly controlled by the IAA, which identified the amounts of exportable surpluses, fixed producers' return, and directly negotiated the selling of the products in the external market. Nowadays, sugar and alcohol exports are subordinated to normal free market conditions. The government still follows up sugar exports but does not interfere or unauthorized any exports of this product.

The sugarcane industry structure reacted to the recent changes implemented in its regulation. According to Belik and Vian (2002), there is an unquestionable movement of capital concentration/ centralization. As added by Shikida et all(2002), high indebtedness

levels, large fragmentation and stagnation of the sugarcane industry, sugar price increases in the crops of 2000 and 2001 and the newly implemented competitive environment contributed to the occurrence of mergers and acquisitions in this industry. These processes aimed at reducing costs by: integrating administrative structures, implementing a more professional administrative management of the *usinas*, benefiting from scale production, tax advantages and capitalization, and obtaining credit and financial landings for expansion and modernization investments. The authors verified 24 processes of M&A in this industry until 2004.

The presence of the Government as a coordinator of the industry was then substituted by newly constituted producers' cooperatives or associations, which are expected to compensate deficiencies observed in individual actions taken by the *usinas*. One of the most representative associations is UNICA (Sugarcane Industry Union), which represents the sugar cane, sugar and alcohol business areas in the State of São Paulo. UNICA is responsible for having developed in the year of 1999 a new system to share revenues among sugarcane and sugar and ethanol producers called CONSECANA. Producers were not obliged to adopt this system, but it became a common practice in the industry. CONSECANA divides the net revenue (excluded taxes) of sugar and ethanol commercialization among sugarcane suppliers and the industry (*usinas*). To attend this goal, it applies:

1. A technical method to evaluate the quality of the sugarcane delivered by the supplier, based on the quantity of contained sugars that may be used in the industrial processing;

2. Average production costs both in the agricultural and industrial activities;

3. Prices of the end products, sugar and ethanol, designated to the internal or international markets; and

4. Production and commercialization characteristics of each industry - which include quantities produced of sugar and ethanol and their end use (fuel, food, chemical industry, exports, etc).

According to UNICA (2007), at the present time, the proportion of the revenue distributed between sugarcane suppliers and industry is as follows:

1. For sugar: 59.5% to suppliers and 41.5% to the industry; and

2. For ethanol: 62.1% to suppliers and 37.9% to the industries.

Another relevant association is Copersucar (São Paulos's Sugarcane, Sugar and Alcohol Producers' Cooperative), which acts along the sugarcane supply chain, from plantation to commercialization. Copersucar commercializes its associates' sugar and alcohol production. Copersucar also plays an important role in research and development through Copersucar's Technological Center (CTC).

Regarding the commercialization instruments, Shikida et all (2002) also point out to the recent development of agents focused exclusively in logistics. Former traders - which most of the time faced a high financial risk, negotiated great volumes of products, provided producers with credit or with payments in advance, and borne prospection and market

development costs - evolved into logistics operators, providers of customized solutions, improving the use of infrastructure, enlarging geographical coverture, and enhancing operational flexibility, technological updating and scale. They do not act in negotiating nor in the production of the goods they commercialize - this is now done by the producers or by the associations with which they affiliate. It should also be stressed that traders are still important – but mainly to the commercialization of sugar. Regarding ethanol, *usina*s are obliged to commercialize their product through fuel distribution companies (except for exports). At present, there are ca. 500 distribution companies operating in the national territory.

As to the needs of strategic stocks -to guarantee supply when unpredicted events may influence the industry's outputs - the only initiative supported by the government since 2002 is the Financing Program of Alcohol Stocks. The total amount of resources designated to this purpose is of about U$ 250 million a year. This is funded through CIDE (a tax on fuels, later addressed in this paper) There is no other financing policy to support or subsidize neither sugarcane production nor sugar or ethanol production.

Concerning the availability of end use technologies, a determinant factor of fuel alcohol demand, it is important to mention that ethanol fueled car prices were at first controlled by the government, but the liberalization of these prices in December 1980 led them to rise, reducing the attractiveness of this technical option. Still, after the ethanol supply crisis of the early nineties, sales of this kind of car showed some recovery (totaling 25% in 1992 and 1993).

Nevertheless, the development of new technological standards in the late nineties and at the beginning of the following century finally put in check the 100% ethanol powered vehicle. As observed by Morceli (2006), the automobile industry concentrated its effort in developing a world concept of car - a car that could be produced anywhere in the world and exported to any country - this means, an engine fired by any type of gasoline C - as the proportion of alcohol or other additives to gasoline vary from country to country. The advent of the flex fuel vehicle (FFV) marked the decline of the 100% ethanol powered vehicle. At the same time, increasing international oil prices stimulated the development of the FFV as well as enabled fuel alcohol to recover its attractiveness compared to fossil fuels.

