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Bioenergy in Brazil: the current scenario of the energy matrix and the biofuel production

Due to its diversified composition, with predominance of renewable sources encouraged by the government over the years, Brazil is one of the countries that stand out in the international energy scene. Likewise, the use of biofuels, biodiesel and ethanol was increased from 2012 to 2018. This study aims to analyze the supply of energy from renewable sources, its participation in the National Interconnected System – SIN, and the part of biofuels regulated by the National Petroleum Agency - ANP to supply the vehicle fleet besides the other equipment with internal combustion engines, in order to evaluate the growing national use of renewable energy sources. The analyzed data demonstrated Brazil's tendency to migrate its energy matrix to a clean and sustainable production model, both for electric power generation and for fuel production. Ethanol has increased its space for direct supply as in addition to gasoline. The biodiesel had growth by the policy of gradual addition to the diesel, besides being added to the generation of electric energy.

Keywords: Bioenergy; Biofuels; Energy and Sustainability; Power supply.

Bioenergia no Brasil: o cenário atual da matriz energética e da produção dos biocombustíveis

Por sua composição diversificada, com predomínio de fontes renováveis incentivadas pelo governo ao longo dos anos, o Brasil é um dos países que se destaca no cenário energético internacional. Analogamente, a utilização dos biocombustíveis, biodiesel e etanol, foi ampliada no período de 2012 a 2018. Objetiva-se neste estudo analisar a oferta de energia por fontes renováveis, sua participação no SIN - Sistema Interligado Nacional e a parcela dos biocombustíveis regulamentados pela Agência Nacional do Petróleo destinada ao abastecimento da frota veicular além dos demais equipamentos com motores a combustão interna, com intuito de avaliar o crescente uso nacional de fontes renováveis de energia. Os dados analisados demostraram a tendência do Brasil em migrar sua matriz energética para um modelo de produção limpo e sustentável, tanto para a geração de energia elétrica, quanto na produção de combustíveis. O etanol ganhou espaço para o abastecimento direto como na adição à gasolina. O biodiesel teve crescimento pela política de adição gradativa ao diesel, fora que ambos, podem ser agregados à geração de energia elétrica.

Palavras-chave: Biocombustíveis; Bioenergia; Energia e Sustentabilidade; Oferta de energia.

Topic: **Desenvolvimento, Sustentabilidade e Meio Ambiente**

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INTRODUCTION

Every day new technologies or effective processes emerge, boosting up an increasing demand for energy/fuel together with the current demands of the population, not only restricted to the Brazilian territory, it stimulates a search for new energy sources/fuels. These may be of non-renewable origin, such as the traditional use of oil for the vehicle fleet supply, for its burning in the production of electric power in some models of thermoelectric plants, or in the opposite direction, as it follows in the world trend, the production of sustainable energy, such as biofuels and the generation of electricity with the use of wind and solar radiation. Therefore, among the needs for nation development, we can point out the demand for electric power that has been growing year after year. Projections made by the Secretary of Mines and Energy (MME) through the Energy Research Company (EPE) in January 2017 indicate that in the next ten years there will be an expansion in the demand for electric energy in all Brazilian territory, thus reinforcing the need for alternatives that may offer generation of energy, in this sense, biofuels occupy a prominent position.

Biofuel is understood to be the one which is generated from renewable biomass, with the potential to partially or completely replace fossil fuels and natural gas in internal combustion engines or at the generation of another way of energy. Nationally, the production of ethanol from sugar cane and biodiesel (through vegetable oils or animal fats), the latter being on the rise, therefore, adding biodiesel to diesel (fossil origin) in variable proportions (ANP, 2019).

According to the Secretary of Mines and Energy - MME (2015), the Brazilian electricity generation matrix is predominantly governed by hydropower, and also by the rainfall regime for its supplies, therefore, the water crisis directly affects the availability for the generation of electric energy, and supplying the population, forcing in the current scenario the activation of other energy sources, such as thermoelectric.

The southeast in 2014 faced a decrease in pluviometric levels which affected, among others, Cantareira system. That year, the lack of rain was partially caused by a lasting anomaly of a high atmospheric pressure system that delayed the transportation of moisture from the Amazon. This fact interfered directly in the pluviometric regime of Cantareira region, causing, in January of 2014, precipitation of 87.9 mm against the historical average of 268 mm, which represents a decrease of 67% (MARENGO, 2015). The national production of energy from renewable sources is 63%, comprising 45% of electricity production and 18% of fuel production, while 86% of the world's energy comes from non-renewable sources (ANP, sd). In view of the above, this study aims to analyze the Internal Energy Supply (OIE) between the matrixes that supply the National Interconnected System SIN and those of the biofuels regulated by the ANP, in order to show the current panorama of the national use of renewable energy sources.

Brazil is able to generate electricity in multiple ways, but the main Brazilian energy matrix is the hydroelectric plant (MME, 2015), and it’s a vulnerable source to the climatic and hydrological conditions that govern the regions where they are located. Due to the adverse conditions that occurred in previous years, the generation of energy through this source was only possible with the use of the reserve capacity of these plants, called dead volume, evidencing the need for expansion of the National Interconnected System - SIN (LAWSON et al., 2017). According to ANEEL (2019), through the data provided in the Generation Information Bank (BIG) the associated power today is 163,347.52 MW, but it will increase to 183,412.65 MW when all units in construction (with no reported deadlines in any of the cases) are completed (Table 1).

