Abstract—A brief history of the Brazilian ethanol industry and its success is presented, such as, today the ethanol consumption for car's fuel supply is higher, cheaper and very much cleaner than the gasoline fuel. In continuation, some of the fallacious myths against the Brazilian sugarcane ethanol are refuted. The evolution of the Brazilian ethanol power industry is showed. Brazil has a potential of, at least, 25,000 MW of sugarcane bagasse and straw power plants installed capacity but great resistance for this distributed generation is provided by the power distribution utilities. Other obstacles like the cost of the connection to the electric grid and tariffs that do not reflect the real benefit of sugarcane biomass generation are presented. Regulatory acts and a green tariff are proposed.

Index Terms—Brazilian power sector, distributed generation, ethanol power industry, renewable energy, sugarcane ethanol power industry.

I. INTRODUCTION

Brazil is a privileged country in terms of sun, water and arable lands. Portuguese sailors discovered Brazil in the year 1500 and one of their first acts was to plant sugarcane. Sugar has been an integrated part of Brazil’s social, political and economic history ever since. Five centuries later, sugarcane is set for another quantum leap, this time to offer to the world a dual source of clean, renewable energy that produces both a biofuel and bioelectricity, at a moment when this is urgently needed. And the Brazilian sugarcane ethanol industry is a case of success: first solving, at that time, the dependence on imported oil, thought the production of an environmental cleaner fuel; and after providing distributed power generation, also cleaner than that supplied by traditional thermal plants. As from March 2008, ethanol consumption produced from sugarcane surpassed that of gasoline representing over 50% of the fuel used by light commercial vehicles in Brazil. Its production and use help reduce greenhouse gas emissions by up to 90% compared to gasoline. And this is happening without deforestation of adverse effects on food prices or supplies. It must be mentioned, also, that today 90% of the new cars are flex-fuel vehicles. Simply put, sugarcane ethanol is by far the most successful and efficient feedstock for the production of ethanol with existing technologies. It stands head and shoulders above alternatives like corn, wheat and sugarbeet in terms of energy and environmental balances, productivity and cost-effectiveness. As the global pioneer and leader in the successful large-scale production and use of ethanol and bioelectricity, Brazil’s sugarcane industry is now working to expand global production, use and open trade of ethanol.

So, in what concerns to a clean, renewable fuel, the sugarcane ethanol has a consolidated position. By other side, the sugarcane ethanol power industry has a long way to run. It have to fight against the following obstacles: the difficulties to connect those biomass power plan to the power grid due to the big resistance from the power distribution utilities; the lack of valorization – by the centralized power system planners - of all the benefits to have distributed power plants closer to the load centers and with an annual complementaridity in relation to the hydro power plants hydrology; the application of distorted tariffs; and the absence of consideration of the environmental benefits provided by then. Those obstacles do not incentive the sugar and ethanol producers to invest in more efficient cogeneration power plants.

II. BRIEF HISTORY OF THE BRAZILIAN ETHANOL INDUSTRY

A. A Clean, Renewable Fuel

In 1975, the Brazilian government launched its National Alcohol Program, known as Proalcool, which diversified the output of the sugar industry. Significant investments were made, with support from the World Bank, to allow for the expansion of areas cultivated with sugarcane and the introduction of ethanol distilleries. Amid the worldwide petroleum crisis, the experience helped reduce Brazil’s vulnerability and increase energy security.

Engineering advances following the second global oil crisis, in 1979, led to the development of engines powered strictly with hydrated ethanol. By 1984, automobiles equipped with “alcohol engines” accounted for 94.4% of overall production by major automakers established in Brazil.

After 1986, the lessened effects of the oil crisis combined with government economic plans designed to fight high inflation to cause a downward slide in the production of strictly ethanol-powered automobiles. This led to an ethanol supply crisis in 1989, and a plunge in the production of ethanol-powered vehicles, which fell to about 1% of all vehicles on the road by 2001.

B. Flex-Fuel: pure ethanol or mixed with gasoline

Falling demand for hydrated ethanol was compensated by
an increase in the use of anhydrous ethanol mixed with gasoline, thanks to the expansion of Brazil’s light vehicle fleet. By then, in 30 years of large scale use of ethanol, Brazil had developed engine technologies and distribution logistics that were unprecedented in the world. The network of fuelling stations in which pure ethanol could be purchased reached 28 thousand.

