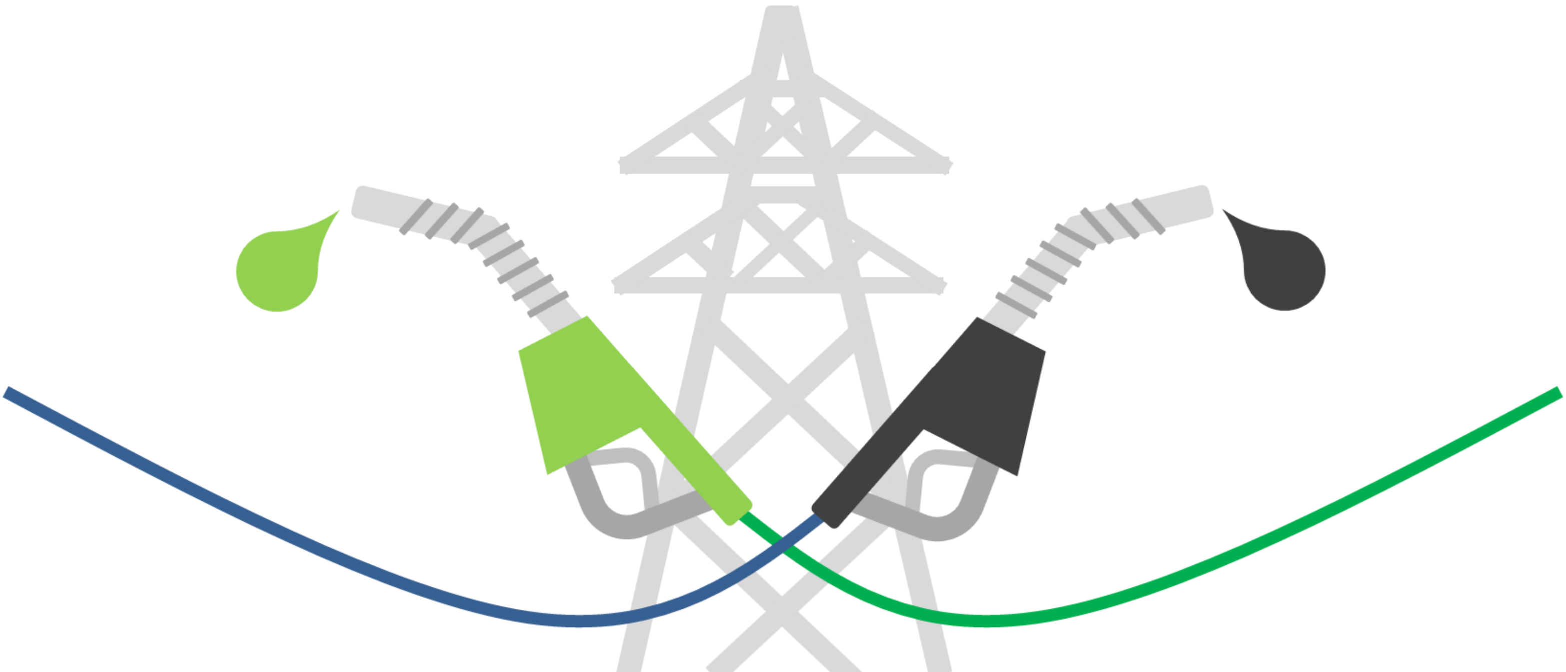
MINISTRY OF MINES AND ENERGY

BIOFUELS CONJUNCTURE ANALYSIS

YEAR 2018



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Biofuels Conjuncture Analysis
Year 2018

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A public company, linked to the Ministry of Mines and Energy, established under Law No. 10,847, of March 15, 2004, the purpose of the EPE is to provide services in the area of studies and research aimed at subsidizing the planning of the energy sector, such as electricity, oil and natural gas and their derivatives, coal, renewable energy sources and energy efficiency, among others.

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To the EPE colleagues who left a little bit of you through the ten editions of the Biofuels Conjuncture Analysis: Antonio Carlos Santos, André Luiz Ferreira dos Santos, Henrique dos Prazeres Fonseca, Patrícia Feitosa Bonfim Stelling, and Pedro Ninô de Carvalho.

The biofuels team especially thanks chemical engineer Antonio Carlos Santos for his invaluable wisdom, contribution and dedication and for the pleasant moments together throughout his career at EPE.

Presentation

The Energy Research Company proudly presents its tenth edition of the Biofuels Conjuncture Analysis, focusing on the year 2018. Every year, the publication consolidates the most relevant facts related to biofuels, which occurred in the year prior to its disclosure. It is launched in the second quarter, after the closing of the sugar-energy crop and the consolidation of statistics of the most important agencies in the area.

The main topics covered are: ethanol supply and demand and its production and transportation infrastructure, the biodiesel market, the share of bioelectricity in the national matrix and in energy auctions, the international biofuels market, the expectations for new biofuels, the greenhouse gas emissions avoided by the use of these renewable energy sources and the monitoring of the National Biofuels Policy (RenovaBio).

In this commemorative edition, in addition to assessing the main events that took place in 2018, the document presents an attached text on the evolution of the role of biofuels in the national energy matrix over the last decade, highlighting security of supply and mitigation of greenhouse gas emissions.

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1. Ethanol Supply

In 2018, Brazilian ethanol production was 32.3 billion liters, a new record, with a 17% increase over 2017. In contrast, sugar production dropped 25% to 28.5 million tons, the same level observed between 2005 and 2006. The sugarcane industry processed 609 million tons of sugarcane, 4.3% less than 2017 (CONAB, 2019a) (MAPA, 2019).

The 2018/19 harvest had a larger destination of the mix for ethanol production, due to the drop of sugar prices in the international market. In addition, it was also influenced by the aging of sugarcane crops due to the low renewal rate, introduction of mechanized harvesting and financial problems by sector units, similarly to previous harvests (CONAB, 2019b).

Domestic corn ethanol production again showed a significant increase, jumping from 413 million liters to 720 million liters. (UNICA, 2019a).

For the 2019/20 crop, we expect the same level of sugarcane milling as the 2018/19 crop, due to the aging of sugarcane, at a below-ideal renewal rate. Rainfall during the year will influence yield and productivity indicators. The production mix should be less alcoholic than the previous season, due to the expected recovery of the international sugar price, due to a more balanced world balance (CONAB, 2019b).

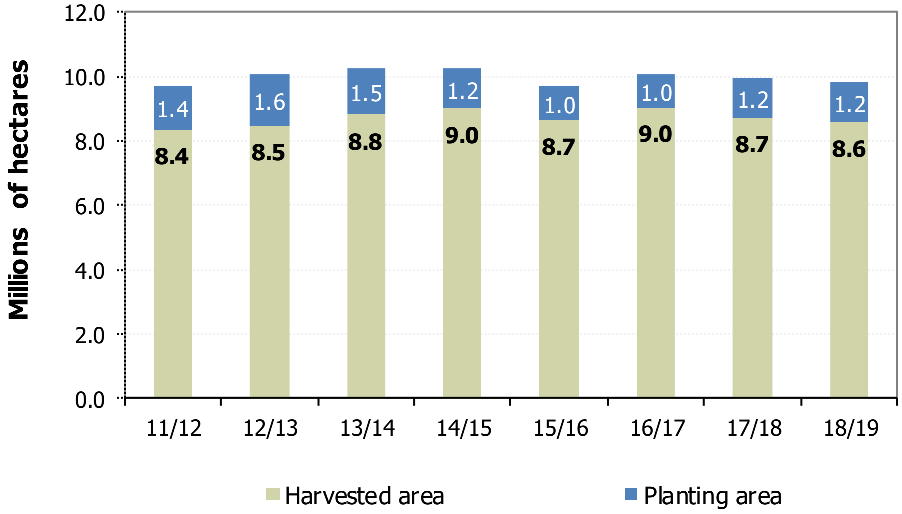
1.1. Sugarcane Area, Agricultural Productivity and Yield

Area

According to the National Supply Company (CONAB), the total area harvested by the sugar-energy sector in the 2018/19 harvest was 8.6 million hectares, down 1.6% from the previous year, a reduction that was observed in almost every region. Leased areas not suitable for mechanized harvesting are being discontinued in sugarcane planting and, as a result, have been allocated to other crops, such as soybeans (CONAB, 2019a) (CONAB, 2019b).

Since the 2013/14 harvest, the area of sugarcane harvested has been fluctuated around 8.8 million hectares (Chart 1). The main reasons include the return of leased areas (and planting of other crops), the existence of few greenfield projects and the shutdown of several existing production units. The planting area was similar to that observed in the previous crop, 1.2 million hectares. Only the Southeast and South regions had an increase in planted area, with growth of 9% and 22%, respectively, compared to the previous period (CONAB, 2019a) (CONAB, 2019b).

Chart 1 – Sugarcane harvested and sugarcane planting area (Brazil)



Source: EPE from (CONAB, 2019a) (CONAB, 2019b)

For the 2019/20 season, CONAB estimates a reduction of 2.4% in the sugarcane harvested area for the sugar-energy sector, reaching 8.4 million hectares. The main reason is related to the state of São Paulo, with a fall of 181,500 ha (-4.1%), driven by the expansion of soybean planting (CONAB, 2019b).

Agricultural Productivity

The average productivity of the Brazilian sugar-energy sector in the 2018/19 harvest was 72.2 tc/ha, a slight decrease of 0.4% compared to the previous one (72.5 tc/ha). The Center-South region, which accounted for 93% of total production, contracted by 2.7%. In the North-Northeast region, there was an increase of 7%. Productivity has remained practically constant due to several factors, such as crop aging, low renewal, lack of investment, mechanized harvesting. In addition, this crop was characterized by drought, especially in the Center-South. (CONAB, 2019a) (CONAB, 2019b).

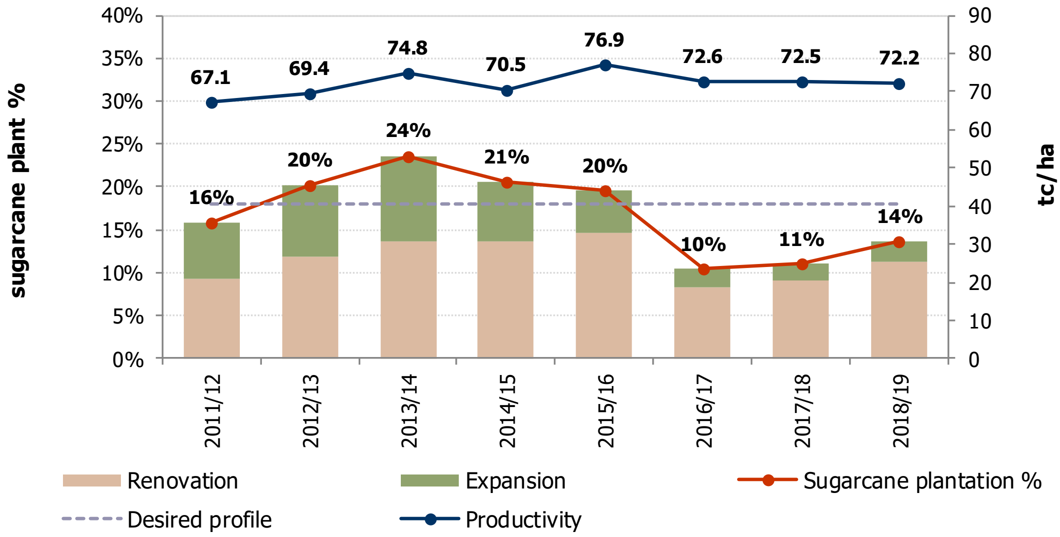
The evaluation of the performance of sugarcane production also requires verifying how the sugarcane cultivation area is distributed, which is differentiated into: reformed, reforming, expansion and ratoon cane area.[1] The share of sugarcane plants[2] (ideal sugarcane/total sugarcane) is 18%, a percentage related to a renewal of sugarcane after five harvests (UNICA, 2017).

Chart 2 presents the evolution of the share of cane plant in the total sugarcane harvested in Brazil, excluding the sugarcane area under reformation (CONAB, 2019a) (CONAB, 2019b).

[1] Reformed area is that which was recovered in the previous crop year and is available for harvest. Area under reformation is one that will not be harvested, as it is in recovery period for sugarcane replanting or other uses. Area of expansion is the class of sugarcane crops that, for the first time, is available for harvest. Ratoon-cane area is one that has been through more than one cut.

[2] Cane-plant area is equivalent to the sum of the reformed and expansion areas.

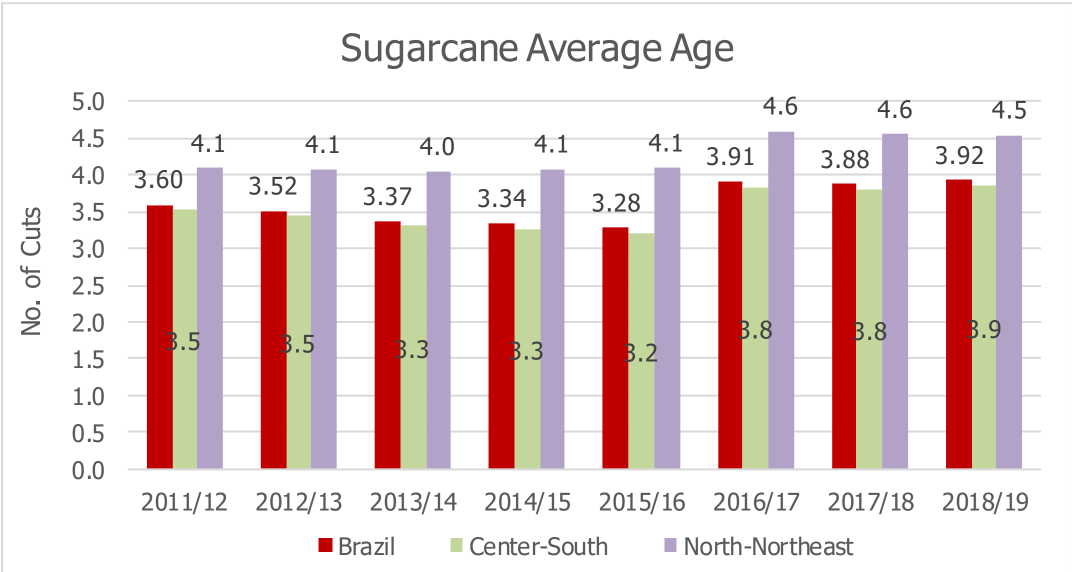
Chart 2 – Share of cane plant in total harvested area and yield (Brazil)



Source: EPE from (CONAB, 2019a) (CONAB, 2019b) and (UNICA, 2017)

The share of cane plant in the 2018/19 crop grew by 3 percentage points over the previous year, from 11% to 14%, still far from the ideal value (18%). Nevertheless, agricultural productivity remained at the same level, since Brazilian sugarcane remains at a high average age,[3] as can be observed in Chart 3. Note also the marked difference between the North-Northeast and Center-South regions.

Chart 3 – Average sugarcane-plantation age (Brazil and regions)



Source: EPE from (CONAB, 2019a) (CONAB, 2019b)

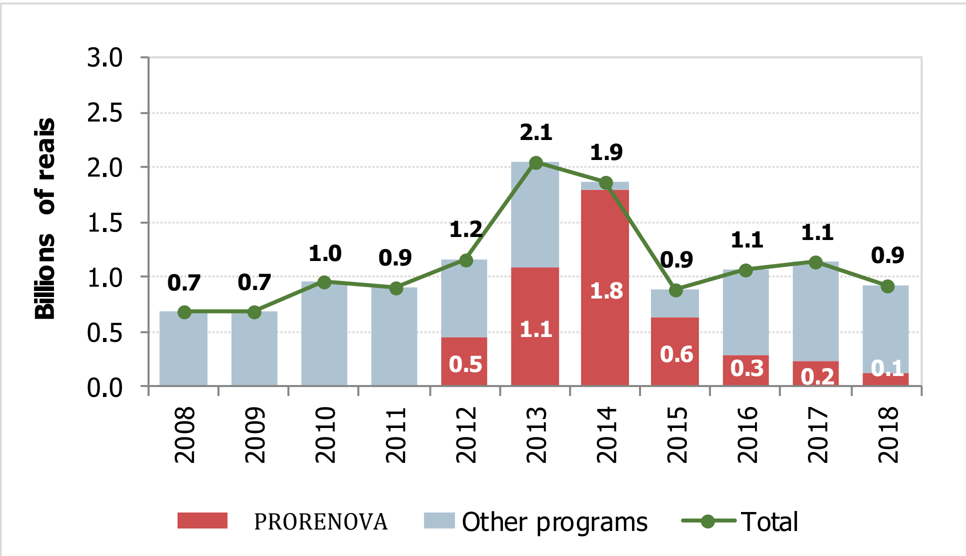
[3] The higher the average cutting stage (sugarcane-plantation age), the smaller the area with younger sugarcane and, consequently, the lower the average productivity, since this latter decreases with each cut.

The previous graph shows that the average age of sugarcane in Brazil had been showing a gradual fall from 2011/12 to 2015/16 crop. However, it increased by 19% in the 2016/17 crop (3.9 cuts), a level that has been maintained. Although the planting area remained at the same extension as the previous crop (Chart 1), in proportional terms, it has increased. This situation should also occur in the next crop (2019/20), that is, the same size of the planting area, with reduction of harvested area. Thus, the estimated productivity by CONAB (CONAB, 2019b) is 73.5 tc/ha, an 1.7% raise from the previous one. If this movement continues, the average age of the cane plantation will decrease in the coming years.

Improvements in the average sugarcane plantation age from 2012 onwards converge with the introduction of BNDES's PRORENOVA (Support Program for Renewal and Implementation of New Sugarcane Plantation).[4] In 2019, the limit per financing operation went from R$20 million to R$150 million, limited to 80% of the project value. Exclusive use for planting protected varieties or potential clones of sugar cane (cane plant) was maintained (BNDES, 2019a).

Chart 4 presents the total amount raised from public financing for sugarcane cultivation, in billions of reais. From 2012, this amount corresponds to PRORENOVA plus the values of other programs in which agricultural machinery and implements are purchased.

Chart 4 – Amount raised from public funding for sugarcane cultivation



Source: EPE from (BNDES, 2019b)

As shown in Chart 4, BNDES total disbursements in the agricultural area for sugarcane cultivation in 2018 were 0.9 billion reais. The chart shows that this global amount is at the same level observed in previous years, except for 2013 and 2014, where disbursement corresponded to almost double this amount (BNDES, 2019b). Looking only at PRORENOVA, it should be noted that in 2018 disbursements decreased by 47% compared to 2017.

[4] In addition to PRORENOVA, there are other programs at BNDES that can be used by the sugar-energy sector: PAISS (Joint Plan for Supporting the Industrial Technological Innovation of the Sugar-Energy Sector), BNDES Finem, Fundo Clima, and ABC (Low Carbon Agriculture) Program (BNDES, 2019e).

Regarding total investments for the sugarcane segment, there was an 11% expansion: R$1.9 billion in 2018 against R$1.7 billion in 2017. It should be noted that investment in the sector had its historical peak in 2010, with the figure of R$7.4 billion.

Sugarcane Yield (ATR/tc[5])

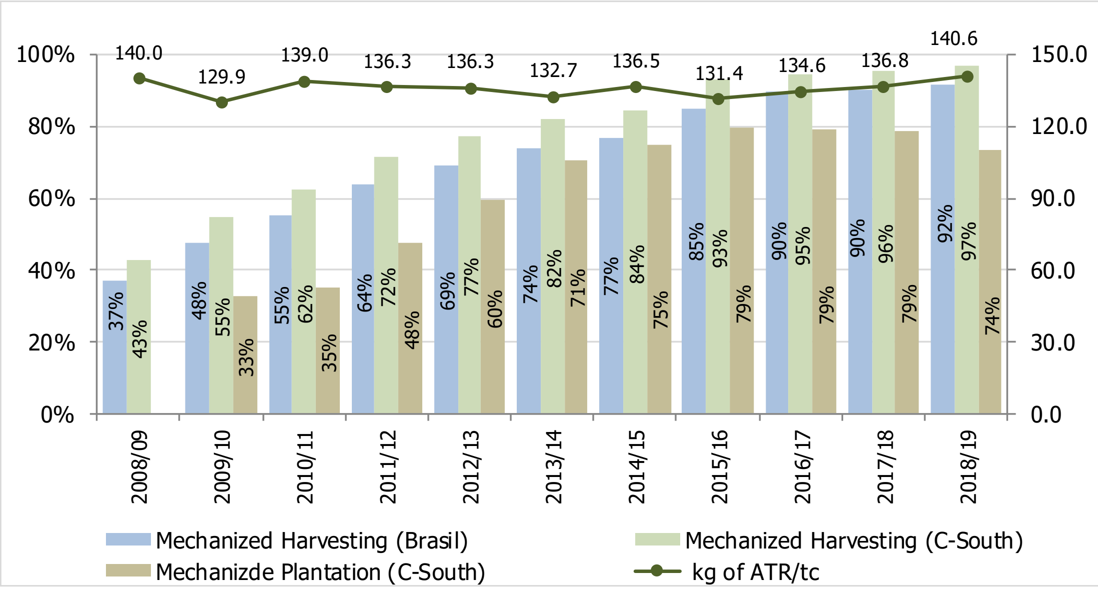
Sugarcane yield in the 2018/19 harvest was 140.6 kg ATR/tc, a 2.8% increase over the previous one (136.8 kg ATR/tc), the best record since the 2008/2009 harvest. (CONAB, 2019a) (CONAB, 2019b). The Central-West, Northeast and Southeast regions presented growth of 6.9%, 4.8% and 1.7%, respectively, highlighting the former, where it reached 147.6 kg/tc. Climatic conditions, age of crops, mineral and vegetable impurities and the lag between the implantation of mechanized plantation and the sugarcane harvesting are the main factors that influence this indicator.

