Recent Advances of Sugarcane Biomass Cogeneration in Brazil

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***Abstract*— the integrated sugar/ethanol/electricity production has launched a new business model – the bioelectricity industry – with a potential to become a "mainstream" energy supply option in the near future in Brazil. Besides being clean, the bioelectricity plants have been winning several hundred MWs in long-term contracts auctioned by distribution companies under the Brazilian power sector framework. These contracts have been awarded on a competitive basis, without any subsidy policy. In addition, bioelectricity plants comply with the requirements of the CDM for selling emission reduction credits. The objective of this work is to discuss the bioelectricity achievements in Brazil.**

***Index Terms*-- Power system economics, power system planning, clean energy, carbon trading.**

I. Introduction

THe need to ensure generation adequacy forms the backbone of electricity markets. The availability of coal and gas reserves and the increase their international trading have made fossil-fuel energy resources (such has coal-fired, gas-fired and oil-fired power plants) key resources in assuring the security of supply worldwide.

Also during the last decades, the consequent (direct) connection between the greenhouse gases[1] in the electricity generation and the increase of the average earth's temperature (global warming) has become a consensus of the scientific community for years [1]. It is also a consensus that the warming effect may be catastrophic for the poorest regions of the planet within decades (nor centuries, as imagined earlier), as the evidences presented by the Intergovernmental Panel on Climate Change (IPCC). As in the security for electricity supply, coal and oil has a central role in the climate question. In the case of oil, this is due to the fact that gasoline and diesel are responsible for almost 100% of the energy consumed in the transportation sector, which in turn contributes with almost 25% of the total emissions of industrialized countries. In the case of coal, it is well known that many industrialized countries are based on coal-fired energy resources.

In this sense, the substitution of fossil fuels by clean energy (such as wind, solar and biofuels) has become very attractive recently, with many countries offering incentive programs for its development[2]. Because some of these programs are based on explicit subsidies, they have been criticized on the grounds of its economic rationale and lack of economic signals for efficiency and technological improvement.

In the case of biofuels, mainly ethanol and biodiesel, a less known facet is its integrated development process, consisting of a multi-commodity business that can generate synergies and develop clean-energy programs on a competitive basis. The Brazilian sugar/ethanol industry is a good example. Ethanol and sugar are produced from sugarcane. As a byproduct of the production process, the sugarcane biomass (waste) is used for electricity cogeneration (*cogen*) (mainly) for self-consumption. Any surplus power is sold to distribution companies. Brazil's sugar/ethanol plants generates to the grid today (2008) more than 3,000 MW during sugar cane harvest.

With the increasing development of ethanol production, more efficient boilers being ordered for the new ethanol plants and more surplus power is becoming available to be sold to the electricity market. Besides, recent changes in the electricity market design [2] have allowed biomass plants to compete for long-term firm energy contracts in the supply auctions carried out yearly by distribution companies. In this framework the cogen from sugarcane biomass (known as *bioelectricity*), has become very competitive [3] (the cogen has a low investment cost – just the incremental cost of installing a more efficient boiler for the ethanol plants) and share additional gains, such as: (a) harvest location close to load centers, implying in reduction in transmission losses and tariffs; (b) full complementarity with hydro resources and (c) possibility to receive carbon credits as clean developed projects. Therefore, bioelectricity plants have been displacing "mainstream" technologies, such as hydroelectric power, combined cycle natural gas and coal-fired plants, in the contracts auctions.

Reference [4] discussed the bioelectricity developments and achievements in Brazil in greater details. We refer the reader to this reference for details on the Brazilian sugarcane and ethanol industries as well as on the details of the developments of the cogeneration of sugarcane biomass.

The objective of this work is to describe the recent (after

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[1] The main GHG are CO_2 and CH_4

[2] For example, wind power being strongly developed in Germany & Denmark; the EU has launched directives on the increase of clean energy in the participant countries, etc.