In March of 2003, Flex-Fuel vehicles were introduced. These could run on ethanol, gasoline or any mixture of the two, thanks to technology that could identify the precise fuel mixture in the tank at any given time, and adjust engine performance to match. The novelty led to a new wave of growth in the sugarcane industry, which was helped along by concerns surrounding the availability and cost of fossil fuels and growing fears about the environment and global warming. All of these combined to make ethanol an increasingly viable and important renewable fuel alternative, for Brazil and the world.

C. Sugarcane today

As of late 2007, sugarcane fields occupied about 7.8 million hectares in Brazil, or about 2% of all arable lands available in the country. This makes Brazil the number one producer of sugarcane in the world, followed by India, Thailand and Australia. Main production region are South-Central Brazil, where close to 90% of overall production is concentrated, and the Northeast, which accounts for the remainder. There are two harvests per year, which allows Brazil to produce sugar and ethanol year round for both the internal market and for export.

With the end of government involvement in the sector in the late 1990s, free market rules became the norm, without subsidies. Sugar and ethanol prices have since been set according to supply and demand variations, while sugarcane prices became hinged on quality and percentage share in the finished products.

To properly manage and balance both production and demands from within the sector, the industry has sought to create market instruments, such as futures trading, while developing new opportunities for both sugar and ethanol through the removal of protectionist barriers. The industry is also heavily involved in efforts to develop standards for ethanol, as a first step to make it a globally tradable environmental commodity.

III. BRAZILIAN SUGARCANE ETHANOL - FALLACIOUS MYTHS VS. FACTS

A. Myth # 1: Deforestation of the Amazon Rainforest

A first myth is that the Brazilian sugarcane ethanol leads to the deforestation of the Amazon rainforest.

The fact is that most sugarcane for ethanol production (90%) is harvested in South-Central Brazil, over 2,500 km (1,550 miles) from the Amazon (See Fig. 1). The remainder (10%) is grown in Northeastern Brazil, about the same distance from the easternmost fringe. This is roughly the distance between Montreal and Vancouver or between Paris and Moscow. There is a very tiny production of sugarcane in the Amazon (less than .2% of the Brazilian total production) that is processed at four mills that were built more than 20 years ago at a time when the government provided fiscal incentives to set up industries in this region to supply the local market. Without subsides these mills would not have been economically viable since the Amazon region does not offer favorable conditions for commercial sugarcane production. For this reason, future expansion is anticipated to continue in South-Central Brazil, primarily in degraded pastures.¹

B. Myth # 2: Displacement of Other Agricultural Activities

A second myth is that sugarcane expansion displaces other agricultural activities into the rainforest.

The fact is that, according to the Brazilian Institute of Spatial Research (INPE), about 65% of recent sugarcane expansion took place on pastures, mostly degraded, in the Central-South of the country. As such, growing sugarcane in these areas do not increase competition for land or displace other crops. Amazon deforestation, which has been going on for many decades, has been caused by a complex set of social and economic factors completely unrelated to the expansion of the Brazilian sugarcane industry. One of the main issues is the absence of clear land titles that leaves the region exposed to rampant land speculation and squatters.

C. Myth # 3: Detrimentation of Food Production and Prices

A third myth is that Brazil is being overrun by sugarcane in detriment of food production and prices.

The fact is that sugarcane for ethanol production in Brazil occupies 3.4 million hectares, or roughly 1% of the country’s 355 million hectares of arable farmlands. The cultivated area is 1/4th of that dedicated to corn, 1/8th of the area planted with soybeans and 1/60th of the land used for cattle farming. With only 1% of its arable land dedicated to sugarcane for ethanol production, Brazil has been able to replace half of its gasoline needs with sugarcane ethanol. While cane production has increased steadily in recent years, food production in Brazil has grown dramatically without any price increases. The 2007 grain and oilseed harvest set a record at 142 million metric tons, a doubling of production in the last ten years. Brazil is

¹ UNICA – Brazilian Sugarcane Industry Association
widely recognized for its diversity and highly efficient agricultural sector – it is the world’s leading exporter of beef, coffee, orange juice, poultry, soybeans and sugar.

D. Myth # 4: More Environment’s Damage than Fossil Fuels

A fourth myth is that ethanol production and use can cause more damage to the environment that of fossil fuels.