The mechanized harvesting of sugarcane was implemented in the country, mainly, to achieve the goals imposed by environmental laws and agreements to reduce burning. However, it is observed that there was a mismatch between the mechanization of harvest and of the planting, in addition to other operations related to its cultivation. Thus, there was an increase in the amount of mineral and vegetable impurities that is carried into the industrial unit, along with sugarcane, degrading its quality.

As indicated in Chart 5, in 2018, the mechanization of the harvest in Brazil rose from 90% to 92%. In the Center-South region, mechanized harvesting increased from 96% to 97% (CONAB, 2019a) (CONAB, 2019b), while mechanization of the crop fell to 74% after three harvests remaining at 79% (CTC, 2019). The combination of these two movements led to an increase in the lag in this producing region, which rose from 17% to 23%. (CONAB, 2019a) (CONAB, 2019b) (CTC, 2019). The reduced share of mechanized planting is related to the replacement of planters in the most traditional regions of the country, in order to seek productivity recovery and cost reduction (due to the high consumption of seedlings and failures in planting with the use of machines), added to the increased use of MEIOSI technique[6] (UDOP, 2019).

[5] Total Recoverable Sugars.
[6] MEIOSI – Inter-rotational Method Occurring Simultaneously.

Chart 5 – Mechanized Harvesting and Planting x Sugarcane Yield



Note: Harvest data were extracted from CONAB (CONAB, 2019a) (CONAB, 2019b) while the mechanization of the planting were obtained from plants associated with CTC (CTC, 2019), which represent only a portion of the sugar-energy sector, not including suppliers. According to CTC (CTC, 2019), in 2018, harvest mechanization in the Center-South was 98%.

Source: (CONAB, 2019a) (CONAB, 2019b) , (CTC, 2019) and (UNICA, 2013a) (UNICA, 2013b) (UNICA, 2014a) (UNICA, 2017)

The Conab (CONAB, 2019b) estimates that the 2019/20 crop will present a 1.4% reduction in yield, reaching 138.7 kg ATR/tc.

It is important to highlight that the main component that interferes with the yield is the amount of total impurities (minerals and vegetables) present in the harvested sugarcane, due to the inadequate introduction of mechanization in agricultural processes, as mentioned above. In 2018, there was an improvement in this content, which fell from 9.7% in 2017 to 9.1%, concomitantly with that of vegetable impurities, which fell from 8.5% to 8.1%. As a comparison, the total impurity content in 2008 was 6.7% (CTC, 2019) (UNICA, 2013a). In this context, it is imperative to continue acting on this factor in order to maintain the recovery of the portion of income that was lost.

In this sense, varietal management[7] and agronomic are essential to the best production performance in terms of productivity and yield, which must be combined with the equalization of crop mechanization. Some important actions in this regard are: the adequacy of the spacing between the sugarcane lines; the size of the field to avoid trampling during harvester maneuvers; the grouping of varieties and height of the swaths, to make the cut closest to the ground;[8] and planting varieties best suited for each type of soil and crop.

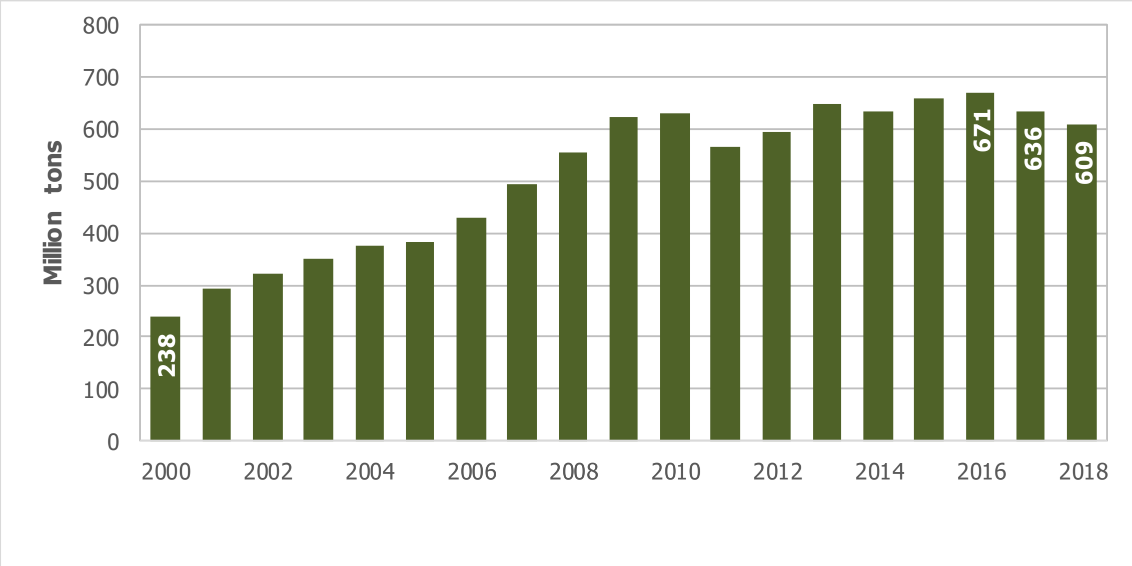
[7] For mechanized harvesting, the more upright the sugarcane remains, the lower the amount of plant and mineral impurities that will be taken into the industrial unit, given the cutting height adjustment of the tips on the harvester.

[8] Sugarcane has a higher sucrose content near the ground.

1.2. Sugarcane Processing

Total processed sugarcane reached 609 million tons in 2018, 4.3% lower than 2017, as presented by Chart 6 (MAPA, 2019). The main reasons were the closure or shutdown of units, as well as smaller area and productivity.

Chart 6 – Annual history of sugarcane processing



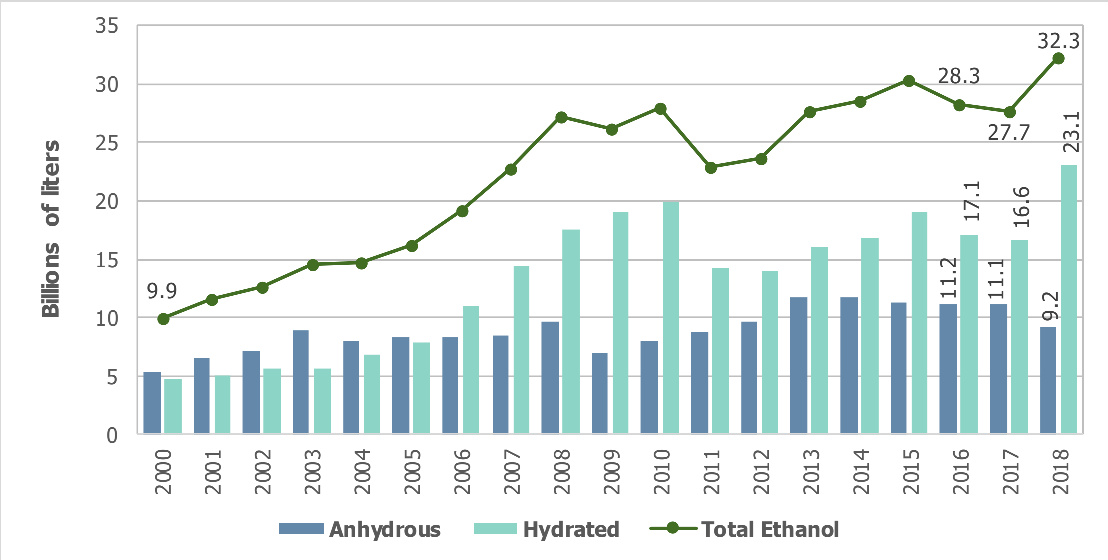
Source: EPE from (MAPA, 2019)

From crop year perspective, sugarcane processed in 2018/19 was 2% lower compared to 2017/18, according to Conab (CONAB, 2019c). Thus, the result in terms of calendar year is expected to be equivalent.

1.3. Ethanol production

In 2018, 32.3 billion liters of ethanol were produced, divided into 23.1 billion hydrous (up 39%) and 9.2 billion anhydrous (a fall of 17%). Thus, the total volume of ethanol produced was 17% higher than 2017, reaching a new historical high, as illustrated by Chart 7 (MAPA, 2019).

Chart 7 – Brazilian ethanol production



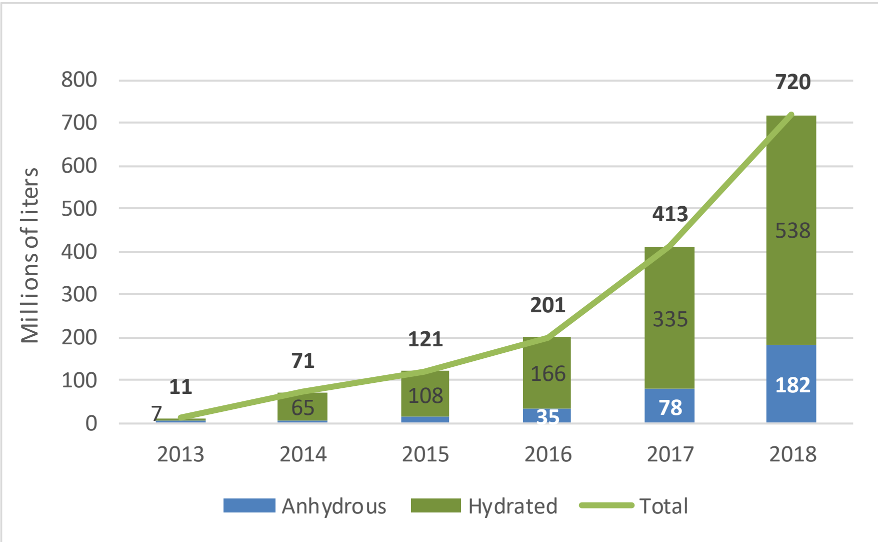
Source: EPE from (MAPA, 2019)

The increase in ethanol production in 2018 was due to the following factors:

- Fall in sugar prices, with surplus 2017/18 crop year (more details in Item 1.4).
- Relationship between average prices of hydrous ethanol and more favorable C-ethanol gasoline (more details in Item 3).

Particularly, ethanol from maize has shown a high growth in the last years (more than 10 times). In 2018, its production, which is concentrated in the states of Mato Grosso and Goiás, reached 720 million liters (see Chart 8), 74% higher than 2017.

Chart 8 – Brazilian corn ethanol production



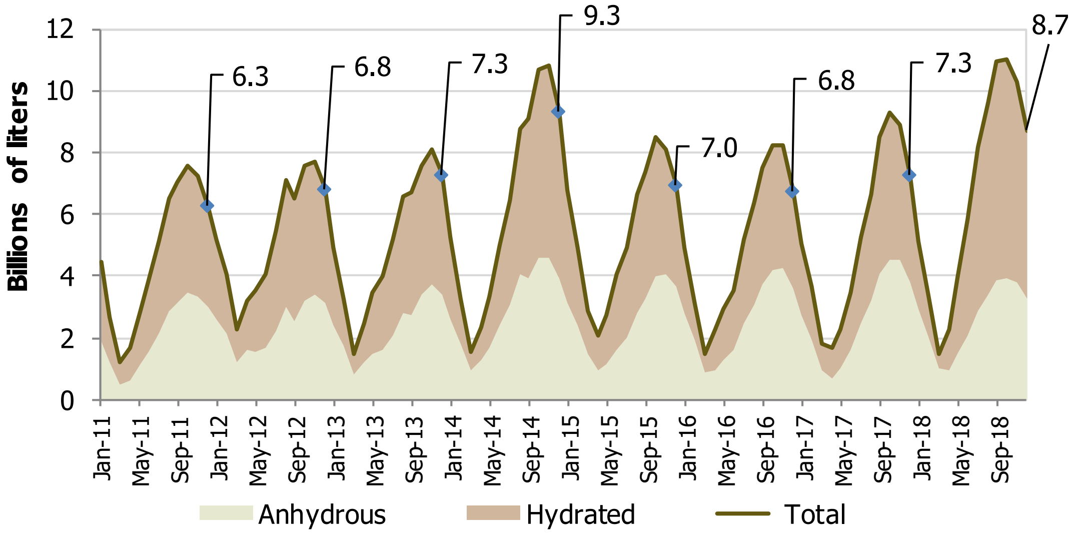
Source: EPE from (UNICA, 2019b)

Conab estimates (CONAB, 2019c) indicate that by 2019 ethanol production from the cereal will be 1.4 billion liters, reaffirming its potential within portfolio options for the biofuels sector and the Brazilian energy matrix.

Ethanol stock

Chart 9 displays the history of physical stock[9] variation of ethanol reported to MAPA. It can be observed that the passage stock,[10] at December 31, 2018 was 8.7 billion liters of ethanol. Of these, 3.2 billion were anhydrous ethanol, which corresponded to a 15% reduction compared to December 2017. Hydrous ethanol had a 58% increase in stocks. In this period, the total volume of fuel ethanol consumed increased by 13.9%, which will be analyzed in Item 2 of this study (MAPA, 2019).

Chart 9 – Monthly evolution of physical ethanol stock



Source: EPE from (MAPA, 2019)

The current rules regarding the mandatory stock of anhydrous ethanol are established by ANP Resolution No. 719, of February 22, 2018. (ANP, 2018c). According to it, at March 31 of each year, the minimum mandatory anhydrous stock for ethanol produced by the plants is 4%. For distributors, it is 10 days of commercialization, and the ANP is authorized to determine the extension to 15 days, if necessary for supply purposes during the off season.

The available stock of anhydrous ethanol observed at March 31, 2019 was 1,656 million liters. (MAPA, 2019), volume that meets the stipulated by the ANP.

In 2018, Draft Legislative Decree No. 61 (SENADO FEDERAL, 2018) proposed to make the system of marketing of hydrated fuel ethanol more flexible so as to allow its suppliers to sell it directly to the dealer, without the need for the distributor as an intermediary agent. This matter has been the subject of much debate and is quite complex. ANP held a Public Contribution Taking

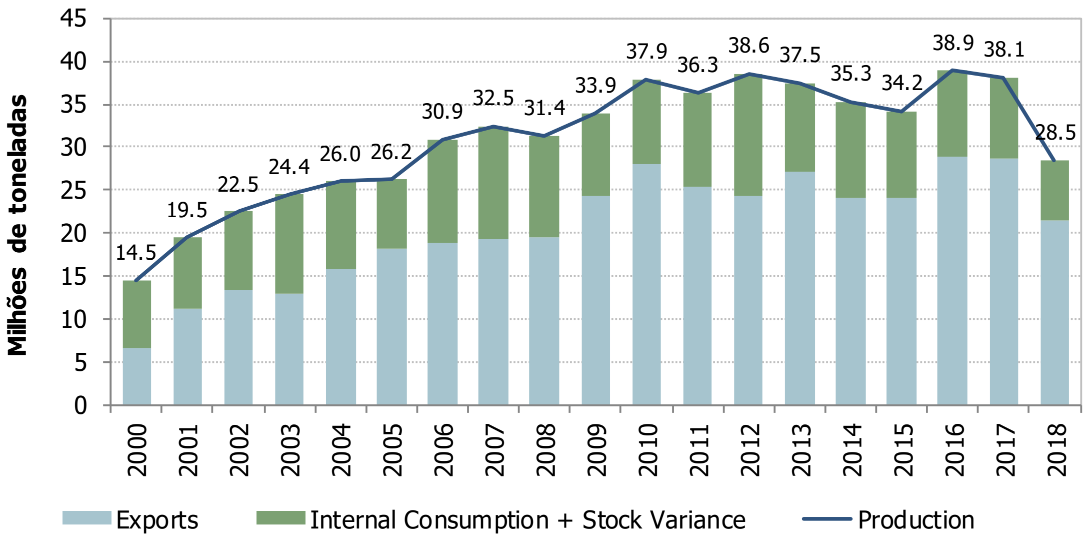
[9] Physical Stock is the actual volume stored in the production unit's tanks, including the volume already sold but not delivered.
[10] Passage stock corresponds to that stored in the production unit's tanks at the end of the calendar year.

(ANP, 2018e) and formed a Technical Group with CADE and the Ministry of Finance (at the time), to evaluate the main aspects related to the topic (ANP, 2018b) (CADE, 2018).

1.4. Sugar production

In 2018, Brazilian sugar production reached 28.5 million tons (25% less than 2017), as can be observed in Chart 10. The decrease of approximately ten million tons in the production of commodity resulted in a reduction of 2.3 million in the "domestic consumption + stock variation" component and a decrease of 7.3 million tons in exports. In 2018, sugar exports were 21.4 million tons (25% reduction), the lowest since 2009. (MAPA, 2019).

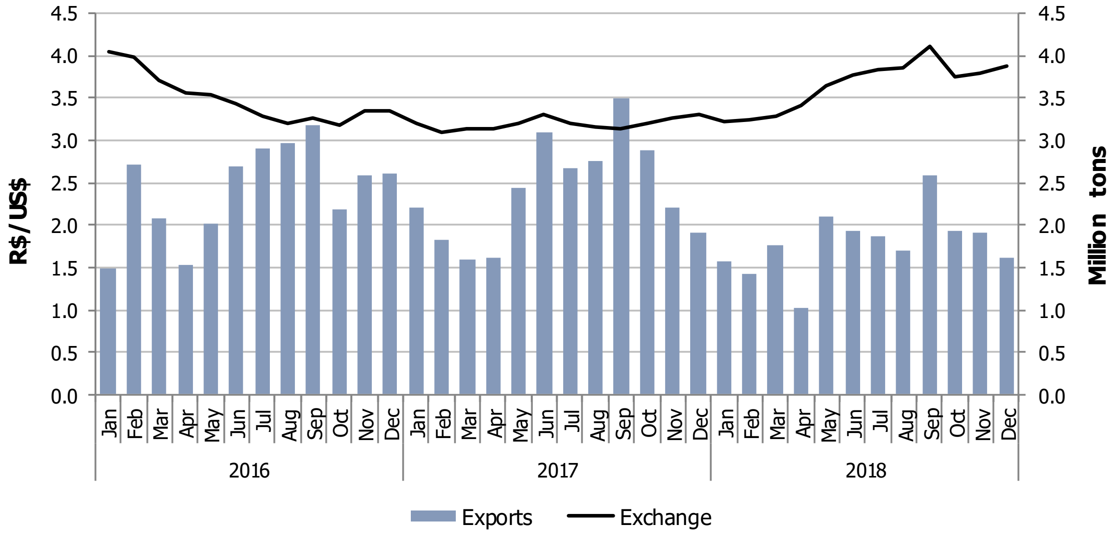
Chart 10 – Brazilian sugar production and exports



Source: EPE from (MAPA, 2019)

Chart 11 shows the behavior of Brazilian monthly sugar exports, which remained well below those observed in previous years. It should be noted that the exchange rate of the dollar showed an upward trajectory during 2018.

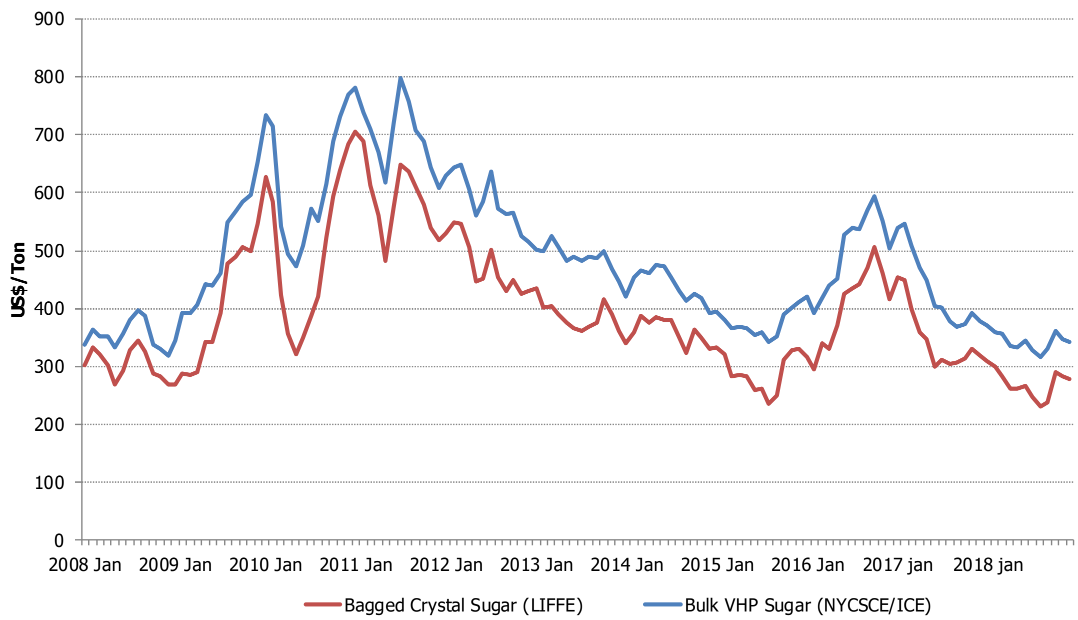
Chart 11 – Brazilian sugar exports and foreign exchange



Source: EPE from (MAPA, 2019) and (MDIC, 2019)

Regarding the average prices of VHP sugar (NYCSCE/ICE) and crystal sugar (LIFFE), there was a decrease of 23% and 21% compared to 2017, respectively, as can be seen from the analysis of the Chart 12.

