COGENERATION – A NEW SOURCE OF INCOME FOR SUGAR AND ETHANOL MILLS or BIOELECTRICITY—A NEW BUSINESS

By

JOSÉ LUIZ OLIVÉRIO and FLÁVIO MALTEMPI FERREIRA

Dedini S/A Indústrias de Base
Rodovia Rio Claro-Piracicaba, km 26.3, CEP 13412-900 Piracicaba, SP, Brazil
Tel: (+55) (19) 3403-3006 www.dedini.com.br
jose.oliverio@dedini.com.br

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Abstract

COGENERATION, energy efficiency and surplus power production are old topics in Brazilian sugarcane mills. However, until 2003, they lacked institutional and regulatory support, when the Brazilian government decided to encourage and regulate alternative electricity production. Today, bioelectricity production in sugarcane mills and sale of the surplus power to the grid is a consistently fast-growing new business. Installed bioelectricity capacity in the Brazilian sugar industry reached 1800 MW in 2007/08. In a public auction on August 8th, 2008, the Brazilian Energy Agency (Agência Nacional de Energia Elétrica – Aneel) determined the bidding rules, including the maximum price to be paid for bioelectricity as reserve energy for the next 15 years, resulting in a total installed capacity of the auction winners of 2385 MW. Projections for 2020/21 foresee that the supply to the grid will be equivalent to 14 400 MW average, and that the revenue generated with this new business will be similar to Brazilian sugar production. This scenario opens opportunities for new energy optimisation technologies. This paper is focused on the use of sugarcane from an energy point of view, and how to (a) maximise the use of energy contained in sugarcane; (b) minimise energy consumption by the sugar and ethanol mills; (c) integrate the electricity production process into the sugar and ethanol process; (d) maximise surplus electricity production. New technologies are integrated to the mill to improve the energy balance: electrical/mechanical drives via planetary gearbox and frequency inverters or electro-hydraulic drives to milling units; fermentation at higher ethanol content using absorption chillers to permit lower temperatures; combined pressurised and vacuum distillation; membrane utilisation for dewatering and dehydration; biogas-from-vinasse production and its subsequent use as fuel; use of sugarcane straw (sugarcane crop residues, i.e. tops, leaves and straw) for fuel; multifuel boilers with high pressure, high temperature and high efficiency (120 bar(g), 530ºC, 89% – LHV); condensation/ extraction turbogenerator. Three hierarchical stages of technology are presented: sugarcane mills of first generation, second generation and third generation. The 'Bioelectricity State-of-the-Art Mill' is presented, and innovations are considered in the design of the complete sugarcane mill.

Introduction

Sugar and ethanol plants in Brazil have operated cogeneration systems for a long time. Until 2003, almost all cycles used by the mills operated with back-pressure turbo-alternators. Although the Brazilian industries have technology for high-pressure cogeneration systems, they have not been used by the mills (Olivéiro and Ordine, 1987; Olivéiro *et al*., 1989). Demand specifically for power from biomass and, particularly, the lack of a well developed market for sale of the surplus energy did not attract investment in more efficient generation systems. The lack of transmission lines connected to the mills has also contributed negatively to the implementation of cogeneration systems to produce surplus energy for export to the grid. Investment in transmission lines was discouraged by the absence of regulations in the sector.

Therefore, the mills energy balances did not consider surplus power generation. Only low-efficiency cogeneration projects were contracted, consisting of low-pressure and low-heat efficiency boilers and turbogenerators, with use of low-efficiency steam drives. Processes were designed for high steam consumption because there was more than enough power produced in the mills and, as a result, optimisation was not needed.

With the increase in electricity demand in recent years, and the imminent risk of blackouts as a result of insufficient capacity, the Brazilian government decided to support and regulate power generation and distribution.

The government quickly diversified the national electric power program to explore the potentials of every power generation sector. In 2002, Proinfa was launched, with the objective of guaranteeing the price of the energy produced from alternative sources and to stimulate investment in cogeneration and electricity export to the grid (Olivério and Ribeiro, 2006). Besides Proinfa, the government also organised four auctions to sell the surplus power produced from biomass.

Along with the new rules, new concepts of cogeneration were designed for the mills, and more modern and efficient technologies began to be used in the cogeneration systems and production processes. Such technologies were grouped into the following categories:

- First Generation: the optimised technologies commercially available to the sugar and ethanol mills; the state-of-the-art solution.
- Second Generation: this includes the anaerobic digestion of the vinasse for biogas production to be used as a fuel in high-pressure boilers. It also includes the use of sugarcane residues (referred to as straw, which are tops, green and dry leaves) in the boilers.
- Third Generation: this is the development of economically feasible technologies for bagasse and straw gasification to be used in combined cycles for surplus power production in the mills.

Energy valuation of sugarcane—surplus bioelectricity production process in sugar and ethanol mills

The energy contained in sugarcane was largely underexploited prior to 2003. The Brazilian mills focused only on the extraction of energy contained in the sugarcane juice, ignoring, in other words, wasting the energy contained in the bagasse and straw (sugarcane crop residues, that means: tops, leaves and straw). By making use of the juice exclusively we can say that only 1/3 of the energy contained in sugarcane is used efficiently.