It is observed that among the monitored sources, the thermoelectric plant is currently the second operational matrix in relation to the associated power, accounting for little more than a quarter of the total production, despite being a non-renewable source, there are other 38 projects underway, granting the thermoelectric, the station of third energy modal (when all the work is completed). Among the ones which are under construction, the wind power plants stand out in the lead with 66 units, but even in larger quantities, when compared to the additional value of 8,141.35 MW to be associated (when all units under construction from all sources are in operation) the wind will only respond by 15%, keeping the thermoelectric power to lead production (Table 1)

Table 1: Current power and energy situation by source in Brazil according to BIG from ANEEL.

Source of Energy	Number of Business	Status	Associated Power	Participation
Wind power	598	In operation	14,722.79	9.01317% [1]
Photovoltaic	2462	Working	1.978,72	1.21135%[1]
Hydropower	1338	In operation	104.227,04	63.80692%[1]
Tide	1	In operation	0,05	0.00003% [1]
Thermoelectric	3008	In operation	42.418,92	25.96851% [1]
Total of the working units:			**163,347.52**	**100% [1]**
Wind power	66	Under construction	1,201.40	15% [2]
Photovoltaic	17	Under construction	458.91	6% [2]
Hydropower	40	Under construction	1.302.10	16% [2]
Thermoelectric	38	Under construction	5,178.93	64% [2]
Total of the under construction units:			**8,141.35**	**100% [2]**
Wind power	151	To be constructed	4,007.05	34% [3]
Photovoltaic	46	To be constructed	1,279.06	11% [3]
Hydropower	126	To be constructed	2,268.19	19% [3]
Thermoelectric	110	To be constructed	4,369.49	37% [3]
Total of the units to be constructed:			**11,923.78**	**100% [3]**
Total of all working units:			**183,412.65**	

[1]In relation to the total energy sources in operation. [2]In relation to the total energy sources under construction. [3]In relation to the total energy sources to be constructed. **Source:** ANEEL (2019).

When all units designated by ANEEL through BIG (2019b) are in operation, hydroelectric plants that currently account for 63% of electric power generation will pass to 59%, denoting the fall in their dependence. Nevertheless, the analyzed scenario shows that the thermoelectric plants will still remain as the second main matrix of electric power generation (from 25.9 to 28%), according to Table 2. It should be taken into account that such projects were made and approved on unknown dates and may not have been considered information on global warming and other damages as well as benefits from clean and renewable sources.

Tabela 2: Participation of each source in relation to the situation correlated to the amount per source and multi-source power generated in MW in Brazil.

Source of Energy	Status	Associated Power (MW)	Participation according to: The future total of each source	All sources
Wind power	In operation	14.722,79	74%	8.03%
Wind power	Under construction	1.201,40	6%	0.66%
Wind power	Costruction not started	4.007,05	20%	2.18%
	Future Total:	**19,931.24**	**Source participation:**	**11%**
Photovoltaic	In operation	1,978.72	53%	1.08%
Photovoltaic	Under construction	458.91	12%	0.25%
Photovoltaic	Costruction not started	1,279.06	34%	0.70%
	Future Total:	3,716.69	**Source participation:**	**2%**
Hydropower	In operation	104,227.04	97%	56.83%
Hydropower	Under construction	1,302.10	1%	0.71%
Hydropower	Costruction not started	2,268.19	2%	1.24%
	Future Total:	107,797.32	**Source participation:**	**59%**
Tide	In operation	0.05	100%	0.00003%
	Future Total:	0.05	**Source participation:**	**0.00003%**
Thermoelectric	In operation	42,418.92	82%	23.13%
Thermoelectric	Under construction	5,178.93	10%	2.82%
Thermoelectric	Costruction not started	4,369.49	8%	2.38%
	Future Total:	51,967.35	**Source participation:**	**28%**
The future total of all sources:		183,412.65		**100%**

When evaluating the values of the sources of energy generation in operation, also by the data of the BIG, it is possible to expand the source origin, its granted powers and actually generated, defining the difference among them and their percentage contribution in the general matrix, which refers to the 163,347.52 MW generated (Table 3).

Table 3: Breakdown of the current Brazilian energy matrix according to ANEEL and their respective participations.

Origin	Amount	Authorized power (MW)	Supervised power (MW)	Difference (MW)	%
Fossil	2442	27,211.03	25,668.38	1,542.65	16.1
Biomass	564	14,856.03	14,760.54	95.49	8.79
Nuclear	2	1,990.00	1,990.00	0.00	1.18
Hydro	1338	108,147.07	104,227.04	3,920.03	64.01
Wind	598	14,768.69	14,722.79	45.90	8.74
Solar	2462	1,987.72	1,978.72	9.00	1.18
Undi-Electric*	1	0.05	0.05	0.00	0
Total	7407	168,960.59	163,347.52	5,613.07	100

*According to ANEEL, this is done according to water kinetics, without further information.