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2007) advances of sugarcane biomass cogen in Brazil. This work is organized as follows: Section II presents an overview of the general world energy security and environment challenges, Section III discusses the role of biofuels, with Section IV describing the key aspects of the ethanol industry in Brazil. The bioelectricity program is described in Section V and Section VI draws the conclusions and perspectives for this industry.

II. Bioelectricity: Background

Sugar and ethanol production require both steam and electric power, which are produced through the combustion of bagasse, the sugarcane residue after crushing for syrup extraction. This use of bagasse as a fuel opens immediately the possibility of producing and selling electric energy surpluses, e.g. by the use of more efficient (higher pressure / temperature) boilers.

This cogeneration opportunity is of course not new. Today, there are more than 3,000 MW is genetrated to the grid during the harvest period. However, most existing ethanol/sugar plants still employ inefficient boilers, and as a result have no surpluses.

According to producers, this relative lack of interest in cogeneration results from past experiences that were not encouraging. The first problem pointed out was the presence of a single purchaser, the electric power distribution utility (disco) in the producer's area. This gave the local disco the leverage to impose energy prices that were below the market.

The second obstacle is related to seasonality of production: there are surpluses only during the harvest period, from May to November. The discos argued that this seasonal energy was not "firm" – i.e. able to support a constant consumption throughout the year – and therefore offered prices that were lower than those paid to "mainstream" generators such as hydroelectric and natural gas-fired plants.

The third factor is that many small-size producers did not have the required knowledge about the electricity business to negotiate with electric power utilities.

Discos, in turn, also had some complaints against the producers, generally related to failures to comply with energy supply agreements.

In 2002 the Federal Government instituted the Proinfa[3] program, aimed at producers of renewable energy. This program provided for the compulsory acquisition of 3,300 MW of power, of which 1,100 MW should come from biomass. Contracts were awarded to projects by order of issue date of the Installation (environmental) License, with a limit for 20% of capacity (220 MW) for each state. The program established a ceiling price for each source of energy, and in the case of sugar cane cogeneration this price was below the market price for electric power, which discouraged producers from participating. As a result, only 685 MW of biomass plants applied for Proinfa contracts.

As will be seen in the next session, the new power sector law solved many of the issues that held back sugarcane cogeneration, opening the way for it to become a "mainstream" energy option.

III. The new power sector regulation

The new electricity sector regulation, approved by the Brazilian Congress in 2004 [2], removed several of the above mentioned barriers:

(i) The firm production capacity of any generation technology is now calculated on the basis of the *average* energy production along the year. As a consequence, seasonality of production is no longer an issue for sugarcane biomass cogeneration[4]. The reason this can be done is that Brazil's hydroelectric plants, which account for 85% of the country's generation capacity, have large reservoirs and can easily modulate any seasonal production.

(ii) Discos can only contract energy through country-wide contract auctions, carried out every year. Any generator may participate in these auctions, regardless of location.

(iii) Generation contracts are long-term (15 years) and fairly simple: the producers receive a fixed payment for their availability plus a compensation for the operating cost when they produce. These contracts are offered three or five years ahead of actual production, thus allowing time for the plant to be built after if it wins the auction.

Rule (i) prevents the "discrimination" against plants with seasonal production, since it allows them to be contracted on the same basis as all other sources. In turn, rule (ii) eliminates the leverage power of local discos, allowing biomass to contract with all discos. Finally, rule (iii) allows the participation of smaller producers: the new contracting scheme reduces investor risks and makes project finance easier. The same contracting rule alleviates the discos' concerns regarding energy production reliability: the producer obligations are clearly spelled in the contracts, together with penalties in case of failure.

There have been several auction for "existing" energy, and three auctions for "new" energy, which awarded contracts totaling more than 53,000 GWh/year with production starting in 2008 through 2011.

