ECONOMIC COMMISSION FOR LATIN AMERICA AND THE CARIBBEAN

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Promoting Energy Efficiency Investments
for Climate Change Mitigation and Sustainable Development

Case study

BRAZIL

IMPROVING ENERGY EFFICIENCY IN BRAZILIAN SUGARCANE INDUSTRY FOR CLIMATE CHANGE MITIGATION AND SUSTAINABLE DEVELOPMENT

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Summary

Brazil has a consolidated sugarcane industry facing an imminent growth perspective, due to ethanol fuel consumption increased demand. Implementing policies to deploy the most efficient usage of biomass will lead to decrease emissions within the power sector.

Sugarcane biomass would replace natural gas in the role of compensating for energy supply deficits during drought seasons, due to the small scale hydro reservoirs of new power stations, as well as for the intermittency of wind power generation.

Offsets of gas in the power sector will certainly be used elsewhere, for example in the transportation and industrial sectors where it will further offset oil demands, meaning there are net emission reductions when indirect effects of such technology deployment are accounted for.

The energy efficiency project described in this report, which was implemented in a sugar and ethanol mill located in south of Brazil, has already suffered a positive influence from some policy reforms introduced since 1998, like Federal Decree nº 2661, which limited burning before sugarcane harvesting, and PROINFA - Program for Incentive of Alternative Sources, in force since 2004, which made feasible power generation based on biomass source, among others, by guaranteeing energy purchasing with subsidized prices. Also these projects were granted with competitive financing options offered by the Brazilian Development Bank - BNDES.

Even so, all these reforms were not sufficient to fully develop the whole potential of power generation based on this source in Brazil. Current electricity production in sugarcane mills is around 20 TWh per year, of which 7 TWh is exported to the grid or less than 1.5% of total Brazilian power production.

According to estimates also based on this report, the installed capacity in sugarcane sector could generate an excess of 34 GW by 2030. This would correspond to 134.5 TWh/year available to export into the power grid, equivalent to 11.7% of the 1,153 TWh projected electricity production in 2030.

Further policy reforms that will impact positively the potential of replication of such a kind of project at a national level include the right to charge for collecting sugarcane waste produced in harvesting, facilitate electrical connection with the national grid and fiscal exceptions for buying equipment, when the entrepreneur invests in extra power production above a low limit to be established.

This more positive new scenario can still be encouraged and made possible to happen by including more broadly applicable financing options and technical assistance, mutually-beneficial agreements between utility companies and mills' owners and greater environmental education, information and regulation about this approach to energy generation.

Finally, ethanol from sugarcane also presents itself as an interesting solution for poor countries which import most of their fuel supplies at great costs. Central America countries like Honduras, Guatemala and El Salvador are examples of this and they have already made some progress to study how to increase and sustain an ethanol production and a consumption internal market.

The sugarcane industry's development made in a more sustainable way, as suggested in this report, will increase the success' odds of such a plan.

Part I. Identification of Energy Efficiency Project type and Sector with scale up potential at the national level

(a) Brazilian Sugarcane and Power Sectors. Energy Efficiency Projects’ Characteristics

(a.1) Brazilian Sugarcane Sector

The agribusiness related to the sugarcane industry in Brazil improved substantially during the 80´s due to a program introduced as a response to the oil crisis, in order to increase ethanol production as a substitute for gasoline - ‘Pro-Alcohol Program’.

Since then, the influence of the sector expanded from an edible industry, producing mainly sugar, to the fuel and power sectors, as it began to export electricity, besides producing ethanol fuel.

Nowadays another incentive to the sector, also related to ethanol fuel enhancement, is forecast, with the purpose of reduction of greenhouse gases emission in the transportation sector.

Some important issues grant the sugarcane industry in Brazil with extraordinary advantages, making it a very competitive energy producer when compared to the rest of world:

- Agriculture and Industry’s technological know-how;
- Equipment and any necessary material for producing ethanol and power can be found in Brazil;
- Available area and good climate for growing sugarcane.

This way Brazil is, along with the USA, one of the world’s largest ethanol producers. The sugarcane sector in Brazil produces both sugar and ethanol in huge quantities, but, as any agricultural crop, its production is affected by external conditions, which demand careful planning to attend the markets of fuel and power production.

The Southeast region is responsible for 90% of Brazilian sugarcane production and its mills provide almost all ethanol consumed in the country. Just São Paulo State responds for more than 60% of total production. The Northeast region focus is oriented to sugar production for exportation purposes (see **Table/Figure a.1**).

TABLE A.1
SUGARCANE AND BAGASSE PRODUCTION- 2009/10

State/Region	Sugarcane - t [A]	Bagasse - t [B]	B/A	Bagasse burnt as fuel - t
São Paulo – SP	362,644,755	99,744,771	28%	88,121,710
Paraná – PR	45,502,881	12,307,701	27%	10,959,826
Minas Gerais - MG	49,923,378	13,573,660	27%	11,885,574
Goiás – GO	40,092,429	11,405,346	28%	10,335,730
Mato Grosso do Sul - MS	23,297,818	6,241,749	27%	5,158,451
Mato Grosso do Norte - MT	14,045,632	4,004,106	29%	3,749,130
Rio de Janeiro - RJ	3,259,987	952,869	29%	814,492
Espírito Santo - ES	4,009,626	1,166,930	29%	1,153,361
Southeast-Midwest	542,776,506	149,397,133	28%	132,178,273
Alagoas – AL	24,269,759	6,956,590	29%	6,263,844
Pernambuco – PE	18,259,333	5,375,389	29%	5,132,962
Paraíba – PB	6,241,756	1,838,513	29%	1,594,009
Rio Grande do Norte - RN	3,515,678	983,966	28%	850,971
Bahia – BA	2,094,547	577,512	28%	560,442
Sergipe – SE	1,480,831	423,095	29%	335,778
Other states	3,377,932	987,078	29%	913,331
North region	880,319	237,526	27%	237,526
North-Northeast	60,120,155	17,379,668	29%	15,888,863
BRAZIL	602,896,661	166,776,801	28%	148,067,137

FIGURE A.1 SUGARCANE MILLS IN BRAZIL - 2010

(a.2) Brazilian Power Sector

Brazil has a long tradition of applying renewable resources in the power and transportation sectors. Primary energy supply is composed of 44% of renewable sources, including hydro, biomass and wind. Hydroelectricity is responsible for almost 80% of the power generated and of the total 117 GW installed in the country, 83 GW are hydroelectric plants of all capacities.

The great participation of hydropower in Brazil’s electricity production makes it the favorable source to expand country’s capacity. There is still a huge hydro energy potential to be explored, but most of it lies in the Northern region of Brazil, where power demand is low and where big reservoirs must be formed in order to stabilize power production.

These big reservoirs have not been constructed due to environmental restrictions and, as a consequence, the risk of power deficit increases in case of prolonged water shortage. The drought that occurred in 2001 prompted the federal government to diversify energy supply sources, favoring the inclusion of a reasonable share of thermopower plants, many powered by natural gas. It also created a market share for other renewable sources of energy such as wind power and biomass.

The rough currently 600 Mt of sugarcane production provides revenues of US$ 28 billion or 2 % of Brazilian GDP. Besides its economic relevance, sugarcane also provides a substantial contribution to the country’s primary energy sources. Around 50% of sucrose in sugarcane is directed to the production of 27 million cubic meters of ethanol per year, 24 million cubic meters supplied to the Brazilian fuel market, which displaces 18 million cubic meters of gasoline, on an energy equivalent basis.

This fact brings a remarkable opportunity for power production from more than 420 sugar and ethanol mills spread out through the country. This concept is based on exploring a better utilization for the bagasse - sugarcane milled stalk, together with a sugarcane waste collection - residues of sugarcane harvesting composed basically of leaves. Today’s practice of burning such waste in the cropland, prior to harvesting, will soon be banned across Brazil.

The sugarcane bagasse provides almost all energy required for processing the sugarcane and several mills are already generating surplus power and selling it to the electrical grid (**see Table a.2**).

TABLE A-2
ELECTRICITY PRODUCTION IN SUGARCANE MILLS - 2009/10

State/Region	Installed capacity - MW	Power Generation - MWh	Self-Power Consumption - MWh	Net Power Export - MWh
Southeast-Midwest	5,162	18,172,728	11,227,285	6,945,443
North-Northeast	754	1,858,697	1,486,534	372,163
BRAZIL	5,915	20,031,425	12,713,819	7,317,606
Power Indexes kWh/t cane		33.2	21.1	12.1

The participation of sugarcane biomass in total power production in Brazil is still small, less than 4% (**see Table a.3**, where biomass includes black liquor and wood).

TABLE A-3
POWER PRODUCTION IN BRAZIL AND GHG EMISSIONS – 2010

Source	GWh	%	MtCO2 eq.	%
Hydro	403,290	78.2		
Nuclear	14,523	2.8		
Biomass	31,523	6.1		
Sugarcane	20,031	3.9		
Others	11,492	2.2		
Wind	2,177	0.4		
Others1	3,481	0.7		
Natural Gas	36,476	7.1	14.59	40.9
Diesel / Fuel Oil	16,065	3.1	12.85	36.0
Coal	8,263	1.6	8.26	23.1
Total	515,798	100.0	35.71	100.0

This data was officially published by the Brazilian Government in the Electrical Energy Statistic Yearbook 2012, released by the Ministry of Mines and Energy through its Energy Research Office - EPE/MME.

Like hydro, nuclear and wind sources, biomass contribution to greenhouse gases - GHG - emissions is considered equal to zero, as, in theory, all gases produced by its by-products' burning would be offset when the plantations grow.

