Sugar Cane Crop Residues and Bagasse for Energy Co-Generation in Brazil[1]

Potencial de Palhiço e Bagaço de Cana-de-Açúcar para Uso na Co-Geração de Energia Elétrica no Brasil

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Abstract: The purpose of this study was to evaluate the potential of sugar cane biomass energy (bagasse and crop residues) for energy co-generation in Brazil. Two different scenarios were considered for crop residues utilization. A first scenario (minimum usage plus bagasse) resulted in 20.94 10^6 MWh production per season, and a second scenario (maximum crop residue utilization, plus bagasse) resulted in 41.46 10^6 MWh production per season.

Keywords: Sugar cane, biomass, bagasse, crop residue, energy.

Resumo: Este trabalho estimou o potencial energético de biomassa de cana-de-açúcar (bagaço e palhiço) possível de utilização para co-geração de energia elétrica no Brasil. Dois cenários foram montados para o aproveitamento do palhiço. Uma mínima utilização junto ao bagaço, resultando em 20.94 10^6 MWh por safra, e uma máxima utilização, também junto ao bagaço, fornecendo 20.94 10^6 MWh por safra.

Palavras-chave: Cana-de-açúcar, biomassa, bagaço, palhiço e energia.

1 Introduction

The objective of this study was to identify the surplus of energy generated by sugar cane crop residues produced from sugar cane harvest. It is based on the increment of this biomass' potential energy, compared with traditional sugar cane bagasse (stalk fiber), due to its importance on the energy matrix chain of alternative sources of biomass.

According to Agenda 21 (ONU, 1992) recommendations and economic expansion of socially responsible and environment-oriented organizations will require their investments to be engaged with the Clean Development Mechanisms - CDM to minimize environmental impacts and at the same time meet an increasing demand.

Thus, the use of native and clean energy and minimization of natural resources will be obviously pursued, especially after the Kyoto Protocol validations in 2005, which will certainly help reinforce this issue

The future has arrived with the 21st Century new agro-industries implanted in Brazil. There will be environmental

[1] Recebido para publicação em 13.9.2006 e aceito em 13.10.2006.
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restrictions to the build up of new power stations, even considering the fact that new industrial parks will need energy to work. Also, favorable to agro-industries, new legislation was created in accordance with the 21 Agenda, to stimulate new sources of energy.

The world demand for new sources of alternative energy results from national programs developed to reduce carbon dioxide production. These programs are currently being implemented in Sweden, France; Mexico; India, Canada; Australia; Colombia; England and other countries. An important element in those policies is the prohibition of the use of petrol-originated additives, such as the Methyl Tertian Butyl-Ether Multi-Ether in gasoline as an anti-combustion agent.

However, manual harvesting of sugar cane crops is currently initiated by a pre-operation that includes setting fire on the crop. According to Ripoli (1991) and Ripoli (2004), such practice leads to a loss of energy from this biomass fraction called crop residue.

São Paulo State Law No. 11.241 of 9/19/2002 states that all sugar cane harvest pre-operation (fire sets) must be abolished in the state by the year 2020. Thus, measures to reduce such operations are already being implemented in harvesting areas as legal methods which will guarantee the development and growth of the state.

However, the deadline given by the State government for total elimination of the pre-operation fire set to harvest is too long and the crop residue energy losses cannot continue causing atmospheric pollution and harm to the population's health.

Besides, Brazil produces 95% of its electrical energy from hydroelectric sources for home and industrial use, dependent on regular periods of rain over the hydrographic basin regions. It is important to mention that sugar cane and alcohol industries are spread geographically throughout Brazil, especially in regions that consume more electrical energy, such as São Paulo State.

Currently, Brazil has 307 power stations of which 128 are installed in São Paulo State, supplying around 85% of all the energy produced in the country. The cultivated area rose from 4.5 million hectares to 5.5 million hectares, equivalent to less than 1% of the total agricultural area of Brazil. This area offers a significant amount of crop residues that could be harvested (Figures 1 and 2). Processing this raw material will enable production of 55% of alcohol and 45% of sugar, according to UNICA (2005).

Sugar cane is cultivated and manufactured over the Center-South and North-Northeast regions of Brazil, allowing two annual harvests. According to Vieira (2003), the best agricultural efficiency rate was obtained from São Paulo State in 2003: 71.3 tons of raw sugar cane per hectare.

Estimate of sugar cane crop residue and bagasse potential power generation

The goal was to evaluate whether there is any advantage in using sugar cane crop residue (tops, leaves, straw, stalk fractions) from sugarcane harvest, as a complementary energy source to using sugar cane bagasse, when fire set pre- operation are discontinued. Also, the study explored whether it will be advantageous to invest in energy cogeneration as well as in machinery acquisition to adequate this process technology, such as volume of crop residue, that could be added physically to the sugar cane bagasse to generate biomass fuel in the caldron the equation (1) was developed. The advantage of obtaining better environmental quality with this methodology should be considered since it uses controlled burning of harvest residues instead of fire set pre-operation.

