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The Brazilian energy matrix: Evolution analysis and its impact on farming

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HIGHLIGHTS

- We analyze the impact of Brazilian energy matrix on farming.
- We highlight the socio-political-economic impact on the agricultural sector.
- We highlight the biofuels potential.

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ABSTRACT

This work proposes a technical and economic analysis of the Brazilian matrix energy evaluation, aiming at the evaluation of impacts inherent to technological innovation involved on energy matrix and the sectoral development. Particular attention is given to biomass energy, natural gas, and conventional fuels, considering their impacts on agricultural activity, identifying the highest potential for investment in this sector. As a result, a clear view of the importance of agricultural sector participation in the context of the Brazilian energy is obtained, not only as a consumer, but mainly through self-production energy policy of waste reuse as biomass and of biofuels.

1. Introduction

A major input of industries is energy. The productive capacity of the segment can be determined by crucial features of energy such as its availability, price, and quality. However, the cost of energy to the Brazilian productive sector has grown consistently above inflation rates (CNI – Confederacao Nacional da Industria, 2007).

A tendency of large industries to invest in technologies related to alternative sources of power generation is encouraged by this aspect, especially those sources based on biomass, in order to take advantage of solid waste from their own production processes. Moreover, the use of waste, or its use for biogas generation, in the agricultural sector is a broad and propitious scenario for its application (DIEESE – Departamento Intersindical de Estatistica e Estudos Socioeconomicos, 2007; Rathmann et al., 2008).

The share of ethanol in the Brazilian energy matrix is increasing, which shows a trend of the Brazilian market acceptance of renewable energy sources. According to data from the Brazilian energy balance, sugar cane based energy increased from 13.8% in 2005 to 14.4% of domestic energy supply (Margarida, 2007).

This participation is one of the factors that contributed to the decline in share of oil in the Brazilian energy matrix in the last 30 years. Other three factors stand out with the ethanol in this restructuring of the energy matrix: the policy of construction of large hydroelectric power plants, the growing share of natural gas in gross domestic supply, and restrictions on use of firewood and charcoal from deforestation, followed by its replacement by other more efficient sources, such as LPG (Barbieri, 2002; Campos, 2002; Alves Filho, 2003; Pires, 2006; Landau, 2008).

The search for new alternatives for energy generation has contributed to the evolution of the Brazilian energy matrix. Albeit slight, initiatives such as the development of biofuels are gaining space and they have gathered support and subsidies, especially from the Federal Government (CETESB – Companhia de Tecnologia de Saneamento Ambiental, 2006; Marques et al., 2006; Dabdoub, 2006).

The environmentalist point of view should also be considered when talking about reform in the Brazilian energy matrix, considering that even renewable energy sources are eventually impacting the environment. According to recent studies (CETESB

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– Companhia de Tecnologia de Saneamento Ambiental, 2006), which highlight the representativeness of renewable sources, including hydropower, such sources have decreased their share in the energy matrix due to limitation in capacity expansion of hydroelectricity and to the priority of the Federal Government. Such policy would increase Brazil's emissions of greenhouse gases and pollutants today such as NO_x and SO_2 (Jacomo, 2006). It should be noted that from the beginning of 2006, thermoelectric power plants represented significant part the energy matrix, about 85%, of which using natural gas as primary fuel.

An overview of the availability and affordability of energy sources and generation potential in Brazil, highlighting the Brazilian public strategy for the following years, concentrates on the promotion of more efficient energy utilization in different sectors of the society and also on diversifying its energy matrix, is given in several works, such as Goldemberg et al. (2002), Gomes (2009), Bajay and Nogueira (2010), Schaffel and La Rovere (2010), Gomes et al. (2012), Santos (2013), Pottmaier et al. (2013).

The potential of the Brazilian sugar cane industry as an electrical power supplier and the impact of modifications in the cogeneration plant on the costs of production of sugar and ethanol have been reported in many works, such as Pellegrini (2011), Vane (2012).

The efforts and perspectives in Brazil for sugar cane ethanol and bioethanol have been reviewed by several authors, such as Soccol et al. (2010), Khatiwada et al. (2012), Kostin et al. (2012).

The emergence of the biodiesel industry in Brazil has also been characterized and analyzed, and an assessment of the extent to which the goals established by the National Biodiesel Production and Usage Program have been reached in works such as Garcez (2009), Silva et al. (2010), Padula et al. (2012), Queiroz et al. (2012), Watanabe et al. (2012), Cunha Junior et al. (2013).