The remaining energy in sugarcane (2/3) is present in bagasse and straw, an energy that was underutilised because the energy efficiency of the mills' cogeneration systems was very low. Regarding the energy contained in straw, this is completely lost because it is burnt in the field before harvesting. The loss of the energy present in straw is very high, representing 1/3 of the total energy contained in sugarcane (Olivério, 2003).

If we sum up the three components of energy contained in one tonne of sugarcane, we will see that such energy corresponds to approximately 1.2 barrels of crude oil, as shown in Table 1. Table 1 also shows the possible transformations of each component of energy as well as its equivalence in barrels of crude oil. By summing up the energy available in total sugarcane to be produced in the Brazilian 2010 season, we will have 1.17×10^{15} kcal available. Current and 2010 projected figures are almost the same.

Table 1—Sugarcane energy potential (Olivério, 2003; Olivéiro and Ribeiro, 2006).

1/3 from juice	Sugars – 153 kg 608 x 10^3 kcal	Sugar – the cheapest food in the world (in kcal)	Energy contained in 1 barrel of crude oil 1386 x 10^3 kcal
		Bioethanol – clean, renewable fuel	
1/3 from bagasse	Bagasse w/ 50 moisture – 276 kg 598 x 10^3 kcal	Electricity – clean, renewable fuel	
1/3 from straw	Straw w/ 15% moisture – 165 kg 512 x 10^3 kcal	Electricity – clean, renewable fuel	
Total	1718 x 10^3 kcal		1 tonne of cane = 1.2 barrels crude oil

Compared to UK, which consumes energy from crude oil, the total energy available in sugarcane produced in Brazil is 124% of the energy from oil (9.41 x 10^{14} kcal) consumed in UK. The energy available in Brazil from sugarcane is 80% of the energy from oil consumed in Germany and 42% of the energy consumed in Japan.

The amount of energy present in sugarcane is huge and is being wasted; for this reason, a production increase of surplus power in the mills to make better use of this energy should be pursued. By means of the equation below, we can see how to increase surplus power generation:

Maximum surplus power in the mill (=) Maximum use of the energy available in sugarcane (–) Minimum consumption in the mill processes

The maximum surplus energy equation (Olivério, 2008; 2009) is very simple, but it helps to understand all necessary changes in the mill for maximum surplus generation.

First, let's analyse the part of the equation that aims at the maximum use of the energy available. Here we should include the use of surplus cane bagasse as a fuel. By using bagasse, the mill will produce more steam than the process requires. It can also replace the back-pressure turbines by condensing turbines with controlled extraction. Another item to be added in the equation is the use of high-pressure, high-temperature boilers with high energy efficiency. Similar to the above, more steam will be produced for condensation besides a higher enthalpy drop in the turbine.

Let us analyse now the part of the equation for minimum energy consumption in the plant. It is necessary to reduce steam consumption in the sugar and ethanol processes to have more surplus steam for condensation and, as a consequence, higher surplus generation. It is also possible to replace the inefficient steam drives by more efficient electrical, electromechanical or electro-hydraulic drives. Therefore, there will be more energy produced with a positive balance in the replacement of the steam drives.

Technologies to maximise surplus bioelectricity production

According to the technological hierarchy presented earlier, let's now detail the technologies used to maximise the surplus power generation by means of a case study. We will present the technological innovations of first and second generation, which are available in commercial scale. The third generation technologies will be presented in the next section, as part of the prospects for bioelectricity production. For our case study, a typical sugar and ethanol mill configuration will be used as a base case with specifications shown in Table 2. We emphasise that, as far as energy is concerned, the specifications of the chosen base case are typically prevalent in Brazil, with more than 70% of the mills with this energy profile.

Table 2—Typical configuration of a sugar and ethanol mill (*).

Crushing capacity – tonnes of cane/hour	500 TCH
Crushing capacity – tonnes of cane/day	12 000 TCD
Effective operation days in one year	180 d/y
Crushing capacity – tonnes of cane/season	2 160 000 TCS
Boiler: steam pressure/temperature	21 bar(g)/ 320°C
Fibre % cane	13%
Process steam consumption (1.5 bar(g))	500 kg steam/tc
Lower Heating Value (LHV) of bagasse (50% wet)	1800 kcal/Kg
Straw: use of 50% of straw collected with the cane (straw weight :17% weight of clean cane, 40% moisture) – LHV:.	2058 kcal/kg
1 000 000 L of anhydrous bioethanol/day –	180. 000. 000 L bioethanol/season
(*) Ref.: ASSIS, P.E.P., INEE, 07/11/01, RIBERÃO PRETO	

First generation technologies

Table 2 contains data for preparation of the energy balance of the sugar and ethanol mills. Figure 1 is a flowchart of a typical mill that does not produce surplus power and represents the energy balance of the base case represented in Table 2. Observing and understanding the flowchart are important to understand the technological innovations that will be described.