The fact is that claims that ethanol production could actually increase carbon emissions compared with fossil fuels are flawed. The basis for such assumptions lack transparency and lead to absurd conclusion that dwindling fossil fuels are better to the environment. Brazilian ethanol produced from sugarcane reduces greenhouse gas emissions by up 90% compared to gasoline, a reduction unmatched by any other biofuel produced by existing technology. This positive balance is not affected by changes in land use. In fact, when compared to crops such as corn or soybeans, sugarcane captures more carbon because it is a unique semi-perennial crop replanted every six years. In addition, the use of degraded pastures – the expansion area of choice for sugarcane in Brazil – actually generates a carbon credit, as sugarcane captures significantly larger amounts of carbon than the quantities originally stocked in this type of land. In addition, the by-products of sugarcane ethanol production (bagasse and straw) are used to produce clean, renewable electricity, currently accounting for 3% Brazil’s power needs and expected to reach 15% by 2015.

E. Myth # 5: Consumes Less Energy than Generates

A fifth myth is that ethanol production consumes more energy than it generates.

The fact is that, when the entire process is considered, from the planting of sugarcane to the use of ethanol as a motor vehicle fuel in what is known as a well-to-tank analysis, sugarcane produces 9.3 units of clean, renewable fuel for every unit of fossil energy utilized. Ethanol produced from other feedstock such as sugarbeet, cereals and grains (corn, barley, wheat, etc.) have between 1/1 and 2/1 ratio today (See Table 1).

F. Myth # 6: No Price Reductions When Added to Gasoline

A sixth myth is that gasoline prices in Brazil are not reduced by the use of ethanol.

The fact is that added to gasoline, ethanol is a key factor to keep fuel prices competitive and more affordable. Recent studies have shown that if ethanol were entirely removed from the fuel supply, gasoline prices in Brazil would rise by 15-30% at the pump. Used as an additive, ethanol is not only an effective fuel extender which makes gasoline supplies last longer, but also an octane booster.

G. Myth # 7: Only Brazil Can Benefit

A seventh myth is that sugarcane ethanol is a unique solution that only Brazil can benefit.

The fact is that more than 100 countries grow sugarcane and most could produce and use ethanol, repeating Brazil’s successful experience. The potential for expansion is impressive. According to FAO, only 10% of the world 200 million hectares (excluding forest and protected areas) available and suitable for sugarcane production are actually used. Most sugarcane producing countries are tropical, developing countries that would benefit from an opportunity for significant economic development. Ethanol production and use creates jobs, fosters development of new technologies, allows for the introduction of cheap renewable electricity in rural areas, cut down on oil imports and provides new export opportunities. Ethanol production in 100 countries would also enhance energy security by reducing the world reliance on only 20 oil producing countries.

IV. BRAZILIAN ETHANOL POWER INDUSTRY

A. Brazilian Sugarcane Biomass Fuels: Bagasse and Straw

Bioelectricity may well be the most significant area for Brazil’s sugarcane industry and one can spark another revolution on the scale of ethanol. Bioelectricity is produced by burning bagasse, the dry, fibrous waste that is left after sugarcane has been processed. This already happens in almost all Brazilian sugarcane mills and ethanol distilleries, but much more energy could be produced if the bagasse as well as the sugarcane straw – the tops and leaves of stalks – were to be burned in high-efficiency boilers. Much of the approximately two thirds of the sugarcane’s theoretical total energy potential, contained in the bagasse and straw, remains unharvested. Sugarcane energy is concentrated roughly one third in juice, one third in bagasse and one third in straw. Until recently the juice has been used to produce sugar and ethanol while the most of the bagasse has been burned in low-efficiency boilers to produce steam and generates bioelectricity to cover only the plant’s own needs. With hydrolysis technologies now under development, it will be possible to produce additional ethanol from bagasse and straw, while the lignin that remains will also be used as biomass to generate additional bioelectricity.

B. The Bioelectricity in Brazil

Brazil is increasingly turning to alternative power generation fuels such as biomass in order to increase power supply and reduce its dependence on hydropower. Biomass power represents around 4.1 percent of the total installed capacity in Brazil at present and most biomass cogeneration is based on sugarcane bagasse. At present, sugarcane bagasse cogeneration accounts for 3.03 percent of the total Brazilian energy matrix.

New analysis reveals that the market reached 3.0 GW in 2007 and expects to reach 12.2 GW in 2014.