Salomon and Silva-Lora have evaluated the organic residues coming from the sugar and alcohol industry (vinasse, molasses and bagasse) and livestock residues (chicken, bovine and swine manure) in Brazil and estimated the electrical power generation potential of biogas from these sources (Salomon and Silva-Lora, 2009).

The Brazilian energy matrix is usually presented in a general way and without highlighting specific considerations about the technologies involved, industry characteristics, regionalism etc. In order to assess the impacts inherent to technological innovation involved in the energy matrix and to the sectoral development, technical and economic analysis of the evolution of the Brazilian energy matrix with the participation of biomass energy, natural gas, and conventional fuels, considering its impact in agricultural activity, identifying the greatest potential for investment in this sector, is proposed.

2. Materials and methods

The information that will be used in this analysis will be obtained from data queries to documents containing the necessary information for this study. The compilation of these data will allow reporting the trend with socio-political-economic of the Brazilian energy matrix, specifically considering their impacts on the agricultural sector.

3. Results and discussion

Recent researches, especially related to the sugar and alcohol sector, specifically within the scope of the agricultural sector, have been highlighted by enabling the reuse of environment aggressive residues, like sugar cane bagasse, molasses, wood chips etc., as energy sources and, in some cases, providing some energy autonomous supply, both electrical and thermal.

A source analysis of Brazilian energy balance shows two major energy sources directly or indirectly linked to the agricultural sector: sugar cane products and charcoal.

The former is represented mainly by ethanol production showing an increase of 17.9% in 2011 relative to 2010, while the final consumption increased by 11.0%. Moreover, sugar cane bagasse consumption as a heat source (biomass), including electrical power generation, increased by 9.2% (EPE – Empresa de Pesquisa Energetica (Brazil), 2012).

Table 1 shows the products of sugar cane in relation to production, net imports, consumption, and production yields between 2010 and 2011 (EPE – Empresa de Pesquisa Energetica (Brazil), 2012).

When analyzing the electrical power generation in Brazil, with respect to domestic supply, generation, net imports, consumption, and capacity, for the period 2010–2011 (Table 2), the autonomous production is noteworthy, given the intense participation of the agricultural sector. In the same period, electrical power domestic supply had an increase of 3.2% as compared to an increase of 3.0% in power generation, including power plants and public service self-generators. In particular, self-generators power plants grew by 5.2% in the same period (EPE – Empresa de Pesquisa Energetica (Brazil), 2012).

The main application of wood in Brazil is to produce charcoal, at the charcoal mills. However, especially in rural areas, it is also used in homes for cooking and heating. In 2011 approximately 21 million tons of firewood were consumed, a decrease of 11.9% over the previous year. Table 3 shows the performance of firewood and charcoal in terms of production, processing, and consumption

Table 1
Sugar cane products.

	Unit	2010	2011	% 11/10
Ethanol production	10^3 m^3	27,924	22,916	17.9
Ethanol imports and exports[a]	10^3 m^3	−1,825	−827	54.7
Stock variations, losses and adjustments	10^3 m^3	−1,685	−360	78.6
Ethanol final consumption	10^3 m^3	24,414	21,729	11.0
Anhydrous ethanol consumption-transports sector	10^3 m^3	7,097	8,435	−18.9
Hydrated ethanol consumption-transports sector	10^3 m^3	16,163	12,216	24.4
Other purposes ethanol consumption	10^3 m^3	1,139	1,060	6.9
Sugar cane ethanol performance	10^3 t	185,080	143,310	22.6
Molasses ethanol performance	10^3 t	17,465	19,557	−12.0
Bagasse thermal consumption[b]	10^3 t	141,173	128,247	9.2

[a] Minus sign for exports and no sign for imports.
[b] It includes self-producers consumption for electrical power generation.

Table 2
Electrical power generation.

	Unit	2010	2011	% 11/10
Domestic supply of electrical power	GWh	551,705	570,188	3.2
Electrical power generation[b]	GWh	515,799	531,758	3.0
Public electrical power plants and stations	GWh	442,803	454,726	2.6
Hydro power plants	GWh	382,599	405,621	5.7
Thermo power plants[b]	10^3 toe	5,178	4,223	−22.6
Nuclear power plants	GWh	14,523	15,659	7.3
Natural gas power plants	GWh	25,832	15,235	−69.6
Coal plants	GWh	6,062	5,625	−7.8
Self-producers power plants	GWh	72,995	77,033	5.2
Net imports	GWh	35,906	38,430	6.6
Final consumption	GWh	464,699	480,120	3.2
Households consumption	GWh	107,215	111,971	4.2
Commercial consumption	GWh	69,718	74,056	5.9
Industrial consumption	GWh	203,350	209,390	2.9
Other sectors' consumption	GWh	40,435	43,397	6.8
Losses related to domestic electrical power supply	GWh	−85,748	−87,524	2.0
Electrical power generation installed capacity[a]	GW	515,798	531,759	3.0

[a] Public electrical power and self-producers plants and stations.
[b] Thermoelectrical plants include those from a nuclear source, too.