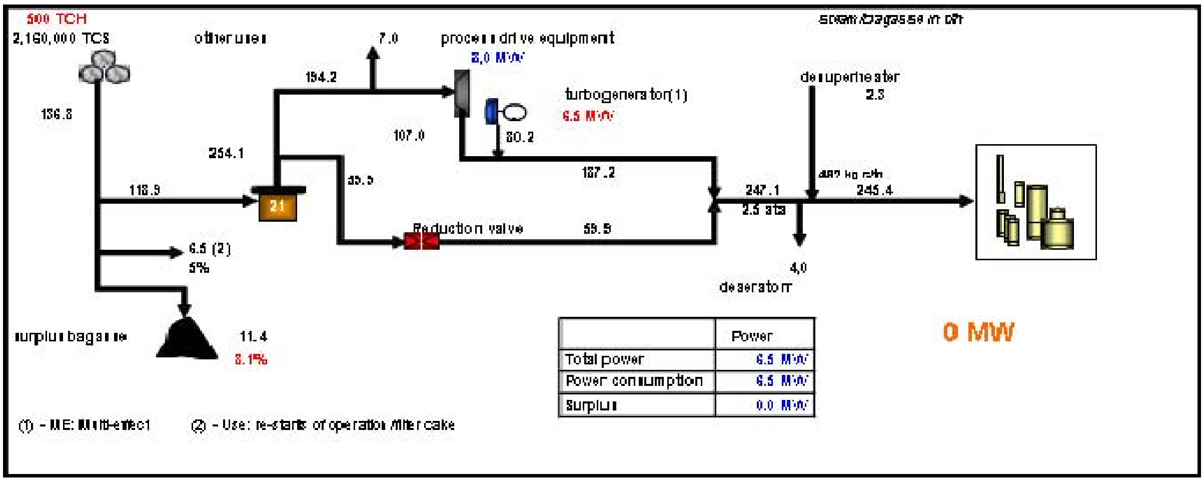

Fig. 1—Flowchart of a typical sugar and ethanol plant (reference for the case study) (Olivério, 2008; 2009).

In the flowchart can be seen the hourly crushing capacity (500 tonnes of cane) and the respective bagasse generation. In the sequence we can see the strategic reserve, 5% (6.5 t/h) of the total bagasse produced, for the plant start-up, re-starts and heating, once at this moment sugarcane is not being processed and generating bagasse to be used in the boiler. We can also see the surplus bagasse, which represents 8.11% (11.4 t/h) of the total.

If we analyse the other end of the flowchart we can find the process steam requirements for production (492 tonnes of steam/tonne of processed cane). By linking the bagasse to the process, we have the boilers, turbogenerators and pressure-reducing valves which will be the goal of the technological innovations, besides the reduction of steam consumption in the production process so that we can draw the maximum energy contained in sugarcane.

In this mill configuration we can see the use of pressure-reducing valves to satisfy the varying process steam demands.

Starting from the configuration of Figure 1 (Olivério, 2008; 2009) and using the equation of maximum energy generation, as presented earlier, a step-by-step overview of the technological innovations and their corresponding surplus power generation is given, until we reach the configuration called ‘State-of-the-Art Mill’.

To facilitate the understanding of the technological innovations that will be presented step by step, Table 3 summarises the operational conditions of the elected plant for our case study.

This same table will be presented at the end of each innovation, showing the changes in process and facilitating the understanding of the changes.

Table 3—Summary of the operational conditions of the case study plant.

	Current	After changes	Unit
Sugarcane crushed/year	2 160 000	–	TCS
Sugarcane crushed/hour	500	–	TCH
Amount of bagasse produced	136.8	–	t/h
Bagasse burnt	118.9	–	t/h
Steam produced	254.1	–	t/h
Steam consumed in the process	492	–	kgs/tc
Steam pressure	21	–	bar(g)
Steam temperature	320	–	ºC
Steam flow at 1.5 bar(g)	187.2	–	t/h
Steam flow at the pressure-reducing valve	59.9	–	t/h
Steam flow for condensation turbogenerator	0	–	t/h
Total power produced	6.5		MW
Power consumed by the plant	6.5	–	MW
Surplus power	0	–	MW

Generation of 4.9 MW of surplus power

A simple strategy to produce 4.9 MW of surplus power is proposed. This strategy consists of replacing the pressure-reducing valve by a back-pressure turbogenerator. When the turbogenerator is used to reduce the pressure of the 59.9 t/h of make-up steam, 4.9 MW of electricity is produced for export to the grid (see Table 4).

Production of 8.7 MW of surplus power

A total of 8.7 MW of surplus power can be generated with the utilisation of higher levels of surplus bagasse. In addition to the 5% reserve for plant re-starts, there is a bagasse surplus of 8.1% (11.4 t/h).

The strategy proposed here is to increase the boiler capacity by making changes in the furnace, so that the surplus bagasse can be burnt. By burning the surplus bagasse, steam output will be 278.6 t/h.

The additional 20.7 t/h of steam to be produced in the boilers will be used to replace the pressure-reducing valve by a condensing/ extracting turbogenerator. The flow of steam (surplus to process heating requirements) passing to the condensing turbine increases production to 8.7 MW of surplus power (see Table 5).

Table 4—Configuration after the changes prescribed for generation of 4.9 MW of surplus power.

