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REDUCTION OF THE CARBONIZATION OF THE ELECTRIC POWER INDUSTRY BY THE USE OF THE COMBUSTIBLE RESIDUES OF THE SUGAR-ALCOHOL AGRO-INDUSTRY

EXECUTIVE SUMMARY

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The following text summarizes the study prepared by Instituto Nacional de Eficiência Energética [Energy Efficiency National Institute] for Instituto Clima e Sociedade [Climate and Society Institute]. It was developed between July 2016 and January 2017, under the coordination of Pietro Erber, with the support of Isaias de Carvalho Macedo, Luiz Augusto Horta Nogueira, Marcos José Marques, Jayme Buarque de Hollanda, Marco Aurélio Palhas de Carvalho, Fernando C. S. Milanez and BC Engenharia.

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ABSTRACT

The utilization of the energy supply potential of the sugarcane began to be structured in the late seventies. In 1984, the National Alcohol Program – PROALCOOL advocated the best use of sugarcane, especially on electricity generation, as well as ethanol production. Unfavorable economic conditions and inadequate regulations prevented, for more than a decade, the development of electricity generation that biomass production in the sugar-energy sector could make possible. However, during the last decade this situation has shown a remarkable and promising improvement.

Under the Paris Agreement, defined at COP 21 and in force since November 4, 2016, Brazil committed itself to contribute to relevant targets for reduction of greenhouse gases (GHG) emissions, by replacing fossil fuels by renewable energy sources, among other measures.

This study estimates the potential contribution of electricity generation from sugarcane biomass to the reduction of GHG emissions by the Brazilian electricity sector, through 2050. It indicates that by 2030 this contribution, plus that from other renewable sources except hydro, may add up to 34% of the total Brazilian electric energy requirements, surpassing the 23% target set at COP 21.

GHG emissions by the electricity sector, due to its consumption of fossil fuels, would diminish from 140 kgCO_2eq/MWh generated in 2015 to 120 kgCO_2eq/MWh in 2030 and to 192 kgCO_2eq/MWh in 2050, under the most unfavorable hypothesis considered in this study.

Estimating that in 2030 the energy final use national matrix will total 415 Mtoe; electricity and ethanol derived from sugarcane, would account for about 9% of this figure. They would therefore meet 50% of the bioenergy participation target in that matrix, set at 18%. This contribution would be supplemented by energy from forest biomass and biodiesel.

Only in the 2000s did the surplus energy generation by the sugar-energy sector become significant. This development, which began about five decades ago, became relevant as the plants managed to avoid buying fuel and electricity for their process, using the biomass residue from their operation. By August 2016, 91 sugar-energy plants, totaling 5190 MW of installed generating capacity, contributed to the electricity sector supply and to reduce fossil fuels consumption, as well as GHG emissions. In 2015 total energy sales to the power sector amounted to 20 TWh.

Although sugarcane energy use already contributes to the reduction of GHG emissions, since it is a renewable energy source and constitutes the second main source of primary energy in Brazil, its contribution to electricity generation

is still much below its potential. Modernization of sugar-energy plants, adoption of new agricultural procedures and techniques, introduction of new sugar cane varieties and improvement of agro-industrial productivity could increase these plants' electricity generation, from 5.5% of the country's total requirements in 2015 to about 10% of these requirements, in 2030 and in 2050. This would avoid emissions of 54 $MtCO_2eq$ in 2030 to 90 $MtCO_2eq$ in 2050, by replacing natural gas consumption in electricity generation.

The amount of electric energy that the sugar and ethanol sector can produce and make available to the electricity market derives from the production of ethanol and sugar. These products determine the quantities of processed cane, from which can be inferred the availability of bagasse and cane straw, which are the fuels used in this context. Estimates of efficiency and internal consumption of power plants allow quantifying their sales to other electric power consumers.

In order to evaluate the use of non-renewable sources for electricity generation, the evolution of the country's electricity demand and the use of the main renewable sources, besides sugarcane (hydro, solar, wind and other biomasses) were estimated. The evolution of demand has been estimated based on government planning reports and on the current economic outlook. Contributions from renewable sources reflect the country's priorities as outlined in its energy plans.