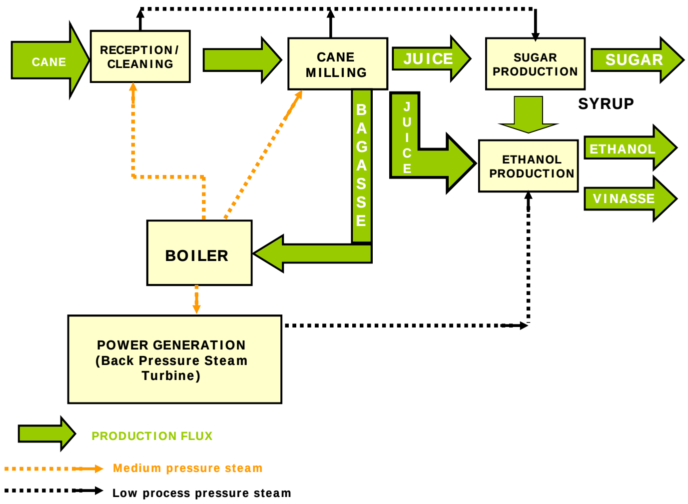
There are other opinions regarding this subject, even for the operation of hydropower stations, as any organic matter flooded in the water reservoir will, eventually, decay and produce GHG somehow.

But for the report's purpose this discussion can be disregarded because the useful burning of sugarcane fiber will produce power that can save a fossil fuel source, like coal or natural gas.

This surplus power generation of the sugar/ethanol mills could be significantly increased by the use of more efficient energy conversion systems and through the recovery of part of sugarcane waste which is burned and disposed today. This additional primary energy source would supplement the bagasse fuel. Nonetheless, cane waste recovery needs development and demonstration pilot plants in order to turn out to be a common practice in the market.

Sugarcane production and processing are highly energy intensive activities, requiring for each ton of cane, under typical Brazilian conditions, 190 MJ in the agricultural area - in the form of diesel oil burned in planter and harvester machines, as well as in the process of bringing sugarcane to the mill, fertilizers and others chemicals - and 1970 MJ in industry - in the form of chemicals and bagasse, although bagasse provides nearly 100% of the energy requirement in the industry (see **Figure a.2**).

FIGURE A.2
CONVENTIONAL MILL BLOCK DIAGRAM



1 Mainly Process Heat Recoveries

Anyway, a life cycle analysis for ethanol production has indicated that for each unit of fossil energy input to the agribusiness system, approximately nine units of useful renewable energy output (ethanol and cane bagasse) will result.

However, this situation has a huge potential for improvement if we bear in mind that ethanol represents only one third of the energy available in sugarcane. From the other two thirds, represented by fiber in bagasse and sugarcane leaves, only part of it is used in the process thus leaving substantial potential for improvements:

Almost 90% of the bagasse is used as a fuel in cane processing, but, very frequently, in a very inefficient way;

Roughly 35% of cane leaves are currently burned prior to sugarcane harvesting to reduce the cost of this operation; the other 65% is harvested unburnt, however the cane waste is left on the ground to decay.

In both cases the net result is that carbon in the fiber returns to the atmosphere in the form of CO2. This fact indicates that with some effort and investments this potentially available fuel (sugarcane fiber) can be saved and used to generate electric power to the grid.

(a.3) Energy Efficiency Projects' Characteristics

In order to accomplish a better sugarcane biomass harnessing, three classes of Energy Efficiency - EE - Projects with strong potential for scale-up can be identified:

i) Use of an efficient technology to generate power;

ii) Improve cane processing's energy efficiency to generate more bagasse surplus;

iii) Harvest unburnt sugarcane and recover a reasonable fraction of the total waste.

The effects of these improvements can be evaluated from data generated in a revamped sugar and ethanol mill located at South of Brazil. The mill adopted measures in order to export power to the grid related to the use of more efficient technology to generate power: installation of one boiler generating steam at 65 bar/480ºC and two steam generator sets, one driven by an extraction/back pressure turbine and the other, by a condensing turbine.

Figure a.3 illustrates a typical mill power exporter diagram and **Table a.4** shows the mill's basic characteristics. Such data supports the analysis developed in this report.

FIGURE A.3
POWER EXPORTER MILL BLOCK DIAGRAM

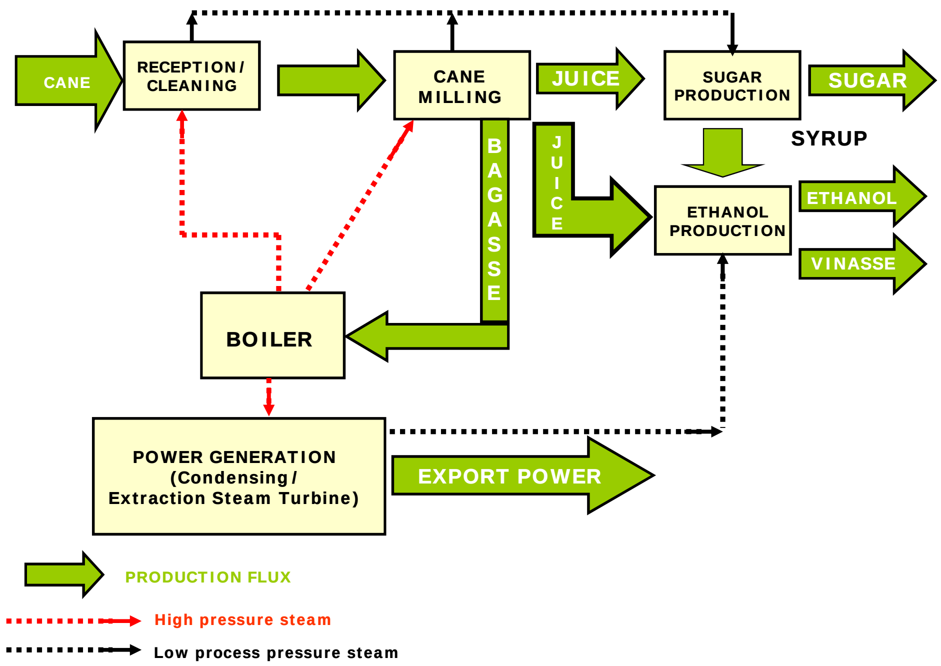


TABLE A.4
MILL'S BASIC OPERATION DATA

Sugarcane production as clean stalks	2 million t per year
Extraction efficiency of the mill	96%
Bagasse consumption (wet basis)	255 kg/t of cane
Planted area	24,000 ha
Sugarcane harvesting season	230 – 270 days (March to November)
Off-season	135 – 95 days
Effective operation	210 days (5,040 hours)
Mills' capacity factor	84 % = 210/250
Ethanol production	50,275 m3 /year
Sugar production	196,000 t/year
Cane processing capacity	400 t/hour
Process steam consumption (1.5 bar)	182.4 t/hour - 480 kg/t cane
Total bagasse production	520,000 t (26 % of cane)
Recoverable waste	166,000 t (49% of total production)
Installed Power Capacity	40 MW
Back-pressure steam turbine with extraction	28 MW (65 to 1.5 bar – 21 bar extract.)
Condensing steam turbine	12 MW (21 to 0.15 bar abs)
Self-power consumption	12,600 kW
Cane dry cleaning system's consumption	1,000 kW

Other measures are still subjected to an economic analysis and they have not been implemented yet. They are related with cane waste collection and energy conservation measures applied in the industrial area in order to reduce process steam consumption. They are briefly described below:

- The cane harvester cleaning system can have the secondary cleaning fan turned off and the primary fan set at a convenient rpm. Therefore, only a partial cleaning of the cane occurs during the harvesting operation, leaving a thinner waste blanket on the ground and the leaves transported with the cane would be stripped off by a dry cleaning system at the processing plant;
- Improvements in the sugar juice processing like molecular sieves for ethanol dehydration, evaporators and condensers installation for internal heat recovery in the sugar juice distillation section and electrification of mechanical drives in the cane milling sector.

The plant can then store part of the bagasse produced during the season in a 60,000 m2 open yard area. This way the new extraction/condensing turbo generator set could operate during sugarcane harvesting season as well as during off season.

Bagasse and cane waste present practically the same composition in carbon (~45%), hydrogen (~6%), nitrogen (0.5 - 1%), oxygen (~43%) and sulfur (~0.1%). The difference is the moisture content which affects the heat value as indicated in **Table a.5**. The high water content in bagasse allows that it can be stored without any risk of getting fire.

TABLE A.5
FUEL DATA UNDER BURNING CONDITIONS

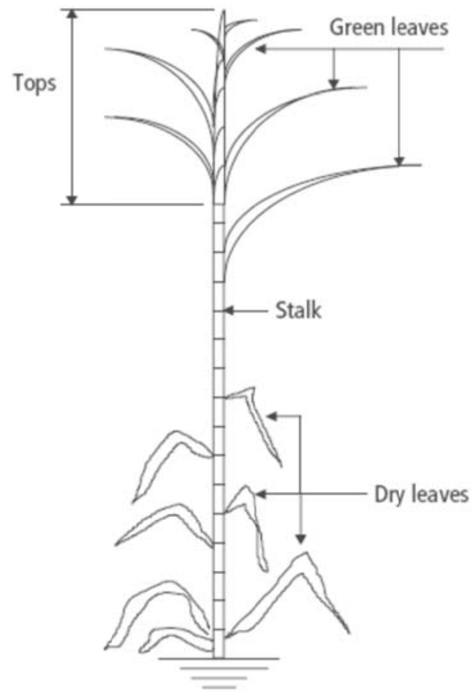
Data collected in the mill	Leaves	Bagasse
Moisture content % weight	25	50
Lower Heat Value MJ/kg (wet basis)	12.0	7.2

The level of harvest mechanization in the mill is presently around 70%. The other 30% of sugarcane plantation is located in areas where harvester machines have no access. Nonetheless, due to agricultural reasons, all sugarcane is burnt before harvesting, because it could not be all left decaying on the field due to agricultural reasons.