Photos: M.L.C. Ripoli.

Figure 1 – Harvesting sugar cane (leaving crop residue on the ground); raking (after 25 days); crop residue after a triple rake operation; bundling (prismatic and cylindrical) and bundles (middle sized of 150 kgf) loaded.
Figure 1 – *Colheita de cana-de-açúcar (permanecendo o palhiço sobre o terreno); enleiramento (após 25 dias); palhiço após enleiramento triplo; enfardamento (prismático e cilíndrico) e fardos (peso médio de 150 kg) carregados.*

Photos: M.L.C. Ripoli.

Figure 2 – Other sugar cane crop residue harvesting processes: using forage harvester with cotton press
Figure 2 – *Outros processos de colheita de palhiço: utilizando colhedora de forragem com prensa de algodão.*

2 Methodology

Starting up from a generic scenario it was possible to make some assumptions about the existing potential of sugar cane crop for possible uses of this biomass crop residue, although the equation supplied allows reaching specific results for each situation of each sugar cane related agribusiness.

Two extreme cases were studied using information from Ripoli (2004) on the availability of residual biomass in the field with minimum collection of 30% or maximum, up to 100% and agricultural efficiency of São Paulo State, as defined by Vieira (2003).

In this paper, the power potential obtained from bagasse use (Pb) and from crop residue (Pp) where defined by:

$$Pb = [TC/H3600] \; . \; [(Tb/TC) \; . \; U \; . \; Qb] \; . \; \eta \qquad (1)$$

$$Pp = [TC/H3600] \; . \; [Tp/TC) \; . \; Frp \; . \; Qp] \; . \; \eta \qquad (2)$$

Thus, overall potential (*Pt*) is:

$$Pt = Pb + Pp \qquad (3)$$

Placing equations (1) and (2) in (3):

$$Pt = [TC/H3600] \; . \; \{(Tb/TC) \; . \; U \; . \; Qb] + [(Tp/TC) \; . \; frp \; . \; Qp]\} \; . \; \eta \qquad (4)$$

where: TC = Tons of cane per hour; Tb/TC = Tons of bagasse per tons of cane (admitted: 0.25); U = Bagasse utilized fraction (admitted: 0.5); Qb = Bagasse heat power (6,270 MJ ton^{-1} of cane); Tp/TC = Tons of crop residue per tons of cane (admitted: min. = 0.06 and max.= 0.17); frp = Crop residue fraction withdrawn (admitted: 0.6); Qp = Crop residue heat power (admitted: 7,524 MJ ton^{-1}); η = Efficiency of the boiler and generator system (admitted: 0.25).

3 Results and Discussion

Starting with the amount of 100 tons of sugar crushed per hour and one season of 200 days (200 x 24 = 4,800 hours) and according with the equations (1) to (4) the values admitted of power and energy are:

Power generated from the bagasse (*Pb*):

$$Pb = [100TC/H3600] \; . \; [0.25 \; . \; 0.5 \; . \; 6{,}270] \; . \; 0.25$$

$$Pb = 5.44 \text{ MWh}$$

Power generated from the crop residue (*Pp*):

Maximum (*PMp*):

PMp = [100TC/H3600] . [0.17 . 0.6 . 7,524] . 0.25

PMp = 5.33 MWh

Minimum (*Pmp*):

Pmp = [100TC/H3600] . [0.06 . 0.6 . 7,524] . 0.25

Pmp = 1.88 MWh

Total power generated (*PT*), bagasse + crop residue, in 100 tons of cane per hour crushed:

$$PT = Pb + Pp \qquad (5)$$

So,

Maximum power obtained (*PMT*):

PMT = 5.44 MW + 5.33 MW = 10.77 MW

Minimum power obtained (*PmT*):

PmT = 5,44 MW + 1,88 MW = 7.32 MW

As in one season are 4800 hours of sugar stalks crushing, so:

Eb = Energy generated from bagasse

Eb = Pb . 4,800 = 5.44 . 4,800 = 26,112 MWh

Maximum energy generated by the crop residue (*EMp*):

EMp = 5.33 . 4,800 = 25,584 MWh

Minimum energy generated by the crop residue (Emp):

Emp = 1.88 . 4,800 = 9,024 MWh

Total energy generates (*ET*), bagasse + crop residue:

Maximum:

ETM = $Eb + EMp$ = 26,112 + 25,584

= 51,636 MWh

Minimum:

ETm = $Eb + Emp$ = 26,112 + 9,024

= 35,136 MWh

Table 1 shows the data obtained, for comparison, considering US$46.62 per MWh.