IV. Bioelectricity: competitive advantages

These new contracting conditions allowed bioelectricity to be potentially competitive in price – the cost of energy generation is the incremental cost of installing a more efficient boiler – and significant in quantity: it would be possible, for example, to sell 3,000 MW of firm energy using just the surpluses of the sugar and ethanol projects now under

[3] Acronym for "**P**rograma de **In**centivo às **F**ontes **A**lternativas de Energia", or Program for Incentives to Alternative Energy Sources.

[4] Note that this measure was not specifically taken for biomass. It also allows wind power and other technologies to be considered firm producers.

construction[5].

Among the additional advantages of bioelectricity, we can mention:

- shorter construction time (around 18 months) provides flexibility which has great value in Brazil, due to uncertainty in demand growth.
- location close to the load center (see Figure 1), which translates into smaller transmission costs.
- wider spectrum of investors, using local resources and foreign investment funds
- easier environmental licensing and the benefits of carbon credits / social insertion

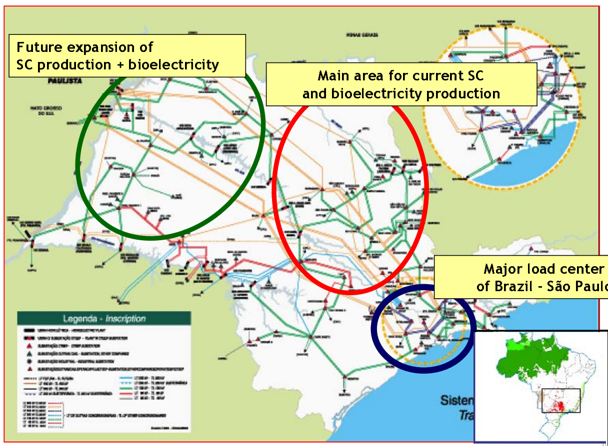

Figure 1 – Location of biomass plants

V. The Bioelectricity Program

The new conditions motivated the producers, through UNICA and in association with Cogen-SP, to create a biomass cogeneration program, known as *bioelectricity*.

A. *First Phase: bioelectricity implementation*

The initial actions of the participants in the program were to collaborate with government bodies (MME and ANEEL) in finalizing and detailing the sector's regulation. These actions included, for example:

- To show that seasonal production of bioelectricity, instead of being an obstacle, actually brings economic benefits the electrical sector. The reason is that the sugar cane energy production season (the harvest period) coincides with *dry* season for hydroelectric plants. In other words, there is a natural *complementarity* between hydroelectric generation and bioelectricity. In economic terms, this means that energy produced by biomass power plants "is worth more" than it was imagined, because in that period electric energy prices are higher than the annual average (see Figure 2).

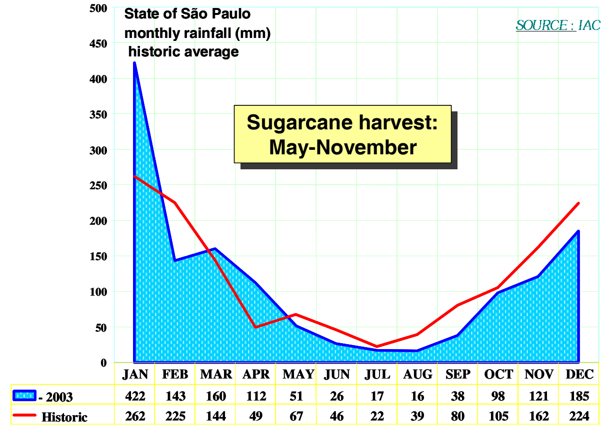

Figure 2 – Complementarity between sugarcane harvest and hydro production

- Support to participation in auctions, including training, economic analysis, auction simulation, assistance for documentation and discussion of commercial conditions (EPE, ANEEL and CCEE; participation in Public Hearings).
- Diffusion/clarification through seminars, visits, Technical Notes, interviews and presentations before MME, CCEE and ANEE.L

The bioelectricity program also acted to decrease the producers' natural concerns regarding the use of higher pressure boilers: even if the technology of these boilers is already consolidated, an accident or malfunction would affect not only the power generation, but the whole sugar and ethanol production.