If the measures related with cane waste collection were implemented, the top leaves, which correspond to approximately 30% of the waste, were still left decaying on the field, providing a natural protection to the soil.

Ideally, around 49% (~70% x 70%) of the waste could be brought to the mill, together with the sugarcane, and it would be separated in a new sugarcane dry cleaning system. After separation, leaves are shredded and burnt in designed boilers, providing a bagasse surplus, which could then be burnt during the off season period (see **Figure a.4**).

FIGURE A.4
SUGARCANE PLANT PARTS



The EE project's types analyzed in this report are defined below:

A - 30% collection of total sugarcane waste produced, which is burnt to produce steam and save bagasse for the off season period;

B - ´A` action plus elimination of the low pressure boiler still used;

C - ´B` action plus revamp of the processing unit to reduce steam consumption, substitution of low efficient steam turbines in the cane milling sector for electric motors and application of steam boilers of higher pressure (90 bar instead of 65 bar).

It is important to notice that these EE projects are all technical feasible and they have been, not simultaneously, already applied in some few mills. The decision to implement them, or not, are only subjected to an economic feasibility analysis.

Some additional improvements, still under research nowadays, are related to hydrolysis processes of bagasse, which would produce further ethanol - cellulosic alcohol - and BIG-GT power systems, which consist of bagasse gasification and burning the synthetic fuel in gas turbines.

These two EE measures are not commercial available yet. In any case, if they prove to be technical and economical feasible in the near future, most probably, they would affect a limited number of new plants and would not change the conclusions of this report.

A general block diagram of type C EE project is shown in **Figure a.5** and **Table a.6** summarizes the results of implementing these EE projects.

FIGURE A.5
OPTIMIZED POWER EXPORTER MILL BLOCK DIAGRAM

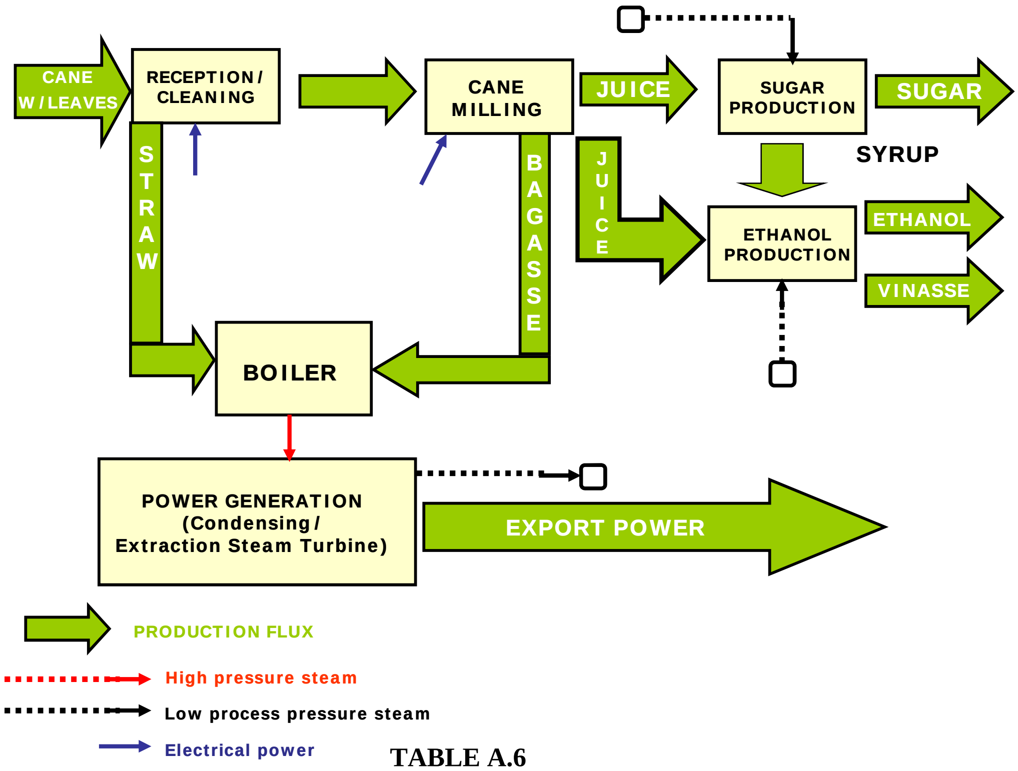


TABLE A.6
POWER GENERATION ALTERNATIVES

Item		Implemented	A	B	C
Process steam consumption	kg/t cane		480		360
	t/h		182.4		136.8
Mill power consumption - kW		12,600	13,600	13,600	14,700
Mechanical power demand - kW		6,600	6,600	6,600	500
High pressure steam boiler capacity (HP)		160 t/h @ 65 bar / 480ºC	160 t/h @ 65 bar / 480ºC	270 t/h @ 65 bar / 480ºC	300 t/h @ 90 bar / 520ºC
Low pressure steam boiler capacity (LP)		130 t/h @ 21 bar / 300ºC	130 t/h @ 21 bar / 300ºC	-	-
Investment – MUS$		63.8	65.0	79.0	135.0
Installed Capacity – MW		40	40	40	72
Annual exported power - GWh		73.6	152.8	171.6	264.4
Power Station Installed Cost - US$/kW		1,595	1,625	1,975	1,875
Power Station Capacity Factor - (%)		21.0	43.6	49.0	41.9
Bagasse consumption			510,000 t (wet basis)		
Cane waste useful collection/ consumption		-		30% / 100,000 t (wet basis)	
Net Power Export Index – kWh/ t cane		36.8	76.4	85.8	132.2
Emission reduction – kt CO2 eq./year[2]		29.44	61.12	68.64	105.76

[2] The useful burning of sugarcane fiber will produce power that, in the most conservative case, will save natural gas in a thermopower station or approximately 400 t of CO_2 equivalent per GWh produced.

(b) Current Policy

The critical point in the implementation of year round power generation in sugar/ethanol mills is the recovery of part of the available biomass waste, which requires that unburnt cane harvesting procedures are taken.

Economic and social reasons had maintained until now the adoption of mechanical harvesting of unburnt cane at a low level. On the opposite direction, environmental pressures to stop cane burning have resulted in laws and regulations that are intended to limit cane burning and to program its phase out by 2031.

TABLE B.1
PHASE OUT OF SUGARCANE BURNING IN BRAZIL (NOTES3)

Year	Federal Decree nº. 2661/1998		São Paulo State Law nº. 47700/2003	
	Mechanical Harvesting	Manual Harvesting	Mechanical Harvesting	Manual Harvesting
2008	50%	N/A	30%	-
2011	50%	N/A	50%	10%
2013	75%	N/A	50%	10%
2016	75%	N/A	80%	20%
2018	100%	N/A	80%	20%
2021	100%	N/A	100%	30%
2026	100%	N/A	100%	50%
2031	100%	N/A	100%	100%

The main social barrier regarding mechanical harvesting is related to unemployment. Between the sugarcane harvesting seasons of 2009/10 and 2008/09 there was a loss of approximately 50,000 job positions due to this process, workers with low proficiency and great difficulties of getting another job. But, apparently this problem is being surpassed as, in 2011, unburnt cane harvesting and mechanization levels have already achieved, respectively, 73.7% and 83%, in Southeast-Midwest region.

Anyway, one harvester machine substitutes approximately 50 workers under current productivity average numbers (454.4 t/day x 9.2 t/day) and around 300,000 workers will have to be trained for being reintegrated to the market, if manual harvesting is totally vanished from the sugarcane business.

Even so, the economic reasons still remain. The additional investment regarding collection of cane waste and its effects on the mill's productivity are issues that must be deeply evaluated. These economic effects are briefly described ensuite:

Changes in soil preparation, sugarcane's planting and tillage, herbicide use, either by simply elimination of any activity or by the difference in agricultural equipment's performance, which can produce positive or negative impacts;

Reduction of milling capacity due to the increase in fiber added to the cane and decrease in juice extraction efficiency due to carryover of sugar by any additional vegetal impurities, milled with the cane, should also be considered.

On the other hand, sugarcane industry has a thirty-year-old history of commissioning low pressure steam boilers, under 30 bar, to attend the thermal and power demand of the processing plant and to get rid of the bagasse, burning it in an very inefficient way.

The industry has little incentive to upgrade its installation, since new 65 to 120 bar boilers are expensive and would result in net biomass waste increase after their own power demand is sufficed.

[3] N/A: not applicable. The sugarcane mechanical harvesting is subjected to present technology only in areas larger than 150 ha and inclination less than 12%.

The selling of the surplus electrical power that can be produced with this fuel could become a strong motivation. But the purchasing of that potential electricity production needs to bring an interesting economical attraction to the mills in order to incentive the sector modernization.

Policies such as the Program for Incentive of Alternative Sources (PROINFA[4]), in force since 2004, have aimed to increase the participation of wind, biomass and small hydroelectric power by guaranteeing purchasing from such projects in 20-year contracts with fixed prices.

However, its effect on sugarcane biomass electricity output was smaller than its initial plans, as power purchase agreements - PPA - signed between 2005 and 2007 incorporated only 685 MW of the sugarcane biomass listed projects' total power capacity of 1,300 MW.