To the Brazilian consumer, this innovation meant flexibility in vehicle fueling which eliminated their exposure to fuel shortage risks. FFV were first commercialized in the Brazilian market in 2003 - in that year they accounted for 2.9% of the total light vehicles sold. In the year of 2006, 56.3%[18] of all light vehicles sold were FFV - produced by six different automobile companies installed in the country, which offer nowadays more than 52 FFV car models. The evolution of the Brazilian FFV Fleet is shown in the following table:

[18] ASSOCIAÇÃO NACIONAL DOS FABRICANTES DE VEÍCULOS AUTOMOTORES - ANFAVEA (2007). *Brazilian Automotive Industry Yearbook.*

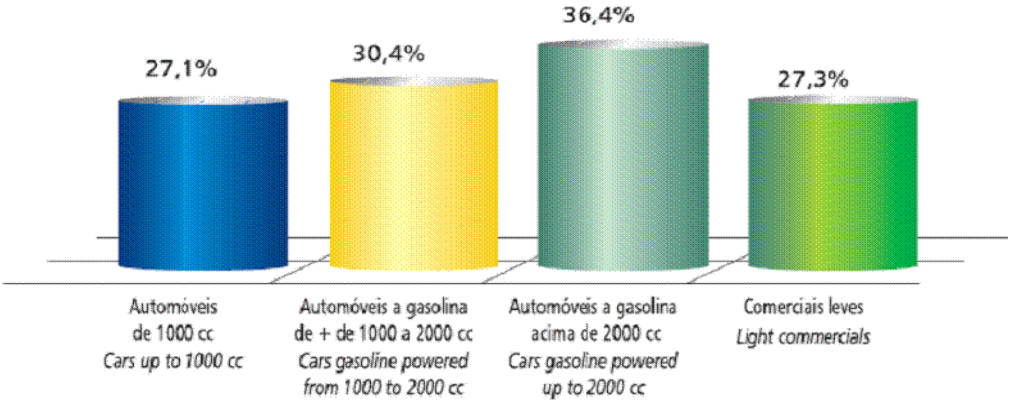
Table 4: FFV (cars and light vehicles) monthly sold in Brazil

Month	2003	2004	2005	2006	2007
Jan	0	13,123	27,439	91,526	121,859
Feb	0	15,654	29,700	93,000	118,134
Mar	26	17,457	40,031	114,961	155,549
Apr	3	23,626	44,955	95,595	146,443
Mai	1,343	22,821	55,633	118,701	167,689
Jun	2,492	27,387	69,221	108,570	
Jul	2,431	30,804	70,704	121,001	
Aug	3,642	31,422	82,173	130,734	
Sep	4,131	36,046	83,597	120,298	
Oct	8,687	30,776	86,294	133,263	
Nov	11,778	35,457	102,128	141,578	
Dec	13,645	43,805	120,229	161,107	
Annual	48,178	328,378	812,104	1,430,334	709,674
FFV Fleet					3,328,668

Source: ANFAVEA

Concerning the demand of FFV vehicles, it should be pointed out that there is a taxation policy which aims at stimulating the demand of less polluting vehicles in Brazil. Different taxation is applied to vehicles depending on their emission and fuel consumption levels. The following figure summarizes tax burden on light vehicles in Brazil.

Figure 7: Tax burden on light vehicles - Share in consumer prices – 2006



ANO YEAR	TRIBUTOS TAXES	AUTOMÓVEIS / CARS					COMERCIAIS LEVES LIGHT COMMER-CIALS
		1000 cc Gas/Álc/Flex fuel Gas/Eth/Flex fuel	+ de 1000 cc a 2000 cc More 1000 cc to 2000 cc		+ de 2000 cc More 2000 cc		
			Gasolina Gasoline	Álcool/Flex fuel Ethanol/Flex fuel	Gasolina Gasoline	Álcool/Flex fuel Ethanol/Flex fuel	
2002 e/and 2003	IPI	9,0	15,0	13,0	25,0	20,0	10,0
	ICMS	12,0	12,0	12,0	12,0	12,0	12,0
	PIS/Cofins [6]	8,26	8,26	8,26	8,26	8,26	8,26
	% no preço/Total share in price	25,7	29,0	27,9	34,2	31,7	26,0
2004 a/to 2006	IPI	7,0	13,0	11,0	25,0	18,0	8,0
	ICMS	12,0	12,0	12,0	12,0	12,0	12,0
	PIS/Cofins [7]	11,60	11,60	11,60	11,60	11,60	11,60
	% no preço/Total share in price	27,1	30,4	29,2	36,4	33,1	27,3

Source: ANFAVEA, 2007.