According to Lawson et al. (2017), there was an increase of interest by thermoelectric plants and nowadays for solar and wind power, the latter two being referred to as dispatchable sources, since they require the base source at the generation time; which differ from hydroelectric plants (with their reservoirs) and thermal systems (which can store fuel such as coal, diesel, natural gas or fuel oil) or even nuclear power plants. Plants that use biomass/waste (renewable energies) also take part at the SIN, and this participation stimulates the increase of energy efficiency and still manages the seasonality of other matrices; however, they still have little performance (LAWSON et al., 2017). Renewable energies contribute to the environment since their implementation/operation little damages nature when compared to conventional sources. Thus, these ones are characterized as unconventional sources, because they are small hydropower plants, solar, wind, oceans, biogas, and biomethane; all contribute to sustainability, and environmental policies (KONRAD et al, 2016).

Having as reference the energy balance sheets of the Energy Research Company (EPE), made available annually, based on data from the prior year to the publication, the energy matrices that participate in the internal energy supply (OIE) are: Hydraulics, Biomass, Wind , Solar, Natural Gas, Petroleum Derivatives, Nuclear, Coal and Derivatives (Table 4 and Figure 1).

Table 4: Participation of each energy matrix in the Brazilian OIE between 2012 and 2017

	Percentage of annual participation (%)					
Base year (Source)	**2012** (EPE, 2013)	**2013** (EPE, 2014b)	**2014** (EPE, 2015)	**2015** (EPE, 2016)	**2016** (EPE, 2017)	**2017** (EPE, 2018)
Hydraulics[1]	76.9	70.6	65.2	64	68.1	65.2
Biomass[2]	6.8	7.6	7.3	8	8.2	8.2
Wind	0.9	1.1	2	3.5	5.4	6.8
Solar	N/P	N/P	N/P	0.01	0.01	0.13
Natural gas	7.9	11.3	13	12.9	9.1	10.5
Oil Derivatives	3.3	4.4	6.9	4.8	2.4	2.5
Nuclear	2.7	2.4	2.5	2.4	2.6	2.5
Coal and derivatives[3]	1.6	2.6	3.2	4.5	4.2	4.1

N/P: With no participation according to EPE. [1]Includes import of electricity. [2]Includes firewood, sugarcane bagasse, bleach and other recoveries. [3]Includes coke oven gas.

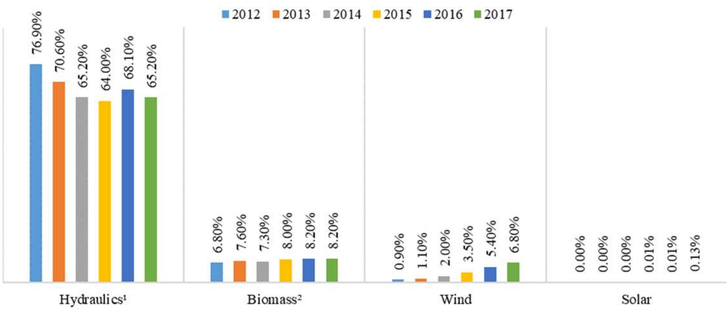

Figure 1: Participation comparative chart of each energy matrix in the OIE of Brazil (renewable sources). [1]Includes electricity import. [2]Includes firewood, sugarcane bagasse, bleach and other recoveries.

Analyzing the presented data, it is possible to observe that the hydroelectric power generation (hydroelectric plants) presented a decrease of 11.7% in the participation of the Brazilian energy matrix between 2012 and 2017, a fact probably occurred when there was the water shortage faced by the country, however, it is still the main source of energy generation. The energy generation from biomass (which can originate biofuels or directly burning) showed a continuous increase, except in 2014, reaching a growth of 1.4% (in 2017) in its participation in relation to 2012, thus the only renewable source present since 2012 to undergo recession and recover while remaining after this growing. It's worth to highlight the production of wind energy, which has a growing share in the same period (an increase of 5.9%) and a solar that went from 0.01% in 2015 to 0.13% in 2017.

Regarding non-renewable sources (Table 4 and Figure 2), the generation energy with the use of natural gas in the OIE has a highlight role, with an increase in the participation in 2013 (an increase of 3.4% over 2012), in 2014 (an increase of 5.1% in relation to 2012) and in 2015 (an increase of 5.0% in relation to 2012) in the face of the water crisis that devastated the country in this period, and there is a need for emergency sources of energy. Similarly, it occurred for the energy generation from petroleum derivatives. There were increases between 2013 and 2015, with a peak reached in 2014 (6.9%), representing an increase of 3.6% in relation to 2012. Since then, it has been suffering a fall in the increase in other alternative sources, reaching 2.5% in 2017, a decrease of 0.8% compared to 2012.

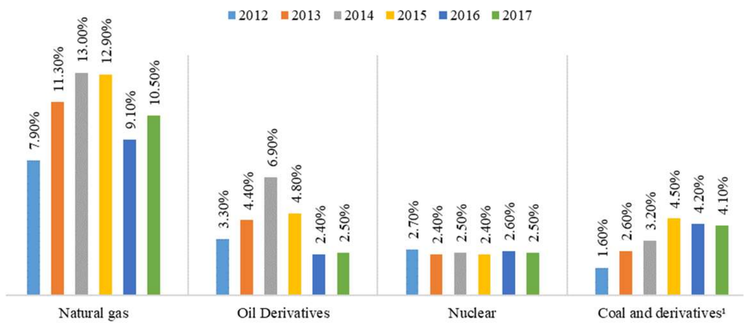

Figure 2: Participation comparative chart of each energy matrix in the OIE of Brazil (non-renewable sources).[1]Includes coke oven gas.