The study addresses the commercialization of the electric energy generated by the sugar-energy sector and highlights the importance of extending the supply period and increasing its reliability. The creation of a mechanism similar to that which operates in the electric sector, based on a pool of generators that jointly supply their purchasers, and the of biomass fuel storage, can contribute to these goals being achieved.

The use of the renewable sources considered here, as well as the increased efficiency in the use of electric energy, will reduce the need for generation from fossil fuels, which in 2015 met 20% of total demand. It was estimated that fossil fuel-based generation could be limited to about 7% of supply in 2030 and 11% in 2050. These results will contribute to the reduction of carbon emissions, and to reach the country's targets set in the Paris Agreement. To assure them, as indicated, it will be of great value that adjustments in the institutional, fiscal, financial and technological bases should be provided.

INTRODUCTION

In line with the country's commitments at COP 21 to reduce its GHG emissions through decarbonisation of the economy, increasing the share of renewable energy sources in the electricity sector is a priority. In 2015, emissions from this sector were 81 MtCO2eq, which justifies and prioritizes the commitment to increase to 18%, by 2030, the share of biomass among primary energy sources.

In Brazil, biomass, particularly from sugarcane, already contributes and may contribute even more to reduce the use of fossil fuels in electricity generation, in transport and in industry, avoiding GHG emission. In 2015, sugarcane products (bagasse, straw and ethanol) accounted for 17 % of the country's domestic energy supply.

In that year, the sugar-energy sector generated 34 TWh, which represented 5.5% of the country's requirements and supplied 20 TWh to the electricity market. Ethanol accounted for 20% of the road transport demand, whose emissions were then 194 MtCO_2eq.

It is estimated that sugarcane biomass could generate 89 TWh in 2030 and 153 TWh in 2050, about 10% of the country requirements in those years, as foreseen in the present study. Thus, it will supply the electricity sector with 70 TWh in 2030 and 133 TWh in 2050, respectively 8% and 9% of other consumers' demands. The participation of sugarcane biomass in fulfilling electric energy requirements could already be doubled, if there were no institutional obstacles, insufficient investments in more efficient industrial facilities and a lack of stable energy policies, particularly with regard to fuel prices - in part now resolved.

As the objective of this study is to estimate the contribution of the sugar-energy sector to the decarbonisation of the country's electricity generation, it was necessary to estimate both ethanol and sugar productions, since biomass production – from which electricity is generated by this sector - depends on the demand of these products. In addition, ethanol contributes significantly to the decarbonisation of the transport energy matrix.

In 2015, the sugar-energy sector produced, in equivalent terms, 29 billion liters of anhydrous ethanol. It is estimated that it could produce by 2030 57 billion liters and that by 2050, production could reach 63 billion liters, which would replace 46 billion liters of gasoline. It is estimated that ethanol production will accelerate in the next few years, so as to reach 45 billion liters by 2025, as a serious internal deficit of fuels for light vehicles is expected in the middle of the next decade, according to ANP (Interview of its Director-General, in 2015).

The 84% increase in sugarcane production over the period considered will allow the production of large volumes of bagasse and straw, part of which can be pelletized, as it is being studied. Densified biomass has a lower moisture content and a higher calorific value, which provides greater thermodynamic efficiency; and it can be more easily stored and transported than the original biomass. Boilers adapted for its use may also burn densified forest biomass, whose demand has shown remarkable growth, especially in Europe; Brazil has very favorable conditions for its production, such as land and climate.

AVOIDED EMISSIONS

Together with the sugarcane contribution to reduce emissions from the electricity sector, the ethanol contribution should be considered. A significant part of the sugarcane biomass used in electric generation is obtained in relation to the production of this fuel, which replaced 40 % of gasoline consumption in 2015, avoiding the emission of 62 $MtCO_2eq$.