Table 3
Firewood and charcoal.

	Unit	2010	2011	% 11/10
Firewood production	10^3 t	83,862	84,909	1.23
Firewood final consumption	10^3 t	55,006	52,793	−4.2
Households firewood consumption	10^3 t	23,471	20,984	−11.9
Charcoal consumption	10^3 t	5,967	6,403	6.8

from 2010 to 2011 (EPE – Empresa de Pesquisa Energetica (Brazil), 2012).

Fig. 1 shows the sectoral share of firewood, with respect to the production, processing, and consumption in the base year of 2011 (EPE – Empresa de Pesquisa Energetica (Brazil), 2012).

Table 4 shows the major economic and energy indicators for the years 2010 and 2011 (EPE – Empresa de Pesquisa Energetica (Brazil), 2012).

In relation to GDP, agriculture grew by 3.7% in 2011 related to 2010. This value is very close to the overall growth of GDP in the country, according to IBGE, grew 2.7% in the same period (EPE – Empresa de Pesquisa Energetica (Brazil), 2012).

It must be noted, though, that this rate of growth was due mainly to the positive performance of crops, with growth in production of wheat (62.3%), herbaceous cotton (33.5%), corn grain (20.9%), and soybeans (11.1%), although there has been a reduction in coffee beans (−16.7%), paddy rice (−3.7%), and beans (−4.4%) (EPE – Empresa de Pesquisa Energetica (Brazil), 2012).

In terms of energy resources, there was a growth of 21.5% in products of sugar cane and a 44.1% increase in the price of firewood, because the replacement of native firewood by firewood from reforestation, which were replaced by other sources such as natural gas, LPG etc. Fig. 2 shows the domestic supply of electrical power, according to the structure of participation of sources in year base 2011 (EPE – Empresa de Pesquisa Energetica (Brazil), 2012).

Table 5 shows the sectoral consumption of energy in periods of 2010 and 2011 (EPE – Empresa de Pesquisa Energetica (Brazil), 2012).

The growth in the energy sector is mainly due to ethanol production. From Tables 4 and 5 it is seen that the 3.7% growth of GDP for the agricultural sector in 2011 was driven by a final energy consumption of 9.8 million toe, corresponding to a decrease of 1.4% with respect to previous year.

In the structure of Brazilian energy matrix (Fig. 3) are clearly observed the transformations resulting from policies, particularly in the period from 1979 through 1985. Specifically, the use of firewood as an energy source is reduced as the nation progresses. In the agricultural sector, rudimentary use of firewood in flour, in grain and leaves drying, in brick kilns, in lime kilns, in the production of homemade sweets etc, gradually lost its importance due to urbanization and industrialization (EPE – Empresa de Pesquisa Energetica (Brazil), 2012).

Regarding participation of biomass, including sugar cane bagasse, firewood and charcoal, alcohol, and other renewable primary sources in final energy consumption, the main consumer sectors are industry with about 52%, transport approximately 14%, and residential consumption close to 13%.

The increase of biomass share in Brazilian energy matrix is directly related to the substitution of fuel oil by charcoal, alcohol production from sugar cane bagasse, and the expansion of charcoal in metallurgical processes.

Although the agricultural sector has a role in the evolution of discrete sectoral energy consumption, it is worth noting its significant participation indirectly mainly through the production of sugar cane.

3.1. The biofuels potential

Historically, the share of the agricultural sector in the Brazilian energy scene began to be highlighted in 1975 with the launch of PROALCOHOL program, which aimed at compensating possible deficiencies in supply caused by the oil crisis. Also in the late 70s, the first studies on biodiesel began at the University of Ceara (current Federal University of Ceara), by Professor Expedito Parente (Rathmann et al., 2008).

By observing the biodiesel production chain (Fig. 4) it is clear its interaction with the agricultural sector, starting from the family farm for the production of grains to be processed through the return of waste for this sector in the form of feed and fertilizer, in addition to its participation in the energy sector as biofuel. Also, there may be a derivation by its reaction with alcohol, emerging a co-product, hydrated alcohol, also known as bioethanol.