Biofuels are defined as biomass-based fuels, thus excluding all fossil fuels. Biofuels are considered renewable because their raw material consists of plants or organic material; since for the formation of plants photosynthesis occurs and throughout the cultivation process until the moment of harvest, these plants remove carbon from the atmosphere, forming a cycle, highlighting as advantage of biofuels the non-emission of sulfur gases (SO_x) and nitrogen (NO_x) (SECRETARY OF MINES AND ENERGY OF RIO GRANDE DO SUL, 2016; ANP, 2018).

A key point that encourages the adoption of biofuels as a way of energy generation is the growing concern about global warming. In addition, the generation of this way of energy creates a beneficial scenario for generating employment and developing less fortunate regions. The use of biofuels in this generation leads to a reduction compared to the current sources of energy in the emission of gases (VIAN et al., 2008). According to the Secretary of Mines and Energy of Rio Grande do Sul, (2016), biofuel has been produced nationally since 1975, driven by the Proálcool program, which encouraged the cultivation of sugarcane to generate ethanol, become the world leader in the production of this fuel.

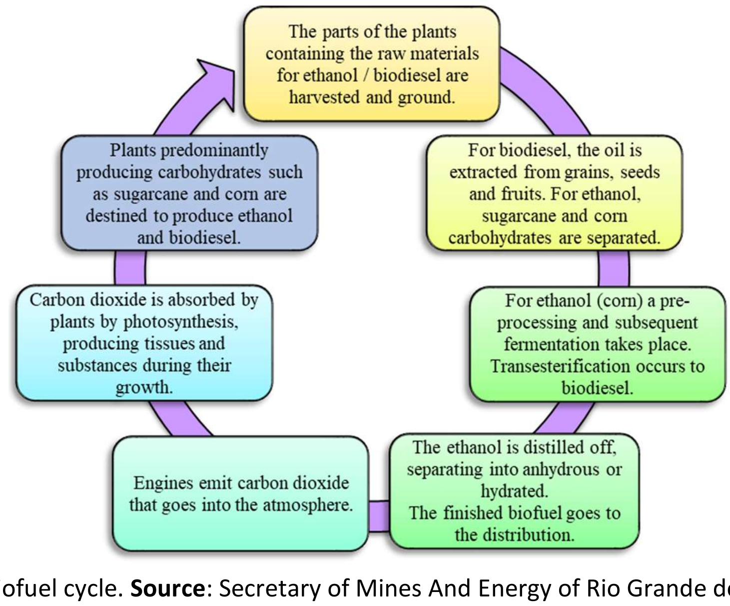

Figure 3: Biofuel cycle. **Source**: Secretary of Mines And Energy of Rio Grande do Sul (2016).

Briefly, the biofuel cycle can be characterized as shown in Figure 3. Throughout the development of plants, such as sugarcane, it absorbs, besides the soil nutrients, carbon dioxide from and expels oxygen during the process of photosynthesis, in which plants retain a part of chemical energy in their composition. After the harvest, the parts designated to the generation of biofuel go through preparation treatments and are separated for the production of the fuel. The product of the conversions (biodiesel, oils, ethanol, among others) is destined for burning in internal combustion engines, thus generating mechanical energy for direct use as in cars and trucks or for electric power generation (as for example in steam boilers).

According to Nogueira et al. (2002) *apud* Energy Research Company- EPE (2014), the biomass base for biofuels can be divided into three groups regarding the type of source: forest energy biomass, agricultural energy biomass or urban waste. Regarding the forest origin, the authors explain that if the cellulose and lignin are to be obtained intrinsic to the material, they are low in moisture content. The biomass of agricultural source is divided in relation to the destination of the product of the crop, thus, when the planting was for the production of energy (for example, cultivation of sugar cane and corn for ethanol production) or when only the waste of some culture are destined for generation (such as straw, peel, stem). Urban wastes, garbage, and sewage, are rich in organic matter, which can mainly produce biogas through anaerobic digestion (Figures 4 and 5).

As stated, the moisture content is very important, since wood is also related to its mechanical properties, the ease of working with this material, its calorific value (of big interest in this case), and other properties (MORESCHI, 2005). The values of moisture content have a direct relation with the useful part of energy contained in the biomass for the energy generation, so the lower the moisture content the greater the useful calorific value (PCU); for this reason, this content is even more shocking than the biomass-forming species (BRAND, 2010)

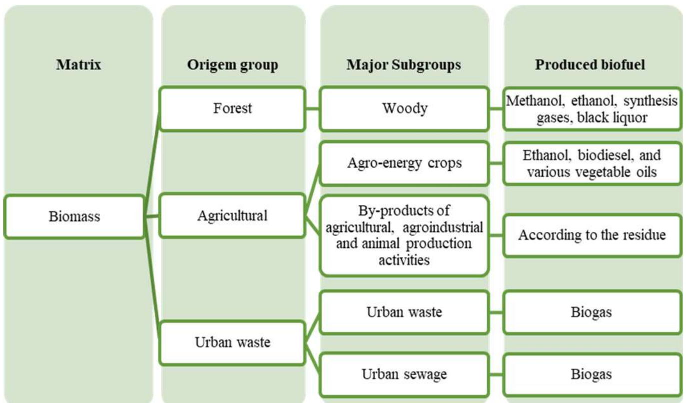

Figure 4: Map of the origin of biofuels according to their groups and subgroups from biomass.
Source: Nogueira et al. (2002) *apud* Energy Research Company - EPE (2014).