In the estimates of GHG emissions avoided by electricity generation and by the production of ethanol, it was considered that the replaced electric energy would be generated from natural gas, and that ethanol would replace gasoline. The emissions resulting from ethanol production were deducted from the benefit of replacing gasoline, and those resulting from sugar production were charged to this product. These estimates are shown on the table below:

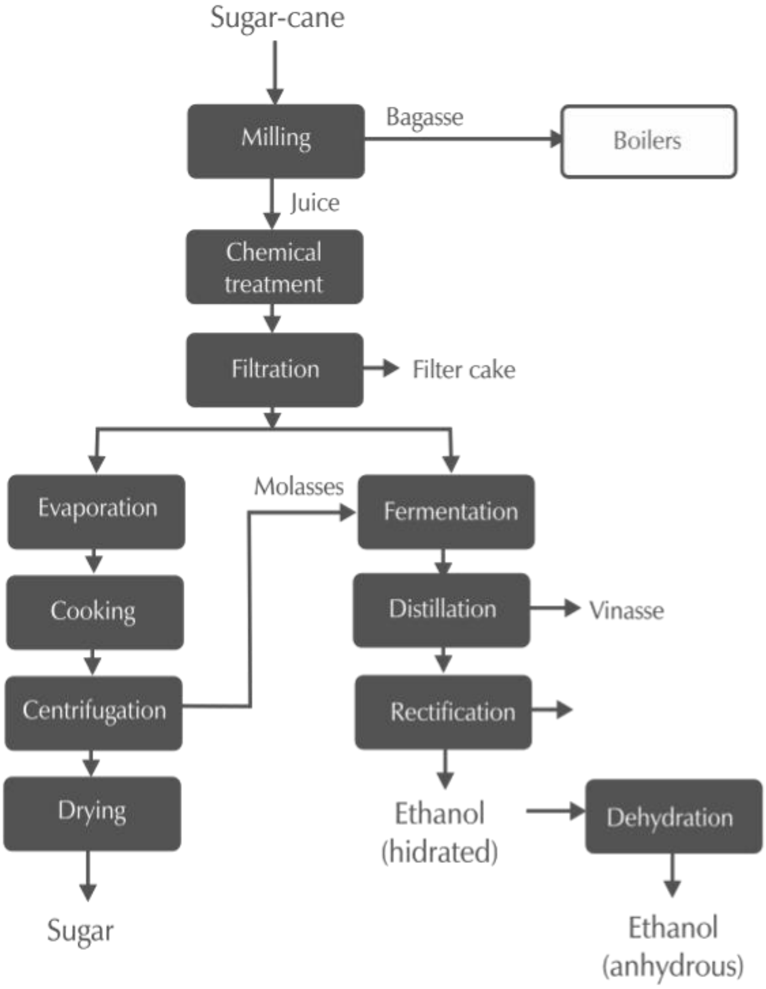
Emissions avoided by sugar-energy products ($MtCO_2eq$)

Year	Electricity Sector	Automotive Sector	Avoided Emissions
2015	17	62	79
2020	25	69	94
2030	54	112	166
2040	75	126	203
2050	89	129	218

The total anthropogenic emissions due to the components of the Brazilian energy matrix in 2015 were 462 MtCO2eq (BEN 2016). Without the excess production in the sugarcane industry, these emissions would have increased by 17%.

SUGAR SECTOR ELECTRICITY GENERATION

The evolution of the electric power generation requirements was estimated up to 2050, as well as the contribution of the sugar-energy sector to their fulfillment. The generation that can be obtained from the main renewable sources: hydroelectric, solar, wind and other biomass was also estimated. With regard to sugarcane energy, estimates were initially made based on sugar cane and traditional agro-industrial technologies, which have had and may still have significant efficiency increases. The generic term sugar cane applies to those varieties of sugar cane grown to maximize the production of sucrose. Results from the use of energy cane, a variety with higher fiber content, will be presented below. The following chart illustrates the sequence of the major steps of sugar and ethanol production. Electric energy generation is a by-product, which in this scheme derives from the energy supplied by the boilers, fed by bagasse and straw:



The following table summarizes the estimates made based on the employment of sugarcane and on the more conservative hypothesis for the expansion of hydroelectric generation:

Required generation and contribution of the main sources

	2015	2030	2050
Total generation (TWh)	***616***	***936***	***1465***
Hydroelectric* (%)	64	57	42
Solar (%)	-	4	11
Wind (%)	4	15	18
Sugar cane (%)	6	10	10
Other biomes (%)	2	5	7
Total renewables (%)	**76**	**91**	**88**
Nuclear (%)	2	2	1
Fossil fuel thermal (%)	22	7	11

(*) includes imports.