From 2007 onwards, PROINFA's fixed price contract model was replaced by specific alternative source auctions for reserve power to complement base hydropower in sufficing existing and perspective demands. Since then, bioelectricity competes with fossil fuel thermopower stations, wind power, and small hydroelectric plants.

The auction for reserve power in late 2011 well illustrates the current status of sugarcane bioelectricity. From a total of 92 projects contracted (3,962 MW); 78 were wind power (1,928 MW), 11 sugarcane bioelectricity (554 MW), 2 were natural gas (1,029 MW), and 1 was an addition to an existing hydropower plant (450 MW).

Wind power has managed to overcome natural gas for the first time in offering lowest prices (around US$ 50/MWh), while sugarcane bioelectricity still ran behind. However, subsidized wind generation can intensify artificially low electric prices, thus imposing economic harm on competitive generators that are needed to maintain system reliability.

Also it is interesting to observe the percentages of offer contracted from each primary energy source. Wind power had 31% of its offer contracted, while natural gas got 23%, and sugarcane bagasse derived bioelectricity had only 20% out of 43 enlisted projects, totaling 2,750 MW offered capacity.

Finally, recurring to the study case, the mill's gross revenue, before taxes, applying currently market values, are as it follows:

- 196,000 t/year of sugar x US$ 490/t of sugar (½ white, ½ VHP[5]) = US$ 96.04 million;
- 50,275 m3 /year of ethanol x US$ 550/m3 of ethanol (½ anhydrous, ½ hydrous) = US$ 27.65 million;
- 73,600 MWh/year x US$ 75/MWh = US$ 5.52 million, which accounts for less than 5% of the total gross revenue.

Also, very often, a long transmission line must be installed to connect the mill thermopower plant to a powerful enough electrical public grid. Investments of a typical 69 kV line are of the order of US$ 150,000 per kilometer and, accordingly to the present regulation, it must be paid by the plant´s entrepreneur. This value compared to total plant investment can be very significant, sometimes reaching almost 50% of total investment.

A hypothetical simulation applying the study case investment data is shown in **Table b.2**.

TABLE B.2
IMPACT OF CONNECTING ELECTRICAL LINE TO TOTAL THERMOPOWER INVESTMENT

Line distance	Line investment	% of total investment Power Generation Alternative			
km	MUS$	Actual	A	B	C
10	1.5	2.4%	2.3%	1.9%	1.1%
50	7.5	11.8%	11.5%	9.5%	5.6%
100	15.0	23.5%	23.1%	19.0%	11.1%
200	30.0	47.0%	46.2%	38.0%	22.2%

4 See box at the end of this chapter
5 Very High Polarization sugar

The Program for Incentive of Alternative Energy Sources - PROINFA, as described in Brazilian Decree No. 5025 of 2004, was established with the objective of increasing the participation of electrical power produced by enterprises based on wind, biomass sources and small hydropower plants (SHP) in the national interconnected electrical system - SIN. The aim of this Program was to promote the diversification of the Brazilian energy matrix, seeking alternatives to increase the electricity supply security and the enhancement of potential regional energy sources.

The Ministry of Mines and Energy was responsible for setting the economic value of each power source, besides the guidelines to develop the program planning. ELETROBRÁS, state owned electrical company, took the role of executing agent, being responsible for resuming contracts and signing Power Purchase Agreements – PPA – with the entrepreneurs. The extra cost incurred, due to subsidized energy prices when hiring these ventures, was divided among all classes of consumers served by the SIN, with the exception of consumers classified in subclass Low-income Residential (consumption equal to or less than 80 kWh per month).

The program had initially envisaged the deployment of 1,110 MW for each one of those sources, totaling 3,300 MW of installed capacity, which in reality resulted into firmed contracts of 1,423 MW of wind power plants, 1,192 MW of SHP and 685 MW of biomass from sugarcane. All the energy produced is guaranteed for a 20 years period PPA.

PROINFA was a pioneering program that propelled these sources, wind energy in particular. The Brazil went in just over 5 years from about 22 MW of installed wind power to the current 1,000 MW. One challenge set by the program’s guidelines was the minimum 60% nationalization index of enterprises, which promoted the strengthening of the Brazilian wind power industry.

By the end of 2012, 127 enterprises have come into operation, which represented the insertion of 2,665 MW in the system, 45 wind farms (980 MW), 62 SHP (1,152 MW) and 20 biomass power plants (533 MW).

(c) Energy Efficiency Potential

The potential energy savings and CO2 emission reductions through the implementation of the EE projects described must be analyzed under two situations:

- Improvements of old mills already in operation;
- Establishment of minimum standard operational conditions for the new mills to be developed in the future.

(c.1) Old Mills

Old mills can be classified per capacity sizes as it is presented in **Table c.1**, a survey accomplished by CONAB, a Brazilian National Supply Company of the Ministry of Agriculture, Livestock and Provision, for the 2009-2010 harvesting season.

TABLE C.1
CLASSIFICATION OF MILLS PER BAGASSE BURNING CAPACITY - 2009/10

Class	t of bagasse burnt per hour	Average milled cane per year - kt	Sugarcane Production - kt	Bagasse fuel -kt
1	> 220 t	5,362	96,512	24,486
2	180 to 220 t	3,542	31,880	7,995
3	160 to 180 t	3,516	38,675	9,240
4	140 to 160 t	2,785	47,352	12,463
5	120 to 140 t	2,393	50,259	12,895
6	100 to 120 t	1,953	56,637	14,092
7	80 to 100 t	1,645	82,266	20,432
8	60 to 80 t	1,298	80,476	19,342
9	40 to 60 t	985	73,864	17,238
10	< 40 t	450	44,976	9,884
	Total		602,897	148,067

CONAB has also made a research on the best practices related to power generation under each class established in **Table c.1**. The results are presented in **Table c.2**.

It is interesting to notice that the mill of the study case would be classified as a Class 6 with a net power export index close to the best ones.

TABLE C.2
BEST MILLS UNDER SIZE CLASSES - 2009/10

Class	Power Generation Index kWh/t cane	Self-Power Consumption Index kWh/t cane	Net Power Index kWh/t cane
1	99.4	26.8	72.7
2	98.7	29.4	69.3
3	65.6	21.3	44.3
4	71.0	25.7	45.3
5	68.1	27.5	40.6
6	62.1	24.4	37.7
7	55.1	27.0	28.1
8	58.1	25.0	33.1
9	44.6	23.2	21.4
10	41.6	20.9	20.7
Average	66.3	25.2	41.0

Some assumptions can now be made:

1. Until 2030, all mills under each class can achieve the operational results observed by the best in its class. Then the exported electricity and CO2 emissions reductions would reach the values shown in **Table c.3**.

TABLE C.3
OLD MILLS OPERATING UNDER BEST PERFORMANCE INDEXES AVAILABLE TODAY IN THE INDUSTRY

Class	Sugarcane Production - kt	Net Power Index kWh/t cane	Exported Electricity GWh
1	96,512	72.7	7,016
2	31,880	69.3	2,209
3	38,675	44.3	1,713
4	47,352	45.3	2,145
5	50,259	40.6	2,041
6	56,637	37.7	2,135
7	82,266	28.1	2,312
8	80,476	33.1	2,664
9	73,864	21.4	1,581
10	44,976	20.7	931
Total	602,897	41.0	24,719(a)
Today exported electricity			7,318(b)
Potential surplus, (a-b)			17,401
Mt CO2 eq. emissions reduction6			6.96

2. Mills under classes [1; 2; 3] would achieve the better operational results through the implementation of the EE project of type C; mills under classes [4; 5; 6] would implement EE project of type B; mills under classes [7; 8] would implement EE project of type A and the mills under classes [9; 10] would achieve, at least, the operational results observed by the best in its class, like the last assumption.

Then the exported electricity and CO2 emissions reductions would reach the values shown in **Table c.4.**

[6] The useful burning of sugarcane fiber will produce power that, in the most conservative case, will save natural gas in a thermopower station or approximately 400 t of CO2 equivalent per GWh produced.

TABLE C.4
OLD MILLS OPERATING UNDER PERFORMANCE INDEXES ACHIEVABLE AFTER IMPLEMENTING EE PROJECTS – 2030

Class	Sugarcane Production - kt	Net Power Index kWh/t cane	Exported Electricity GWh
1	96,512	132.2	12,758
2	31,880	132.2	4,214
3	38,675	132.2	5,113
4	47,352	85.8	4,063
5	50,259	85.8	4,313
6	56,637	85.8	4,860
7	82,266	76.4	6,286
8	80,476	76.4	6,149
9	73,864	21.4	1,581
10	44,976	20.7	931
Total	602,897	83.4	50,268(a)
Today exported electricity			7,318(b)
Potential surplus, (a–b)			42,950
Mt CO2 eq. emissions reduction			17.18

(c.2) New Mills

Greenfield mills under development all have plans for harvesting more than 3 Mt of sugarcane per year. Small mills have little chances to survive in the future, as competition increases and the business's scale-up significantly decreases costs.

Official forecasting predicts a sugarcane production of 1,140 Mt in 2030 (see **Table d.2** in Assessment Methodology) to accomplish future fuel ethanol and sugar demands. It is reasonable to consider that, if a new policy has success in achieving the EE potential, these mills will implement the best EE project identified (type C) and that the small mills (class 9 and 10) will fail to continue in the market.

This way, under this new scenario, there would be an additional 1,140,000 - 602,897 (today production) + 118,840 (classes 9 and 10 mill production) = 655,943 kt of sugarcane satisfying the new best net export energy index - 132.2 kWh/t cane, instead of the currently best one - 72.7 kWh/t cane. The exported electricity and CO2 emissions reductions values in this case are shown in **Table c.5**.