	Before	After changes	Unit
Sugarcane crushed/year	2 160 000	2 160 000	TCS
Sugarcane crushed/hour	500	500	TCH
Bagasse produced	136.8	136.8	t/h
Bagasse burnt	118.9	118.9	t/h
Steam produced	254.1	254.1	t/h
Steam consumption in the process	492	492	kgs/tc
Steam pressure	21	21	bar(g)
Steam temperature	320	320	ºC
Steam flow at 1.5 bar(g)	187.2	**247.1**	t/h
Steam flow at the pressure-reducing valve	59.9	0	t/h
Steam flow for condensation turbogenerator	0	–	t/h
Total power produced	6.5	**11.4**	MW
Power consumed by the plant	6.5	6.5	MW
Surplus power	0	**4.9**	MW

Table 5—Configuration after the changes prescribed for production of 8.7 MW.

	Before	After changes	Unit
Sugarcane crushed/year	2 160 000	2 160 000	TCS
Sugarcane crushed/hour	500	500	TCH
Bagasse produced	136.8	136.8	t/h
Bagasse burnt	118.9	**130.3**	t/h
Steam produced	254.1	**278.6**	t/h
Steam consumption in the process	492	492	kgs/tc
Steam pressure	21	21	bar(g)
Steam temperature	320	320	ºC
Steam flow at 1.5 bar(g)	247.1	**250.9**	t/h
Steam flow at the pressure-reducing valve	0	0	t/h
Steam flow for condensation turbogenerator	–	**20.7**	t/h
Total power produced	11.4	**15.2**	MW
Power consumed by the plant	6.5	6.5	MW
Surplus power	4.9	**8.7**	MW

Production of 34.8 MW of surplus power

In the previous steps, there was no need for major technical innovation to meet 8.7 MW of surplus power. The focus of the next strategy will be the boilers, which will be replaced by equipment with high thermal efficiency, high pressure and high temperature (65 bar(g) / 485ºC). The efficiency of the condensing/ extracting turbogenerator is also assumed to be increased. In this scenario, the equipment is assumed to be upgraded to include features such as:

- De-super heating system for better outlet steam temperature control.
- Fully automated systems for ash removal.
- Single-pass evaporators eliminating maintenance of the stream-gases baffles.
- Cooled grates allowing high temperature of the combustion air.
- Heat exchangers designed for greater heat recovery.
- Turbines with high isentropic efficiency.

By adding these features, steam production will be 293.8 t/h, which will be directed to a condensing extracting turbo-generator. Extraction at 21 bar(g) for the process equipment drives is assumed; the equipment drives operate at 1.5 bar(g) of back-pressure, because extraction of the same goes to the process. The other extraction is 1.5 bar(g) to meet the remainder of the process steam demand. The remaining 38.6 t/h of steam will pass through the condensing turbine stage. With this configuration, 34.8 MW of surplus power will be produced (see Table 6).

Table 6—Configuration after the changes prescribed for production of 34.8 MW.

	Previous	After changes	Unit
Sugarcane crushed/year	2 160 000	2 160 000	TCS
Sugarcane crushed/hour	500	500	TCH
Bagasse produced	136.8	136.8	t/h
Bagasse burnt	130.3	130.3	t/h
Steam produced	278.6	**293.8**	t/h
Steam consumed in the process	492	492	kgs/tc
Steam pressure	21	**65**	bar(g)
Steam temperature	320	**485**	ºC
Steam output at 1.5 bar(g)	250.9	**248.2**	t/h
Steam output at the pressure-reducing valve	0	0	t/h
Steam output for the condensation turbogenerator	20.7	**38.6**	t/h
Total power produced	15.2	**41.3**	MW
Power consumed by the plant	6.5	6.5	MW
Surplus power	8.7	**34.8**	MW

Production of 40.7 MW of surplus power

The focus in this scenario is on the minimum consumption of power by the plant: reduction of the process steam consumption and replacement of steam drives by electromechanical or electro-hydraulic drives. Reduction of process steam consumption from 492 kg steam/tonne of cane to 400 kg/tc is possible with the technological innovations described below.

It is possible to bring down the process steam consumption to 400 kg/tc approximately, by designing the fermentation unit to receive more concentrated juice and then produce wine with higher alcohol content (11.0ºGL or higher), which permits that the distillation unit operates with a specific steam consumption of 2.6 kg/litre of anhydrous ethanol. This requires that the fermentation unit be automated and a CIP (cleaning-in-place) system implemented to keep the process heat transfer surfaces in good condition. Production of anhydrous ethanol utilises molecular sieve technology with low steam consumption. In addition, it is important to use indirect vapours from first effect for the distillery heating by using falling-film evaporators, which operate with very low load loss. The results of this scenario are summarised in Table 7.

Production of 50.7 MW of surplus power. The State-of-the-Art Mill

To obtain 50.7 MW of surplus power and introduce the state-of-the-art mill, again we refer to the maximum surplus energy equation. By observing the part of the equation relating to maximum use of the available energy, we will replace the 65 bar(g)/485ºC boilers by 100 bar(g)/530ºC boilers, which have the following technological advances:

- Single drum boilers.
- A suspension fired combustion system. This system ensures stable combustion operation and rapid response to changes in steam demand during operation. With systems of this type, an increase of the steam generation capacity can be expected,

with the greater vertical dimension of the boiler permitting adequate dimensioning of the furnaces.