In 2015, the country's hydroelectric generation was only 360 TWh, quite lower than that normally considered for the 92GW installed capacity, due to exceptionally poor hydrological conditions. The figure considered in the above table includes imports of 34TWh, almost all from Itaipu Binacional. Regarding the evolution of hydro generation, if the hypothesis of greater expansion had been adopted, its share in 2030 would be 58% and, in 2050, it would be 46%.

Net electricity imports are expected to decrease gradually to about 20 TWh, by the end of the period, since almost all of them currently come from the sale of part of the Paraguayan share of Itaipu plant, which is expected to decline. There will be other exchanges with neighboring countries but, at present, it is not possible to assess their energy balance. In addition to sugarcane, other biomasses will also be important renewable sources for electricity generation, such as forest biomass, both that used directly for thermoelectric generation and by-products from the pulp and paper industry, such as black liquor, wood chips and wood pellets. In 2015, this contribution was 14 TWh. It may increase substantially, as indicated in the table above.

NEW AGRO-INDUSTRIAL TECHNOLOGIES

The above estimates are based on current technical coefficients and their probable evolution, assuming that the raw material is sugarcane, with possible genetic improvements and increases in agro-industrial efficiency. However, several new technologies are being experimented in the sugar-energy sector, especially for the production of cellulosic ethanol, or E2G, which uses part of the biomass and, as a result, can reduce its availability for electric generation. Another is the use of the so-called energy cane, a variety that presents higher productivity per hectare, higher fiber content and lower sucrose content per tonne harvested, as indicated in the table below:

Sugar Cane x Energy Cane

	Units	Sugar Cane	Energy Cane
Productivity	t/ha	70 - 80	180 - 185
Fiber	%	12.5	22 - 26
Ethanol E1G[1]	Liters/t cane	73	50 - 54
Electric Energy	kWh/t cane	47	183 - 232
Ethanol E2G[2]	Liters/t cane	11.3	43

The higher productivity of energy cane, in tonnes per hectare, compensates, with excess, its lower production of ethanol, in liters per tonne of cane. Both the production of E2G and that of energy cane are still recent experiences, with different levels of success.

At present, both the success and the extent of diffusion of energy cane and the use of bagasse and straw in the production of E2G are uncertain. Although the experience with both is not yet ample and extended, the available experience is promising enough to be considered in this study. Both energy cane and E2G production can achieve better results with the improvement of their technologies; in the latter, the enzymatic transformation of cellulose and hemicellulose into sugars is its crucial point. With regard to energy cane, the result of the first harvests will indicate the validity of this option. Finally, it is observed that the E2G technology may be adapted for the use of other biomasses, also rich in cellulose.

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[1] E1G - Ethanol produced by fermentation and distillation of sugar cane juice
[2] E2G - Ethanol produced from cellulosic sugar cane residues into ethanol by means of enzymatic hydrolysis.

It was sought to evaluate the effect of the use of these new agro-industrial methods, particularly the use of energy cane. On the other hand, the diffusion of E2G production would reduce, rather than increase, the electricity production.

This report compared estimates of emission reductions resulting from the replacement of natural gas consumption by sugarcane biomass in the generation of electric energy, and of gasoline by ethanol, when ethanol production is favored by the production of E2G and when the use of biomass to generate electricity is maximized. Two examples of use of sugar cane and one of energy cane were considered. It was found that, in terms of avoided emissions, the results are similar. Therefore, they do not allow to establish a preferential route only based on this parameter. Each case will depend on its specific technological characteristics, the environmental conditions and the fuels that will be replaced.