TABLE C.5
OLD AND NEW MILLS OPERATING UNDER PERFORMANCE INDEXES ACHIEVABLE AFTER IMPLEMENTING EE PROJECTS - 2030

Class	Sugarcane Production - kt	Net Power Index kWh/t cane	Exported Electricity GWh
1	96,512	132.2	12,758
1	655,943	132.2	86,711
2	31,880	132.2	4,214
3	38,675	132.2	5,113
4	47,352	85.8	4,063
5	50,259	85.8	4,313
6	56,637	85.8	4,860
7	82,266	76.4	6,286
8	80,476	76.4	6,149
Total	1,140,000	118.0	134,467(a)
Today exported electricity			7,318(b)
Potential surplus, (a–b)			127,149
Mt CO2 eq. emissions reduction			50.86

Other intermediate scenarios can be derived:

TABLE C.6
OLD MILLS OPERATING UNDER BEST PERFORMANCE INDEXES AVAILABLE TODAY NEW MILLS ACHIEVE BEST EE POTENTIAL – 2030

Class	Sugarcane Production - kt	Net Power Index kWh/t cane	Exported Electricity GWh
1	96,512	72.7	7,016
2	31,880	69.3	2,209
3	38,675	44.3	1,713
4	47,352	45.3	2,145
5	50,259	40.6	2,041
6	56,637	37.7	2,135
7	82,266	28.1	2,312
8	80,476	33.1	2,664
9	73,864	21.4	1,581
10	44,976	20.7	931
Old Mills	602,897	41.0	24,719
New mills	537,103	132.2	71,005
Total	1,140,000	84.0	95,724(a)
Today exported electricity			7,318(b)
Potential surplus, (a–b)			88,406
Mt CO2 eq. emissions reduction			35.36

TABLE C.7
OLD AND NEW MILLS OPERATING UNDER BEST PERFORMANCE INDEXES AVAILABLE TODAY – 2030

Class	Sugarcane Production - kt	Net Power Index kWh/t cane	Exported Electricity GWh
1	633,615	72.7	46,063
2	31,880	69.3	2,209
3	38,675	44.3	1,713
4	47,352	45.3	2,145
5	50,259	40.6	2,041
6	56,637	37.7	2,135
7	82,266	28.1	2,312
8	80,476	33.1	2,664
9	73,864	21.4	1,581
10	44,976	20.7	931
Total	1,140,000	55.95	63,784(a)
Today exported electricity			7,318(b)
Potential surplus, (a–b)			56,466
Mt CO2 eq. emissions reduction			22.59

TABLE C.8
OLD MILLS KEEP THEIR STATUS QUO AND NEW MILLS OPERATE UNDER BEST PERFORMANCE INDEXES AVAILABLE TODAY – 2030

Class	Sugarcane Production - kt	Net Power Index kWh/t cane	Exported Electricity GWh
Old Mills	602,897	12.1	7,318
New mills	537,103	72.7	47,687
Total	1,140,000	48.3	55,005(a)
Today exported electricity			7,318(b)
Potential surplus, (a–b)			47,687
Mt CO2 eq. emissions reduction			19.08

(d) Assessment Methodology

The assessment of electricity production and sugarcane industry for 2030 in Brazil is available in the National Energy Plan - PNE 2030. This document, also released by EPE/MME, is revised from time to time and the last available edition of 2007 shows the power distribution by source in a different way from the Electrical Energy Statistic Yearbook 2012.

The power produced by sugarcane is the net exported to the electrical grid. Mill's electricity self-consumption is added to self-generation, which includes, beyond other sources, waste from paper and cellulose industry composed of black liquor and wood that do not produce enough surplus power to export to the grid (see **Table d.1**).

TABLE D.1
POWER PRODUCTION IN BRAZIL AND GHG EMISSIONS - 2030

Source	TWh	%	Mt CO2 eq.	%
Hydro	817.6	70.9		
Nuclear	51.6	4.5		
Sugarcane Biomass	33.5	2.9		
Wind	10.3	0.9		
City trash	6.8	0.6		
Others	12.5	1.1	28.43	29.4
Self-generation	97.8	8.5		
Natural Gas	92.1	8.0	36.84	38.1
Diesel / Fuel Oil	N/I[7]	-	N/I	-
Coal	31.4	2.7	31.40	32.5
Total	1,153.6	100.0	96.67	100.0

It becomes clear from sugarcane industry assessment (see **Table d.2**) that some estimated numbers are under evaluated when they are compared with 2010 historical statistics showed in **Tables a.1 and a.2**.

On the other hand, cellulosic ethanol is still a promise today in 2012 and the forecasting in 2007 was that, in 2010, 300 kt of bagasse would be used as raw material to produce ethanol, together with a 5% waste sugarcane collection, what did not happen in reality.

[7] Not informed, included in "Others" and "Self-generation"

]

TABLE D.2

SUGARCANE BUSINESS ASSESSMENT UNTIL 2030 - PNE 2030

Mt	2005	2010	2020	2030
Sugarcane production	431	518	849	1,140
Total biomass	117.8	141.9	233.5	313.5
Bagasse (dry basis)	57.8	69.7	114.6	153.9
Waste (dry basis)	60.0	72.2	118.9	159.6
Waste collection	0%	5.0%	14.9%	20.0%
Available biomass	57.8	73.3	132.3	185.8
Biomass destination				
Ethanol Production	0.0	0.3	17.7	18.7
Power Production	57.8	73.0	114.6	167.1
Planted area (Mha)	5.6	6.7	10.6	13.9

MW installed capacity	2005	2010	2020	2030
Old Mills				
With no power surplus	250	140	90	30
Back pressure turbines		1,380	1,260	1,400
Extraction / Condensing turbines		150	420	590
BIG/GT			170	460
Subtotal	250	1,670	1,940	2,480
New Mills				
Back pressure turbines	90	410	1,560	2,770
Extraction / Condensing turbines	10	90	560	1,160
BIG/GT			50	420
Subtotal	100	500	2,170	4,350
Total	350	2,170	4,110	6,830

The forecasted required area for sugarcane harvesting in 2030 - 13.9 million of hectares - would represent just 3.8% of the total available farming area in Brazil, roughly 366 Mha.

Although these data were used to assess the potential of future power generation burning sugarcane biomass, very soon they will have to be updated, when a new edition of 2030 Energy Plan is released.

Regarding this subject, EPE/MME has released since 2006 a Decennial Energy Expansion Plan - PDE. The 2021 version is now under public scrutiny and this edition also holds an official title of the Climate Change Mitigation Plan for the energy sector in Brazil.

The data concerning sugarcane production and wind/biomass power generation have already increased, as it is shown in **Table d.3**.

The potential exported electricity was based on a net export energy index of 77.1 kWh/t of milled cane, average value observed in the last power auctions regarding sugarcane's mills, without any waste collection. The potential exported power amount would be added by an extra 80.6 TWh, in 2021, if this fuel was considered.

TABLE D.3
SUGARCANE BUSINESS ASSESSMENT AND WIND/BIOMASS FORECAST POWER INSTALLED CAPACITY UNTIL 2021 - PDE 2021

Mt	2011	2015	2021
Sugarcane production	554	808	1,155
For ethanol	273	492	781
For sugar	281	316	374
Total biomass	236	343	491
Bagasse (wet basis)	150	218	312
Waste (wet basis)	86	125	179
Waste collection	N/I	N/I	N/I
Sugarcane Potential Power Production			
Installed capacity - GW	8.4	12.2	17.4
Exported electricity - TWh	42.9	62.2	89.4
Forecast GW installed capacity			
Wind	1.0	8.0	16.0
Biomass (mainly sugarcane)	8.0	10.0	13.0

The sugarcane production has decreased from 2009/2010 to 2010/2011 as the whole business was affected by 2008 world financial turmoil, associated with climatic problems in 2010, which caused a investments' reduction related to plantation renovation and the establishment of new mills, besides closing some small ones.

Nowadays a political economical decision to delay gasoline fuel price adjustment, to keep inflation rate under control, is still discouraging new investments and total sugarcane production of 572 Mt in 2011/2012 was below the 642 Mt previously projected.

Also, some interesting issues to point out in this plan concerning future electrical power generation and sugarcane production in the 2012-2021 ten years period are:

- Power installed capacity will increase 56% or 66 GW, from 117 to 183 GW, within the Electrical National Integrated System;
- 61% (40 GW) of this capacity have already been contracted through the New Power Auctions completed until 2011, mostly hydropower stations located in the North region with small capacity reservoirs. While the forecast of growth in storage capacity of water reservoirs by the end of 2021 is only 5%, the increase of installed capacity of hydropower stations is of 40%;
- The other 39% missing parcel (26 GW) will come from renewable sources, besides natural gas;
- Wind farms shall account for more than 60% of this missing parcel, reaching an installed capacity of 16 GW by 2021, surpassing the 13 GW expected from biomass;
- Ethanol fuel internal consumption demand will almost triple by the end of 2021, from 22 to 62 billion liters per year (total production will more than double, from 27 to 68 billion liters) and, on the other hand, sugar production forecast to supply the market will pass from 39 to 52 Mt per year, only 1/3 superior. As a consequence, sugarcane share for ethanol production will pass from almost 1/2 to more than 2/3 of total production.

Nonetheless, the baseline considered in this report will be the expected power exported to the grid in 2030 by the sugarcane industry as indicated in PNE-2030.

This scenario keeps old mills' today exported electricity and considers that new mills will export only 48.7 kWh/t of milled cane. The energy efficiency potential is shown in **Table d.4**.