Biodiesel is defined by ANP (2018) as being the one constituted by alkyl esters of carboxylic acids of long chain, originated by transesterification and / or esterification of greases, vegetable / animal fats, in order to comply with Technical Regulation ANP Resolution no. 45, of 8/8/2014. According to the EPE (2018), the production of biodiesel in 2017 was composed of soybean oil (65%) and beef tallow (12%). In October 2018, biodiesel production reached its highest volume of monthly production with 500.2 million liters; in the same month, the annual national production reached 4.4 billion liters, and in 2017 it obtained an amount of 4.3 billion liters (increase of 2.27%). This increase in production was stimulated mainly by

Resolution 16/2018 of CNPE (National Energy Policy Council), which foresees an increase in the addition of biodiesel in diesel from 8% to 10%, in March 2018; in parallel with the increased demand for diesel oil due to resumption of economic growth after the recession period (ROITMAN, 2018). This Resolution nº 16/2018 contributed to the continuous increase in biodiesel production in 2018 except in May (Figure 6).

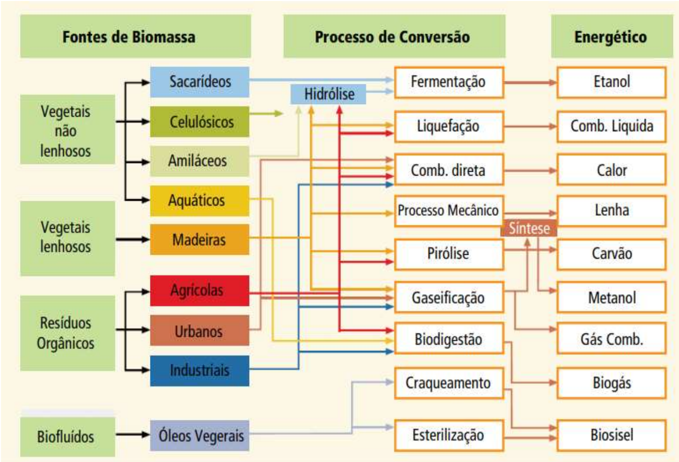

Figure 5: Conversions and obtained bioenergy.
Source: ANEEL, 2003 (apud Ministry of Mines and Energy, 2007).

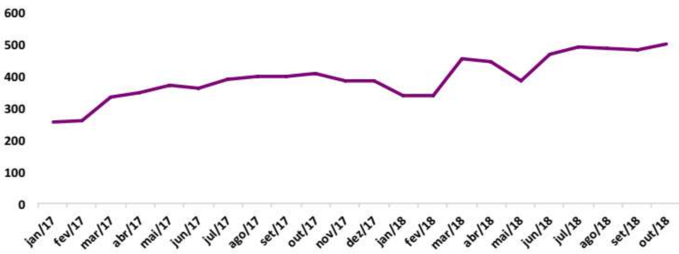

Figure 6. Monthly production of biodiesel in millions of liters. **Source**: ROITMAN (2018).

According to Roitman (2018), when comparing biodiesel production values in October 2018 with 2017, there is a 6.0% increase in sales and a 28.7% increase in consumption. The strike of truck drivers in parallel to the increase in diesel prices spoils their sales, in contrast, the increase of 2% of the biofuel in the fossil fuel stimulated its production. As in March / 2018 there was an increase in biofuel in diesel, the characteristic curves of its consumption became closer due to the increase in biofuel consumption, which in October / 2018, was close to 10% of the amount of fossil fuel (Figure 7).

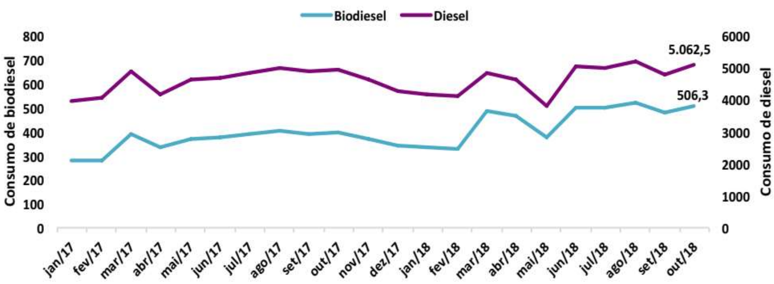

Figure 7: Monthly consumption of biodiesel and diesel, in millions of liters, between 2017 and October 2018.
Source: Roitman, 2018.

Due to the rise in the price of gasoline added to the increased availability of biofuels, it was possible for hydrous ethanol to obtain 2.0 billion liters sold in October / 2018; in the same month, sales were 12.9% higher than in the previous month and sales were 47.7% higher than in the same period of 2017 (ROITMAN, 2018). Ethanol can be considered a liquid biofuel from renewable biomass and it can be used to supply internal combustion or power generation engines, as well as regulated by Law No. 12,490, dated 9/16/2011. Ethanol may be an anhydrous type, used in the mixture of gasoline A for the formulation of gasoline C (pursuant to ANP Resolution No. 19 of 15/4/2015); or hydrous ethanol which is the version used directly for the supply of internal combustion engines in order to comply with ANP resolutions no. 19, 15/4/2015 and no. 681, 5/6/2017 (ANP, 2018).