We also emphasize the importance of achieving greater diffusion of the use of high efficiency generating plants with high pressure boilers, to ensure the production of more electric generation surpluses, as well as the economic and financial recovery of a significant part of sugar-energy companies, harmed by the adverse conditions recently imposed by the energy sources price policy.

ELECTRICITY COMMERCIALIZATION

The contribution of the sugar-energy sector to meet the demand for electric energy depends on an appropriate business environment, that does not hinder or discourage the necessary investments and that allows competitive prices to be practiced.

From the beginning of the last decade, when distributed generation and its sales to distribution utilities were regulated, the sugar-energy plants began to install equipment that allowed them to produce surplus electric energy. Until then, their energy sales were negligible. The new institutional environment and BNDES support were fundamental for the effective participation of the sugar-energy sector in the electricity sector.

The sugar-energy sector is based on a semi-perennial crop, with a cycle of replanting every 5 or 6 years in the case of sugarcane and 10 years or more for energy cane. It requires significant investments in agricultural and industrial equipment, and in agricultural and biological technology. The possibility of changing the proportions of the supply of sugar and ethanol contributes to stabilize its revenue, but the variability of these proportions is usually limited to a ratio of up to about 40/60, and vice versa.

All marketing of electric energy in the Brazilian system is done by bilateral contracts. The characteristics of these contracts need to be adapted to the nature of the transaction: regulated or free.

The contracts of a regulated nature are part of the Regulated Contracting Environment - ACR. These contracts are between generation agents and distribution agents, and leftovers from distribution agents may be contracted. In the ACR, the sale prices of electric energy to distribution agents are defined based on specific auctions, carried out at the initiative of the regulator - ANEEL.

The free contracts are intended to meet the demand of free consumers and of the trading agents themselves, such as the coverage of energy sales contracts, and are part of the Free Contracting Environment (ACL). In this environment, agents are free to negotiate the purchase of energy, establishing amounts, prices and terms of the supply.

Both the contracts made in the ACL, as in the ACR, need to be registered at the Electric Energy Trading Chamber (CCEE), which verifies their compliance with the rules and regulations, collects the measurements of the energy generated and consumed by each agent and promotes the compatibility of the practiced values with the contracted ones, accounting for any differences. The latter are settled by the Differences Settlement Price (PLD), whose values, defined by ANEEL, derive from the short-term marginal cost.

Most energy sales, both in the Regulated Contracting Environment to distribution utilities, and in the Free Contracting Environment to final consumers, are usually made through medium or long-term contracts. However, price variability in the spot market offers the possibility of possible sales at prices well above those achieved in the auctions for contractual sales, so that several industries reserve part of their availability to be traded in that market.

In August 2016, the number of active contracts registered at CCEE was 2218. Of these, 1505 are being supplied; the others will enter into force between 2018 and 2021. Only 16 are by quantity, the remaining by availability (must generate when requested by ONS). These 16 total almost 925 MW and have a physical guarantee of 380 avg. MW, but the amount sold was157 avg. MW. They constitute reserve energy, from the auctions held in 2010 and 2011.

From 2004 to 2015, the sugar and alcohol sector sold 1622 avg. MW to distribution utilities and free consumers of the electricity sector, based on 120 projects. 75% of this energy was directed to the regulated contracting environment (ACR), through contracts of 20 to 25 years, and 25% to that of free contracting (ACL), with short and medium term contracts. Of these, 79% are from 2 to 4 years and the other have longer terms.

The ceiling prices of the last four auctions ranged from R$ 209.00 to R$ 281.00 per MWh and the spot market price (PLD) in August 2016 was R$ 94.00 per MWh.

It is considered opportune to study the creation, in the sugar-energy sector, of a procedure similar to the MRE (Energy Reallocation Mechanism) adopted in the electricity sector, in which this mechanism of coordination of the hydro plants operation provided an energy gain 20% higher than the sum of the contributions of each plant if they operated competitively. The MRE determines the total contribution of the set of hydro plants and allocates the amount generated by the plants, with defined rules. In addition to optimizing the operation of the generators set, this generator pool enables the plants to cover any faults in one of them, not being individually exposed to the penalties provided in the marketing agreements.