TABLE D.4
MILLS OPERATING UNDER PERFORMANCE INDEXES ACHIEVABLE AFTER IMPLEMENTING EE PROJECTS VERSUS PNE-2030

	Sugarcane Production - kt	Net Power Index kWh/t cane	Exported Electricity GWh
Total	1,140,000	118.0	134,467(a)
Baseline	1,140,000	29.4	33,500(b)
Old mills	602,897	12.1	7,318
New mills	537,103	48.7	26,172
Potential surplus, (a–b)			100,967

The effects of the EE projects' implementation on the distribution of primary energy sources of the Brazilian Electrical Power Mix and the potential reduction of GHG emissions are discussed in **Part II**.

PART II. Analysis of policy reforms and/or other actions required to change current conditions/barriers

(e) Social-Economical, Environmental and Policy Analysis

In order to achieve a better benefit from the EE potential identified and to make sugarcane biomass the second source of electrical power production in Brazil, after hydro, all the stakeholders involved in the business should discuss it more openly and try to identify which policy reforms and other actions are required.

The scenario described in Part I creates some barriers that have to be overcome.

(e.1) Social-Economical Analysis

The phase out of sugarcane burning in Brazil before harvesting should take into consideration issues such as unemployment rate increase.

The impacts of mechanical harvesting cause to sugarcane industry less qualified employees could be minimized by specific programs to qualify such professionals and guarantee jobs to the local population, by reducing the serious educational problem that still exists in Brazil.

Although much less technical complex than hydrolysis processes of bagasse and BIG-GT power systems, waste collecting from the field still needs some technical development, in order to find the best practices to be applied on each specific mill, subjected to different climate and soil conditions and logistic characteristics.

When the mill has its harvesting process totally mechanized, harvesting chopped unburnt cane, leaving part of the waste in the field, the costs for operations such as transportation, processing, agronomic impacts, cane productivity difference, soil compaction effects should be charged to the cane waste brought to the mill.

Few mills are collecting unburnt cane from the field and average data are difficult to obtain and they have no statistical relevance yet. But average distance from the harvesting fronts to the mill is definitively a limiting condition and values above 16 km begin to make this collection very expensive.

Nevertheless, an ideal sugarcane plantation with the mill placed in the center of a circle of 16 km gives a gross area of 80,000 ha, big enough to produce more than 5 Mt of sugarcane per year, size of the biggest mills under development.

Waste sugarcane collection needs further investigation and an effort towards a thoroughly analysis of all costs involved in the process of bringing cane stalks with leaves to the mill’s processing unit. This will allow the entrepreneur to know how much is the value of the fuel and, as a consequence, which are the extra operational costs the exported power shall support.

The power sector business is an extraordinary one for the sugarcane industry, which requires specific personnel and careful planning for attending PPAs with long mature periods of minimum 15 years. There are costs and risks associated with the initiative that must be taken care of.

Although bioelectricity from sugarcane biomass has become increasingly competitive for large-scale generation expansion, its potential is still largely unused. Two issues contribute to this fact:

- Tax incentives given to wind power, which make its power generation cheaper;
- Unequal dispute conditions with natural gas, which is considered to be able to provide firm energy when required, differently from sugarcane bagasse, which, until now, would be able to generate power just during cane harvesting season.

The initial investment is increased not only by the extra cost of the power station to be installed, but also by bigger electrical substations and transmission lines, sometimes of long distance, necessary to connect to the public grid.

The currently economic situation of many entrepreneurs does not allow any further debts and the influx of external capital is strictly necessary to make it feasible and, under currently conditions, the surplus income due to selling power has little relevance to the overall business.

Regarding the small participation of electricity selling revenue in overall sugarcane business, type C EE scheme, if adopted by the mill analyzed in the study case, would multiply by 3.6 this value, increasing to approximately 14% the power income share.

On the other hand, initial investment would more than double, from US$ 63.8 to US$ 135 million, which leads to the next analyzed fiscal and financing issues.

Fiscal and Financing Issues

Wind power got a special tribute approach, excepting national windmill manufactures from federal taxes, with the objective of promoting a faster implementation of this kind of industry in Brazil. Some states follow federal government and they give fiscal incentives if the wind industry settles down close to where many wind farms projects were planned. This policy has proved to be a very successful one.

The machines used in a thermopower station inside a sugarcane mill, like boilers, steam turbines, condensers, are not subjected to any special fiscal regime.

This kind of equipment is also used in the oil industry, which nowadays has an extraordinary growth prospect of almost tripling its size in the next 20 years, due to the off-shore pre-salt oil reservoirs recently discovered.

Also an industrial strategic policy was launched to substantially increase the local content of such a kind of equipment supply. So an adverse situation arises and investment costs tend to increase if no counter measures are taken.

This has already been perceived when someone compares the estimated investment cost of US$900/kW in a new sugarcane mill's power station, as predicted in PNE-2030 with the current observed costs of the case study, roughly double this value, in the range of US$ 1,625 to US$ 1,975/kW (see **Table a-6**).

São Paulo state offered during a certain time period tax value added exemption for mills upgrading its boilers, but the program had little support.

Brazilian Development Bank (BNDES) supports projects aimed at diversification of the national energy matrix and contribute to its sustainability through an alternative energy line, which includes projects of bioelectricity, biodiesel, ethanol, wind energy, solar energy, small hydropower plants and other alternative energy sources.

Private companies with headquarters and administration in Brazil, as well as individual entrepreneurs are eligible to request financing at competitive rates.

However, wind farms lead this budget by a very large amount when compared to the others. BNDES has closed 2012 with a volume of loans to the sector of wind energy of R$ 3.4 billion, 47.8 % higher than 2011, when there was the highest jump for this segment, of R$ 808 million in 2010 to $ 2.3 billion.

For comparison, regarding the sugarcane sector, BNDES has approved in 2012 the funding of R$ 488.6 million for the implementation of a 120 MW cogeneration electric power unit, including the associated transmission line, of a new sugar and ethanol plant in the Midwest region, with a capacity of 4.1 million metric tons of sugarcane per crop.

This just reflects the new enterprises under development, as already explained in **Part I (b) Current Policy**, and it can't be interpreted as a funding limitation policy. Of the total R$ 156 billion BNDES disbursements in 2012, R$ 20.833 billion were for the so called green economy, which includes renewable energies and energy efficiency with R$ 13.271 billion, 8% higher than 2011.

On the other hand, the special Climate Fund of the bank, linked to the Ministry of Environment to guarantee resources to support projects or studies and funding of projects that have as their goal the climate change mitigation, excludes biomass from sugarcane in the Renewable Energies subprogram.

(e.2) Environmental Analysis

Although none information about GHG emission due to sugarcane burning in the field before harvesting was provided, under the excuses that sugarcane growth offsets such a emission source, some statements can be derived:

- Burning waste biomass inside a boiler, under controlled conditions, emits much less ashes than lightning a fire on the field;
- Ashes from the fire on sugarcane plantations affect people's health of those living close to the field, reason why decree-laws were promulgated forbidding these fires in the future.

Also sugarcane production growth will depend much more on ethanol fuel demand than on sugar increase consumption in the future. The present forecasting of more than doubling the current annual 27 billion liters production by the year 2021 to 68 billion will impact even further the environmental pressures related to cane burning and vinasse disposal and they can jeopardize the industry future development.

Vinasse is a by-product produced in the alcohol distillation process, not generated when sugar is produced instead. Its high biological content makes it a natural fertilizer, since it is spread along the entire cropland.

Vinasse disposal on the field can be environmentally dangerous to water streams and underground aquifers, if not properly done, spreading it through the whole plantation from which, in essence, the organic nutrients came.

(e.3) Policy Analysis

Power contracting auctions define which projects will supply projected energy demands into following years with a surplus safety margin. Within main power supply auctions, generally dominated by hydropower offer, environmental pressures have pushed against the construction of new large scale hydro reservoirs, as already stated.

As a result, low seasonal hydropower supplies calls for increased demand from other sources, in great part supplied by gas fired plants, raising concerns about increased CO2 emission levels.

Drought periods suitably coincide with the sugarcane harvesting seasons, creating an ideal condition for the insertion of further sugarcane derived bioelectricity into the grid, partly offsetting more expensive gas power. Besides of that, it avoids extra CO2 power generation emission, together with emissions from the degrading biomass in the field, in a business as usual scenario.

This advantage is already taken into consideration in a parcel of the fixed selling electricity price formation, considered negative in sugarcane biomass for the establishment of the auction price offer, but natural gas competes in an uneven condition, when a variable surplus fuel cost is allowed to be added to the final price offer, in case the power plant is called to be dispatched in any situation.

On the other hand, wind farms have gotten another advantage to bid in power auctions as transmissions lines necessary to strengthen the electrical grid and make connections easier and cheaper for the entrepreneur were added to the Brazilian Transmission Expansion Plan, integral part of PDE-2021.

This was based on the Federal Decree nº 6460 of 2008 which established incentives to the inserting of transmission lines of exclusive use for sharing among biomass, wind and small hydro power plants, aiming to become these projects feasible and take full advantage of their environmental, operational and social economic extra benefits. Not surprisingly, just sugarcane mills located in the Midwest have asked for sharing transmission costs in 2008 new power auction, as line connecting distances can easily reach 200 km in this region.

Regarding a specific researching and development program for the sector, an effort in this direction is the new BNDES-FINEP (Studies and Projects Financing Office of the Ministry of Science, Technology and Innovation) Plan - PAISS - to support technological innovation in the sugar-energy sector and sugar-chemical industrial sector.