- Reaction turbogenerators. These are more efficient equipment.
- Automation. Appropriate automation systems for boilers, turbogenerators and total process consumption of 2.0 kg steam/litre of anhydrous ethanol.

Table 7—Configuration after the changes prescribed for production of 40.7 MW.

	Before	After changes	Unit
Sugarcane crushed/year	2 160 000	2 160 000	TCS
Sugarcane crushed/hour	500	500	TCH
Bagasse produced	136.8	136.8	t/h
Bagasse burnt	130.3	130.3	t/h
Steam produced	293.8	293.8	t/h
Process steam consumption	492	**400**	kgs/tc
Steam pressure	65	65	bar(g)
Steam temperature	485	485	ºC
Steam flow at 1.5 bar (g)	248.2	**210.3**	t/h
Steam flow at the pressure-reducing valve	0	0	t/h
Steam flow for condensation turbogenerator	38.6	**76.5**	t/h
Total power generated	41.3	**58.7**	MW
Power consumed by the plant	6.5	**18**	MW
Surplus power	34.8	**40.7**	MW

To reduce process steam consumption to nearly 300 kg steam/tc, it is necessary to:

- Maximise the heat recovery of the condensate and make use of the flash vapours heat.
- Increase the alcohol content in fermentation to the range of 13.0ºC with the use of a fermentation chiller-type cooling system to permit operation in lower temperatures (e.g. 28.0ºC), steam consumption in distillation will be lower. To reduce the use of Power, a lithium – bromide (LiBr) absorption chiller should be used (using the hot stillage as a heating source), instead of traditional chillers (mechanical compression type: reciprocating, centrifugal, screw) that need more energy.
- Use split-feed distillation which can reduce specific steam consumption to levels below 1.8 kg of steam/litre of ethanol.
- Use membranes for ethanol dehydration, which also contributes to reduce steam consumption as compared with molecular sieves. Total steam required will be 2.0 kg/litre of anhydrous ethanol. This scenario is summarised in Table 8.

Table 8—Configuration after the changes prescribed for production of 50.7 MW.

	Before	After changes	Unit
Sugarcane crushed/year	2 160 000	2 160 000	TCS
Sugarcane crushed/hour	500	500	TCH
Amount of bagasse produced	136.8	136.8	t/h
Bagasse burnt	130.3	130.3	t/h
Steam produced	293.8	**295.7**	t/h
Steam consumed in the process	400	**300**	kgs/tc
Steam pressure	65	**100**	bar(g)
Steam temperature	485	**530**	ºC
Flow of steam extracted at 1.5 bar(g)	210.3	**170**	t/h
Steam flow at the pressure-reducing valve	0	0	t/h
Steam flow for condensation turbogenerator	76.5	**118.7**	t/h
Total power produced	58.7	**69.9**	MW
Power consumed by the plant	18	**19.2**	MW
Net surplus power	40.7	**50.7**	MW

Figure 2 is a schematic representation (Olivério, 2008; 2009) of the first generation technology bioelectricity production scenario summarised in Table 8.