Chart 12 – International prices for VHP and crystal sugar



Note: New York Stock Exchange (NYCSCE/ICE) – Contract 11 and London Stock Exchange (LIFFE) – Contract 407.

Source: EPE from (MAPA, 2019)

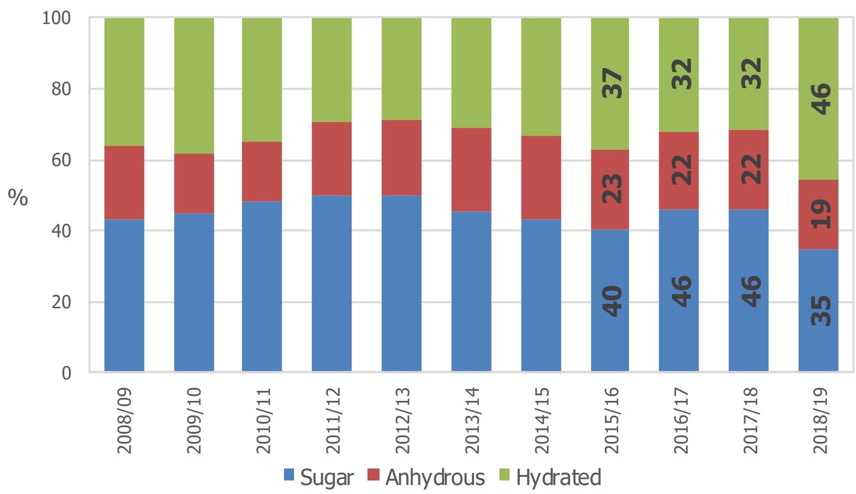
The 2017/18 world crop had a positive balance (supply/demand), in the order of 8.2 million tons, with the stock/consumption ratio at 47.7%. For the 2018/19 harvest, the expectation is that occurs a surplus of 480 thousand tons and a stock/consumption ratio of 47.3%. This estimate is mainly due to high inventories and above-expected production in India and Thailand. For the 2019/20 crop, it is estimated a deficit of 2.3 million tons, with a stock/consumption ratio of 45.5%. It is important to highlight that this scenario is influenced by the maintenance of the more alcoholic production profile of the Brazilian Center-South crop, as well as by the elevated final sugar stock referring to the world balance. (DATAGRO, 2019).

Several factors can influence the world sugar market, such as global stocks, the oil market and the exchange rate. Other factors may also contribute. For example, the World Health Organization recently recommended that sugar free consumption be less than 10% of daily energy consumption to reduce overweight and obesity. (WHO, 2015). Thus, some countries, such as Mexico, France, Norway and the United Kingdom have initiatives in this direction, which may reduce the demand for this product. In 2018, in Brazil, the Ministry of Health signed an agreement with food industry associations to reduce 144,000 tons of sugar in cakes, cake mixes, milk products, chocolate, sugary drinks and filled cookies. (MS, 2018).

1.5. Production mix

In 2018, the percentage of ATR destined for ethanol production showed great growth, increasing from 54% to 65%, especially hydrated, which jumped from 32% to 46% of the total mix of production (CONAB, 2019a), as shown in Chart 13. It should be noted that throughout the period analyzed, Brazilian plants have allocated most of the RTA to ethanol. At the end of the 2018/2019 crop, with surplus in the world sugar balance and the fall in its price, there was an even greater destination for ethanol production. In the next harvest, this distribution should present a slight variation for sugar, but remaining in a mostly alcohol profile, as world stocks are still high (see item 1.4).

Chart 13 – Production mix (sugar x ethanol)



Source: EPE from (CONAB, 2019a)

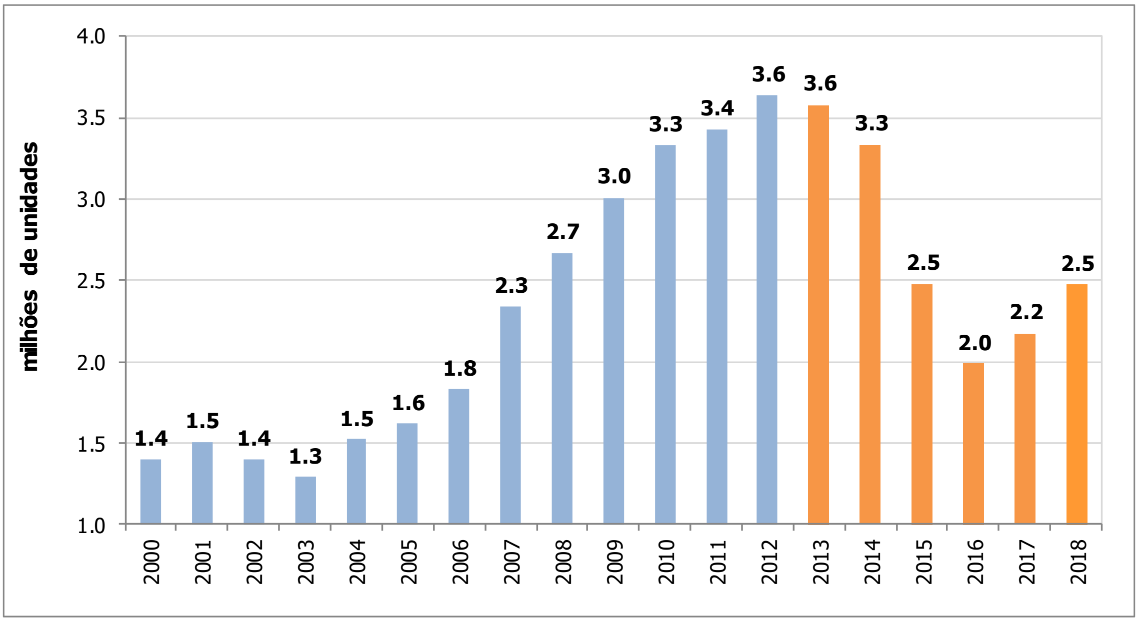
In 2018, the ATR compensation in the state of São Paulo was R$0.57/kg (CONSECANA, 2019), similar to that observed in 2017.

2. Otto Cycle Demand

2.1. Licensing and fleet of light-duty vehicles

In 2018, 2.5 million new light-duty vehicles were licensed in Brazil, 13.8% more than in 2017 (ANFAVEA, 2019). This second successive increase, after a period of four consecutive declines, led annual licensing to the same level as in 2015, still below the record 3.6 million units licensed in 2012 and 2013, as shown by Chart 14.

Chart 14 – Licenses of light vehicles



Source: EPE from (ANFAVEA, 2019)

Of the total licensing of light-duty vehicles, by segmentation, 84.8% were automobiles and 15.2% light commercial vehicles. In fuel separation, the category *flex fuel* 87.6%, followed by diesel-powered vehicles with 8.9%, gasoline with 3.3%, and a small percentage of hybrid vehicles (3,970 units, 0.2% of the total). In terms of motorization, for the ninth consecutive year, most cars with 1.0 to 2.0 engines were licensed, accounting for 63.1% of the total. (ANFAVEA, 2019).

The commercialization of used vehicles[11] slightly increased in 2018 (0.4% over 2017) to 14.3 million units, representing 84.8% of total vehicle sales (new + used). There was a significant decrease of 52.1% in sales of used cars (0 to 3 years), from 2017 to 2018, which reached 2.4 million units, the lowest value of the last five years. On the other hand, there was a 29.4% increase in sales of older used vehicles,[12] reaching 11.9 million units (FENAUTO, 2019).

[11] This includes used motorcycles and heavy commercial vehicles.
[12] Used vehicles with more than 3 years old. Includes motorcycles and heavy commercials.

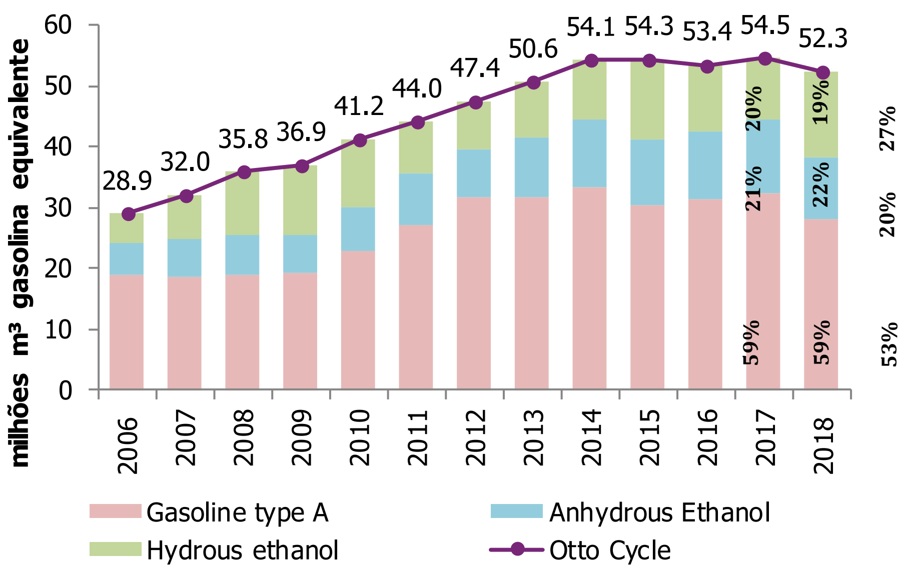
As for motorcycles, in 2018, 958,000 new units were licensed, 17.6% more than in the previous year, according to data from ABRACICLO (ABRACICLO, 2019). This was the first increase after a period of six consecutive falls.

As a result of the licensing observed in 2018, the Brazilian Otto cycle light vehicle fleet grew 1.4% and remained at around 37 million units, with the technology *flex fuel* representing 76.4% of the total.

2.2. Fuel demand of Otto cycle fleet

Total energy demand for Otto cycle light-duty vehicles in 2018 was 52.4 billion liters of gasoline equivalent, a decrease of 4% over the previous year. In the distribution by fuel, gasoline type A dropped from 59.2% to 53.4%, accompanied by anhydrous ethanol, which decreased from 22.2% to 19.5%, as shown by Chart 15. The share of hydrous ethanol increased significantly: from 18.7% to 26.9%. This movement caused total fuel ethanol to increase its share from 40.8% to 46.5%, increasing the renewability of the Otto cycle matrix. (EPE, 2019a). The reasons for this behavior will be cited in the next section of this document.

Chart 15 – Otto cycle demand and share of different fuels

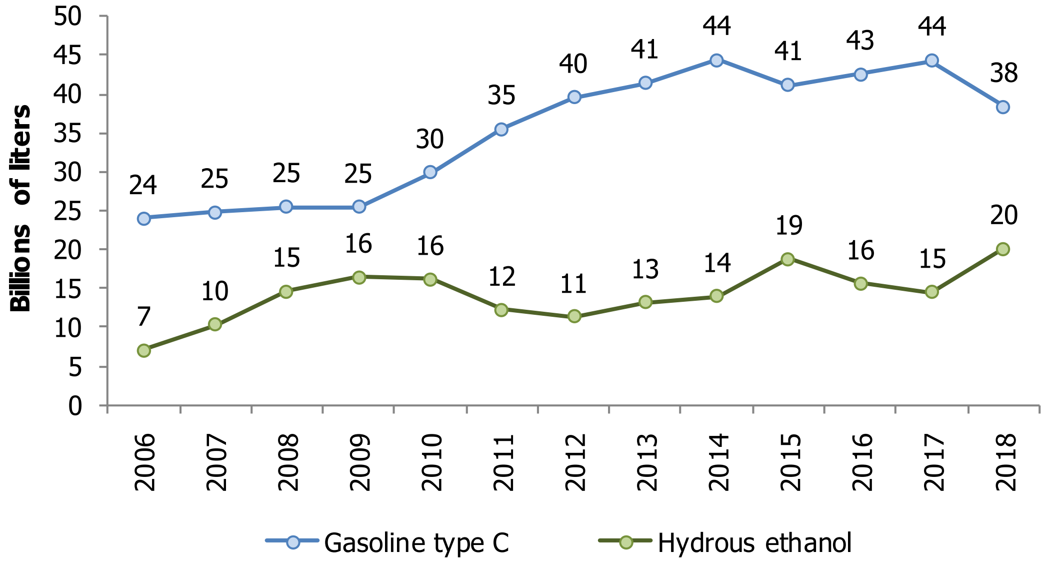


Note: Demand data excludes the CNG share.

Source: EPE from (EPE, 2019a)

Demand for hydrous ethanol in 2018 totaled 20.1 billion liters, representing a significant growth of 38.6% over the previous year and consumption of gasoline type C reached 38.4 billion liters, down 13.4% in relation to 2017 (EPE, 2019a), as Chart 16 illustrates.

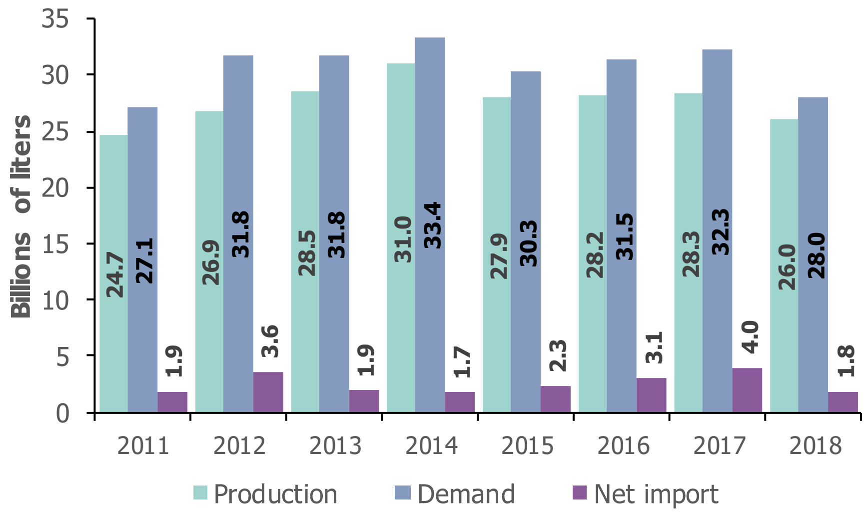
Chart 16 – Annual demand for hydrous ethanol and gasoline type C



Source: EPE from (EPE, 2019a)

Chart 17 presents the evolution of demand, production and net import of gasoline type A, for the period 2011-2016.

Chart 17 – Production, demand and net import of gasoline type A



Source: EPE from (EPE, 2019a)

In 2018, while domestic demand for gasoline type A decreased by 13.1% from the previous year to 28 billion liters, its production decreased 8.2% to 26 billion liters. The trade balance of gasoline type A was 1.8 billion liters of net imports, decreasing to less than half of the volume imported in the previous year (4 billion). (EPE, 2019a). Refinery processed oil load was slightly reduced, 0.5% from 2018 (ANP, 2019d). While the demand for fossil diesel fell 1%, its production by the national refining park grew 2.4% (more details in item 6).

3. Economic Analysis

3.1. Otto cycle fuel prices

The year 2018 was marked by the significant increase in hydrous ethanol prices, which accompanied the even higher increase in gasoline type A prices, as will be seen below. The production profile of the plants has become even more alcoholic, as the fall in sugar prices in the international market has accentuated, following a trend that began in 2017. Regarding gasoline, the price at the refinery has undergone several adjustments, due to Petrobras' international price parity policy[13] (PETROBRAS, 2018a) (PETROBRAS, 2018b) (PETROBRAS, 2018c) (PETROBRAS, 2018d) (PETROBRAS, 2019a) (PETROBRAS, 2019b).

With Decrees No. 9,101, of July 20, 2017, and No. 9,112, of July 28, 2017, the government changed the taxation of PIS/COFINS on the importation and sale of fuels, including gasoline and ethanol. Thus, the PIS/COFINS levied on ethanol has remained at R$241.81/m3 and for gasoline, at R$792.5/m3 (BRASIL, 2017a) (BRASIL, 2017b).

In addition, in several months of 2018, the National Council for Finance Policy (DO) released new Fuel Reference Prices, establishing changes in the End-Consumer Weighted Average Price (PMPF),[14] which serves as a parameter for ICMS taxes (CONFAZ/MF, 2019).

Thus, for a demand for Otto cycle fuels lower than that observed in the previous year (-3.9%), hydrous ethanol consumption showed a significant increase of 37.5%, while for gasoline type A there was a reduction of 13.4% (EPE, 2019a).

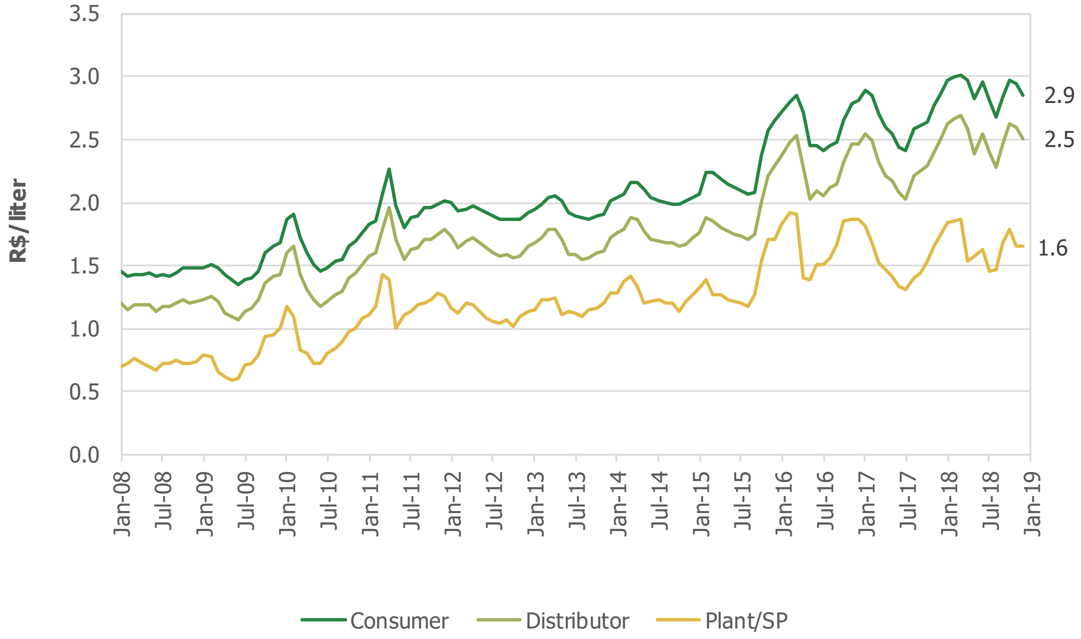
Chart 18 presents a comparison of average prices[15] hydrous ethanol to the consumer (Brazil), the distributor (Brazil) and the plants (São Paulo).

[13] It should be noted that, as part of the truck stoppage negotiations, on May 28, 2014, Petrobras announced the Relevant Fact – Temporary Diesel Price Subsidy Program, informing that the federal government had announced a reduction in the price of the road diesel oil of R$0.46 per liter, reducing the tax burden and subsidy to be paid by the Federal Government (PETROBRAS, 2018a). As pointed out in this Relevant Fact, the initial reduction was maintained for 60 days and after this period diesel price adjustments became monthly. Petrobras said it would not subsidize the price of diesel and would not incur losses, as it would be reimbursed by the Union. The receipt of this grant was communicated by Petrobras as Material Fact on different dates. (PETROBRAS, 2018b) (PETROBRAS, 2018c) (PETROBRAS, 2018d) (PETROBRAS, 2019a) (PETROBRAS, 2019b) (PETROBRAS, 2019c). No changes were reported in the International Price Parity Policy for Gasoline and other fuels.

[14] The changes were in the following states: AC, AL, AP, ES, MA, MT, PI, RR, RS, SP and TO.

[15] Average prices weighted by Brazilian production of the federation units are in current values.

Chart 18 – Hydrous ethanol prices



Source: EPE from (ANP, 2018g) and (CEPEA/ESALQ, 2019).

The difference between the minimum and maximum prices of hydrous ethanol to consumers throughout 2018 was R$0.33/liter (12%, between August and March), lower than those observed in the last two years: in 2017, R$0.48/liter (20% between July and January), and in 2016, R$0.44/liter (18% between July and March).

By early 2018, the price of ethanol was on the rise. Accompanying the movement of the crop, it became cheaper over the year and subsequently increased. Comparing to the same months of 2017, the differences in values reached R$0.53 per liter (equivalent to 22%). Note that the average annual margins on hydrous ethanol resale remained virtually unchanged between 2015 and 2018, with an average of R$0.36/liter. On the other hand, the increase in distribution margins was 13% in 2018, reaching R$0.87/liter. It should be noted that there had already been a significant increase in 2017, when margins reached R$0.77/liter, a 30% increase over the previous year. Hydrous ethanol prices at the plant (in São Paulo) were higher than in 2017, in all months except December. The largest price increases at the plant occurred in March (22%) and June (23%).

Average annual prices for hydrous ethanol and gasoline type A for the consumer are shown in Table 1, as well as the relative average price (PE/PG) and its variations.