In sugarcane biomass plants, the energy input can be estimated each year with great precision, reducing the uncertainty about the production capacity. However, a plant may suffer technical problems that interrupt production, climatic effects that reduce the availability of bagasse and straw, among others.

Sugar-energy producers associated in a pool, similarly to the hydroelectric producers that make up the MRE, would be seen by the electricity sector as a marketing unit, which would sign contracts with the other agents of the system. The allocation of the result of the pool would be made based on the production of each generator, during the year or harvest period, regardless of the time in which this generation occurred.

SUPPLY AND DEMAND BALANCE

We considered the more conservative demand evolution, called Scenario B, which reflects the economic outlook in the coming years and the government and society's efforts to increase efficiency in energy use. The evolution of generation was estimated for the sugar-energy sector, for hydroelectric, solar, wind and forest biomass plants. A (conservative) hypothesis was also considered for the contribution of nuclear energy to the reduction of fossil fuels consumption, since from these hypotheses, the complementary generation needs were evaluated in six situations, characterized by two expansion trajectories of hydro generation, and three possibilities of evolution of the cane sector: only sugar cane, 20% energy cane in 2050 and 40% energy cane in 2050. The following tables summarize the results, in 2030 and in 2050, and indicate the natural gas consumption that would be necessary to produce the complementary electric energy:

Supply and demand balance in 2030 (TWh)

	Sugar Cane		**4% Energy Cane**		**8% Energy Cane**	
Demand	*936*		*936*		*936*	
Cane	89		95		101	
Solar	39		39		39	
Wind	145		145		145	
Other biomasses	48		48		48	
Hydroelectric	547	530	547	530	547	530
Total renewable supply	868	851	874	857	880	863
Nuclear	20		20		20	
Natural gas generation	48	65	42	59	36	53
Gas generating capacity (GW)	6	9	6	8	5	7
Natural gas consumption(Mm^3/day)	24	33	22	30	19	27

Supply and demand balance in 2050 (TWh)

	Sugar Cane		20% Energy Cane		40% Energy Cane	
Demand	*1465*		*1465*		*1465*	
Cane	153		176		200	
Solar	154		154		154	
Wind	263		263		263	
Other biomasses	99		99		99	
Hydroelectric	681	613	681	613	681	613
Total renewable supply	1350	1282	1305	1237	1397	1329
Nuclear	20		20		20	
Natural gas generation	95	163	72	140	48	116
Natural gas generation capacity (GW)	13	22	10	19	6	16
Natural gas consumption (Mm^3/day)	48	83	37	70	24	59

As indicated in the above tables, two hypotheses were formulated for increasing hydroelectric generation by 2050. In that year, in the worst case the natural gas consumption would be 83 Mm^3/day, about 62% higher than the country's consumption in 2015. With the introduction of the energy cane, there would be significant reductions in the consumption of gas (or other fuel), mainly in 2050, with the larger expansion of hydroelectric generation.

CONCLUSIONS AND RECOMMENDATIONS

- Estimates of electricity generation by the main renewable primary sources, presented in this study, indicate that they could limit the participation of fossil fuels generation to about 7% of global demand in 2030 and 11% in 2050. GHG emissions, also in the most unfavorable assumptions considered, would be 111 MtCO_2eq in 2030 and 278 MtCO_2eq in 2050, considering only the use of natural gas. They would represent, respectively, 42% and 256% increases relative to the 2015 emissions.

- The expansion of wind and solar generation, as well as that of hydroelectric and forest biomass, were estimated with less detail than the contribution of sugarcane biomass. In all cases, however, it was sought to take into account the possible environmental, financial, technological and institutional limitations that could affect its development, which by the end of the studied period should fall short of the currently estimated potential. Fossil fuel-based generation complements these estimates.