So far, 20 different business' projects have gotten a R$ 1.5 billion budget under this plan, most considering the use of biomass from sugarcane as raw material and, not, as a fuel. They are divided into three lines of research: development of economically viable technologies for producing cellulosic ethanol, which accounts for the majority of the budget; biochemists production and biomass gasification.

(e.4) Main Identified Barriers

Table e.1 summarizes the main barriers stopping the full sugarcane bioelectricity production development, from the most critical to the ones considered less effective, concerning the creation of a positive business atmosphere.

The decreasing order of importance from ***critical to significant*** with intermediate degrees - ***essential and imperative*** - were somewhat arbitrary and they should be understood as an incitement to discuss the subject.

A next further step would be try to correlate how the overcome of these barriers helps to achieve each of the intermediate scenarios as considered in **Part I (c) Energy Efficiency Potential**.

TABLE E.1
MAIN BARRIERS STOPPING THE FULL SUGARCANE BIOELECTRICITY PRODUCTION DEVELOPMENT

	Kind of Barrier	Degree of Importance	Description
1	Economical	Critical	Not charging for extra fuel collected
2	Economical	Essential	Powerful electrical transmission line usually far away from the mills
3	Economical	Imperative	Inflation of equipment prices due to a limited offer
4	Technological	Imperative	Waste collecting from the field still needs some technical development
5	Social	Imperative	Unemployment rate increase due to mechanical sugarcane harvesting
6	Economical	Significant	Wind power generation costs too low
7	Environmental	Significant	Vinasse disposal and burning of sugarcane before harvesting in the field under new restriction rules
8	Technological	Significant	Focusing research and development mainly on cellulosic ethanol production technologies

(f) Scale-up Policy Design Considerations

This report has considered the insertion of three main EE configurations to the sugarcane business: (i) modernization of existing mills with bagasse burning capacity greater than 160 t/hour, including installation of extractor-condensing turbines, producing steam at 90 bar and 520ºC, reducing steam processing demand to 360 kg per t of cane and operating year-round with the useful collection of 30% of available cane waste; (ii) new plants using the same configuration suggested for the existing big mills and

(iii) modernization of existing mills with bagasse burning capacity lesser than 160 t/hour, including installation of extractor-condensing turbines, producing steam at the minimum pressure of 65 bar and 480ºC and also operating year-round with the useful collection of 30% of available cane waste.

Installed capacity in sugarcane sector could generate excess 34 GW compared to 6.8 GW projected in PNE-2030. This would correspond to 134.5 TWh/year available to export into the power grid by 2030, equivalent to 11.7% of the 1,153 TWh projected electricity production in 2030.

As a result, avoided GHG emissions would amount to 59.24 MtCO2 in 2030 or 61% of power sector projected emissions in 2030, also according to PNE-2030, where sugarcane biomass would generate enough power to phase-out coal generation and would reduce the necessary power produced in natural gas thermopower stations (see **Table f.1**).

TABLE F.1
POWER PRODUCTION IN BRAZIL AND GHG EMISSIONS CONSIDERING EE PROJECTS' FULL IMPLEMENTATION - 2030

Source	TWh	%	Mt CO2 eq.	%
Hydro	817.6	70.9		
Nuclear	51.6	4.5		
Sugarcane Biomass	134.5	11.7		
Wind	10.3	0.9		
City trash	6.8	0.6		
Others	12.5	1.1	28.43	76.0
Self-generation	97.8	8.5		
Natural Gas	22.5	2.0	9.00	24.0
Diesel / Fuel Oil	N/I[8]	-	N/I	-
Coal	-	-	-	-
Total	1,153.6	100.0	37.43	100.0

The intermediate scenarios, as established in **(c) Energy Efficiency Potential**, can be appraised as it follows, where Success Rate **-** SC **-** is defined as:

$$SC(\%) = \frac{(\text{Sugarcane Power Production - 134.5 TWh})}{(\text{134.5 TWh - 33.5 GWh})} \ ;$$

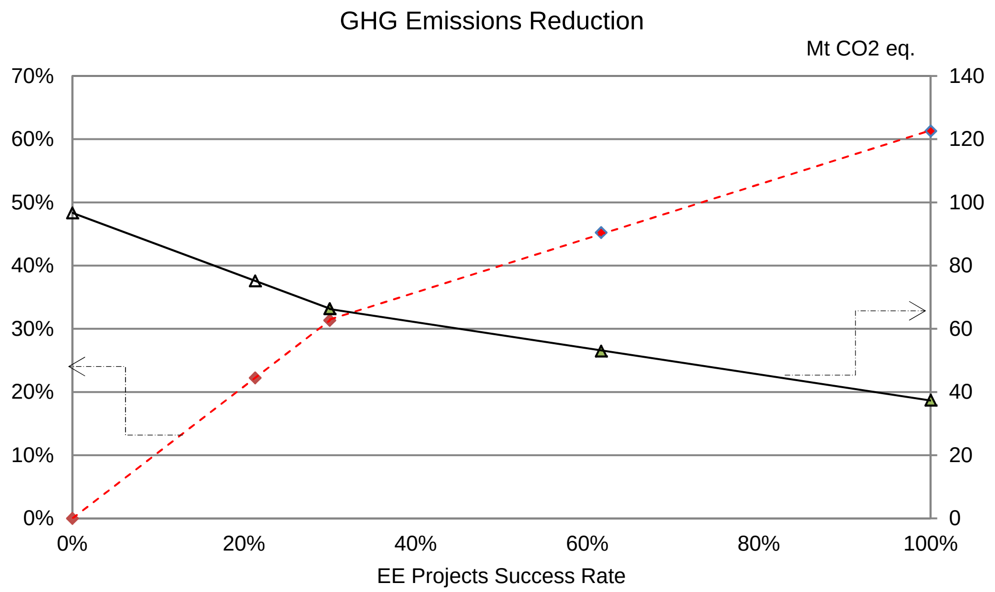
And 134.5 TWh is the best scenario generation for sugarcane biomass in 2030 and 33.5 TWh is the forecasted power generation from sugarcane biomass, according to PNE-2030. **Table f.2** and **Figure f.1** summarize these results.

TABLE F.2
POWER PRODUCTION IN BRAZIL AND GHG EMISSIONS UNDER INTERMEDIATE SCENARIOS – 2030

Success rate	Sugarcane power production - GWh	% of total	Natural Gas power production - GWh	% of total	Coal power production - GWh	% of total	GHG emissions - Mt CO2 eq.
100%	134,500	11.7	22,500	2.0	-	-	37.43
62%	95,700	8.3	61,300	5.3	-	-	52.95
30%	63,800	5.5	92,100	8.0	1,100	0.1	66.37
21%	55,000	4.8	92,100	8.0	9,900	0.9	75.17
0%	33,500	2.9	92,100	8.0	31,400	2.7	96.67

[8] Not informed, included in "Others" and "Self-generation"

FIGURE F.1
EFFECT OF SUCCESS RATE OF EE PROJECTS ON TOTAL 96.67 MT CO2 EQ GHG EMISSION FORECAST FOR POWER SECTOR - 2030



(f.1) Impacts of Policy Reforms on Energy Efficiency Projects Scale-up

All Federal and State Decrees already issued which have been mentioned in this report, namely:

- nº 2661/98: federal law concerning the phase-out of sugarcane burning in Brazil;
- nº 5025/04: federal law establishing PROINFA - Program for Incentive of Alternative Sources in Power Generation;
- nº 6460/08: federal law concerning the electrical transmission connection lines of exclusive use for sharing among biomass, wind and small hydro power plants;
- nº 47700/03: state law concerning the phase-out of sugarcane burning in São Paulo;

were important and, at some degree, they have spurred the employment of sugarcane wastes in power production, improving the overall sector efficiency.

Also, BNDES funding for upgrading power utilities units of existing sugarcane mills and special electrical connection and market rules issued by ANEEL - Brazilian Electricity Regulatory Agency - have incentived the entrepreuner to invest in the power business.

The two most relevant ANEEL Normative Resolutions are related to eletrical grid access discounts and market availability:

- nº 77/2004 establishes a 50% reduction on the transmission and distribution electrical systems tariffs of power stations up to 30 MW, including both power production and final consumption, when this power is generated by an alternative encouraged source;
- nº 247/2006 frees consumers with a power demand bigger than 0,5 MW to buy its energy from alternative encouraged source producers, without further notice to the local utility.

Nevertheless, clearly, there is still a huge gap between the power generation potential of sugarcane mills and the current energy available to the electrical grid, as it was intensively explored in **Part I (c) Energy Efficiency Potential of this report.**

Some additional recommendations can be sugested to remove the bottlenecks identified in **Part II (e)** and scale-up, in a national level, such a kind of EE projects implementation within the sugarcane industry.

They could help to achieve scenarios close to the best one predicted for sugarcane biomass in 2030, allowing the full development of the sugarcane bioelectricity available potential.

The suggested policy reforms are described herein, following the same order as the barriers identified before, in **Table e.1**:

Power Auction rule revision allowing the entrepreneur to charge for the extra fuel collected when harvesting sugarcane with leaves

A mill that has introduced cane waste harvesting can produce enough firm power in case the rain season comes late, with the bagasse saved during harvesting season.

This aspect should be considered as a great advantage sugarcane biomass can offer and, somehow, should be valued accordingly in future power auctions' rules.

Regarding this subject some mills already sell, with better prices, part of its available power in the free electrical market, through bilateral agreements. Also a biomass thermopower plant, based on eucalyptus tree, has got the right to charge for its fuel in a PPA signed in 2008.

Goal: Identify a competitive value for charging the waste collected with the sugarcane stalks.