Whereas from 2008 diesel sold must contain 2% of biodiesel, at first that would imply a demand of 782 million liters of biodiesel per year (ANP – Agencia Nacional do Petroleo, 2005; Republica Federativa do Brasil, 2005).

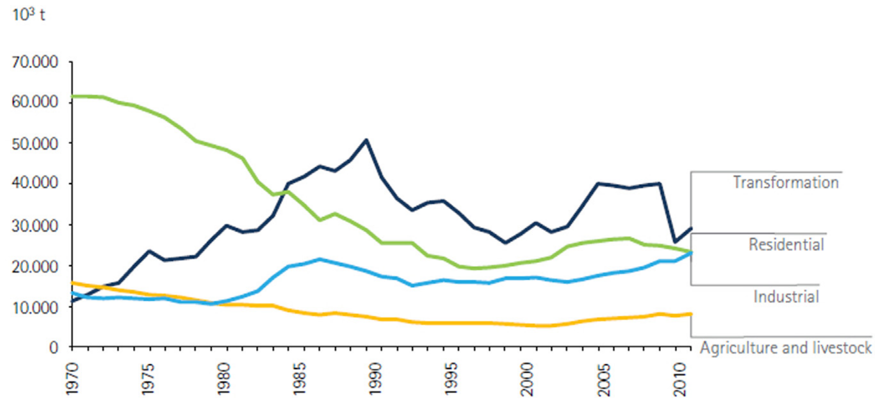

Fig. 1. Sectoral use of firewood.

Table 4
Economic and energy panorama.

	Unit	2010	2011	% 11/10
Population	10^6 inhab	191.6	193.2	0.8
Gross domestic product-GDP[a]	10^9 US$	2,250.8	2,312.3	2.6
Industry	10^6 US$	439,444	446,393	1.5
Services	10^6 US$	1,607,795	1,656,780	2.9
Agriculture and livestocks	10^6 US$	102,195	106,184	3.7
Current average prices of energy sources				
Petroleum and its by-products	US$/m^3	1,298.2	1,417.9	8.4
Natural gas	US$/10^3 m^3	459.7	611.4	24.8
Charcoal	US$/m^3	65	82.9	21.5
Hydraulical and electrical power	US$/MWh	199.2	218.9	9.0
Firewood	US$/m^3	8.1	14.5	44.1
Hydrated ethanol	US$/m^3	943.1	1,202.1	21.5
Foreign energy dependency[b,c]	10^6 US$	23,077	33,538	31.1

[a] US$ current values during 2011, average exchange rate in 2011 (Banco Central do Brasil: US$ 1.00=R$ 1.68).
[b] 1 kW h=860 kcal; Petroleum reference=10,000 kcal/kg; lower heating values – LHV; criteria according to the International Energy Agency – IEA and other international organizations.
[c] Ratio between net energy imports and domestic energy supply.

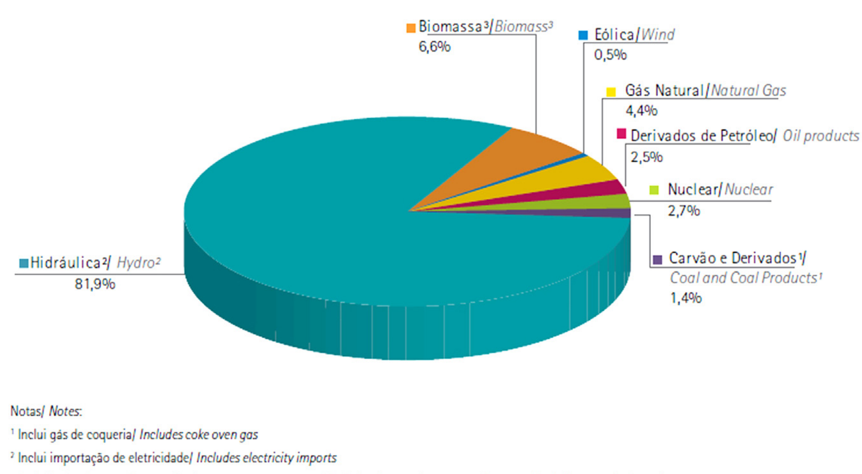

Fig. 2. The Brazilian energy matrix for year 2011.

So there will be an established need for the availability of oil to obtain biodiesel, ensuring market to the small farmer production. However, this market is sensitive to changes in international prices; it is not surprising the producers' preference for foreign trade (Vital Brazil et al., 2009; Blair, 2011).