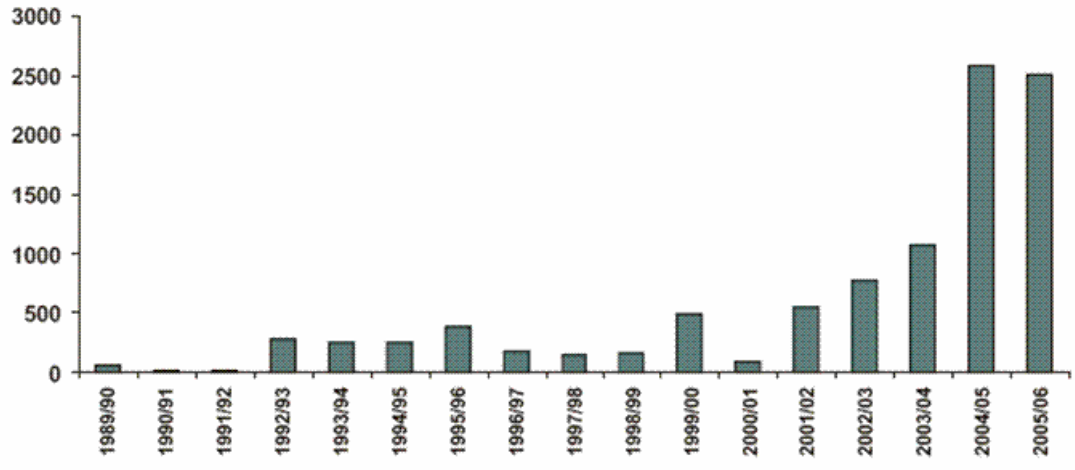
Still with respect to taxation policies, it should be stressed that the once imposed PPE was extinguished with the end of Petrobras' monopoly in the oil and gas industry in 1997. The resources collected through PPE (applied on fuels) were used to promote natural gas and its derivatives, oil derivatives and fuel alcohol. PPE was then substituted by CIDE.

5. Final Considerations

As argued by Goldemberg et all (2003), interventionist policies in the seventies and eighties created the basis of a very competitive renewable fuel industry, whose competitiveness was reinforced by the market liberalization in the nineties and in the beginning of the following century. Even so, the Brazilian ethanol industry may be characterized as a very recent one and therefore, the Brazilian experience, as a successful case study.

The growing number of automobiles in the world is currently responsible for about one quarter of global petroleum consumption (Goldemberg, 2006). Many countries are now aware of the consequences of greenhouse gases emission and the role played by the transportation sector. This is one of the reasons why Brazilian ethanol exports have been growing lately (figure 8). There are, however, other countries which have been implementing efforts into supporting the establishment of an ethanol industry in their territories as well. In 2006, for example, the USA produced more ethanol than Brazil (16.14 and 16.00 billion liters, respectively). The difference resides still in the competitiveness of sugarcane for ethanol production compared to other raw materials (table 5). In many countries, industries based on those depend on interventionist (e.g. subsidies) or protectionist (e.g. quotas) policies, or both.

Figure 8: Evolution of Brazilian alcohol exports (million liters)



Source: Ministry of Agriculture, Livestock and Food Supply (2007)

Table 5: Ethanol production costs

	US$/l	Raw Material
Brazil	**0.20**	**Sugarcane**
USA	**0.40**	**Corn**
EU	**0.60**	**Beet, Wheat**

Source: Brazilian Ministry of Agriculture, Livestock and Food Supply

Still quoting Goldemberg (2006):

> "*If ethanol from sugarcane were to replace 10% of the gasoline consumed in the world (34.7 million TJ in 2000, according to the IEA (2003)), carbon emissions would be reduced by 66 million tones (Ceq) per year. This is equivalent to approximately 1% of the world's emissions, or one fifth of the Kyoto Protocol target (IPCC 2001).*"

Undoubtedly, Brazil will take the lead in the development of an international ethanol market, but there is a recurrent concern by other countries when deciding whether they will add sugarcane ethanol to their gasoline or not. No one wants to depend on a single supplier, be it of fossil fuels or of ethanol.