- The difficulties that have been observed to satisfactorily equate the social and environmental impacts of the hydroelectric expansion bring limitations to the exploitation of the inventoried potential currently quantified. It was assumed that in 2050, in a conservative hypothesis, the generation of 613 TWh would be ensured (including 20 TWh imports), using 63% of the installed and inventoried potential, indicated in the BEN 2015, of EPE/MME. In 2015, hydro generation was 394 TWh, including 34 TWh net imports, mostly from Paraguay, and generated by Itaipu Binational plant.

- The demand and supply scenarios presented, and their respective GHG emissions, indicate a strong dependence on hydroelectric energy and on biomass. The importance of the former does not elude the uncertainties that its contribution presents, in the face of difficulties encountered in its expansion and operation. In addition to these, there is a risk of significant changes in hydrological regimes due to climate change, which may also affect other renewable sources.

- The generation of electric energy from sugarcane biomass is a by-product of ethanol and sugar production, the former having a potential market growth greater than that of sugar, considering the country's current participation in the world market for this product.

- The replacement of gasoline by ethanol leads to a reduction close to 3 tCO_2eq per m^3 of ethanol, also taking into account the effects arising from the use of biomass resulting from electric energy generation. A similar result will be obtained if heavy vehicles using diesel are modified to use ethanol in hybrid drive systems.

- The demand and supply balances presented here indicate the relative importance of their main components, in the various hypotheses considered.

They show that, in 2030, as the share of energy cane varies from 0% to 8%, the net emissions avoided by the replacement of natural gas by cane biomass in generation of electric energy may vary from 54 $MtCO_2eq$ to 78 $MtCO_2eq$. These represent, respectively, 4.3% and 6.2% of the NDC predicted for 2030, of 1.25 $GtCO_2eq$ (IPAM – Instituto de Pesquisa Ambiental da Amazônia – Institute of Environmental Research of the Amazon Region, 2016). In 2050, the avoided emissions would be at least 90 MtCO2eq. The use of cane varieties more conducive to electric generation would increase this benefit.

- In the present study, the average incremental demand rate considered is 2.5% per year, until 2050. If it were 2.2% in the same period, in 2050 demand would be 11% lower. In this case, there would be no need for generation from fossil fuels in 2050. Although values estimated over a 35-year horizon involve a high uncertainty, these results highlight the importance of increasing efficiency in the use of electricity and reducing losses in its transport.

- In order to meet the generation requirements considered in this study, the generation capacity expansion schedule defined in PDE 2024 (Energy Development Plan 2024) could be changed, without harm, until the middle of the next decade. It is observed that in 2024 the difference of the estimate of this study in relation to that of PDE 2024 is 143 TWh. It is equivalent to the contribution of Tapajos River development projects, which integrate that Plan, plus part of the new thermoelectric generating capacity from natural gas and other fossil fuels.

- The supply of electricity from the sugar-energy sector of the Center-South region, which is the largest producer, occurs approximately during the period of lower hydrology of the Southeast and Northeast basins, from April to November. Therefore, it postpones the depletion of reservoirs and reduces the need for fossil fuels

- Besides the advantageous seasonality for the electricity sector, sugar cane supply has been shown to be particularly reliable. UNICA (Union of Sugar and Ethanol Producers) statistics show that, in national terms, since 1980 only in 1981 and 2001, production decreased slightly more than 10% compared to the previous year. In the Center-South, these decreases over 10% occurred in 1981, 2001 and 2012.

- The densification of bagasse and straw, which facilitates its storage, can contribute to extend the generation of electric energy beyond the harvest period and will provide greater guarantee of supply. Some new plants in the Center-South region already generate surpluses in the off-season, without densifying the biomass, due to the lack of adequate stimuli.

- A more detailed analysis by the sugar-energy sector should be made about the convenience for generators of pooling their operation, in order to favor the marketing of their electric energy and to increase the reliability of their supply to the market. A mechanism analogous to that adopted by hydro generators (MRE) to value their electricity generation, could stimulate new investors in the sugarcane sector and a larger presence in the free market.