Regarding its participation in the Brazilian market, the curves that represent the behavior of (anhydrous/ hydrous) ethanol, present a seasonality whose peak of production happens between July and August and the minimum in January and February, according to 2017 and 2018, another point in this period was the increase in the production of hydrous ethanol to distance (increase) of the anhydrous after February/2018 (Figure 8).

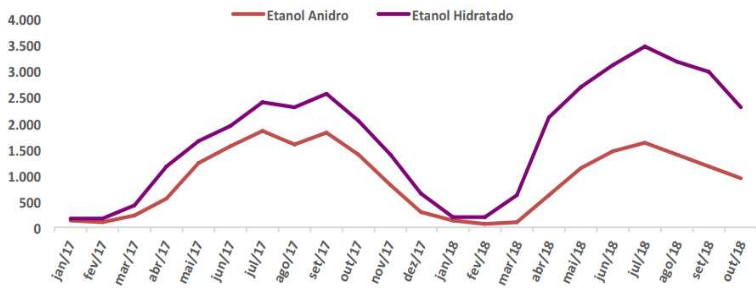

Figure 8: Monthly production of ethanol (anhydrous and hydrous), in millions of liters, between 2017 and October 2018. **Source**: ROITMAN, 2018.

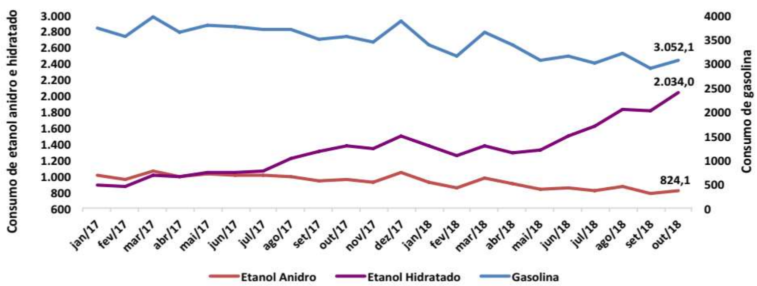

Figure 9: Comparison chart between consumption of anhydrous, hydrous ethanol, and gasoline between 2017 and October 2018. **Source**: ROITMAN, 2018.

It is observed that from May/2018 there was a growing demand for hydrous ethanol by consumers (marking a slight drop in anhydrous), which led to a reduction in sales of gasoline; although it is higher in volume sold (Figure 9). The anhydrous ethanol has a lower calorific value (ICP) of 6,750.0 kcal kg^{-1} while the hydrous one develops an ICP of 6,300.0 kcal kg^{-1}, whereas gasoline (type c) has 9,400.0 kcal kg^{-1}; the biodiesel (B100) has the intermediate value to the previous ones, with 9,000.0 kcal kg^{-1}.

As for density values, in the same fuel sequence, we have 0.791 t m^{-3}, 0.809 t m^{-3} and 0.880 t m^{-3} (ANP, 2018b). These values denote that gasoline (type c) gives greater energy to the vehicles, followed closely by biodiesel (B100), anhydrous and hydrous ethanol respectively. It should be noted that the engines powered by gasoline/ethanol are not the same as those that consume fossil diesel and/or biodiesel, although they are internal combustion, their operating cycles are different (Otto for gasoline/ethanol and for diesel fossil/biodiesel, is the Diesel cycle).

According to data from ANP, based in 2012, chosen for being the data from which ethanol is found, it is possible to notice the superiority of the ethanol production volume compared to biodiesel, and the comparison in Figure 10 measured in cubic meter and in Figure 11 in bep[1] (barrel of oil equivalent).

Focusing on Figure 10, it can be seen that the volume of biodiesel and hydrous ethanol, even without the December/2018 data, already surpasses previous years in significant amounts, and anhydrous ethanol, if an average of eleven months of 2018, reached 838,934.2 cubic meters per month, maintaining this value for the last month of the year, it would accuse a deficit in relation to 2013 to 2017, this with an amount of 10,067,210.2 m³ in 2018.

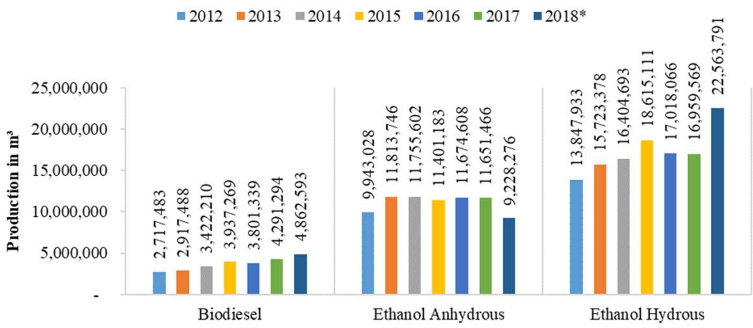

Figure 10: Brazilian production in cubic meters of biodiesel and ethanol (anhydrous / hydrous) produced annually from 2012 to 2018. * December/2018 values not counted in the graphs. **Source**: ANP (2019).