Table 1 – Average and relative annual prices of hydrous ethanol, gasoline type C (PE/PG)

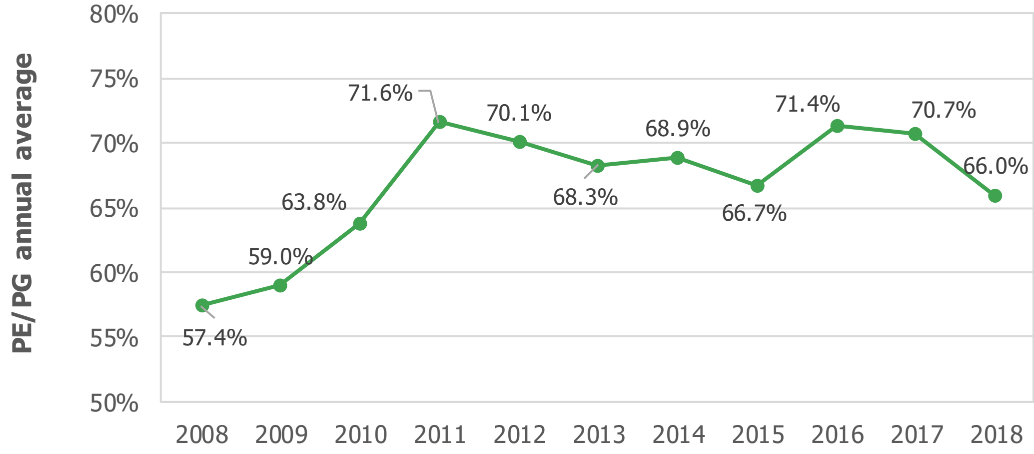
Year	Ethanol Hydrated (R$/liter)	Var. (% yearly)	Gasoline type C (R$/l)	Var. (% yearly)	PE/PG	Var. (% yearly)
2008	1.44	1.5	2.51	-0.2	0.57	1.8
2009	1.49	3.3	2.52	0.5	0.59	2.7
2010	1.64	10.6	2.57	2.2	0.64	8.2
2011	1.96	19.1	2.73	6.2	0.72	12.2
2012	1.92	-2.1	2.74	0.1	0.70	-2.2
2013	1.95	1.7	2.86	4.4	0.68	-2.5
2014	2.05	5.1	2.98	4.3	0.69	0.8
2015	2.24	9.1	3.35	12.6	0.67	-3.2
2016	2.63	17.7	3.69	10.1	0.71	7.0
2017	2.66	1.0	3.76	2.1	0.71	-1.0
2018	2.90	8.9	4.40	16.8	0.66	-6.6

Source: EPE from (ANP, 2018g)

In 2018, in general, the behavior of hydrous ethanol prices over the months of the year was similar to that observed for gasoline type A.

The average value of hydrous ethanol at the pump was R$2.90/liter in 2018, an increase of 8.9% compared to the previous year, while gasoline type A was 16.8% more expensive, corresponding to R$4.40/liter. The price of biofuel increased less than that of gasoline type C, which resulted in a 6.7% reduction in relative price (PE/PG), compared to 2017. As a result of this drop, in 2018, the average price to price ratio was 66.0%, considered favorable to ethanol consumption, and representing the lowest ratio since 2011. O Chart 19 illustrates the change in relative annual average price (PE/PG) since 2008.

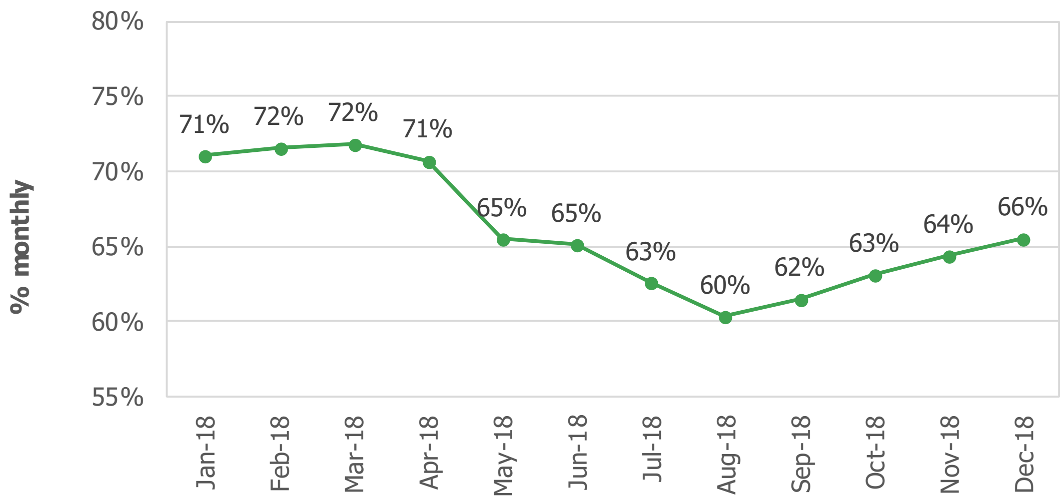
Chart 19 – Price relationship between hydrated and gasoline type C (PE/PG)



Source: EPE from (ANP, 2018g)

The monthly PE/PG relative price during 2018 is illustrated in Chart 20. In January, the PE/PG ratio was 71%, increasing slightly in February and March to 72%, and returning to the initial level in April. From then on, it showed a downward trend until August, when it reached a minimum of 60%, rising gradually in the following months, and reaching 66% in December. Thus, during eight months of the year, hydrous ethanol was competitive. It should be noted that São Paulo and Minas Gerais, representing 47% and 10% of total ethanol production in the country, respectively, presented a PE/PG ratio exactly equal to the national average profile, with the months from May to December favorable to consumption of ethanol. We highlight the states of Goiás and Mato Grosso, which showed a favorable PE/PG ratio for biofuel consumption throughout 2018.

Chart 20 – Monthly PE/PG ratio in 2018

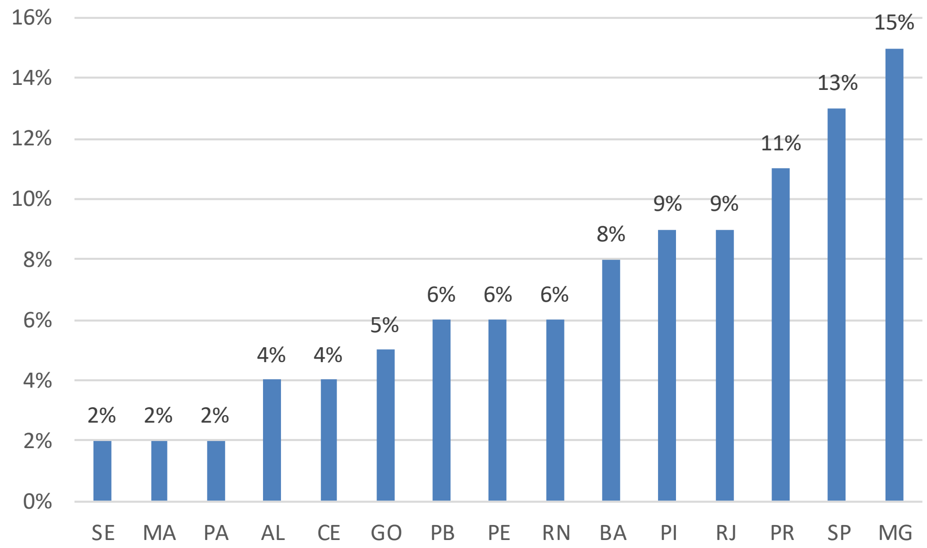


Source: EPE from (ANP, 2018g)

3.2. ICMS on Otto cycle fuels

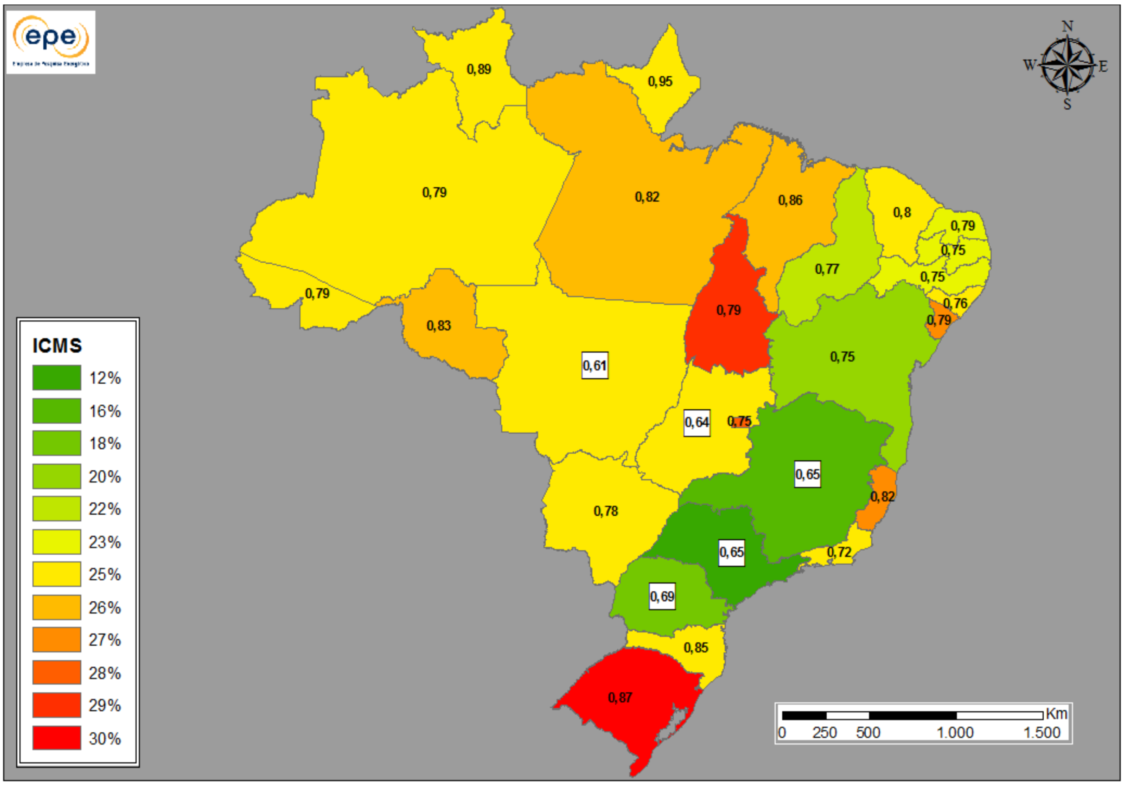
In 2018, similarly to the previous year, 15 states continued to have differentiation in the ICMS rates for ethanol and gasoline, as a way of promoting the biofuel market, as illustrated by the Chart 21. Minas Gerais and São Paulo maintained the largest difference between taxes, 15% and 13%, respectively.

Chart 21 – Tax Differentiation – ICMS (gasoline x ethanol) 2018



Source: (CONFAZ/MF, 2019) and (FECOMBUSTIVEIS, 2018)

Figure 1 illustrates the relationship between ICMS taxation and the competitiveness of hydrous ethanol in Brazilian states.



Source: EPE from (ANP, 2018g), (CONFAZ/MF, 2019) and (FECOMBUSTIVEIS, 2018)

Figure 1 – Ethanol ICMS rate and PE/PG ratio by state in 2018

In 2018, the average PE/PG ratio for Brazil was 66.0%. The state of Mato Grosso had an average annual ratio of 60.5%, the lowest in the country. In São Paulo, largest producer and consumer,[16] the average ratio was 64.7% (the ICMS tax rate for ethanol is the lowest in the country, 12%). In Minas Gerais, which has the second lowest rate (16%), the annual PE/PG value was 65.3%. The least competitive states were Amapá and Roraima, where the price of ethanol averaged 95% and 89% of the price of gasoline type A, respectively, and was equal to or slightly lower than the price of fossil derivatives in several months of the year.

[16] São Paulo accounted for 47.1% of national ethanol production (anhydrous and hydrated) and 44.8% of Brazilian hydrous consumption in 2018. (MAPA, 2019).

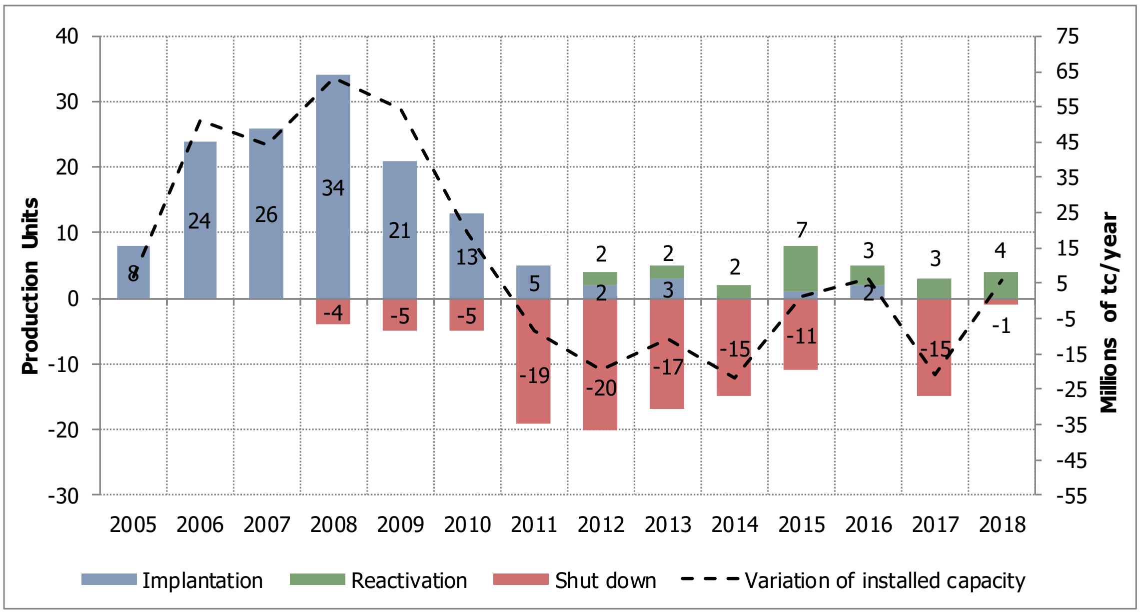
4. Production Capacity and Ethanol Transport Infrastructure

4.1. Productive capacity

In 2018, four production units reactivated,[17] with aggregate grinding capacity of 8 million tons. On the other hand, a unit with a capacity of 2.2 million tons was closed. This year, there was no implementation of any new sugarcane ethanol unit. The annual balance thus amounts to an increase of about 6 million tons.

Chart 22 shows the flow of deployment, reactivation and shut down of units between 2005 and 2018. The number of new deployments has fallen significantly since 2011. The nominal sugarcane grinding capacity is estimated to have increased by 171 million tons over the period, considering deployed, decommissioned and reactivated units.

Chart 22 – Flow of sugarcane plants in Brazil



Source: EPE from (MAPA, 2019) and (UNICA, 2014b)

According to MAP (MAPA, 2019), the number of sugar and alcohol units in operation in December 2018 was 369, corresponding to an effective milling capacity of about 750 million tons.[18] Therefore, adopting the milling performed in 2018, which was approximately 609 million tons, the occupancy rate of the sugar and alcohol industry was 81%.

In 2018, a small flex unit (associated with sugarcane plants) of corn ethanol was established, totaling 7 plants alike. The total corn processing capacity is 2.1 million tons per year and the

[17] Current accounting does not include: units identified as producing spirits (including those registered in MAPA); non-sugarcane ethanol producing units and those that came to a standstill and returned in the same calendar year.

[18] The calculation considers the units that paralyzed operations up to December 31, 2018, as well as the grinding capacity growth in the same year. It also considers an average capacity factor of 90%.

ethanol production capacity is about 900 million liters/year. According to the National Corn Ethanol Union, seven units under construction were identified, mostly of the type full, which will add 2.2 billion liters to the production capacity of ethanol from this cereal (UNEM, 2019).

According to the ANP, at the end of December 2018, 370 units were able to sell anhydrous and hydrous ethanol,[19] whose production capacities were 126 thousand m^3/day and 233 thousand m^3/day, respectively, of which 152 needed ratification of the capacity, and so they have pending status in the tax documents. In addition to these units, there were two requests for the construction of new plants, which will add a capacity of 310 m^3/day of anhydrous and 607 m^3/day of hydrous. (ANP, 2019c).

MAPA controls the units in the sugar and alcohol sector that are in operation, including the sugar plants. The ANP controls units that are able to sell anhydrous and hydrous ethanol, even if they are not in operation on a certain date. The differences between the reports of the two entities are due to the different objectives pursued.

4.2. Pipelines

Figure 2 introduces Logum's integrated ethanol logistics system, which consists of its own pipeline project and the use of existing (LOGUM, 2018) pipelines, sporting a maximum annual transport capacity of up to 6 billion liters of ethanol (LOGUM, 2019).

Source: (LOGUM, 2019)

Figure 2 – Integrated logistics system for ethanol

The sections of the ducts that are already in operation are:

[19] The report does not characterize whether the unit is operating or is at a standstill and there are no exclusively sugar producing units. Includes one unit full of corn.

Owned: Ribeirão Preto (SP) – Paulínia (operating capacity of 2.8 billion liters/year) and Uberaba (MG) – Ribeirão Preto (SP) (operating capacity of 1.8 billion liters/year);

Subcontractors: Paulínia (SP) – Barueri (SP); Paulínia (SP) – Rio de Janeiro (RJ) and Guararema (SP) – Guarulhos (SP).

Tank storage capacity (usable volume) at system operating terminals is 619 million liters (LOGUM, 2019).

In 2018, the volume of ethanol handled was 2.4 million liters, 14.3% more than the previous year. That year, Logum obtained a financing of R$1.8 billion from BNDES, with which they intend to expand the network with an additional 128 km of pipelines: one stretch to São José dos Campos (SP), with 36 km, and another to São Caetano do Sul (SP), with 92 km, passing through Guarulhos (SP); besides the implantation of a storage terminal in this last city. With the completion of new investments, scheduled for 2021, an increased handling capacity to over 8 billion liters/year is expected. (BNDES, 2019f) (REUTERS, 2019).

4.3. Ports

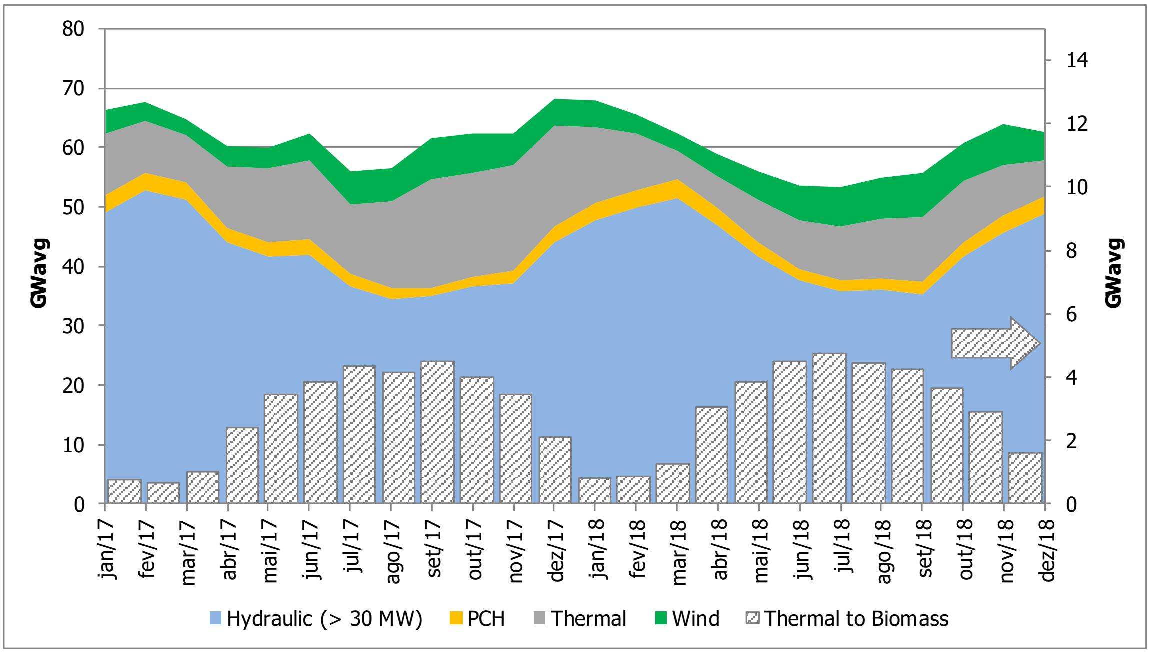
The port remained in 2018 as the major international trade route for ethanol, covering 99% of the exported (1.7 billion liters) and imported (1.8 billion liters) volume. The Port of Santos – SP represented 87.0% of exported volumes, followed by Paranaguá – PR, with 12% (MDIC, 2019). São Luís Port – MA (65.4%) continued to be the main port of entry for imported ethanol (1.2 billion liters) followed by Santos Port (19.7%) and Suape Port – PE (8.2%). The Northeast Region entry volumes decreased compared to 2017, but remain the majority, around 80% of the total (MDIC, 2019).

5. Bioelectricity

The share of biomass thermal generation has become increasingly significant on the national scene. Between January and December 2018 there was a 5.0% increase in injection compared to the same period of 2017. Sugarcane bagasse remains the most used fuel. However, there was a considerable increase in the share of other biomass in the export of energy to the National Interconnected System (SIN), as described in item 5.2.