According to (ABIOVE – Associacao Brasileira das Industrias de Oleos Vegetais, 2010), Brazil would have a daily capacity of extracting soybean oil sufficient to meet the daily demand of biodiesel B2, which would be approximately 2.5 million litres. Table 6 shows the ability of this major oilseed producing states.

Biodiesel production chain generated demand of products that can be crucial to the economic viability of biofuel production. The main ones are: glycerin, lecithin, bran, and oilseed cake (Vital Brazil et al., 2009).

Table 5
Final energy consumption by sector.

	Unit	2010	2011	% 11/10
Total final consumption	10^3 toe	223,501	228,928	2.4
Commercial	10^3 toe	6,731	7,124	5.5
Public	10^3 toe	3,636	3,758	3.2
Transportation	10^3 toe	69,720	73,989	5.8
Households	10^3 toe	23,562	23,374	−0.8
Agricultural and livestocks	10^3 toe	10,027	9,891	−1.4
Energy	10^3 toe	24,258	22,376	−8.4
Total industrial consumption	10^3 toe	85,567	88,416	3.2
Cement	10^3 toe	4,157	4,638	10.4
Mining and pelletization	10^3 toe	3,182	3,289	3.3
Textiles	10^3 toe	1,212	1,201	−0.9
Ceramics	10^3 toe	4,455	4,672	4.6
Pig-iron and steel	10^3 toe	16,445	17,669	6.9
Iron-alloys	10^3 toe	1,695	1,555	−9.0
Non-ferrous products	10^3 toe	6,492	6,885	5.7
Chemical	10^3 toe	7,214	7,464	3.3
Food and beverages	10^3 toe	23,244	22,972	−1.2
Pulp and paper	10^3 toe	10,131	10,180	0.5
Other non-specified industries	10^3 toe	7,338	7,891	7.0

It was demonstrated a cost estimate of the production of biodiesel from soybean oil by (Ferres, 2003). The values obtained indicated a cost of biodiesel production from US$ 394.78 per metric ton. However, from an estimate of the generation of 15% glycerin as a by-product of this process, it would obtain a reduction of US$ 77.79 for the total cost per metric ton.

4. Conclusions

As time goes by, the socio-economic evolution of the country generated characteristics, previously unattainable, which are closer to the rural areas and the base of its economy.

Previously, farmers were restricted to be energy consumers and to use firewood as fuel to provide heat. However, new technologies that have been developed have provided to convert unwanted solid residues in energy source, making these farmers energy producers, and in some cases even reaching the thermal and/or electrical energy self-sufficiency.

Some typical examples for use in gasification processes for thermal energy production are the bagasse from sugar cane, straw,

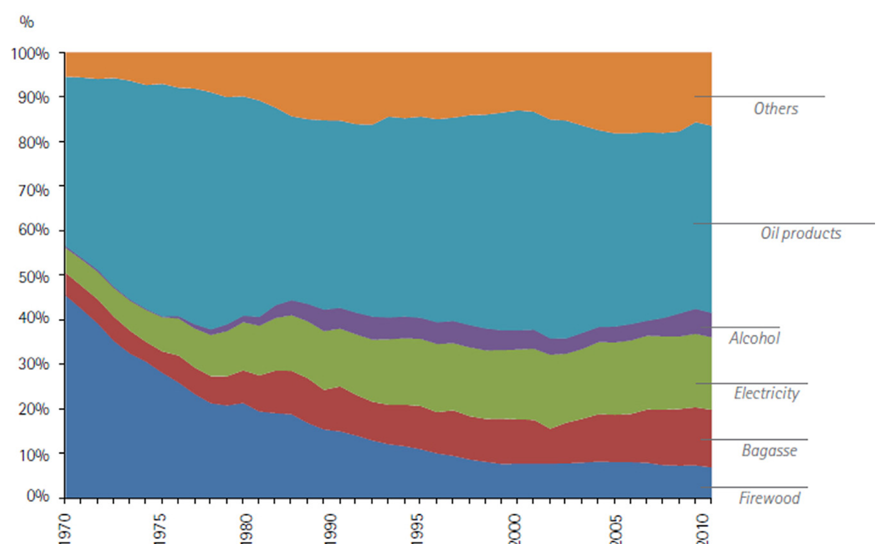

Fig. 3. Evolution of participation by sources in Brazilian domestic electrical power supply from 1970 to 2011.