The strategy consisted in negotiating with BNDES progressively better financing conditions for projects with more efficient boilers. This way, the "demonstration effect" is stimulated: if a pioneering producer successfully uses a more efficient boiler (e.g., of 67 bars), this will reduce the others producers' concerns.

The result of this first phase of the program was quite positive: several projects, totalizing 3657 MW, sold energy in the new energy and reserve auctions from 2005 to 2008..

B. *Second Phase: integrated business model*

The objective of this second phase is to demonstrate the advantages of an electricity supply contract, whose income represents more than 15% of plant gross revenue, to the ethanol / sugar production business. A first advantage is related to the fact that there are few long-term contracts in the sugar and ethanol sector. As a consequence, producers have difficulty in offering guarantees for new loans based on future incomes. The existence of fifteen-year contracts power purchase contracts has already stimulated the creation of "receivables" funds, and increases the producer's range of financing options.

A second advantage is hedging against commodity price and currency fluctuations. Because the electricity contract brings a stable revenue in local currency, it protects the producer against sudden oscillations in the export market prices (typically, sugar and in the future, ethanol), as well as

[5] Brazilian sugarcane production is expected to increase from 450 million tons in 2008 to 750 million tons in 2012. If all the new mills use efficient (67 bar) boilers, this expansion will inject 3,000 firm MW into the grid.

exchange rate fluctuations, such as the current strengthening of the R$ against the US$.

Finally, the possibility of getting carbon credits for both electricity production (which displaces coal or natural gas plants) jointly with credits for ethanol production (which displaces gasoline) is a potential revenue source.

C. Bioelectricity today

The electric sector regulation provides many incentives to biomass cogeneration, together with other renewable energy sources. It also removed most of the obstacles to sugarcane cogeneration, bur even so, a few hurdles still remain, and new problems may arise with the spread of biomass cogeneration.
The main incentives besides Proinfa are:

- Special incentives for direct sales to final consumers, including a 50% discount in the "wires" tariff (both producer and consumer) and the right to sell to consumers larger than 0.5 MW (other generators can sell directly only to consumers larger than 3 MW) – these incentives apply to all renewables, but only to plant smaller than 30 MW;
- Special PPA auctions in which distribution utilities must purchase energy exclusively from renewable sources (i.e. biomass, wind and small hydro) – the first such auction is scheduled for June 2007;
- Special loan terms with BNDES, including lower spreads and loans corresponding to a larger percentage of project cost – terms get progressively better with boiler efficiency;
- Distribution utilities are allowed to purchase up to 10% of their needs from distributed generators (which include biomass cogeneration) though special competitive processes outside the framework of nationwide auctions.
- Reserve Auction of the year of 2008. The possibility for the Brazilian Energy Commercialization Chamber (CCEE) to carry out reserve auctions to ensure system security of supply, was established in the new electricity sector regulation of 2004. Energy bought from them has to be sold directly in the spot market and not through bilateral contracts. The 2008 Reserve Auction was specifically designated for buying bioelectricity. In there CCEE bought 548 of firm MW, through fifteen years contract, of which 524 firm MW were from sugar cane plants.
- Change in the regulatory framework to carry out an specific transmission reinforcement auction to collect MWs generated by a large number of bioelectricity plants under construction in the Brazilian Centerwest region. Furthermore, other auctions of this type are planned for other regions

The main obstacles are:

- Some sugarcane growers still do not plan to produce bioelectricity for various reasons: fear of entering a new business with several large, established players; difficulty in understanding the electric energy contract, the auction rules and the rules of the short-term market for electricity; and some are simple not aware of the possibilities and economics bioelectricity;
- Need for more transparency in the setting of auction parameters, especially those that take into account the fact that most of bioelectricity occurs during the dry season – sugarcane growers complain that the lack of transparency and changes from one auction to the next discourage participation;
- Auctions for the purchase of distributed generation have been hampered by a very low overall ceiling price set by the Federal Government;

The spread of biomass is turning areas that were net consumers of electric energy into net producers, at least during the harvest period. This kind of transition was not foreseen when the existing regulations for transmission and distribution were written, and requires some adaptation.