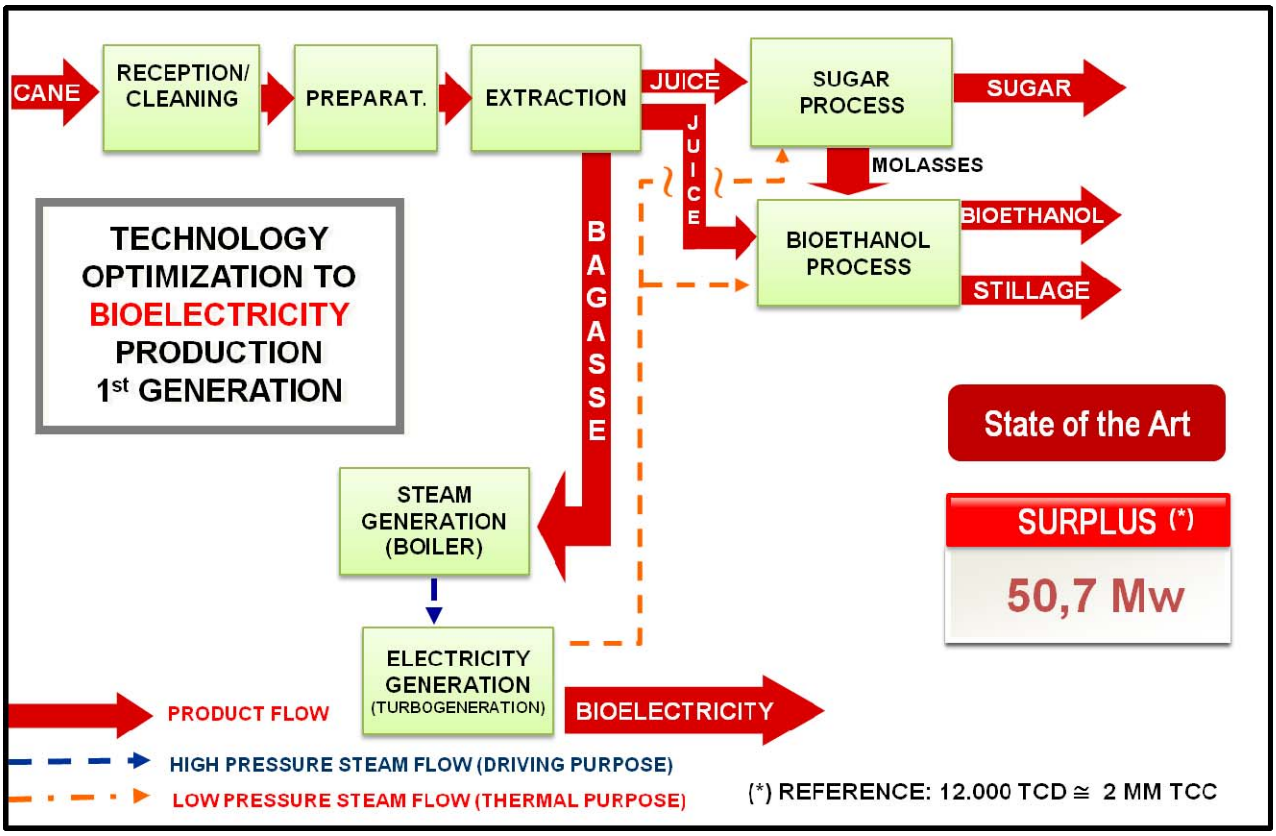

Fig. 2—Production flowchart – sugar, bioethanol and surplus bioelectricity – 1st generation.

Second-generation technologies

The state-of-the-art mill makes use of the maximum energy embodied in juice and bagasse. However, the energy contained in vinasse and crop residues can also be utilised. Taking advantage of both sources is part of the second-generation technologies.

To make use of vinasse, an anaerobic biodigestion system is required. Besides treatment of the mill effluents, it also generates biogas.

This technology is already available at a commercial sugar industry scale. The biogas generated must be pressurised and sent to burners installed in the biomass boiler.

This additional energy in the boiler will generate more steam, which will be used in the condensing turbine. By this means, surplus power will increase from 50.7 MW to 55.7 MW.

Let us consider now the use of 50% of the straw (harvest residue) as feedstock. Similar to biogas, this feedstock will be burnt in the boiler, generating more steam for the condensing turbine and, therefore, more surplus electricity.

Technologies and operational changes associated with the recovery of straw are currently still under development and are expected to be ready for commercial application in the near term. Multi-fuel boilers capable of burning bagasse, biogas and straw are already commercially available.

With the introduction of biogas and 50% of the crop residues, surplus power generation can reach 83.9 MW. Figure 3 is a schematic representation of second generation technology bioelectricity production (Olivério, 2008; 2009).

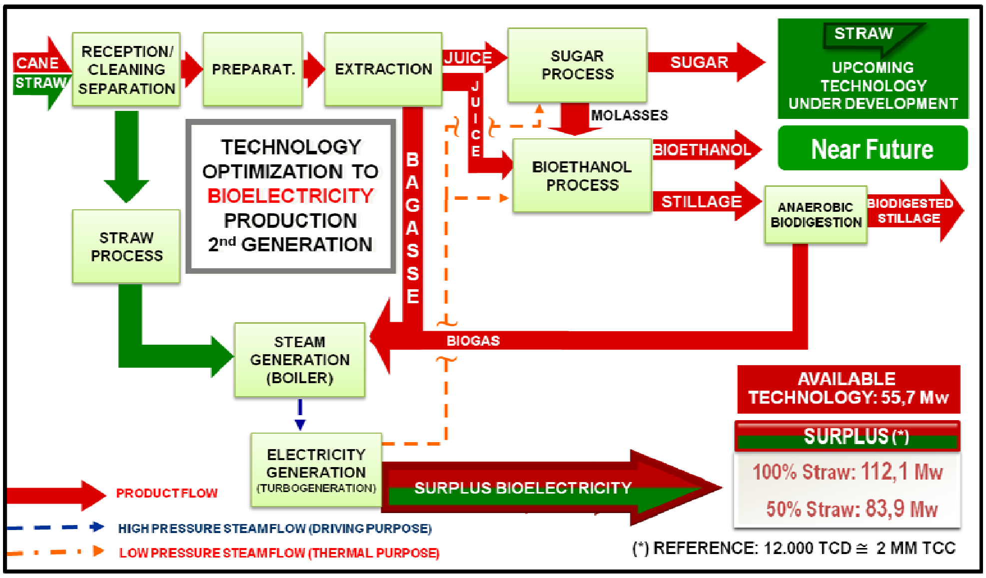

Fig. 3—Production flowchart – sugar, bioethanol and surplus bioelectricity – 2nd generation.