Besides the results shown in Table 1, the adoption of crop residue (Figure 1) as renewable fuel will allow framing the industry in the administrative system of the Clean Development Mechanisms – CDM, creating ways to commercialize environmental commodities or carbon credits to countries which do not have conditions to minimize their CO_2 emissions in the atmosphere. Thus, regardless of the amount of crop residue in the fields after harvest, any amount available will justify its utilization to cogeneration of energy, with no more fire set pre-operations, allowing compliance with the new Brazilian Legislation which allows sugar cane fires to be set only until 2020, improving environmental quality, reducing diseases generated by environmental pollution and complying with the Kyoto Protocol without creating financial loses.

It is important to point out that the availability of biomass such as crop residue and bagasse will be greater during sugar cane crop harvest periods, which correspond to the period when East Brazilian hydroelectric water reservoirs are at their minimal levels.

Considering that Brazil's annual production is around 385 million tons of sugar cane per year (Alcoolbras, 2005), in an area of 5.5 million ha and considering that, according to Ripoli (2004), the availability of crop residue is around 4 to 12 tons per hectare; and the average agricultural efficiency of around 71.3 tons ha^{-1} (Vieira, 2003) it will be possible to estimate how much electrical energy will be available from the sugar cane sector to energy dealers. It should be kept in mind that energy will be a source of additional income, according to the Proinfa

(2005) table prices to the sector, allowing more employment opportunities and electrical energy supply, vital to implementation of new enterprises in various Brazilian sectors, once those units are spread throughout Brazil.

Table 2 shows the results from solutions for these equations under minimum and maximum conditions, with the values used representing the Brazilian potential for sugar cane biomass use to obtain energy cogeneration and possibly add extra income to the sector activities. The actual Brazilian sugar cane crushing is 385 10^6 tons per season.

It is necessary to point out that the use of advanced technology and less energy losses from the industrial units will result in even better financial gains.

The sugar cane sector has an edge in industrial parks; financial assets; and consultancy in the country. Public legislation taking these factors into consideration should be created.

If we consider that 18 turbines of 700 MW of Itaipu Hydroelectric from Paraná River produce 12,600 MW or 110.37 10^6 MWh per year, the potential energy value that the sugar cane sector can offer to public dealers with biomass is very significant, compared to Itaipu's potential during drought periods.

Table 1 – Biomass used to generate eletric potential (MW) using 100 TC/H at possible different uses of biomass (200 days/season)
Quadro 1 *– Biomassa usada para gerar potencial (MW) usando 100 TC/H em diferentes possíveis usos de biomassa (200 dias/safra)*

Biomass use	Potential (MW)	Energy Generated per Season (MWh)	Harvest Gross Revenue (US$)
Bagasse (50%)*	5.44	26.112	1.112.893
Crop residue (Minimum)	1.88	9.024	384.603
Crop residue (Maximum)	5.33	25.584	1.090.390
Bagasse + Crop residue (Minimum)	7.32	35.136	1.497.496
Bagasse + Crop residue (Maximum)	10.77	51.696	2.203.284

TC/H = Tons of sugar cane per hour. *Consider a surplus of bagasse in relation to its own consumption and caldrons with high efficiency.

Table 2 – Brazilian potential for sugar cane biomass use to obtain energy cogeneration of 385 10^6 tons of sugar cane crushed, during 200 days/season
Quadro 2 *– Potencial de uso de biomassa de cana-de-açúcar no Brasil, para obtenção de co-geração de energia a partir de 385 10^6 toneladas de cana-de-açúcar esmagada em 200 dias/safra*

Biomass	Potential (MW)	Energy generated (MWh 10^6)	Revenue (US$ 10^6)
Bagasse (50%)	4,363	20.94	892.56
Crop residue minimum	1,508	7.24	308.57
Crop residue maximum	4,276	20.52	874.56
Bagasse and crop residue minimum	5,871	28.18	1,201.03
Bagasse and crop residue maximum	8,638	41.46	1,767.02

The relation of energy created by the Itaipu hydroelectric and the potential of energy generated by sugar cane biomass is 41.46%, which means that the sugar cane sector can contribute half of Itaipu's production without occupying agricultural land with floods and without having to create new energy transmission lines. It should also be kept in mind that sugar mills and distilleries are already spread all over the country boosting employment as well. Thus, sugar cane biomass use in Brazil is strategically important to ensure availability of electrical energy all year round

Currently, the amount of non- specialized jobs (1.5 10^6) created by the sugarcane sector is very important to the Brazilian people, due to its capability of reaching different levels of skills and geographic distribution. It maintains an important agribusiness chain in Brazil involving companies, generators of financial assets; other producers; work force training and development units; research institutes and transport companies, contributing directly and indirectly to enhance quality of life in terms of environmental concern and social responsibility.

4 Conclusions

Based on the estimated results obtained in this study, it is clear that the use of sugar cane biomass represents a great potential to produce energy in Brazil, especially .when fossil fuels, primarily oil have become limited and plagued by high costs.

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