It is noticed from figure 11 that even anhydrous or hydrous ethanol has 2,250, and 2,700.0 kcal kg^{-1}, respectively, unless biodiesel, due to its productions being two to three times larger, these ones deliver the matrix energy, values higher than biodiesel in any period among those calculated. It can be observed that of these three, biodiesel was the one that presented more stable behavior (growth in this case).

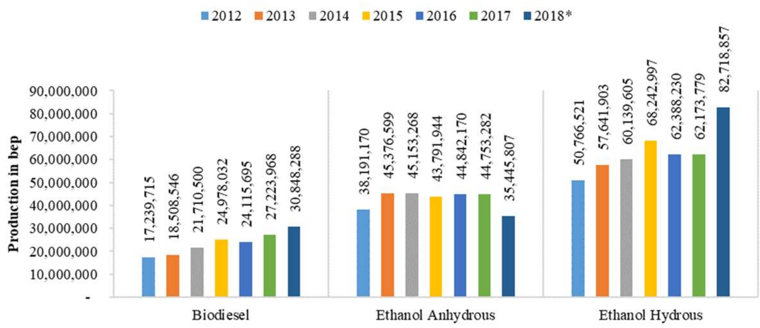

Figure 11: Production of biodiesel and ethanol (anhydrous/hydrous) produced annually from 2012 to 2018. *December/2018 values not counted in the graphs. **Source**: The author, based on ANP data (2019a and 2019b)

The growth of the domestic supply of energy and fuel is a necessity for the country non-stagnation, so it is important to establish a projection of this growth. Based on projects that do not cause serious restrictions to its operation, it is estimated that from December 2018 until the same month of 2025, there will be an increase in electricity production of approximately 23,032 MW (FERNANDA et al., 2018).

[1]bep - barrel oil equivalent: it is a unit of energy measurement - 1 bep = 1.390.000,0 kcal.

From this amount, added over the next five years, presented by the authors, it is observed that among the energy matrixes, all of them except the thermoelectric plant is from the renewable origin, being the one that suffers an increase of production until 2020 and after that, it declines. In contrast, biomass energy generation expands its performance in the Brazilian energy matrix on a constant basis, it is also expected that hydroelectric power generation will peak in 2019 and a subsequent reduction with fluctuations between 2021 and 2023 (Table 5).

Table 5: Projection of energy generation according to the generating matrix in the SIN between 2018 and 2023, values in MW

	2018	2019	2020	2021	2022	2023	Total
Thermoelectric	499.74	796.38	2,100.79	1,334.50	50.00	-	4,781
Biomass	50.00	100.82	246.87	715.65	-	3,523.70	4,637
Solar	374.80	497.26	30.00	694.00	494.86	-	2,091
Hydropower	711.11	3,402.54	1,833.00	32.00	71.22	35.18	6,085
SHPP	58.40	96.69	365.79	525.77	230.54	31.05	1,308
Wind	785.65	1,726.40	222.90	-	487.10	906.93	4,129
Total	2,479.70	6,620.09	4,799.35	3,301.92	1,333.72	4,496.86	23,032

Source: Fernanda et al. (2018)

Based on the data of Table 5 and Figure 12, it can be denoted that until 2021 the solar matrix will be the one that will show the greatest growth when compared to the previous period; such growth is small in 2020 and with a great expansion the following year. The Small Hydroelectric Power Plants (SHPPs) tend to grow in the coming years, but with a decline in their production projected after 2022. It should be noted that although there is a reduction, this refers to production in relation to the previous year. However according to Table 5, in 2021 the peak production of this matrix is predicted. The energy generated by biomass shows strong growth, even if Fernandes et al. (2018) omit their share for 2022, but when analyzing the other data, there is a strong indication of large-scale production (also visible in the graph, Figure 12, based on the next three biennia). Among the renewable sources presented, the wind was the one that was expressed as the most oscillating, with periods of production that appears in the first place (2018, surpassing the hydroelectric ones) as in another one that is in last position (2019). It should be noted that due to gaps in the data of Fernandes et al. (2018), Figure 12 was restricted from 2018 to 2021 since as of this year there is an absence of values in certain energy modalities that are not explained.

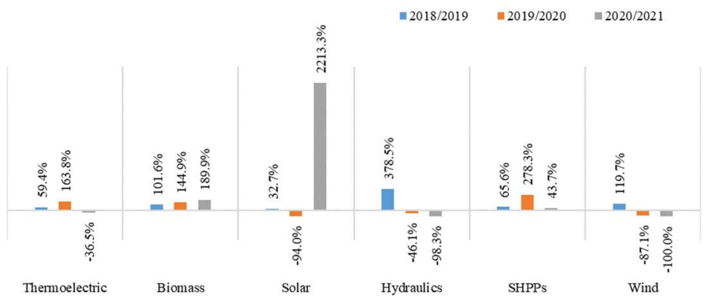

Figure 12: Graph of the projection of energy generation in MW in the SIN between 2018 and 2021
Source: Fernandes et al. (2018)

The stable growth values presented by biodiesel are in part sustained by the government's imposition on adding it to fossil diesel. According to CNPE Resolution 16/2018, the successive addition of biodiesel to diesel oil is declared until 2023 when the value will reach 15%. It is the responsibility of the distribution companies to add 1% per year, and by 2019 the current 7% will increase to 11% and from there until their limit in 2023.