Enhance methods of decreasing costs of electrical connection of the mills to the grid

ANEEL Resolution nº 77/2004, concerning transmission and distribution tariffs' discount, should be revised, removing the limit of 30 MW of power injected in the grid.

Although sugarcane biomass power plants should take advantage of the Federal Decree nº 6460/08, São Paulo state, biggest sugarcane producer, defends a politics that transmission lines' construction is a Federal Administration's basic responsibility for developing infrastructure, not of the private sector.

Goal: Decreases electrical interconnection costs to the public grid of sugarcane mill's power stations.

Establishment of special fiscal and funding schemes for high efficient mills

The suggestion here would be to make available a special fiscal regime, as it was established for the wind industry, in case a mill invests to generate above a minimum level to be negotiated between the stakeholders.

Another help could come from increasing subsidized funding from development banks for buying high efficient and sizable equipment applied in central power stations of sugarcane mills, such as high pressure boilers and condensing-extraction steam turbines.

Goal: Decreases initial cost investments of new power generation units in high efficient sugarcane mills.

Launch specific research technical program concerning sugarcane waste collecting from the field

The development of partnerships among private and public research organizations focusing on technological innovations for collecting sugarcane waste should bring better solutions concerning this subject.

Goal: Perform a thoroughly analysis of all costs involved in the process of bringing cane stalks with leaves to the mill's processing unit would help to establish a fair price for the power produced based on sugarcane wastes.

Launch educational and specific training programs in rural areas

Launch a specific program to qualify professionals involved in manual sugarcane harvesting and guarantee jobs to the local population in order to improve the education system close to rural areas while reducing, at the same time, Brazilian social economical differences and the exodus of poor people to great cities.

Goal: Increase the sugarcane waste availability for useful purposes without social pressure against it.

Launch specific power auctions with special rules in order to enhance biomass fuel from sugarcane

São Paulo state defends a politics that future power auctions should be done regionally rather than in a national basis, focused just on biomass.

Sugarcane biomass would replace natural gas in the role of compensating for energy supply deficits during drought seasons, due to the small scale hydro reservoirs of new power stations, as well as for the intermittency of wind power generation.

Goal: Justify the advantages of charging an extra cost for the sugarcane waste collected and allow a surplus price for the power generated in high efficient mills.

Increase environment restriction rules regarding vinasse disposal and burning of sugarcane before harvesting in the field

All such environmental threats can be eliminated if a mill is developed under the EE measures discussed in this report. A feasible waste collection means that average distance from the harvesting fronts to the mill is small enough to also allow a proper vinasse disposal.

If nor properly disposed over the sugarcane plantation, other solutions should be enforced, for example, vinasse bio digesting, which increases initial investment's costs and encourages a better mill's development planning.

Goal: Stress vinasse disposal restrictions and speed up the banning of sugarcane burning along the whole country would help the development of better solutions for employing sugarcane processing wastes.

Reform research and development focus of ethanol production technologies

The specific plan created for the sector **-** PAISS **-** to support technological innovation in the sugar-energy sector and sugar-chemical industrial sector could add a fourth line of research related to sugarcane waste best practices for burning it to produce extra power.

Goal: Reduce power generating costs based on sugarcane waste fuel.

(g) Conclusions and Final Recommendations

Brazil has a consolidated sugarcane industry facing an imminent growth perspective. Implementing policies to deploy the most efficient usage of biomass will lead to decrease emissions within the power sector. Offsets of gas in the power sector will certainly be used elsewhere, for example in the transportation and industrial sectors where it will further offset oil demands, meaning there are net emission reductions when indirect effects of such technology deployment are accounted for.

A possible new forecast for 2030 power production and GHG emissions could be as shown in **Table g.1**, where coal power plants totally shut down, nuclear expansion was limited to just a new station already on stream (ANGRA III **-** 1,200 MW) and natural gas power plants would diminish their operation. Wind power production was increased as it has already been forecasted in PDE-2021 plan, considering a total installed capacity of 16 GW with an average production factor of 33%.

TABLE G.1
POWER PRODUCTION IN BRAZIL AND GHG EMISSIONS – 2030

Source	TWh	%	Mt CO2 eq.	%
Hydro	817.6	70.9		
Nuclear	24.2	2.1		
Sugarcane Biomass	134.5	11.7		
Wind	46.3	4.1		
City trash	6.8	0.6		
Others	12.5	1.1	28.43	83.7
Self-generation	97.8	8.5		
Natural Gas	13.8	1.2	5.52	16.3
Diesel / Fuel Oil	N/I[9]	-	N/I	-
Coal	-	-	-	-
Total	1,153.6	100.0	33.95	100.0

The assessment of this 2030 Brazilian electricity generation sector scenario with 2010 data (**Table a.3**) reveals that although total power production more than double, from 515.8 to 1,153.6 TWh, greenhouse gases emission diminishes 5%, from 35.71 to 33.95 Mt CO2 equivalent.

Sugarcane biomass would replace natural gas in the role of compensating for energy supply deficits during drought seasons, due to the small scale hydro reservoirs of new power stations, as well as for the intermittency of wind power generation.

This more positive new scenario can be encouraged and made possible to happen by including more broadly applicable financing options and technical assistance, mutually-beneficial agreements between utility companies and mills' owners and greater environmental education, information and regulation about this approach to energy generation.

Finally, ethanol from sugarcane also presents itself as an interesting solution for poor countries which import most of their fuel supplies at great costs. Central America countries like Honduras, Guatemala and El Salvador are examples of this and they have made some progress regarding this subject with the financial and technical help of Brazilian and American governments to study how to increase and sustain an ethanol production and a consumption internal market.

This effort has been extended to Caribbean and African countries in order to create a worldwide market less vulnerable to USA and Brazil, which are responsible today for approximately 85% of the world ethanol's production.

The sugarcane industry's development made in a more sustainable way, as suggested in this report, will increase the success' odds of such a plan.

[9] Not informed, included in "Others" and "Self-generation"

LIST OF ABBREVIATIONS

ANEEL	Agência Nacional de Energia Elétrica (Brazilian Electricity Regulatory Agency)
bar	pressure unit = 1 x 105 N/m2 or 0.987 atmosphere
BIG-GT	Biomass Integrated Gasifier Gas Turbine
BNDES	Banco Nacional de Desenvolvimento Econômico e Social (Brazilian Development Bank)
CO2 eq.	Equivalent carbon dioxide
CONAB	Companhia Nacional de Abastecimento (National Supply Company)
EE	Energy Efficiency
EPE	Empresa de Pesquisa Energética (Energy Research Office)
FINEP	Financiadora de Estudos e Projetos (Studies and Projects Financing Office)
GDP	Gross Domestic Product
GHG	Greenhouse gases
GW	gigawatt = 109 Watt
GWh	gigawatt hour
ha	hectare = 105 square meters
km	kilometer = 103 meters
kV	kilovolt = 103 Volt
kW	kilowatt = 103 Watt
kWh	kilowatt hour
MJ	megajoule = 106 Joule
MME	Ministry of Mines and Energy
Mt	mega (106) metric tons
MW	megawatt = 106 Watt
MWh	megawatt hour
PAISS	Plano de Apoio à Inovação dos Setores Sucroenergético e Sucroquímico (Support Technological Innovation Plan in the Sugar energy Sector and Sugar-chemical Industrial Sector)
PDE	Plano Decenal de Expansão de Energia
	(Decennial Energy Expansion Plan)
PNE	Plano Nacional de Energia
	(National Energy Plan)
PPA	Power Purchase Agreement
PROINFA	Programa de Incentivo às Fontes Alternativas de Energia Elétrica (Program for Incentive of Alternative Sources in Power Generation)
SIN	Sistema Interligado Nacional (Brazilian Interconnected Electrical System)
t	metric ton
TW	terawatt = 1012 Watt
TWh	terawatt hour

REFERENCES

ANEEL Normative Resolution 77/2004: Establishes procedures for reduction of transmission and distribution tariffs of power stations up to 30 MW based on biomass and other alternative encouraged sources, 2004.

ANEEL Normative Resolution 247/2006: Lays down conditions for electric power generation projects based on alternative encouraged sources, for electricity commercialization with unit or set of consumer units whose load is greater than or equal to 500kW, 2006.

CONAB/MAPA - National Supply Company/ Ministry of Agriculture, Livestock and Provision, The Thermopower Generation based on Sugarcane Bagasse in Brazil. 2009-2010 Sugarcane Harvesting - Performance Analysis, 2011.

EPE/MME - Energy Research Office/Ministry of Mines and Energy, PNE 2030, National Energy Plan for 2030, 2007.

EPE/MME - Energy Research Office/Ministry of Mines and Energy, Electrical Energy Statistic Yearbook, 2012.

EPE/MME - Energy Research Office/Ministry of Mines and Energy, Decennial Energy Expansion Plan 2021, PDE-2021, 2012.

FEDERAL DECREE nº2661/98: Law concerning the phase-out of sugarcane burning in Brazil, 1998.

FEDERAL DECREE nº5025/04: Law establishing PROINFA - Program for Incentive of Alternative Sources in Power Generation, 2004.

FEDERAL DECREE nº6460/08: Law concerning the electrical transmission connection lines of exclusive use for sharing among biomass, wind and small hydro power plants, 2008.

PNUD-CTC - United Nations Development Program - Technological Center of Sugarcane, Biomass Power Generation: Sugarcane Bagasse and Trash, Piracicaba, São Paulo, Brazil, 2005.

STATE DECREE nº47700/03: Law concerning the phase-out of sugarcane burning in São Paulo, 2003.