In 2018, the share of energy exported from sugarcane in the national electricity matrix was 3.9%, maintaining the same level of the previous year. The sugarcane plants injected in the SIN 2.5 GWavg, very close to the total verified in 2017, only 1.6% higher. Chart 23 presents the seasonal share of sugarcane biomass in electricity generation in 2017/2018. Complementarity with the water source is noted, since the increase in bioelectricity generation occurs during the harvest, at the same time as the dry season (CCEE, 2019).

Chart 23 – Share of sugarcane biomass in electricity generation



Source: EPE from (CCEE, 2019)

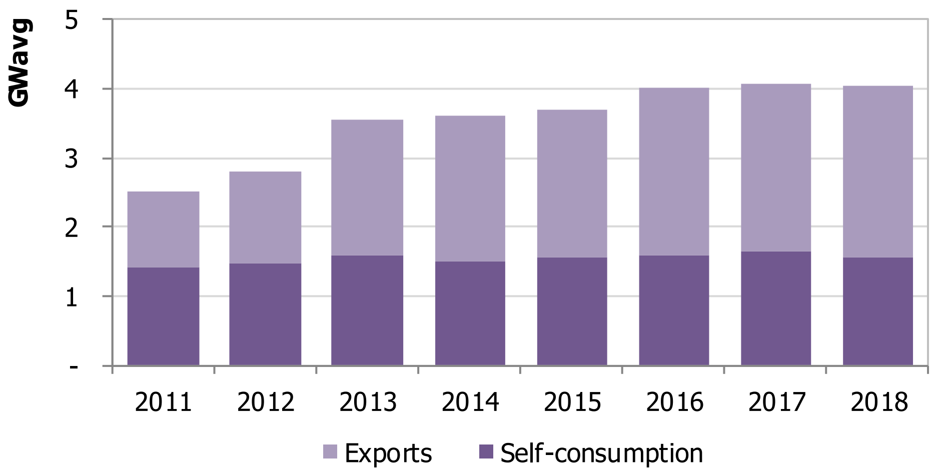
5.1. Energy exporting and trading

In addition to energy self-sufficiency, sugarcane biomass plants are characterized by the supply of energy to SIN.[20]

[20] The sugarcane industry plants sell electricity in the Regulated (ACR) and Free (ACL) Contracting Environments. In ACR, the energy purchase and sale operations are concentrated through bids in which new, reserve (LER) and alternative sources (LFA) auctions are held. The auction model was structured to ensure greater transparency and competition in energy trading. In the ACL, the generation, trading, importation, exportation and free consumers act in freely negotiated bilateral purchase and sale agreements, and distributors are not allowed to purchase energy in this market. In addition, there is the Incentive Program for Alternative Sources of Electric Energy (PROINFA), created in 2004 (CCEE, 2019); (ELETROBRÁS, 2018)).

According to Chart 24, in 2011-2018, there was a growth in electricity generation from this source, driven by the increase in electricity exports, with the share of self-consumption remaining at the same level. Note that over the last three years these values have remained stable.

Chart 24 – Self-consumption and energy exported by sugarcane biomass plants



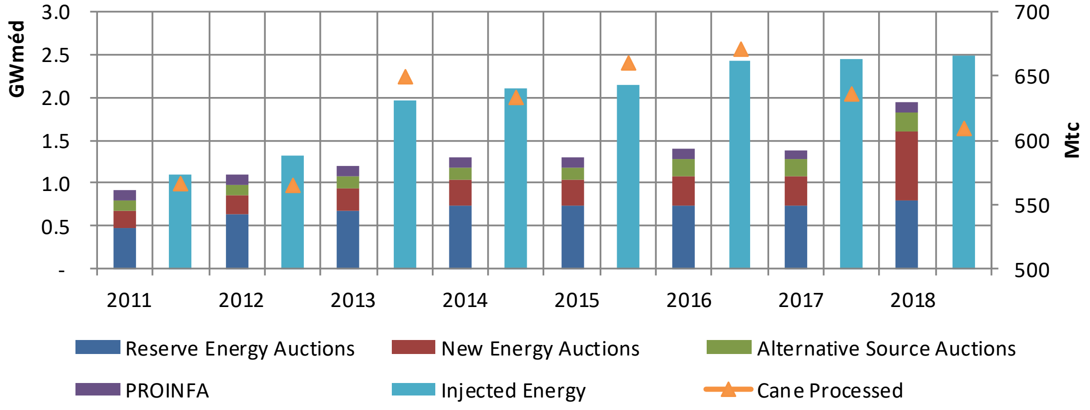
Source: EPE from (CCEE, 2019) and (EPE, 2019a)

Of the 369 sugarcane biomass plants in operation in 2018, 200 traded electricity, three more than the previous year. Of those that export energy to SIN, part operates exclusively in ACL (60%) or ACR (20%) and the remainder (20%) sells in both contracting environments.

In order to increase the competitiveness of sources derived from biomass and stimulate the growth of bioelectricity in the Brazilian electricity matrix, the federal government promoted the creation of regulatory mechanisms and incentive policies, such as specific auctions. In 2018, the first reserve energy auction (LER 2008) exclusively dedicated to biomass completed 10 years. On this occasion, more than 590 MWavg were contracted, the maximum amount recorded, with the commissioning scheduled for 2009 and 2012.

In 2018, the sugar-energy plants had contracts of 1.5 GWavg. As a result of the events that year, the sugarcane plants added 27 MWavg through LEN A-4 and A-6. (CCEE, 2019). Chart 25 highlights the increase in the amount exported to the SIN (ACR and ACL), the total contracted by modality via energy auctions and the sugarcane processed in recent years. In 2018, even with a 4.3% reduction in the amount of sugarcane processed, there was a small increase in SIN injection (1.6%), which is attributed to the efficiency process of the main groups in this segment.

Chart 25 – History of energy exported to SIN and processed sugarcane



Source: EPE from (CCEE, 2019) and (MAPA, 2019)

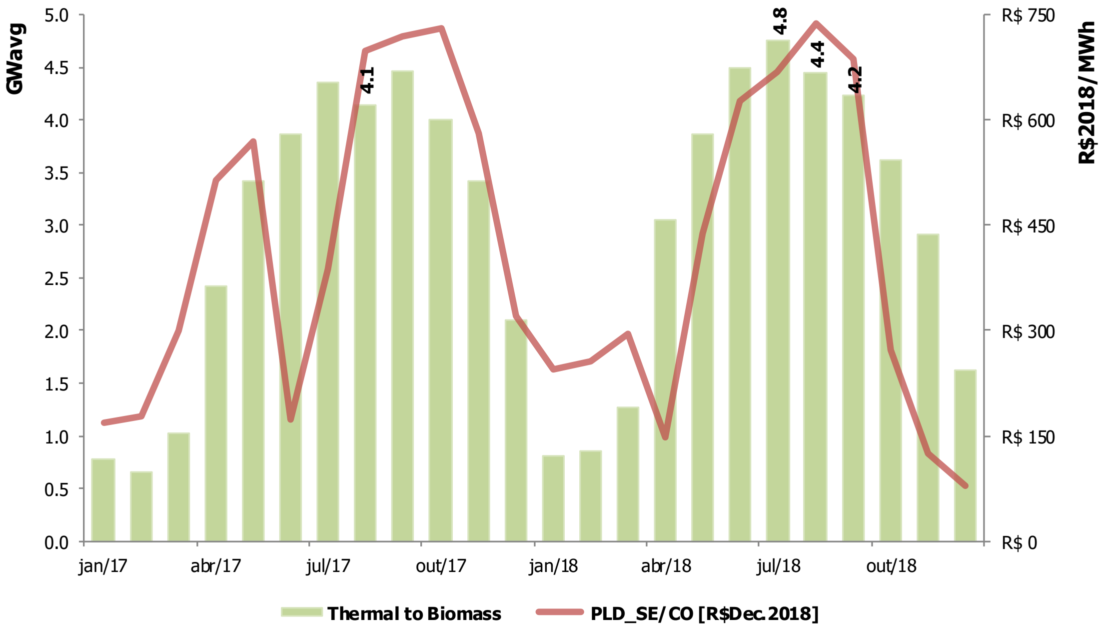
In 2018, thermal plants continued to play a significant role in demand supply (CCEE, 2019). O Chart 26 illustrates the monthly injection of energy into the SIN by sugarcane biomass thermals versus the PLD (Differences Settlement Price) price[21]), in 2018 reais. It can be noted that, in 2017 and 2018, generation occurred homogeneously during the harvest, when the smallest contribution from hydroelectric plants is observed, which increases the demand for thermal energy.

The values stipulated by ANEEL for the PLD in 2018 were R$505.18/MWh as the upper limit (5.4% decrease) and R$40.16/MWh for the lower value (increase of 19.2%).[22] The fluctuation in the PLD price recorded throughout 2018 was due to several factors, mainly the hydrological uncertainties observed in the period. (ANEEL, 2019).

[21] Updated weekly, this parameter aims to find the optimal solution of balancing the present benefit of water use with the future benefit of water storage, measured in terms of the expected fuel economy in thermal power plants.

[22] In 2017, the limits ranged from R$533.82/MWh to R$33.68/MWh. The boundary values for the PLD defined for 2019 were R$513.89/MWh and R$42.35/MWh, an increase of 1.7% and 5.5%, respectively, over the previous year.

Chart 26 – Thermal generation of sugarcane biomass versus PLD



Note: The PLD is calculated for the N, NE, S, SE/CW submarkets. In this graph, the value used for comparing the submarket is that for SE/CW.

Source: EPE from (CCEE, 2019)

The units continued their efficiency movement, since there was an increase in electricity exports per ton of sugarcane processed, as mentioned. Federal incentives contributed to this trajectory, such as the BNDES financing lines. The amounts financed by this bank to encourage bioelectricity rose from R$21 million in 2017 to R$94 million in 2018 (BNDES, 2019b).

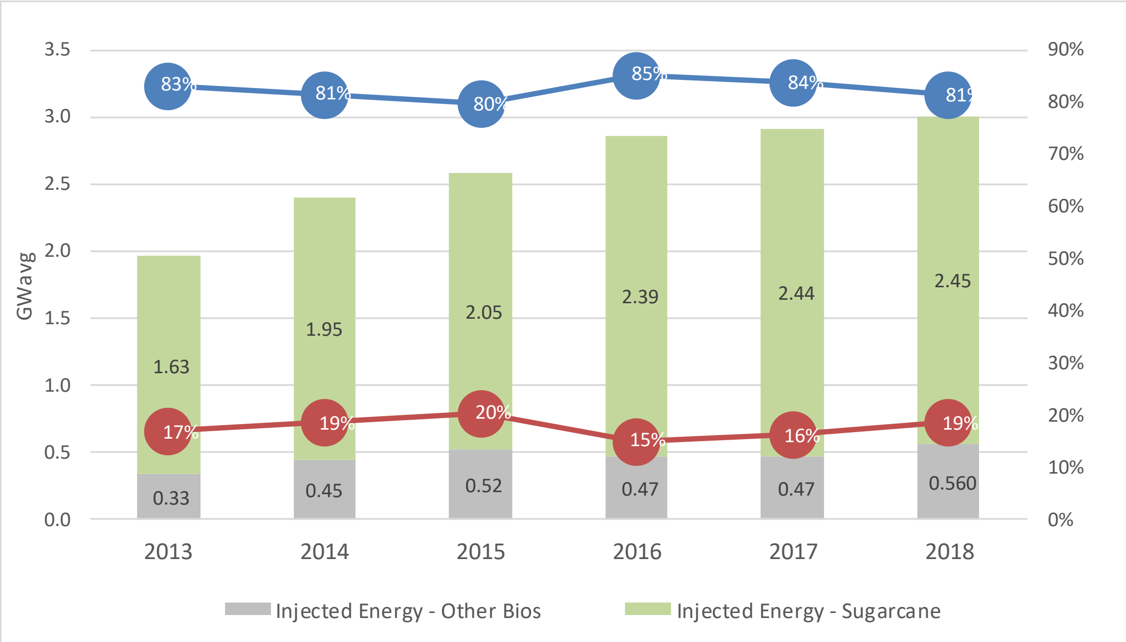
5.2. Bioelectricity of other biomass

In the last five years, there was a significant increase in the exportation of electricity from biomass. In addition to the aforementioned sugarcane by-products, in 2018 560 MWavg were generated in projects that use fuel derived from animal or vegetable organic matter, which corresponded to a significant increase of 18% compared to the previous year.

The generation through these other biomasses (excluding sugarcane) represented 1.1% of the electric matrix in 2018. Noteworthy is the black liquor (65%), largely driven by the growth of pulp production in the last five years, biogas (15%) and forest waste (10%). With less sharing, there are contributions from elephant grass, charcoal, rice husk, auto-oven gas and firewood.

The share of these sources in the total composition of energy exported by biomass in SIN went from 17% in 2013 to 19% in 2018. Although your contribution has remained at the same level, 230MWavg were added, as shown in Chart 27.

Chart 27 – Share of other biomass X sugarcane



Source: EPE from (CCEE, 2019)

Unlike sugarcane, which has a well-defined seasonality, and consequently a high variation of the energy exported to the grid, the generation from other biomass can be said to be more controllable and deterministic, mainly due to the possibility of storage of the fuel. Note that this is an important attribute for the electricity sector, contributing to the increase of energy security and systemic reliability, at a time of great challenges and structural changes occurring in the energy generator park.

6. Biodiesel

In 2018, 5.4 billion liters of biodiesel were consumed in Brazil, an increase of 26.7% compared to 2017. This year, there was a direct increase of two percentage points of mandatory addition of biodiesel to the fossil diesel blend, reaching the B10 blend.

Due to the National Program for the Production and Use of Biodiesel (PNPB), started in 2005, over 34.7 billion liters of this biofuel have been produced by December 2018. Comparatively, Brazil has maintained its position as the second largest producer and consumer of biodiesel in the international ranking, preceded by US, and succeeded by Germany and Argentina. (MME, 2017a).

Although Law No. 13,263 (BRAZIL, 2016) was expected to increase the mandatory percentage of biodiesel to 9% in March 2018, CNPE Resolution No. 23 of November 9, 2017 (CNPE, 2017), determined that the mandatory addition, in volume, would be directly of 10% on that date, in the entire national territory. Even so, the possibilities of up to 15% increase envisioned by law were maintained after specific tests. MME Ordinance No. 80 (MME, 2017b) indicated that the deadline for completion and validation of B15 trials would be January 2019, with a final report to be published in March of that year.

6.1. Use of biodiesel blends in engines and vehicles

6.1.1. Tests for Validation of Mixtures B10 and B15

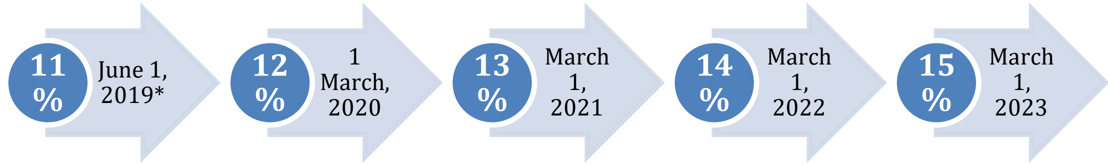
On April 30, 2018, the MME Consolidated Test Report for Validation of B10 Use was published by MME. According to this document, the companies that performed the experiments had their results approved in the application with the different systems, engines, equipment and vehicles, and there was no problem reported during their tests (MME, 2018).

As provided by Law No. 13,033, there is also the possibility of voluntary use of this biofuel, in a higher percentage than required, for specific cases (BRAZIL, 2014).

Tests for B15 utilization were completed in January 2019, and the final report issued in March 2019. (MME, 2019b). It is noted that CNPE Resolution 16/2018 (CNPE, 2018) authorizes the increase of the percentage of biodiesel in the mixture, up to 15%, provided that the conditions for approval of engine tests with this content are met.

Although there has been a general opinion in favor of increasing the use of biodiesel in this document, some companies do not recommend the adoption of B15, considering the need to improve the specification of this biofuel, in key characteristics to maintain its quality. (MME, 2019b).

CNPE Resolution No. 16, published October 29, 2018 (CNPE, 2018), proposed a preliminary schedule, indicating that the increase in the percentage of biodiesel in the mixture with diesel should be 1% per year from 2019, reaching the value up to 15% by volume, in 2023. Therefore, it is observed that, as determined in this Resolution, the percentage increases must occur according to the values and dates present in Figure 3.



Note: * The entry into force of 11% is postponed.

Source: EPE from (CNPE, 2018).

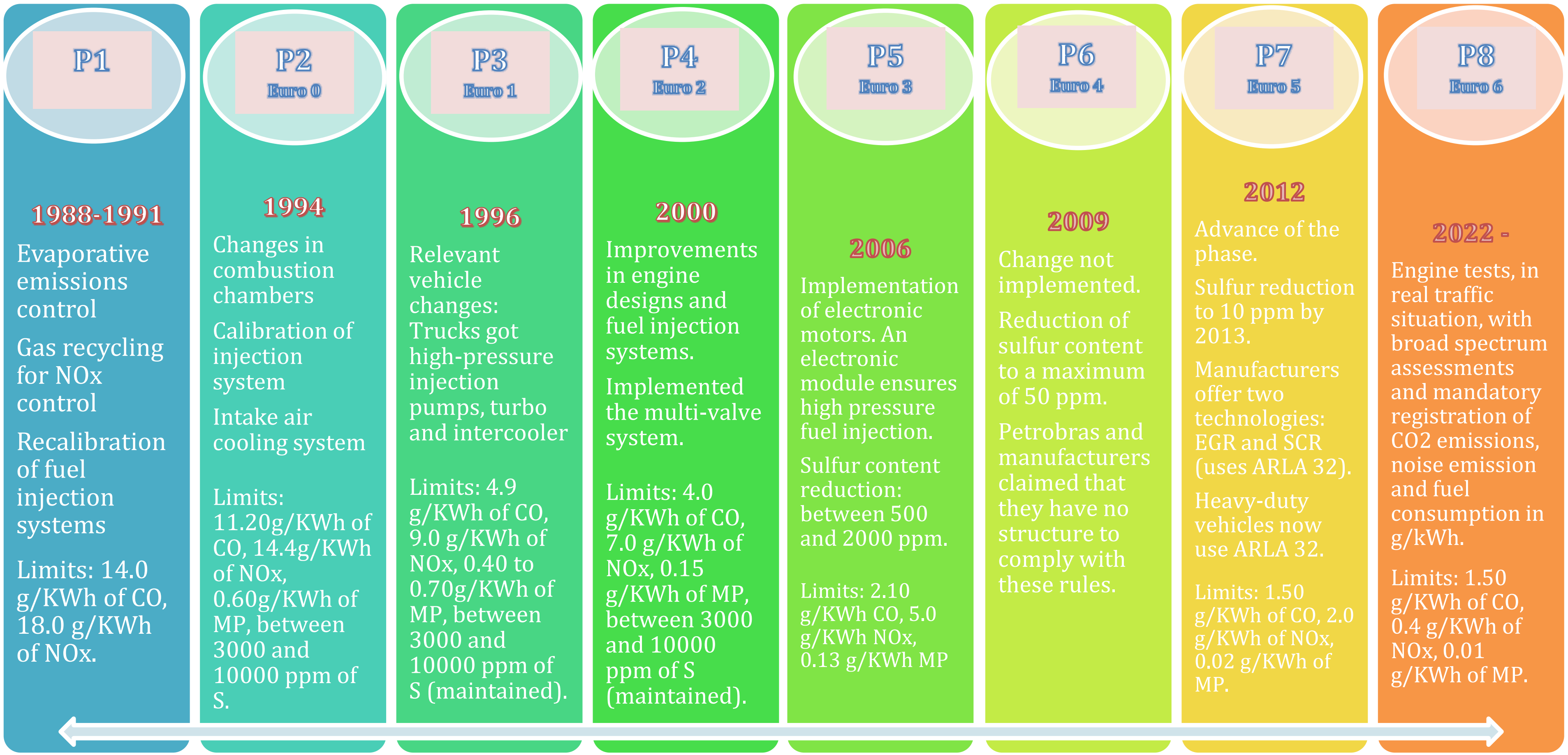
Figure 3 – Evolution of the percentage of biodiesel addition to diesel

6.1.2. PROCONVE

PROCONVE, the Motor Vehicle Air Pollution Control Program, whose standards are regulated by the National Environment Council (Conama), was created on June 6, 1986, by CONAMA Resolution No. 18, which defined the first limits for light- and heavy-duty vehicles, and contribute to meeting the PRONAR Air Quality Standards (MMA, 2019a). In October 1993, Law 8,723 reaffirmed the obligation to reduce emission levels of vehicular pollutants (BRASIL, 1993), which, to a certain extent, contributed to the technological development of the manufacturers of fuel, engine and autoparts, so that domestic and imported vehicles could meet the limits established in this program.

PROCONVE is divided into phases throughout its 31 years of implementation, allowing ever smaller levels of pollutants to be emitted by engines.

THE Figure 4 presents the different phases and dates of the program, highlighting the main features or innovation of each of them.



Source: (MMA, 2019a)

Figure 4 – PROCONVE deployment strategy for vehicles

Regarding the expected changes in the P8/Euro 6 phase, attention should be paid to the increase in biodiesel content in the mixture, as studies by the automakers show that Euro 6 engines are not prepared to receive biodiesel blends in diesel above 7%, which conflicts with the fuel already available in the Brazilian market with content of 10% (B10). At this stage of the program, the use of this new engine technology requires detailed study to assess its impacts on the market, given its higher cost of both initial and operational investment (10 to 15% increase) and improved infrastructure for supplying S10 and ARLA32 diesel engines, as P8 (Euro 6 equivalent) engines are extremely sensitive to diesel quality (NTU, 2019).