Technological trends in bioelectricity production

Third-generation technologies under development include bagasse and straw gasification for the production of synthesis gas to power advanced cycle bioelectricity plants. With the application of this technology, it will be possible to operate an integrated gas turbine combined cycle (IGCC) in the mills. In this cycle, the biogas produced from vinasse and the syngas from bagasse and straw will be used in the gas turbine, which drives the generator and produces surplus power. The gases that leave the gas turbine are directed to a heat recovery steam generator (HRSG). Steam generated in the HRSG goes to a steam turbogenerator configured similarly to the processes described earlier. After the development and availability of this technology in commercial scale, surplus power production can be as high as 110 MW. In this case, gasification of bagasse and 50% of crop residues are assumed; if 100% of the crop residues could be transported from the field to the mill to produce syngas, surplus power generation would be as high as 150 MW (Olivério, 2008; 2009).

A diagram of the third generation technology is shown in Figure 4 (Olivério2008; 2009), forecast for long term implementation.

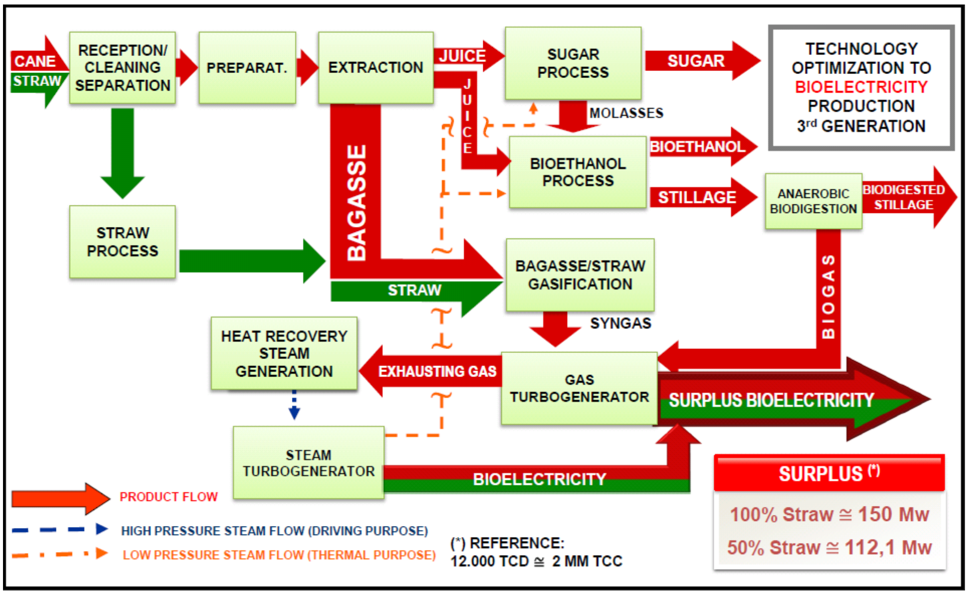

Fig. 4—Production flowchart – sugar, bioethanol and surplus bioelectricity – 3rd generation.

Bioelectricity—a new business in sugarcane sector

With the new rules introduced by the Brazilian government and with the use of the technologies presented in this paper, large scale production of surplus power represents a new business for the sugar and ethanol mills.

With the technologies currently available, there is great flexibility for retrofits of the existing plants.

In new projects (Greenfield), the implementation of new technologies is much easier, because the mill is designed according to the concept of maximum use of the energy contained in sugarcane.

It is also important to emphasise that the payback for a retrofit in the existing plants is 4–5 years, depending on the technological solution chosen (Olivério, 2008; 2009).

A good way to evaluate the success of the bioelectricity program is the growing interest of the industry in the biomass energy auctions that have been promoted in Brazil. The amount of installed power generation capacity as a result of the Brazilian programs for production of energy from biomass is increasing, as can be seen in Table 9 (Olivério, 2008; 2009)

Table 9—Summary of the MW contracted in auctions and installed.

Auctions		Contracted in auction	
		Winner projects Nº	Installed MW
1st Auction of new energy	Dec.05	7	270
2nd Auction of new energy	Jun.06	6	188
3rd Auction of new energy	Oct.06	5	234
1st Auction of altern. sources	Jun.07	12	542
4th Auction of new energy	Aug.08	31	2385
Total		61	3619

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COGÉNÉRATION – UNE NOUVELLE SOURCE DE REVENUS POUR LES USINES A SUCRE ET D'ÉTHANOL
Ou
BIOELECTRICITY—UNE NOUVELLE ENTREPRISE

Par

JOSÉ LUIZ OLIVÉRIO et FLÁVIO MALTEMPI FERREIRA
Dedini S/A Indústrias de base.
Rodovia Rio Claro-Piracicaba, km 26,3, CEP 13412-900 Piracicaba, SP, Brésil
Tél: + (55) (19) 3403-3006 www.dedini.com.br
jose.oliverio@dedini.com.br

MOTS CLEFS: **Cogénération, Bioelectricity,**
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Résumé