The Brazilian sugar and alcohol sector envisages to market
electricity surplus to the national grid. In order to produce marketable amounts of electricity, the sector is expected to invest in new technologies, including cogeneration equipment. There is a clear trend toward the implementation of boilers with higher steam-production capacity. New boilers and steam turbines with higher capacity and efficiency would substantially increase the electricity surplus the mills would be able to sell.

C. Obstacles to the Ethanol Power Industry Expansion

Unattractive prices are discouraging companies looking to sell their excess electricity to the national grid. Brazilian sugar and alcohol plants produce around 95% of their electricity needs, purchasing the remaining 5% from national-grade transmission and distribution (GT&D) companies. Plants claim that the prices they pay to those companies for this additional power are several times higher than the prices paid by GT&Ds for the plants’ electricity surplus.

Another significant restraint for the cogeneration market is the lack of connection to the grid. In addressing this, many sugarcane cogeneration plants are working on building generation distributive center units that will collectively transmit electricity cogenerated in the mills and input it into the grid.

Structured tax and financial policies would serve as a driver for the expansion of sugarcane bagasse cogeneration technologies. Government and related regulatory agencies should develop clear planning and regulatory structures in order to boost cogeneration capacities in sugar mills. This includes the easy and efficient connection to the grid, and the establishment of fair prices to pay back the high investments of the mills.

V. CONCLUSIONS AND PERSPECTIVES

As already said, the Brazilian sugarcane ethanol industry is a case of success. There are innovations in all areas.

In terms of transportation, the Brazilian automotive industry is now selling the “second-generation” of flex-fuel cars that do not more need a little separated tank for gasoline that was used to start the vehicle in very cold days.

Current technology for production of ethanol from biomass relies on processes of fermentation and distillation and requires feedstocks that contain sucrose (sugarcane, sugar beet, etc.) or starch (corn, wheat, cassava, potato, etc.). Global demand for alternative, sustained fuel sources has created the need to experiment with new feedstocks and develop innovative processes for the production of ethanol. Generally speaking, “second-generation” biofuels are those produced from cellulosic and hemicelluloses, which can be found in agricultural and forestry residues as well as organic wastes. There are others emerging processes, such as gasification, that may be able to produce hydrocarbons from biomass feedstocks such as sugarcane bagasse.

Research into hydrolysis technology is advancing quite rapidly in many countries and that second-generation ethanol will become viable within the next five years. In Brazil, sugarcane and bagasse are particularly attractive as feedstocks for the production of second-generation ethanol because they would allow for increased fuel production without expanding cultivated areas.

Conservative estimates indicate that hydrolysis has the potential to increase ethanol production by around 40 liters per ton of sugarcane, raising the current average of 85 liters per ton of sugarcane in South-Central Brazil to around 125 l/t. By 2020, the introduction of second-generation ethanol, together with new varieties of sugarcane, should allow for continued growth of production without further expansion of planted area.

For centuries, sugarcane fields around the world have been burned before cutting to facilitate the manual harvest. New technology to mechanize the harvest with considerable efficiency gains is now in place. In an effort to gradually phase out manual cutting, more than 130 sugar and alcohol mills have subscribed a “Green Protocol” with the São Paulo State Government. This calls for the eradication of pre-harvest burning by 2014 in areas where harvesting can be mechanized and by 2017 where mechanization is currently not feasible – for example, where the cane is planted on steep slopes. With the harvest fully mechanized, the straw will no longer be wasted. Instead, it will be collected and burned along with the bagasse in high efficient boilers (more than 60 bars), thus allowing a growing number of sugar and ethanol plants to sell their surplus bioelectricity to the national grid. At the start of the 2008/2009 harvest, about 50% of the sugarcane harvest in São Paulo State was already mechanized.

The possibility of generating surplus power has been under consideration by the Brazilian sugar/ethanol mills for many years, but several factors have hindered the realization of the potential. Changes in the regulatory framework and privatization of the power sector have changed the background towards more favorable conditions to generate and sell electricity. This has created a new surge of interest among the mills and several projects are being developed contemplating small- to medium size systems for surplus power generation during the crushing season. Larger systems with more than 100 kWh/t cane to be injected in the grid, operating the year round, will require fuel supplementary to bagasse. Countries or areas that have installed such larger systems, such as Mauritius, Reunion, Guadaloupe and Hawaii, are using fossil fuel for the off-season operation. In Brazil, it has been implemented the use of straw as a supplementary fuel to increase the power generation capacity of mills.