The results obtained by PROCONVE show that the strategy for its implementation was correct, and its success is due to the progressive adoption of increasingly restrictive phases, which has made it one of the most successful programs, from an environmental point of view. Since the implementation of this program, initially established pollutants as CO and NOx have this emission limits gradually reduced, and other important pollutants such as particulate matter (PM) and sulfur content have been inserted in the program as well. It can be seen that the vehicles sold today emit on average 98% less carbon monoxide than they emitted before their implementation (average 75 g/KWh). The CO emission limit set at P1 (1988-1991) was found to be 14 g/KWh; today it corresponds to 1.5 g/KWh (MMA, 2019a).

For heavy-duty vehicles, pollutant reductions were 80%, which greatly benefited metropolitan regions. Technologically, advances have focused on catalyst introduction, electronic fuel injection and improvements in the fuels themselves. (MMA, 2019a).

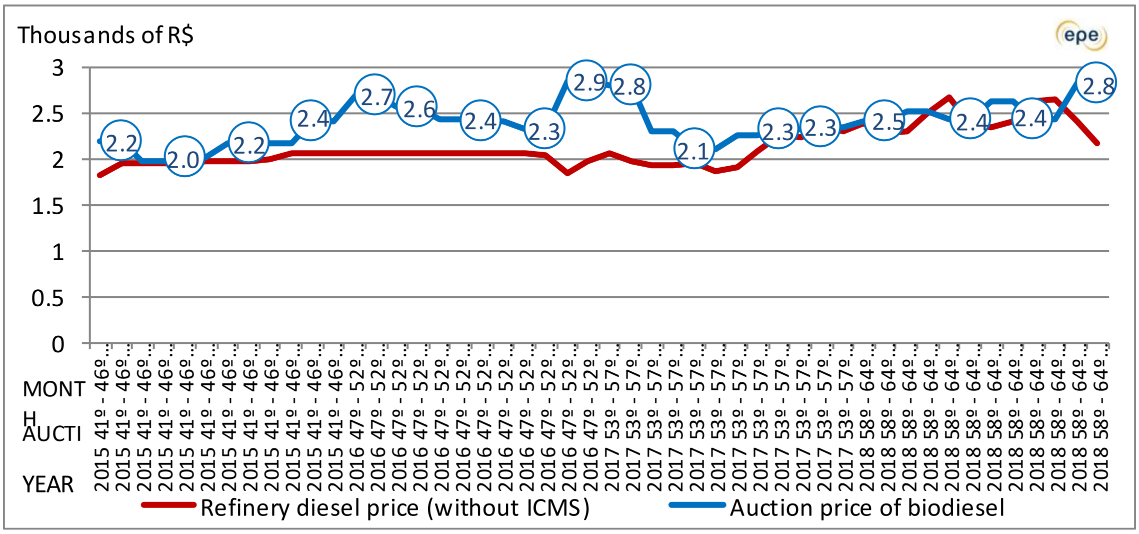
The continuity and maintenance of PROCONVE's success should focus on what emerged as a real gain for the environment, aiming at the establishment of new technological phases and even greater restrictions on emissions, as well as constant monitoring of air quality in the country. (MMA, 2019a).

6.2. Biodiesel Auctions & Prices

The ANP held six auctions from January to December 2018 for biodiesel purchasing by fuel distributors, totaling 64 since the program began. The last event (N. 64) was scheduled for delivery in early 2019. As shown in Chart 28, there was an approximation of the average selling prices[23] between biodiesel and fossil diesel, which occurred in 2017 and was perpetuated by 2018, culminating in the slightly higher diesel price than biodiesel in November this year, when compared at the door price of their respective producers (former alcohol plant versus former refinery). It should be noted, however, that the proper price assessment must take into account the reference place of comparison. That is, the competitiveness assessment requires the addition of freight and other incurred costs (taxes, etc.) to the distribution base where the mixing will occur.

[23] Diesel in the refinery and biodiesel in the producer.

Chart 28 – Average prices – biodiesel and diesel without ICMS

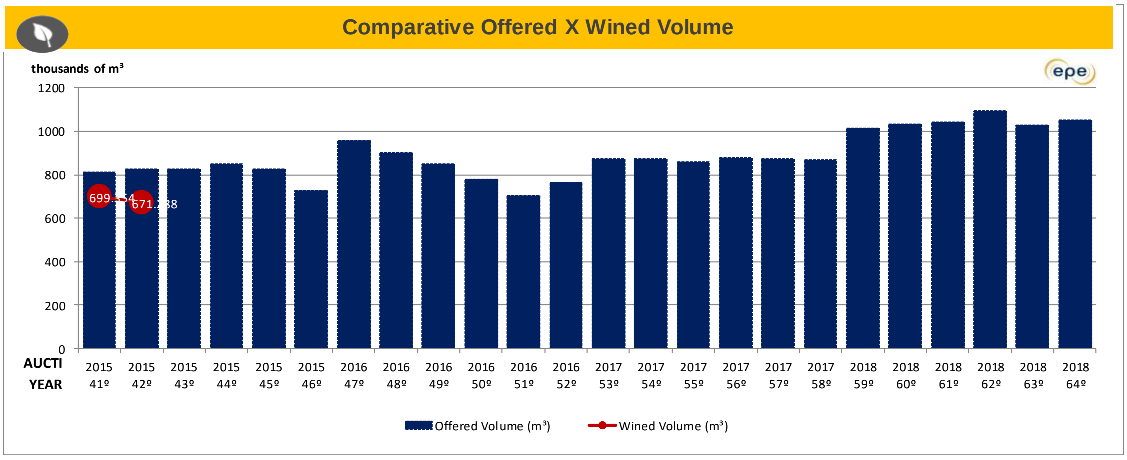


Note 1: Biodiesel prices correspond to the indicated auctions.
Note 2: The price of diesel corresponds to its value at the refinery.
Note 3: Diesel and biodiesel prices are presented in current values.

Source: EPE from (ANP, 2018f)

According to Chart 29, it is possible to note an increase of approximately 20% in the volume of biodiesel offered in the auctions relative to 2017, while the volume sold was 30% higher, due to the increase in the mandatory percentage for B10. It can be seen that in some auctions such as the 61st and 63rd, the volumes offered were almost entirely sold, as in 2017.

Chart 29 – Biodiesel volume in Auctions – Offered vs. Wined



Source: EPE from (ANP, 2018f)

CNPE Resolution No. 3, published on October 2015 (CNPE, 2015), defined guidelines for authorizing the marketing and voluntary use of biodiesel, in excess of the percentage of its mandatory addition to diesel.[24] The ANP has established the rules for authoritative biodiesel, in

[24] The maximum volume percentages of biodiesel addition to diesel oil are: 20% in captive fleets or road consumers served by supply point; 30% in rail transport; 30% in agricultural and industrial use; and 100% in experimental use, specific or other applications (CNPE, 2015).

order to take advantage of and stimulate the conditions that can make it competitive with diesel, especially in regions far from oil refineries and with abundant production capacity.

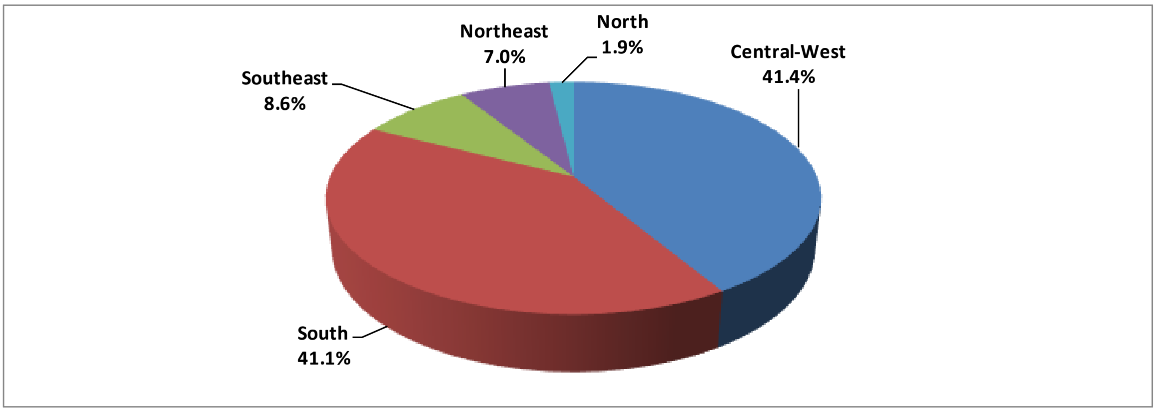
Authoritative biodiesel is traded through auctions[25] at a later stage than the mandatory volume. Some current rules were changed from the 48th auction (in 2016) to reduce bureaucracy. Specific projects that use mixtures other than those provided for in the legislation are exempt from submitting to auctions, which may require the purchase of direct biodiesel from producers, but require authorization from the ANP.

Although for the year 2018, a little over 133 million m^3 of authoritative biodiesel was offered, less than 10% of this total was sold. Trading for voluntary use took place in auctions 59th to 64th, with movement of 11.3 million m^3 of biodiesel and R$26.9 million (ANP, 2018f), below expectations for the sector.

6.3. Regional production and installed capacity

The Central-West and South regions produced 82.5% of all biodiesel consumed in the country in 2018, as indicated by the Chart 30.

Chart 30 – Regional biodiesel production in 2018

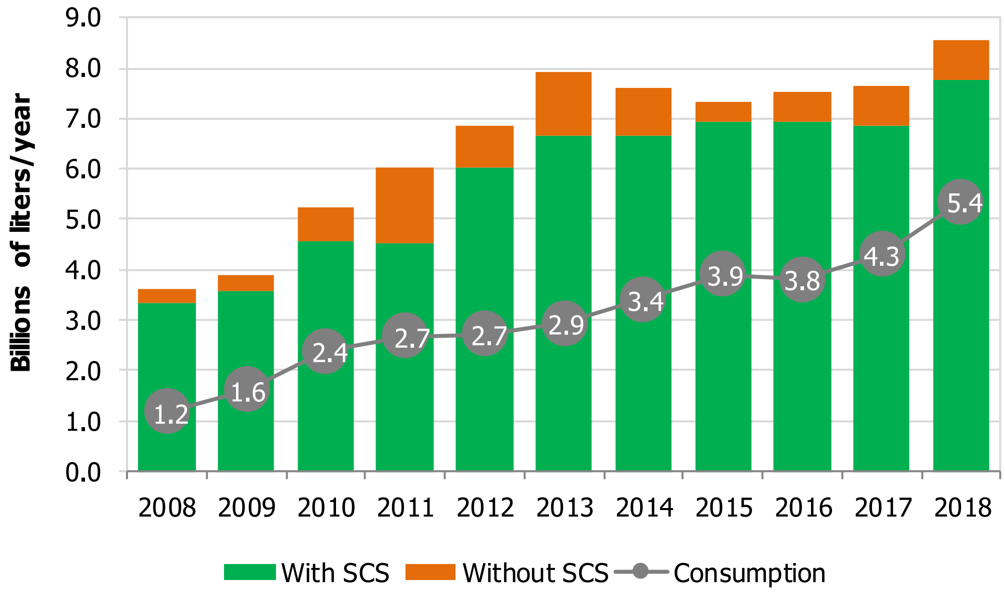


Source: EPE from (ANP, 2018d)

Installed biodiesel processing capacity in the 51 plants of the country reached 8.5 billion liters in December 2018, 11.8% higher than December 2017, according to Chart 36 (ANP, 2018d). It is also possible to observe that biodiesel consumption, 5.4 billion liters, corresponded to 63% of the installed capacity in the country, which demonstrates that there is potential for the production growth of this biofuel. (ANP, 2018d).

[25] The auctions are held in two stages. In the first, the producing plants make their offers considering exclusively the volumes offered and not sold during the regular auction. In the next step, the distributors make purchases for customers who are interested in using biodiesel in levels above 10% already established. The ordinance states that the consolidated result of the auction shall discriminate the biodiesel volumes and the prices for the two markets separately, the regular mandatory mix and the voluntary use market.

Chart 31 – Installed biodiesel production and consumption capacity



Note: The Social Fuel Seal (SCS) is a distinction given to companies that produce biodiesel that use products from family farms in their production chain. The objective is to guarantee income and stimulate the social inclusion of producing families. Biodiesel producers and SCS holders benefit from access to better financing conditions from financial institutions.

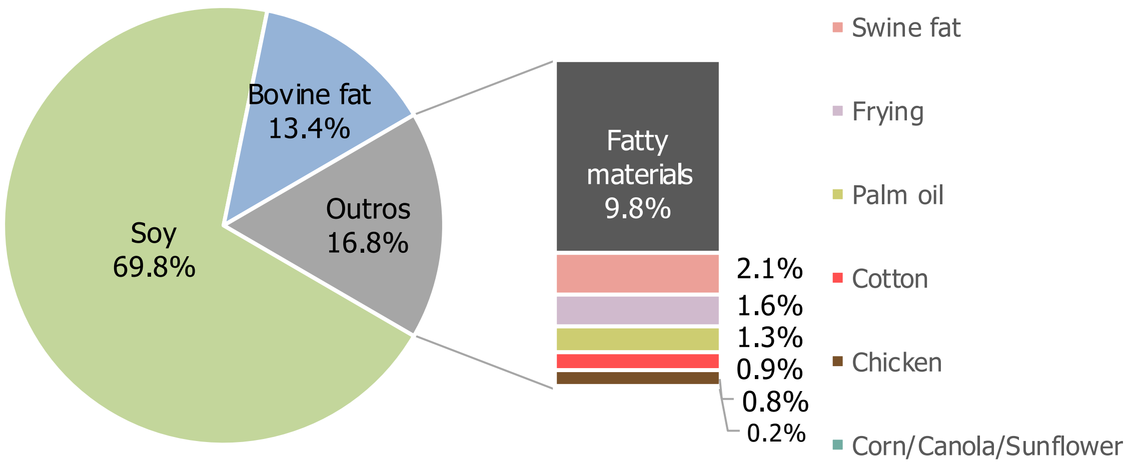
Source: EPE from (EPE, 2019a) and (ANP, 2018d).

Biodiesel production was 5.4 billion liters, an increase of 24.7% over the previous year, while diesel B consumption grew only 1.6%. Thus, the increase in the mandatory percentage was the main reason for this growth in biofuel production. On the other hand, diesel production by the national refining park increased 2.4%. In this context, fossil fuel imports fell by 10% to 11.6 billion liters. This value was not higher due to the increase in biodiesel consumption.

6.4. Raw Material for Biodiesel

Of all biodiesel consumed in 2018, 3.7 billion liters were produced from soybean oil, which is a 20.5% growth between January and December 2018 compared to 2017. As illustrated by Chart 32, this input remained in 2018 as the main raw material for obtaining biodiesel, with a share of 69.8%, followed by bovine fat, with 13.4%.

Chart 32 – Share of raw materials for biodiesel production (%)



Source: EPE from (ANP, 2018d)

Soybean production in Brazil was 121.3 million tons (113.8 million in 2017), an increase of 6.6% compared to the previous year. Soybean oil production was 8.7 million tons, an increase of 2.6%. Domestic processing increased 7.1% compared to 2017.

Soybean processing capacity is 63.6 million tons per year, according to the Brazilian Vegetable Oil Industries Association (ABIOVE, 2018a) (ABIOVE, 2018b). Due to the fact that the legislation in force favors the exportation of grain, this industry operates idly. Table 2 summarizes the situation of the soy complex in 2018.

Table 2 – Soy complex[26]

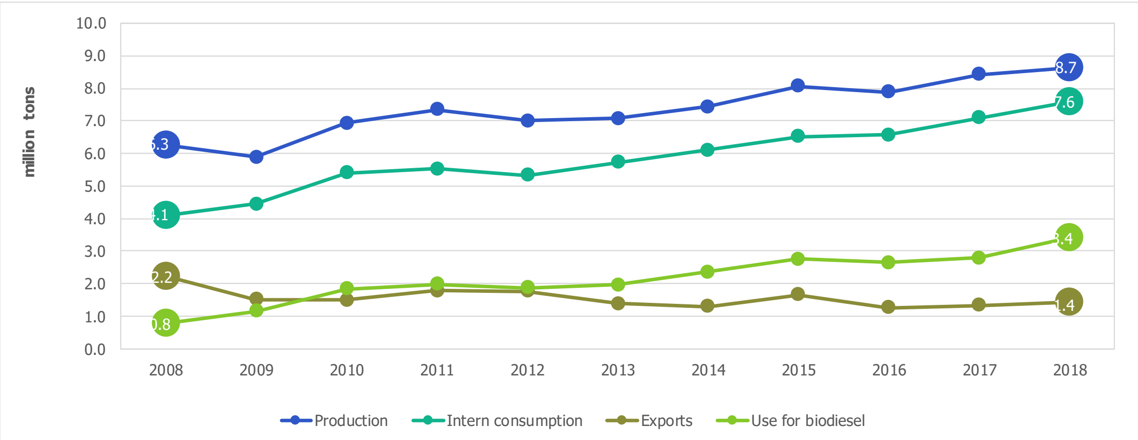
Millions of tons	2017	2018	Δ% (2017-2018)
Soybean production	113.8	121.3	6.6%
Installed Soybean Processing Capacity	63.0	63.6	0.9%
Soybean export	68.2	83.8	23.0%
Processed soy	41.8	43.6	4.2%
Soybean meal produced	31.6	32.8	3.9%
Soybean oil produced	8.4	8.7	2.6%
Soybean oil export	1.34	1.42	6.3%
Consumption of food oil and others	7.1	7.6	7.1%
Soybean oil consumption for biodiesel	2.8	3.4	21.4%

Note: The density considered for soybean oil was 0.92kg/l.

Source: (ABIOVE, 2018a) (ABIOVE, 2018b), (ANP, 2018d)

Chart 33 illustrates the behavior of the Brazilian soybean oil market since 2008.

Chart 33 – Soybean Oil Market



Note: Domestic consumption includes biodiesel oil, food and other uses.

Source: EPE from (ABIOVE, 2018b)

According to data from (ABIOVE, 2018b), soybean oil production between 2008 and 2018 grew by 38%. This growth rate is much lower than the volume destined for biodiesel production, which went from 0.8 million to 3.4 million tons, an increase of 325% over the same period. On the other hand, soybean oil exports decreased by 36% in this period, mainly from 2013. It is

[26] The values referring to domestic consumption of soybean seed and other purposes were not considered.

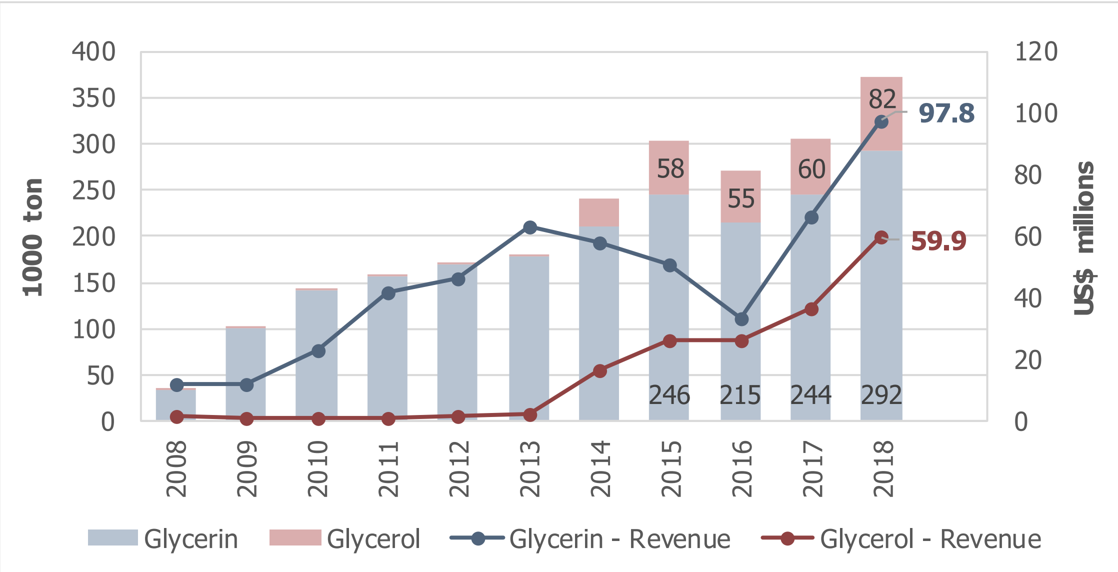
observed that this downward trend is accompanied by the increased use of this oil for biodiesel, with the increase of mandatory percentages.

6.5. Biodiesel Co-Products

Crude glycerin is a co-product of the biodiesel chain, which corresponds to approximately 10% by mass of the biofuel produced. In 2018, it is estimated that around 0.5 million tons were produced and its total exportation was 292 thousand tons, 19.4% higher than the previous year, as shown by the Chart 34. Revenue from crude glycerin exports was US$97.8 million, 47.4% more than in 2017. China remains the largest export destination, with 79% of the total (MDIC, 2019).

Glycerol is a classification for refined glycerin, which has better prices in the international market than crude glycerin, and several plants are installing equipment for its purification, aiming at better recipes. Glycerol exports grew rapidly between 2013 and 2016. In 2018, it totaled 82 thousand tons, an increase of 35.7% over the previous year. Revenue also increased from $36.6 in 2017 to $59.9 million in 2018, up 63.5%.