LA COGENERATION, l'efficacité énergétique et la production d'électricité excédentaire sont des anciennes rubriques dans les usines de canne du Brésil. Toutefois, jusqu'en 2003, le soutien institutionnel et réglementaire n’existait pas, le gouvernement brésilien a alors décidé d'encourager et de réglementer la production d'électricité. Aujourd'hui, la production de bioelectricity dans les usines de canne et la vente d’électricité au réseau sont de plus en plus importantes. Le potentiel de bioelectricity dans l'industrie du sucre brésilienne atteint 1800 MW en 2007–2008. Pendant une vente aux enchères le 8 août 2008, l'agence brésilienne de l'énergie (Agence Nacional de Energia Elétrica – Aneel) a déterminé les règles d'appel d'offres, y compris le prix maximal à payer pour la bioelectricity comme énergie de réserve pour les 15 prochaines années, ce qui se traduit par une capacité installée totale de 2385 MW. Les projections pour 2020–21 prévoient que l'alimentation de la grille sera équivalente à 14 400 MW, et que les revenus générés par cette nouvelle entreprise seront comparables à la production de sucre brésilien. Ce scénario ouvre des opportunités pour les nouvelles technologies d'optimisation énergétique. Ce document est axé sur l'utilisation de la canne d'un point de vue énergétique pour (a) optimiser l'utilisation de l'énergie contenue dans la plante (b) pour réduire au minimum la consommation d'énergie par les usines de sucre et d'éthanol (c) pour intégrer la production d'électricité dans le production du sucre et de l'éthanol (d) pour maximiser la production d'électricité excédentaire. Des technologies nouvelles sont intégrées à l'usine pour améliorer le bilan énergétique: approche mécanique/électrique ou electro-hydraulique pour la conduite des moulins; fermentation a des concentrations d'éthanol plus fortes à l'aide de refroidisseurs pour permettre des températures plus basses; distillation combinée sous vide et pressurisée; utilisation de membrane pour la déshydratation; production de biogaz a partir de la vinasse et sont utilisation comme carburant; utilisation de la paille comme carburant; chaudières capables d’utiliser plusieurs carburants, à haute pression, température et d'efficacité élevée (120 bar(g), 530ºC, 89% – LHV); turbogénérateur de condensation/extraction. Trois étapes hiérarchiques de la technologie sont présentées: usines de canne a sucre première génération, deuxième génération et troisième génération. L’usine Bioelectricity « dernier cri » est présentée et des innovations sont considérés pour la conception de l'usine de canne complète.

COGENERACIÓN – UNA NUEVA FUENTE DE INGRESOS PARA PLANTAS DE AZÚCAR Y ETANOL
o
BIOELECTRICIDAD – UN NUEVO NEGOCIO

Por

JOSÉ LUIZ OLIVÉRIO y FLÁVIO MALTEMPI FERREIRA
Dedini S/A Indústrias de base.
Rodovia Rio Claro-Piracicaba, km 26,3, CEP 13412-900 Piracicaba, SP, Brésil
Tél: + (55) (19) 3403-3006 www.dedini.com.br
jose.oliverio@dedini.com.br

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Resumen

COGENERACIÓN, eficiencia energética y producción de energía para la venta son temas antiguos en los ingenios brasileros. Sin embargo, no contaron con soporte institucional y regulatorio hasta 2003, cuando el gobierno brasilero decidió impulsar y regular la producción alternativa de producción de electricidad. A la fecha la producción de bioelectricidad en los ingenios y la venta de energía a la red son un nuevo negocio de rápido y sostenido crecimiento. La capacidad instalada de bioelectricidad en la industria azucarera brasilera alcanzó 1800 MW en 2007/08. En una licitación pública en Agosto 8, 2008 la Agencia Nacional de Energía Eléctrica determinó las reglas de comercialización, incluyendo el precio máximo a ser pagado por bioelectricidad como una reserva de energía por los próximos 15 años, lo que resultó en una capacidad total instalada de los ganadores de la licitación, de 2385 MW. Las proyecciones para 2020/21 anticipan que el suministro a la red será equivalente a un promedio de 14 400 MW, y que los ingresos netos generados con este nuevo negocio serán similares a los de la producción de azúcar de Brasil. Este escenario abre oportunidades para nuevas tecnologías de optimización energética. Este trabajo se enfoca sobre el uso de la caña desde un punto de vista energético y como (a) maximizar el uso de energía contenida en la caña (b) minimizar el consumo de energía de las plantas de azúcar y etanol; (c) integrar el proceso de producción de electricidad con el proceso de producción de azúcar y etanol; (d) maximizar la producción de energía exportable. Nuevas tecnologías se incorporan a las plantas para mejorar el balance energético: accionamientos electromecánicos con engranajes planetarios e inversores de frecuencia o accionamientos electrohidráulicos par a las unidades de molienda; fermentación a contenidos más altos de etanol usando chillers de absorción para permitir temperaturas más bajas; combinación de destilación presurizada y en vacío; uso de membranas para deshidratación; biogás a partir de vinaza y su uso como combustible; uso de los residuos de cosecha como combustible; calderas multicombustible con altas temperaturas, presiones y eficiencias (120 bar(g), 530ºC, 89% – PCI); turbogeneradores de extracción condensación. Se presentan tres etapas jerárquicas de tecnología: ingenios de primera, segunda y tercera generación. Se presenta el ingenio 'estado del arte' en bioelectricidad y las innovaciones son consideradas en el diseño del ingenio completo.