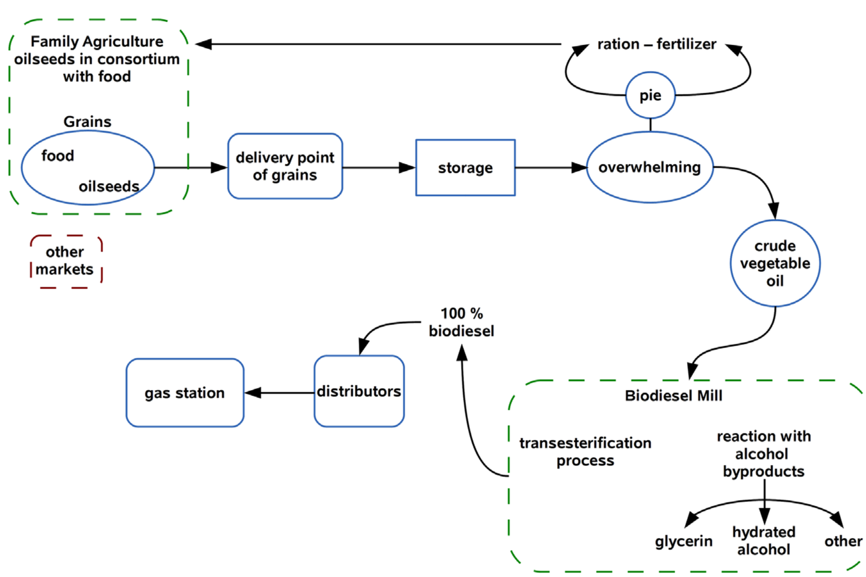

Fig. 4. Biodiesel production chain (Vital Brazil et al., 2009).

Table 6
Oilseeds processing capability (values in metric tons/day).
Source: http://www.abiove.org.br/capacidade_br.html.

State	2001	2002	2003	2004	2005	2006	2007	2008	2009	%
PR	31,500	28,650	28,950	31,765	32,115	32,950	33,850	35,150	34,150	20.7
MT	10,820	14,500	14,500	20,600	21,000	21,400	22,000	24,800	29,300	17.7
RS	19,000	20,150	20,100	19,700	21,200	23,600	24,800	25,800	28,500	17.2
GO	8,660	9,060	10,320	16,920	18,150	18,800	19,650	19,250	20,050	12.1
SP	14,700	12,950	14,450	14,950	15,600	16,400	16,650	17,780	17.780	10.8
MS	7,330	6,630	6,980	7,295	8,295	9,360	9,560	9,575	12,725	7.7
MG	5,750	6,450	6,350	6,400	6,600	6,600	6,600	6,600	6,800	4.1
BA	5,200	5,460	5,460	5,344	5,344	5,500	5,500	5,530	5,530	3.3
SC	4,130	4,050	4,000	4,034	4,034	4,034	4,034	4,034	4,034	2.4
PI	260	260	1,760	2,360	2,360	2,460	2,460	2,530	2,530	1.5
AM	–	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	1.2
PE	400	400	400	400	400	400	400	400	400	0.2
CE	200	–	–	–	–	–	–	–	–	–
MA	–	–	–	–	–	–	2,000	2,000	1,500	0.9
TOTAL	**107,950**	**110,560**	**115,270**	**131,768**	**137,098**	**143,504**	**149,504**	**155,449**	**165,299**	**100**

Note: PR – Parana; MT – Mato Grosso; RS – Rio Grande do Sul; Go – Goias; SP – Sao Paulo; MS – Mato Grosso do Sul; MG – Minas Gerais; BA – Bahia; SC – Santa Catarina; PI – Piaui; AM – Amazonas; PE – Pernambuco; CE – Ceara; MA – Maranhao.

and wood chips, among others. Another example highlights the possibility of feedlot manure of animals with the intention of concentration of methane gas originated in their process of decomposition for energy purposes.

Still in the sugar and alcohol sector, there are policies of reusing waste from production processes of sugar and alcohol for thermal power generation, as well as the specific production of ethanol.

The cultivation of oilseeds for biodiesel production incentive has also been a growth factor of agricultural economy.

All these features have value-added to the GDP of the agricultural sector. As the culture of renewable energy is inserted in a specific group of the society, it opens the way for new business opportunities and it makes possible the use of energy from solid waste.

So, the importance of participation of the agricultural sector in the national energy context, not only as consumers, but mainly through self-production energy policy of reusing solid waste as biomass and biofuels, is clearly seen.

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