Chart 34 – Export of crude glycerin and glycerol

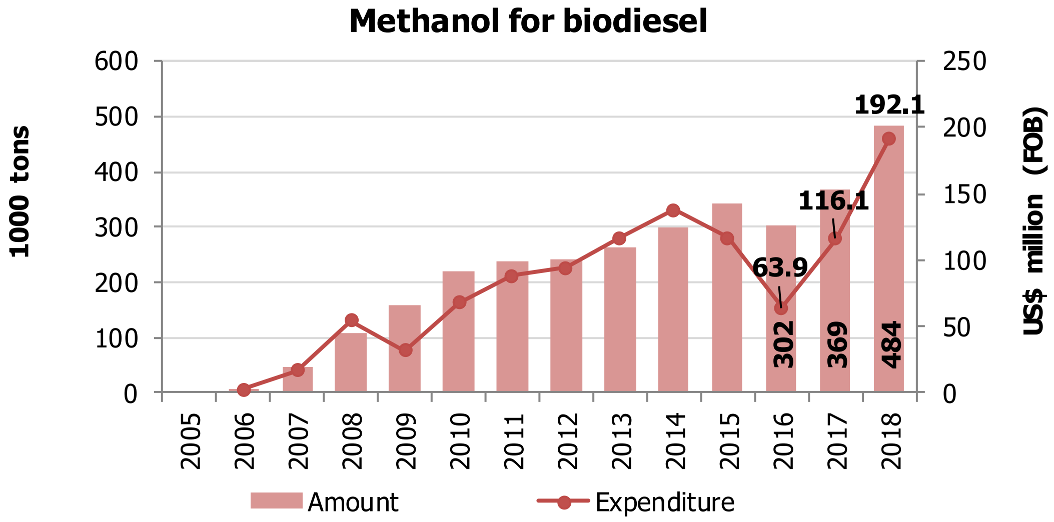


Source: (MDIC, 2019)

6.6. Methanol

Methanol is a fundamental input for obtaining Brazilian biodiesel. USA concentrates world production due to the low prices of natural gas, which is the basic raw material for its production. Brazil imported 484,000 tons of this input for biodiesel production, most of which came from Chile, Trinidad and Tobago, Venezuela and Saudi Arabia. Chart 35 shows the amount of methanol imported exclusively for biodiesel production and the resulting expenditure. The total in 2018 was 31.4% more than 2017 and the expenditure totaled US$192 million (65.4% greater than 2017). (ANP, 2018d) (MDIC, 2019). The increase in imports of this input is directly related to the increase in biodiesel production volumes, due to the increase of the mandatory percentage in 2018.

Chart 35 – Imports of methanol for biodiesel



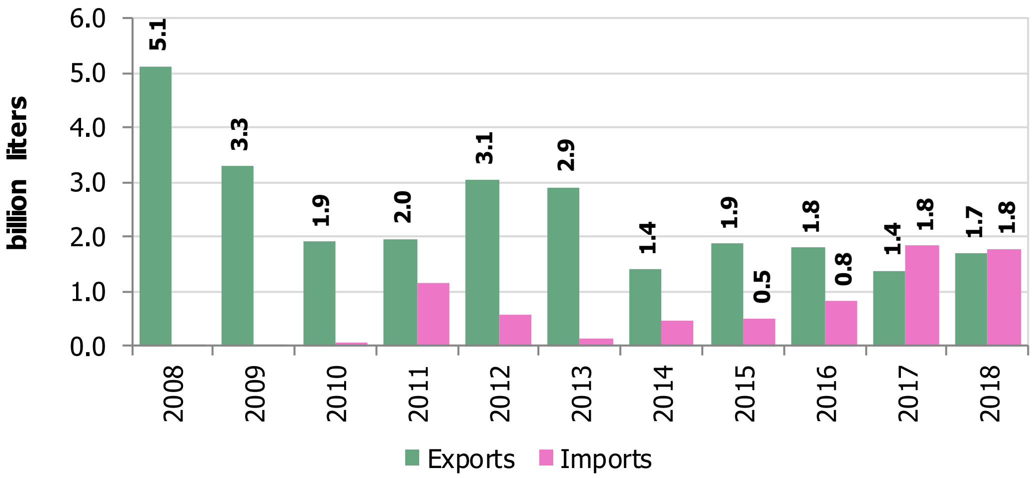
Source: EPE from (ANP, 2018d) and (MDIC, 2019)

7. International Biofuels Market

In 2018, the characteristics of the international biofuels market were support for policies to encourage energy efficiency and/or promote more advanced energy sources and the modest volumes traded. The two main countries, Brazil and the United States, maintained their high share in this market, with 85% of production and marketing. (RFA, 2019).

In 2017, for the second consecutive year, Brazil was a net importer of ethanol, with the United States as an exclusive supplier. In 2018, the imported volume was 1.8 billion liters, same as the previous year, compared to an export of 1.7 billion liters (Chart 36), 0.3 billion higher than in 2017 (MDIC, 2019).

Chart 36 – Brazilian exports and imports of ethanol – 2007 to 2018

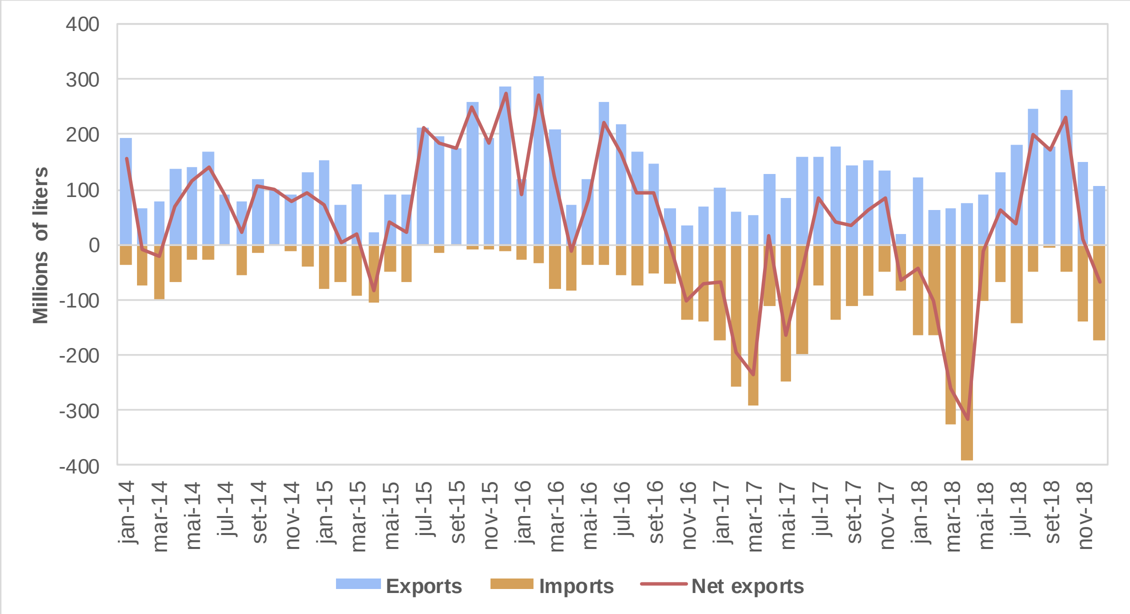


Source: EPE from (MDIC, 2019)

Since January 2017, Brazilian ethanol imports had already shown significant volumes, with net exports only in the intense harvest months (Chart 37). In a measure to limit increasing imports, on August 29, 2017, the Brazilian government approved CAMEX Resolution 72[27] (CAMEX, 2017), whose effects expire at the end of August 2019 and is a subject of negotiation between the Brazilian and US governments. However, even though there was no increase in imported volumes compared to 2017, ethanol imports remained high.

[27] CAMEX Resolution 72 establishing an Import Tax exemption (20%) on imported biofuel volumes by up to 150 million liters per quarter (which cannot exceed 1.2 billion liters in 24 months) (CAMEX, 2017).

Chart 37 – Monthly exports and imports of ethanol – 2017 to 2018



Source: EPE from (MDIC, 2019)

In relation to biodiesel, world trade remained concentrated between Europe, Argentina and the United States, with no relevant share of Brazil in traded volumes.[28]

United States

In 2018, the United States produced 61 billion liters of fuel ethanol, of which 54 billion were destined for the domestic market. (EIA, 2019a). There was no big change from the previous year. Its demand, linked to gasoline by the E10 blend, has been stable at around 50 billion liters. (EIA, 2019b). The outflow for excess ethanol volumes has been the foreign market, in which the country has become the world's largest exporter of biofuel since 2014.

In 2018, net exports reached a record 6 billion liters (RFA, 2019), most of which is dedicated to Brazil (1.8 billion), followed by Canada (1.3 billion).

For advanced biofuels, due to the difficulty in establishing commercial production of cellulosic ethanol, the EPA (*Environment Protection Agency*) again decreased the original values of the RFS targets for this biofuel share, as shown in Table 3 (EPA, 2018). It can be seen that in November 2018, the EPA reduced its target set for that year from 26.5 billion liters to 1.1 billion to match the actual volume produced. On the other hand, it has increased its biomass diesel target from 3.8 billion liters to 8.0 billion to meet the global advanced fuels target.

[28] From October to December 2018, Brazil exported 77 tons of biodiesel to the United States.

Table 3 – RFS final volumes (billion liters)

	2018*	2018	2019*	2019	2020
Cellulosic biofuels	26.5	1.1	32.2	1.6	
Biomass diesel	3.8	8.0	3.8	8.0	9.2
Advanced biofuels	41.6	16.2	49.2	18.6	
Renewable fuels	98.4	73.0	106.0	75.4	

*Original volumes as released in the Energy Independence and Security Act of 2007.

Source: (EPA, 2018), (EUA, 2007)

European Union

On 13 November 2018, the European Parliament approved a series of changes to climate and energy action plans for the European Union. For 2020, the current Triple 20 goals prevail: 20% reduction in GHG emissions compared to 1990, 20% share of renewable sources in energy consumption (with 10% in automotive consumption) and 20% increase in energy efficiency compared to 1990). By 2030, the targets will be increased to 40%, 32% and 32.5% respectively (EC, 2018).

Current plans focus on advanced sources of energy such as second-generation biofuels. The bloc will limit the share of traditional biofuels (sugarcane and corn ethanol and oilseed biodiesel) to a maximum of 7% share in energy demand by 2020 and gradually diminished so that by 2030 their share will no longer be accounted for in meeting the target.

8. New Biofuels

The conjuncture of oil prices and the economic situation of developed countries, still recovering, have reduced investments in plants and advanced biofuels projects in the world. The worldwide implementation of commercial lignocellulose (E2G) ethanol production continues at a slow pace, while other advanced biofuels (e.g., HVO and BioQAV) and advanced automotive technologies (e.g., hybrid and electric vehicles) have received increasing attention.

In Brazil, there are the Bioflex-I commercial plants of GranBio, in São Miguel dos Campos (AL), with a nominal capacity of 60 million liters, and of Raízen, in Piracicaba (SP), with a capacity of 42 million. There is also the experimental project at the Sugarcane Technology Center (CTC), with a capacity of 3 million liters. (GRANBIO, 2017) (RAÍZEN, 2018). Business units faced technical challenges and made adjustments to their processes, still operating below nominal capacity. Granbio operated for a few months in early 2019 and is expected to resume operations at the beginning of the Northeast harvest in August. Between 40 and 45 million liters of cellulosic ethanol are expected by 2020. The company has included technology licensing and sales in its product list, and expects to market its first technology license in 2019 (NOVACANA, 2019).

Abroad, E2G projects have failed to reach commercial production. Abengoa (Salamanca/Spain) and Beta Renewables (Crescentino/Italy) (ETHANOL PRODUCER MAGAZINE, 2017); (NOVACANA, 2017) shut down in 2017. DowDupont sold its lignocellulosic ethanol plant (Nevada/USA) to German biofuel company Verbio (LANE, 2018), as announced in the company's restructuring plans.

Among the new biofuels, HVO (*Hydrotreated Vegetable Oil*) and aviation biokerosene (BioQAV). HVO is a fuel obtained through hydrotreating[29] vegetable oils, with the same chemical structure as petroleum derivatives, which is characterized as a *drop-in*[30] fuel. HVO technology, in addition to producing a diesel-like product, can also be adapted to produce other fuels (such as BioQAV). HVO production has been growing in Europe and the United States, with around 15-20% share in renewable diesel (about 5 million tons in 2017) (KELLENS, 2018).

For BioQAV, the United Nations International Civil Aviation Organization (ICAO/UN) has established an emission reduction agreement with airlines called CORSIA (*Carbon Offsetting and Reduction Scheme for International Aviation*), which sets carbon neutral growth in the aviation industry from 2021 onwards. (ICAO, 2018).

In addition to emission compensation and energy efficiency promotion instruments, CORSIA provides for the use of alternative aviation fuels that are *drop-in*, particularly those with ASTM International certified processes (*American Society for Testing and Materials International*), see Table 32. The raw materials employed are defined as technologies pass the "*Aviation Fuels*" subcommittee's approval process from ASTM International (ASTM, 2018).

[29] Reduction reaction with hydrogen.
[30] Alternative fuel that can replace the fossil equivalent without engine adaptation.

Table 4 Approved Technology Routes for Production of Alternative Aviation Kerosene

Route Name	Raw material	Main product	Maximum mix	Producing companies
HEFA-SPK	fats, oils and greases	Iso- and N-paraffins	50%	UOP, Nesta and Syntroleum
FT-SPK	agricultural and forest waste, wood, and solid waste	Iso- and N-paraffins	50%	SASOL, Shell and Syntroleum,
FT-SPK/A	agricultural and forest waste, wood, and solid waste	Iso-, N-paraffins and aromatics	50%	SASOL, Shell and Syntroleum,
ATJ-SPK	renewable raw materials (sugar cane, corn or forest waste)	Iso- and N-paraffins	50%	GEVO, Cobalt and Lanzatech
SIP	sugars	Paraffins	10%	Amyris

Source: (ASTM, 2015) (ASTM, 2018)

Observing the ASTM International certified technological processes, the following raw materials available in Brazil can be used more promisingly (in alphabetical order): babassu, sugar cane, macauba, palm, forest resources (eucalyptus) and soy.

It is important to emphasize that there are still industrial and economic challenges for BioQAV to be competitive, in Brazil and worldwide, with aviation kerosene of fossil origin. In order to deepen its knowledge on this subject, EPE collaborated with the German Agency for International Cooperation, GIZ[31] project to create a reference model for the use of sustainable synthetic fuels in Brazil, which sought to analyze the real costs of fuels, including “hidden” fuels (*hidden costs*). Thus, it was intended to enable local opportunities for alternative aviation fuels, based on economically restrictive logistic supply conditions. Research has indicated that synthetic aviation fuel is expected to be economically competitive after 2030.

[31] IKI Project – Alternative Fuels without Climate Impact. Between October 2017 and April 2018, EPE welcomed a German specialist for his exchange program, who developed his Master's dissertation in Renewable Energy Management on the subject of alternative aviation fuels at the Cologne University of Technology (Technische Hochschule Köln). (ROTH, 2017).

9. Greenhouse Gas Emissions

Brazil plays a prominent international role in discussions and negotiations on climate change. A whole legal framework has been built in the country whose objective is to promote the use of renewable sources, especially biofuels. Another important step towards this end was taken in December 2017, with the establishment of the National Biofuels Policy – RenovaBio, which will be addressed in item 10 of this document (BRASIL, 2017c).

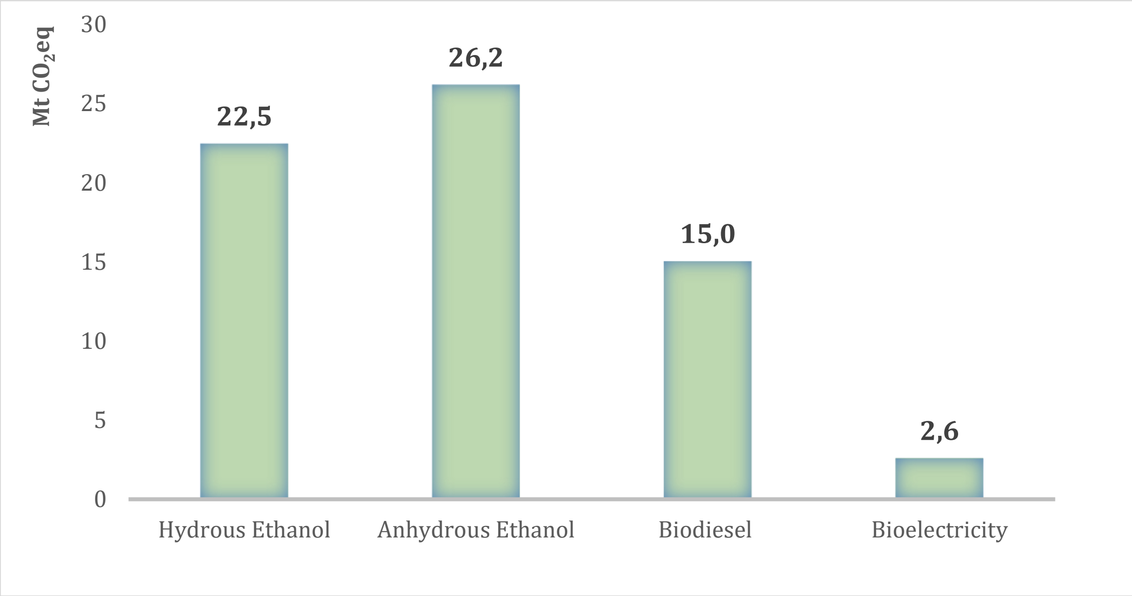
The high share of renewables in the national energy matrix provides a significant reduction in GHG emissions. As for liquid biofuels, emissions avoided by the use of ethanol (anhydrous and hydrated) and biodiesel, compared to fossil equivalents (gasoline and diesel), totaled 66.3 $MtCO_2$ in 2018.

In addition to liquid biofuels, sugarcane bioelectricity also contributes to reducing CO_2. To estimate the avoided emissions, the tCO emission factor $_2$ per MWh generated was used, calculated by the Ministry of Science, Technology and Innovation (MCTI, 2019). This indicator has fluctuated in recent years, both due to the higher thermal share of various fossil fuel sources in electricity generation in times of water scarcity, as well as the greater contribution of other renewable sources, such as wind which presents increasing injection. In 2018, the reduction in fossil thermal generation (13%) and the growth of wind (13%) and hydro (12%) caused a reduction of 20.2% of this factor, from 0.093 tCO_2/ MWh to 0.074 tCO_2/ MWh.

Considering the exported energy and the self-consumption by the sugarcane units, the CO values$_2$ avoided are expressive. However, the reduction in the matrix emission factor directly impacted this indicator, since the amount of energy generated by sugarcane biomass plants remained unchanged in 2018. Thus, the amount of avoided emissions in 2018 was 20% lower than in 2017 (3.3 $MtCO_2$), totaling 2.6 $MtCO_2$, 1.0 from self-consumption and 1.6 $MtCO_2$ of exported energy.

Chart 38 illustrates avoided emissions from biofuels (anhydrous and hydrous ethanol and biodiesel) and sugarcane bioelectricity.

Chart 38 – Biofuel Avoided Emissions in 2018 – Brazil



Source: EPE from (EPE, 2019a), (IPCC, 2006), (ROSA, OLIVEIRA, COSTA, PIMENTEIRA, & MATTOS, 2003) and (MCTI, 2019)

10. RenovaBio

The National Biofuels Policy (RenovaBio), promulgated by Law No. 13.576, on December 26, 2017 (BRASIL, 2017c), emerged from the initiative to enhance the national potential of renewable sources, associated with the commitments made by Brazilian government at the international level on climate change in 2015 at COP21.

RenovaBio's operation is based on three main instruments: the annual carbon intensity reduction targets (gCO2/MJ) for a minimum of ten years, the Biofuels Certification and the Decarbonization Credit (CBIO), as presented by EPE (EPE, 2018a). In addition, public policies to encourage biofuels are also developed over the years, such as mandates for the mandatory addition of biofuels to petroleum products, mechanisms for tax differentiation between renewables and fossils, as well as financing lines.

The year 2018 was important for the implementation of that policy, as several structuring actions were carried out. After several meetings, the RenovaBio Committee forwarded the proposal of the national fuel matrix emission reduction targets for a 10-year period, which have been approved and published by CNPE in June 2018, through CNPE Resolution No. 5 (CNPE, 2018) .

In November, the ANP approved the ANP Resolution 758/2018 that regulates the Certification of the Efficient Production or Importation of Biofuels, art. 18 of Law No. 13.576/2017, as defined by the requirements for the accreditation of inspector firms responsible for this Certification, and the criteria for calculating the Energy-Environmental Efficiency Rating of biofuel producer and importer (ANP, 2018a). Among the items in this resolution is RenovaCalc, a tool that calculates the carbon intensity of a biofuel (in g CO2 eq./MJ), comparing it with its equivalent fossil fuel, to prove the environmental performance of biofuel production.

With the publication of the resolution, the process of accreditation of inspector firms began, registering four companies until June 2019, namely: Green Domus Sustainable Development Ltda. EPP; SGS ICS Certificadora Ltda.; Totum Institute for Business Development and Management Ltda. and Carlos Alberto Vanzolini Foundation. Consequently, interested parties emerged to carry out the certification process of their production, which will culminate in the issuance of the Certificate of Efficient Biofuels Production. As of the date of publication of this document, two companies have put into public consultation their certification processes, one for biodiesel, which uses recycled oil as input for production and a first-generation sugarcane ethanol producer. (ANP, 2019a) .