VI. Conclusions and Perspectives

As discussed in this work, the integrated sugar / ethanol / electricity production has become the new business model – the bioelectricity industry - and has the potential to become a "mainstream" energy option in the near future in Brazil. This is motivated by a "window of opportunity" due to the combination of strong growth of sugar/ethanol sector, new power sector regulations and start of Kyoto initiative.

Bioelectricity presents several valuable attributes, such as: smaller size projects (typically 30 MW for retrofitting of existing plamnt and 100 MW for greenfield projects), which create a portfolio effect – diversifies risk of construction delays; wider range of investors (local private funds, foreign investment funds) and easier environmental licensing. It is also important to mention that some sugarcane producers are obtaining access to the capital markets including Initial Public Offer (IPO) in stock exchanges, which indicate a higher degree of maturity in the industry and possibility of long-term commitments.

In this sense, several important achievements have materialized:

- Several hundred MWs of bioelectricity plants have already signed long-term electricity supply contracts with the distribution companies. These contracts have been awarded on a competitive basis (public auctions), without any subsidy policy;
- as a consequence, financial funds of receivables tied on the energy supply contracts sold were created with the objective of leveraging investment in new plants;
- support of the Brazilian National Bank for Development (BNDES) tying more favorable financing conditions to more efficient boilers (which will produce more surplus firm energy)
- creation of integrated programs for equipment production by manufactures such as Dedini and Siemens.

The bioelectricity alternative has become a win-win situation for consumers and environment, relying on private investment and competition and illustrating the integration process of the agriculture and industrial sectors in a new sector with a large economic potential for Brazil, the industry of bioelectricity.

VII. References

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VIII. Biographies

Sérgio Granville has a PhD degree in Operations Research from Stanford University. He joined PSR in 2000 and is currently engaged in risk management for energy markets and software development for power systems, including integrated bioenergy model.

Priscila Lino has a MSc in OR from UFRJ and a MBA in Corporate Finance from PUC-RJ. She joined PSR in 2000 and has been coordinated studies in the following areas: (i) economic and financial evaluation of projects; (ii) asset valuation, including distribution, generation, transmission and trading companies; (iii) distribution tariff projection for final consumers (iv) regulatory assessment for foreign investors; (v) due-diligence studies for IADB and (vi) studies on the opportunities of an integrated bioenergy model.

Francisco Ralston has a BSc in Electrical Engineering with emphasis in Telecommunications and Optimization from PUC-Rio. He joined PSR in early 2007 and has been working since in projects related to Financial Evaluation of Energy Generation Projects. Before joining the PSR team, he worked in Banco BBM for two and a half years as an intern and junior analyst.

Luiz Augusto Barroso, IEEE Senior Member, has a PhD degree in optimization from COPPE/UFRJ, Brazil. He is a senior analyst in PSR, where he has been coordinating economic studies and researching on power systems economics, planning and operation, focusing on hydrothermal systems. More recently, he has been involved on the opportunities of an integrated bioenergy model.

Mario Veiga Pereira, IEEE Member, has a PhD in Optimization from COPPE/UFRJ. He is the president of PSR and he is currently engaged in regulatory studies and the development of new methodologies and tools for risk management in competitive markets. Since 2004 he has been involved in the design of Brazil's Bioelectricity Program (aimed at developing an integrated ethanol / sugar / electricity / carbon credits business model), in cooperation with the sugarcane producers and the cogeneration association.