Bioelectricity is power generation having vegetable biomass as fuel. For the sugar and ethanol sector this normally means cogeneration – producing two types of energy, thermal and mechanical – using just one fuel, the biomass (bagasse and/or sugarcane straw) as the primary energy source. With current technology, Brazil sugarcane sector has the installed capacity to generate 1,800 average megawatts (MW/year) in 2007/2008. Bearing in mind that industry estimates for 2020/2021 indicate a sugarcane harvest of one billion ton, the bioelectricity from bagasse should then be 7,600 MW/year, reaching 14,400 MW/year when both bagasse and straw become available thanks to mechanical harvesting. Even
greater amount of energy could be generated if the sugar and ethanol producers receive a fair tariff that would give incentive to implement combined-cycle plants, as the example that can be seen in Fig. 2 bellow.

![Crisciomal - New Cogeneration Plant Project](image)

More efficient power generation can be obtained by the use of the existing technology of condensing/extraction steam turbine (CEST) or the advanced technology of biomass integrated gasification/gas turbine (BIG/GT).

Generating bioelectricity offers numerous benefits: the environment impact is low and producers can obtain carbon credits, while project are relatively small. This means reduced risks, in particular of the kind that frequently cause construction delays in large-scale hydroelectric projects. Moreover, bagasse and straw cogeneration represents a boost for the Brazilian equipment industry and creates numerous jobs, while drawing on know-how developed over many years of cogeneration for internal consumption and at sugar and ethanol plants.

Bioelectricity from sugarcane is a particularly interesting for Brazil because so much of the country’s generation comes from large hydroelectric power plants far away from the load centers. The sugarcane harvesting period, when the most biomass is available, coincides with the dry season when hydroelectric power plants sometimes has to reduce the production in order to avoid big depletion on the reservoirs. This makes the two sources of electricity complementary. In addition, the majority of sugar/ethanol mills are located fairly close to the most populous region of Brazil, where the power load is the highest.

VI. RECOMMENDATIONS

After the comprehensive analysis done in the previous items, the authors make the following recommendations in order to minimize the bottlenecks of the sugarcane power generation expansion in Brazil:

1. Share with the distribution companies the costs for the interconnection of the sugar/ethanol power plants into the national power grid.
2. Accelerate the process of the sugarcane harvesting mechanization in order to maximize the availability of sugarcane bagasse and straw to be used in high efficient boilers (more than 60 bars).
3. Improve the carbon credit certification process for the biomass power generation thought the utilization of sugarcane bagasse and straw.
4. Implement combined-cycle plants to increase the efficiency and output of sugar/ethanol power stations.
5. Implement the existing technology of condensing/extraction steam turbine (CEST) or the advanced technology of biomass integrated gasification/gas turbine (BIG/GT).
6. Reformulate completely the criteria of the centralized Brazilian power system expansion planning studies in order to consider, by one side, the benefits of the annual power generation complementation between the hydroelecric and the sugar/ethanol power plants; and, by other side, the benefit of the location of those distributed biomass power generation close to the load centers. The COGEN/SP is developing technical and economic studies to explore the positive externalities of the bioelectricity, which is produced in the dry periods, and so, in complement to the base hydroelectric energy that is produced in the yet period. Studies from the Brazilian National System Operator indicate that each 1,000 MWa of bioelectricity in the Southeastern Region correspond to add more 4% of water in the reservoirs. Furthermore, the COGEN/SP studies should include the benefits of investments reduction (or even avoid) on the transmission and/or distribution grids, which are overloaded, with the injection of sugarcane ethanol distributed power plants close to the load centers. And also the environmental benefits in the referred studies are been considered.
7. Reformulate completely the criteria of definition of the tariffs by the centralized Brazilian power system expansion planner that privileges diesel and oil thermal power plants in detriment to the biomass power plants.
8. Create a special “green tariff” that considers all the environmental benefits provided by the sugarcane ethanol power plants in comparison with the greenhouse gas emissions of the fossil fuel power plants. So, as the European legislation example, the “green tariff” would be a price composition that considers the benefits of the complementarities, of the losses reduction and of the environmental gains.

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2 COGEN/SP – Paulista Association of Cogeneration
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