RESULTS AND DISCUSSION

Analyzing the variations of the matrices determined by EPE in the period 2012-2017, it can be observed that wind energy was the one with the greatest growth, increasing its production from 2013 to 2014 by 81.17%, with this generation modality being the only one without any resection in the period; although its share reached only 6.8% in 2017 for the OIE. As for the OIE of these matrices, of non-renewable energies, natural gas leads in all years (2012-2017), although it has undergone great variations, passing through two consecutive recessions in its production. The hydroelectric plants lead production as a source of energy, but suffered consecutive decreases in participation over five years, steadily declining with the exception of the 2015/2016 biennium. Between 2014 and 2016, it is observed, through the variations, that there are discrete changes in the preference for the matrices of the renewable source (Figure 13).

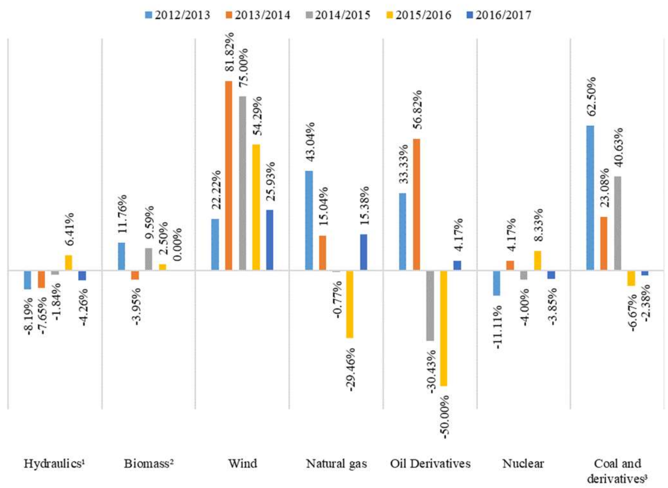

Figure 13: Variations in the Brazilian energy matrix between 2014 and 2017 (The share of solar energy omitted in this graph, being null between 2014 and 2016, with growth of 1,200.0% in 2016/2017)[1]Includes electricity import. [2]Includes firewood, sugarcane bagasse, bleach and other recoveries. [3]Includes coke oven gas

As for the biofuels regulated and measured by the ANP, based on the period from 2012 to 2018 (excluding December), it can be verified that ethanol production occurs predominantly. Although ethanol has a higher volume of production than biodiesel, it had lower growth rates. By evaluating the data according to the variation of biennial volume production, the biennium 2015-2016 had a decrease in the production of biofuels, marking also the largest recession of this one through the data of the ANP, with greater impact on the ethanol that had the following biennium also with decrease of production. It should be noted that the production of hydrous ethanol had the highest increase in the period and the anhydrous the biggest fall, reflecting the events of the gasoline price increase and the truckers' strike, which helped to overcome the recession of two biennia (Figure 14).

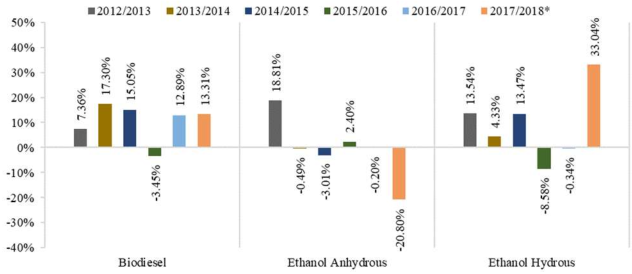

Figure 14: Percentage change in volume of production in the biennia between 2012 and 2018
*Values for the month of December / 2018 not counted in the graphs

The increasing production values of biodiesel and hydrated ethanol reinforce the growth projections for the sector, focusing its destination for transportation purposes. As a result, with the oscillations in the price of gasoline and its high cost, the domestic demand on the part of the drivers has been ethanol, linked to the use of diesel engines (trucks, buses, vans and some models of pickup truck and equipment agricultural) of biodiesel with progressive participation in the mixture with the fossil fuel, a phase of migration and greater uses of biofuels occurs. Another fact that tends to boost this market is the use of them in systems of the generation of energy, through its burning for conversion to heat and this destined to the generation of steam in boilers and subsequently in electric energy, for example. The fact is based on the projection of Fernanda, Pereira, and Martins (2018), and in Table 2, it is noted that in 2023 the largest participation in the SIN will be given by biomass.

CONCLUSIONS

Brazil is an avant-garde country in the use of biofuels because of its ethanol production since the 70's with the Proálcool program, which has made it today the leader in the production of this biofuel, although with its production variation in the period 2012- 2018, with great demand in 2018 among other factors, for the price of the gasoline.

Biodiesel has been expanding in the same period for ethanol, with higher growth in 2018 due to the regulations that increase its presence in fossil diesel until it reaches 15% in 2023. This fact encouraged the production, which still in volume is lower than ethanol. The Brazilian market for biofuels regulated by the ANP demonstrates growth potential both for the generation of electric energy and for supplying the national fleet of automobiles and other equipment with an internal combustion engine. The data show that in Brazil in the next years, there is an adoption of renewable energies as growing sources of electricity production, leaving aside polluting and aggressive means.

In the panorama of the internal supply of energy, there are migration trends for renewable sources, both pointed out by the previous years and by the projected projections; which would impact on a new configuration of the energy matrix geared towards renewable sources, thus providing environmental, economic and social gains.

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