- The estimated sugarcane production in 2050, 84% higher than that of the 2015/16 crop, associates a 50% increase in planted area with a 23% increase in agricultural productivity. Such an increase in planted area would require only 2.5% of the area currently occupied by livestock. The PNE 2050 (National Energy Plan 2050) considers a 37% increase of sugarcane tonnes per hectare in the same period.

- The success and effectiveness of the use of energy cane or other fiber-rich varieties to reduce generation based on non-renewable sources will also depend on the part of the biomass that will be allocated to the production of E2G, as the latter would reduce the amount of biomass that would be used to generate electricity.

- The choice of producing cellulosic ethanol or electricity will depend on the market conditions, as well as on the signaling that the sugar-energy sector receives from the energy and environmental policies defined by the government. It is estimated that GHG reductions per ton of processed cane are similar, whether E2G or electricity are the main option, both when using sugar cane and when using energy cane. Thus, the option will depend on which fuel will be replaced, as well as on the specific characteristics of the cane used and on the facilities in which it will be processed.

- The diesel fuel generation at peak hours, currently estimated in 2015 at around 8,000 MW, led to an annual consumption of around 1.6 million m^3 of this fuel, responsible for the annual emission of about 4 million tonnes of CO_2eq. The contribution of the sugar-energy sector, in this context, would require a more effective and comprehensive action of that sector and of the free market of the electricity sector itself, as practiced in other countries.

- The effective contribution of the sugar-energy sector to avoid GHG emissions both in electricity generation and in ethanol production strongly depends on a proactive governmental stance, through stable energy policies, particularly with regard to tax incidence and resulting prices of ethanol and of competing fuels. The taxation of ethanol should reflect its positive externalities and the importance of its participation in the energy matrix, so that the results proposed by the country at COP 21 are achieved.

- Given that the supply of electricity from the sugar-energy sector will depend on the production of cane for sugar and ethanol production, it will be desirable for the government to stimulate the efficient use of this fuel, so that it can compete more favorably with its fossil competitors. The government could contribute to the development of the market for light vehicles that exclusively or preferably use ethanol, by prioritizing in its fleets vehicles designed for this purpose, as was done in PROALCOOL. Beyond this potential market, there are currently about 4 million cars fueled only with ethanol, whose annual replacement is already a significant market. The automotive industry could be encouraged to produce such vehicles, also through the adaptation of existing mechanisms, such as INOVARAUTO.

- The generation from forest biomass contribution was estimated from targets set in the Paris Agreement, although an even more expressive generation may be sought, either from the former or from other biomasses. The share of forest biomass-based generation considered here ranges from 2% of the country's demand in 2015 to 7% in 2050. These estimates include both electricity generation and use of by-products from the paper and cellulose industry, now dominant.

- Goals for producing biofuels, food security and sustainable development can be achieved simultaneously, according to the report *Reconciling Food Security and Bioenergy: Priorities for Action*, released in June 2016. This document and the study on forest biomass, object of Annex VI, show that available area is not a limiting factor for the simultaneous production of food and bioenergy in the world. This report recommends the adoption of strategies to deal with: local risk factors, engagement of local populations, encouragement of the compatibility of food and bioenergy co-production, adoption of flexible crops, and planning to diversify local markets with the use of residues such as straw and sugarcane bagasse, for example.

All these observations and recommendations call for effective measures to make them viable. Amongst them:

- Justify economically, technically and environmentally the proposed evolution of the country's energy matrix;
- Indicate, with the instruments of government in the tax and financial areas, the priority given to the development of the proposed programs and projects;
- Develop and maintain transparent processes to follow the projects necessary to the established targets;
- Redirect the Sectorial Funds linked to the energy sector so as to effectively support the priority topics, stimulating research and innovation in key areas.
- Stimulate new investors in order that the necessary expansion of the sugar-energy sector is carried out, integrating agents from different sectors, incorporating new concepts and management practices.
- Promote a broad mobilization in support of energy efficiency, with special attention to the use of ethanol and to electricity generation from renewable sources.
- Create mechanisms to measure the externalities of the use of ethanol in the socio-environmental and economic plans.