Perhaps the most important role to be played by Brazil is disseminating the technologies developed related to sugarcane production (varieties, plague control, efficiency gains). One may identify in such international policy a chance to help developing industries in more needing countries, which, on the other hand, benefit from similar climate conditions as well as from vast land availability.

6. References

ASSOCIAÇÃO NACIONAL DOS FABRICANTES DE VEÍCULOS AUTOMOTORES - ANFAVEA (2007). *Brazilian Automotive Industry Yearbook*. São Paulo, SP. Brazil.

ARAÚJO, J. L. R. H.; COSTA, A. M. A.; CORREIA, T.; MELO, E. (2007), "Reform of the reforms in Brazil: Energy contracting and electricity prices", in Sioshansi, F. P. (ed.) *Electricity Market Reform: What Have We Learned? What Have We Gained?* (Elsevier, in print).

BELIK, W.; VIAN, C. E. F. (2002). "Desregulamentação Estatal e Novas Estratégias Competitivas da Agroindústria Canavieira em São Paulo" in *Agroindústria canavieira no Brasil: evolução, desenvolvimento e desafios*. São Paulo: Atlas.

BRAZILIAN PRESIDENCY NUCLEUS FOR STRATEGIC AFFAIRS – NAE (2005). *Cadernos NAE* – nº 2 (jan. 2005) - Brasília, DF, Brazil.

CONAB (2007). "*Acompanhamento da Safra Brasileira – Cana-de-Açúcar – Safra 2007/2008 – Primeiro Levantamento – Maio/2007*". Brasília, DF, Brazil.

COSTA, M. L. O. (2003). *Setor sucroalcooleiro: da rígida intervenção ao livre mercado*. São Paulo: Editora Método.

GOLDEMBERG, J. (2006). "The ethanol program in Brazil" in *Environmental Research Letters* 1 (October - December 2006).

GOLDEMBERG, J.; COELHO, S. T.; NASTARI, P. M.; LUCON, M. (2004). “Ethanol learning curve - the Brazilian experience” in *Biomass and Bioenergy* 26 - pp. 301 - 304. Elsevier.

JAPAN BANK FOR INTERNATIONAL COOPERATION – JBIC (2006). “*Estudo Prospectivos para Fomento dos Biocombustíveis no Brasil – Relatório Final*”. Brasília, DF, Brazil.

MACEDO, I. C. (2005). “Produção de energia pelo setor de cana-de-açúcar: substituição de combustíveis fósseis” in *A Energia da Cana-de-Açúcar – Doze estudos sobre a agroindústria da cana-de-açúcar no Brasil e a sua sustentabilidade*. São Paulo: Berlendis & Vertecchia: ÚNICA – União da Agroindústria Canavieira do Estado de São Paulo.

MACEDO, I. C. (2005). “Competitividade da agro-indústria brasileira da cana-de-açúcar” in *A Energia da Cana-de-Açúcar – Doze estudos sobre a agroindústria da cana-de-açúcar no Brasil e a sua sustentabilidade.* São Paulo: Berlendis & Vertecchia: ÚNICA – União da Agroindústria Canavieira do Estado de São Paulo.

MINISTRY OF AGRICULTURE, LIVESTOCK AND FOOD SUPPLY (2007). *Balanço Nacional da Cana-de-Açúcar e Agroenergia – 2007*. Brasília, DF: MAPA/SPAE.

MINISTRY OF AGRICULTURE, LIVESTOCK AND FOOD SUPPLY (2006). *Brazilian Agroenergy Plan 2006-2011* - Secretariat for Production and Agroenergy. - Brasília, DF: Embrapa Publishing House

MORCELI, P. (2006). “Futuro para o álcool brasileiro” in *Revista de Política Agrícola* - Ano XV - Nº 3 - Jul./Ago./Set. 2006 - Secretaria de Política Agrícola do Ministério da agricultura, Pecuária e Abastecimento, Brasília, DF.

SHIKIDA,P. F. A.; NEVES, M. F.; REZENDE, R. A. (2002). “Notas sobre Dinâmica Tecnológica e Agroindústria Canavieira no Brasil” in *Agroindústria canavieira no Brasil: evolução, desenvolvimento e desafios*. São Paulo: Atlas.

SOUZA, Z. J. (2002). “Evolução e Considerações sobre a Co-geração de Energia no Setor Sucroalcooleiro” in *Agroindústria canavieira no Brasil: evolução, desenvolvimento e desafios*. São Paulo: Atlas.

ÚNICA (2007). “*Produção e uso do Etanol combustível no Brasil – Respostas às questões mais freqüentes*”. São Paulo, SP, Brazil.