In April 2019, the MME placed in public consultation a new proposal for RenovaBio's 2020-2029 cycle of fuel matrix decarbonization targets, which will be ratified by CNPE in July this year. (MME, 2019a).

In June 2019, ANP published ANP Resolution No. 791/2019, which provides for the individualization of annual mandatory greenhouse gas emission reduction targets for the commercialization of fuels (ANP, 2019b) . This resolution details how the global targets will be apportioned to the distributors' individual targets, as well as the list of fossil fuels that have commercial-scale substitute biofuel, which will influence individual targets.

For the second half of this year, it is expected the publication of the last resolution that will deal with the issue, maturity, distribution, intermediation, custody, negotiation and other aspects related to the Decarbonization Credits (CBIO), financial instrument traded in an organized market (B3 S.A.). In parallel, the ANP is developing the RenovaCalc System and the Ballast Formation System of the Invoices for the Issuance of CBIO, which will assist in the control and storage of information necessary for the operation of RenovaBio (PLURAL, 2019).

Thus, with the entire regulatory framework in place and the start of certifications of biofuel producers or importers, RenovaBio will be able to fully operate by 2020, bringing economic, social and environmental benefits to Brazil.

11. The Role of Biofuels in the National Energy Matrix

11.1. Introduction

Brazil is internationally recognized for its wide availability of energy resources. On the one hand, the country has very favorable edaphoclimatic conditions and extensive land availability, which favors the use of renewable sources. On the other hand, Brazil has the gigantic Pre-Salt oil province, besides having one of the world's leading uranium reserves and dominating the nuclear fuel cycle. Thus, the national energy matrix is quite diverse and stands out worldwide for the high degree of use of biomass, hydraulic resources and, more recently, wind and solar energy.

In the vehicular matrix, the sharing of renewable energy sources is particularly significant, to which several public policies for the promotion of biofuels contributed, which included actions by government, sector agents and civil society. Among the regulatory and economic instruments that organize public policies, EPE (EPE, 2016b) highlighted the mandates of adding biofuels to petroleum derivatives, the mechanisms of tax differentiation between renewables and fossils, and financing lines.

By mandate, all automotive gasoline currently sold at retail outlets contains 27%[32] of anhydrous ethanol, as well as the diesel sold, which has 10% biodiesel added. In addition, a considerable portion of Otto cycle energy demand is supplied by hydrous ethanol, equivalent to 26.7% in 2018. (EPE, 2019a).

Among the important public policies to encourage biofuels that were developed by the Brazilian government over the years, we highlight the National Alcohol Program (PROALCOOL), in the 1970s, the insertion of technology *flex fuel* 2003, and the National Biodiesel Production and Use Program (PNPB) in 2005.

More recently, the National Biofuels Policy (RenovaBio), which has been structuring since the enactment of Law No. 13,576 of December 26, 2017, has revealed other great opportunities for Brazil. EPE (EPE, 2018a) stressed as the most relevant purposes of this policy: to promote the appropriate expansion of the production and use of all biofuels in the Brazilian energy matrix, with emphasis on the regularity of supply, and to collaborate with predictability for the competitive share of different biofuels in the national fuel market. RenovaBio also aims to cooperate in meeting Brazil's commitments under the Paris Agreement under the United Nations Framework Convention on Climate Change.

This is the tenth edition of the Biofuels Conjuncture Analysis. During the period since the first publication, some changes have been observed in the national matrix and surely others will come. In order to Brazil be prepared to take advantage of the favorable circumstances ahead, it is important to understand the important role of biofuels in the energy transition. This process, usually long and constant, is not limited to the changes observed in the primary energy matrix.

[32] Gasoline premium contains 25% anhydrous ethanol, according to MAPA Ordinance No. 75 (MAPA, 2019b). However, it accounts for a very small fraction of fuel sales.

It also brings along profound changes in the converters' technological base, consumption patterns, socioeconomic and environmental relations, as well as geopolitical implications.

This article aims to present the changes in the national energy matrix over the last 10 years, highlighting the role of biofuels. The study reports the main public policies and how they reflected in the national energy supply, the benefits of adopting these renewable sources and how their contribution may be fundamental for the energy transition in Brazil to occur with the appropriate appropriation of our national wealth.

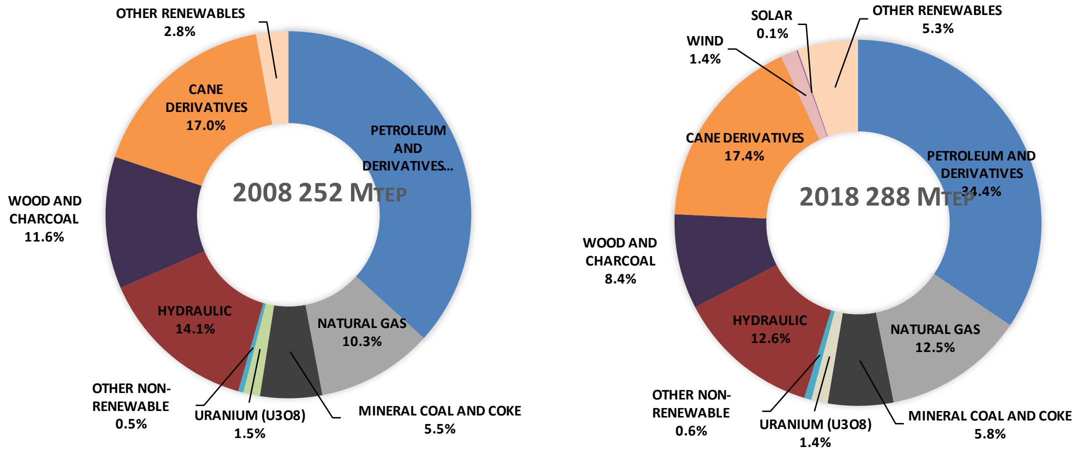
11.1.1. National Energy Matrix

The Brazilian energy matrix has a significant portion of its internal energy supply from renewable sources, which corresponded to 45% in 2018. (EPE, 2019a). The country has several alternatives for the use of these energy resources, due to the presence of important watersheds, favoring the construction of hydroelectric dams, and for its edaphoclimatic characteristics, which enable the generation of biomass. In addition, the wind regime and insolation also offer favorable conditions for the insertion of wind and solar in the electrical matrix.

The public policies adopted by the Federal Government over the years, associated with the natural conditions of the country, allowed Brazil to present a great diversity of renewable sources in its energy matrix. Such a variety comprises liquid biofuels, predominantly ethanol and biodiesel; solid biofuels, the most relevant being sugarcane bagasse; and gaseous, with the still incipient share of biogas.

Harnessing renewable resources in the national matrix is seen as one of the most promising options for a sustainable energy future. We highlight the presence of biomass, which increased its share due to the advent of new technologies with high efficiency and lower environmental impacts in its use, including contributing to the mitigation of global warming. As illustrated by Chart 39, for the years 2008 and 2018, even with the 36Mtep increase, this share remained above 40%, while the world average was 14% in 2017 (IEA, 2019). It can also be observed that sugarcane derivatives are the second main source in the domestic energy supply, only behind oil and its derivatives. Although its percentage share in the period remained at the same level, there was a growth in absolute values over 5Mtoe.

Chart 39 – Internal energy supply by source – 2008 and 2018



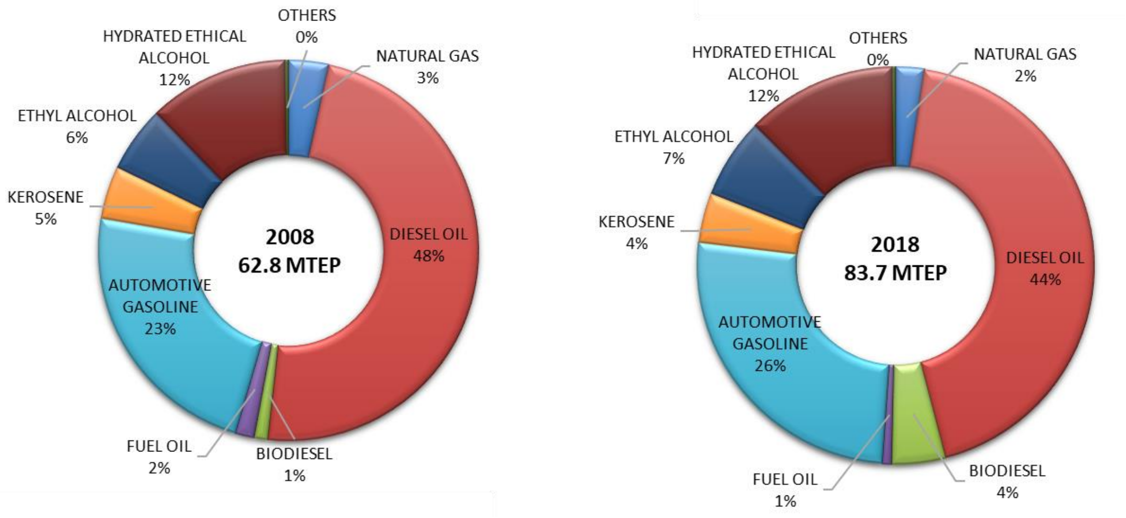
Source: (EPE, 2019a)

11.1.2. Sectoral Analysis

Brazil's final energy consumption accounts for a significant share of sugarcane derivatives in various sectors of economic activity: in transportation, they represent 19% of the energy consumed; in the industrial sector, 16% (in the food and beverage segment, 69%); and in the energetic, 50%. Ethanol (anhydrous and hydrated) is used in Otto cycle engines and bagasse is an energy source for steam production in the manufacture of ethanol and sugar. In addition, sugarcane biomass is destined for electric power generation, being part consumed in the plants and part injected into the National Interconnected System (SIN).

Brazil presents itself as a success story regarding the demand for biofuels in the transport sector. As illustrated by Chart 40, its share increased from 18.7% in 2008 to 23.1% in 2018, which represents an increase of about 8 Mtep (approximately 40% of the increase in the entire sector). Of particular note is the increase in the share of biodiesel, which increased from 1% to 4% of the final energy consumption of the vehicle matrix in the period (EPE, 2019a).

Chart 40 – Energy matrix – transport sector – 2008 and 2018



Source: (EPE, 2019a)

The trajectory of the contribution of the main biofuels that make up Brazil's energy matrix is described in the next section.

11.2. Ethanol

In Brazil, most ethanol production is intended for energy use as fuel in motor vehicles, in a mixture with gasoline (anhydrous) or pure (hydrated). In addition, ethanol has non-energy use, mainly in the composition of alcoholic beverages, cleaning products and paints.

Proálcool spread its fuel consumption with the development of vehicles powered exclusively by ethanol, which led to an extraordinary increase in national production in the 1970s. Subsequently, demand for hydrated was driven by the introduction of vehicles *flex fuel* in 2003, which allow the choice of fuel at the time of refueling. The expectation of increased demand for ethanol in Brazil and worldwide led to the internationalization and concentration of the sector and attracted the interest for investments in the sugarcane industry, as pointed out by EPE. (EPE, 2013).

The composition of the Brazilian light vehicle fleet (37 million) is mostly *flex fuel,* 76.4% in 2018, as a result of the significant share of this category in licensing, since its introduction in the automotive market. It should be noted that price parameters are of vital importance for the choice of *flex* vehicle owner. Thus, several aspects related to the supply and demand of ethanol are fundamental to the competitiveness of this biofuel against its substitute, gasoline type A.

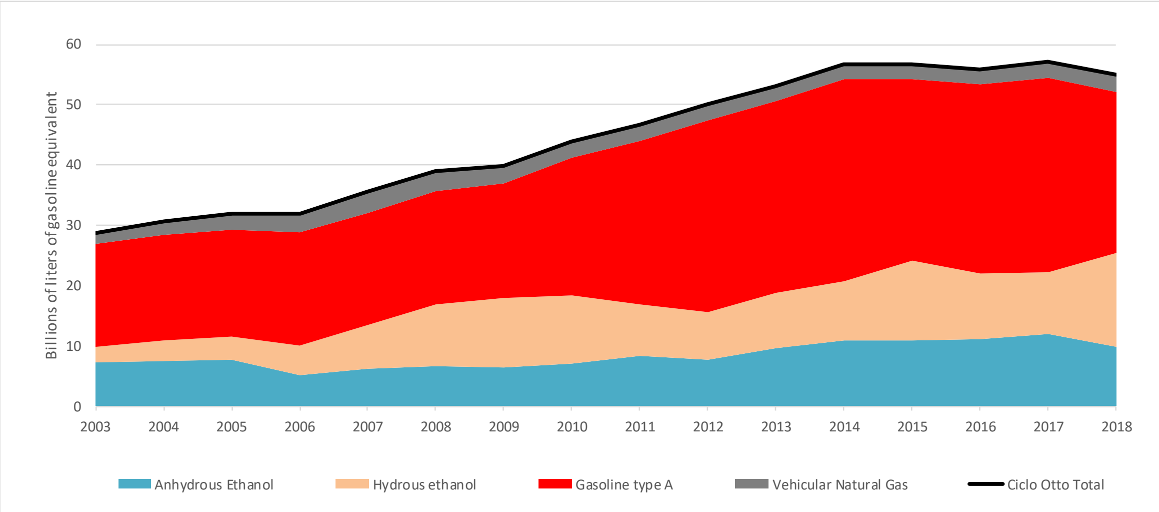
On the supply side, fuel ethanol consumption is influenced by the price of sugar in the international market, the development of ethanol and sugar production capacity, as well as the evolution of agricultural production factors and production costs, a theme that was deeply studied in EPE (EPE, 2014). It should be noted that although the main input for ethanol production is sugarcane, in recent years the use of corn has expanded significantly (see item 1). On the demand side, this relationship is also impacted by vehicle efficiency and, as described in

EPE (EPE, 2017b), for the various items that form the price of these fuels, such as CIDE, PIS, COFINS and ICMS.

It is noteworthy that the mandates of anhydrous addition to gasoline type A, currently at 27%, also contributed to the growth of ethanol production (EPE, 2016b). Additionally, through financial incentives related to BNDES financing lines, various activities of the sugar-energy sector were contemplated through programs such as PRORENOVA, PASS, PAISS, PROGEREN, FINEM, as detailed in EPE. (EPE, 2016b).

As a result of the variation in these various factors, fuel demand for ethanol grew by 9.1 billion liters between 2008 and 2018. It is observed in Chart 41 the evolution of the share of anhydrous and hydrous in the consumption of the Otto cycle (in equivalent gasoline).

Chart 41 - Ethanol's share in the consumption of the Otto cycle 2008-2018



Source: (EPE, 2019a)

Ethanol production is estimated to have prevented the importation of 218 billion liters of gasoline type A in the 2008-2018 period, given the other constant conditions, namely: Otto cycle demand, average fuel prices, national gasoline type A production, among others.

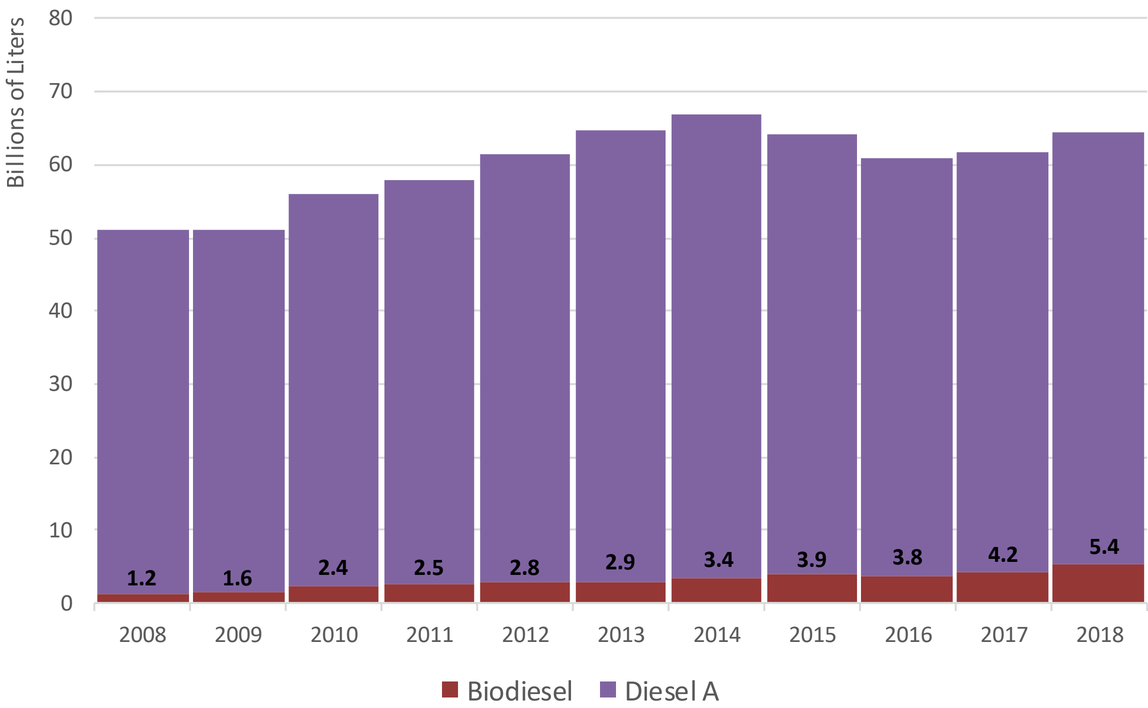
11.3. Biodiesel

The National Biodiesel Production and Use Program (PNPB), established through Law No. 11,097/2005 (BRASIL, 2005), was the instrument that inserted this biofuel into the national energy matrix. Its conception was based on three basic pillars: social inclusion through family farming, environmental sustainability and economic viability. The Program was built in order to allow, through different technological routes, the use of the various oilseeds in Brazil, according to the potentialities of each region, reducing the economic inequalities between them.

However, although the country has a diversity of fatty inputs, the main raw materials used for the production of this renewable fuel since the implementation of the program are soy and animal fat, with an average of 75% and 17%, respectively. Production was also strongly regionalized: in 2018, the Central-West and South regions together accounted for 83% of total production.

Although Law No. 11,097/2005 stipulated a mandatory addition schedule starting at 2% biodiesel in diesel (B2) in January 2008, and reaching 5% only in 2013, B5 was brought forward to January 2010, by public policy decision, as authorized by law. This content remained until 2014, when Law 13,033 set it to rise to 6% in July and 7% in November of that same year (BRAZIL, 2014). In 2016, Law 13,263 (BRASIL, 2016) established a mandatory elevation schedule to 8%, 9%, and 10% within 12, 24, and 36 months after its enactment. Thus, in March 2017, B8 became effective. The mandatory addition was directly changed from 8% to 10% in March 2018, by CNPE decision, as authorized by Law. It is observed through the Chart 42 the evolution of biodiesel consumption in the diesel cycle.

Chart 42 - Biodiesel share in the diesel cycle consumption 2008-2018



Source: (EPE, 2019a)

In addition to the biodiesel mandate, the Federal Government also provided tax incentives to stimulate and direct the development of the sector, such as the reduction of PIS/COFINS rates, the Social Fuel Seal and BNDES financing lines, such as the Financial Support Program for Biodiesel investments for “all stages of biodiesel production, including storage and production flow logistics” (BNDES, 2006).

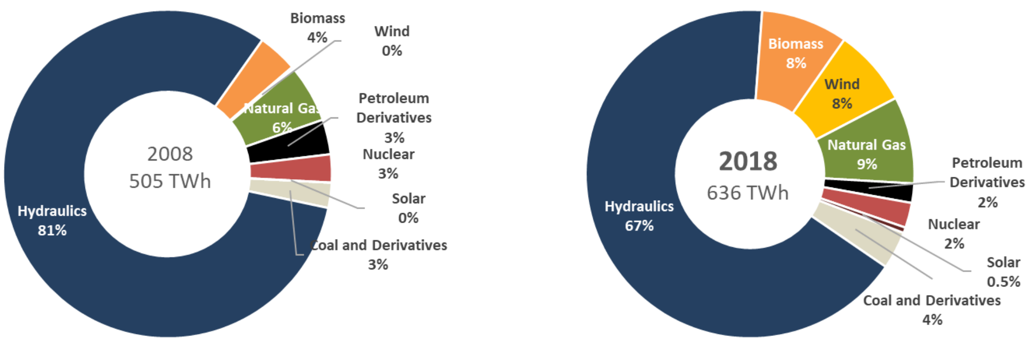
It is estimated that biodiesel production prevented the importation of 27 billion liters of diesel A in the period between 2008 and 2018, considering constant all other conditions, namely: diesel cycle demand, average fuel prices, national production of diesel A.

Note that the CPNE (CNPE, 2018) authorized the increase of the percentage of biodiesel blending in diesel from 1% per year from 2019 to 15% in 2023, which indicates that its share in the matrix will increase in the coming years. However, it is noteworthy that such an increase will occur, provided that the conditions for approval of tests on engines for this grade are met, as determined by Law 13,263/2016.

11.4. Bioelectricity

The electric matrix also leverages the presence of renewable resources. Hydroelectric plants continue to be the main source of electricity in our country, although their share is decreasing, as shown below.

Chart 43 – Electrical Matrix – 2008 and 2018



Source: (EPE, 2019a)

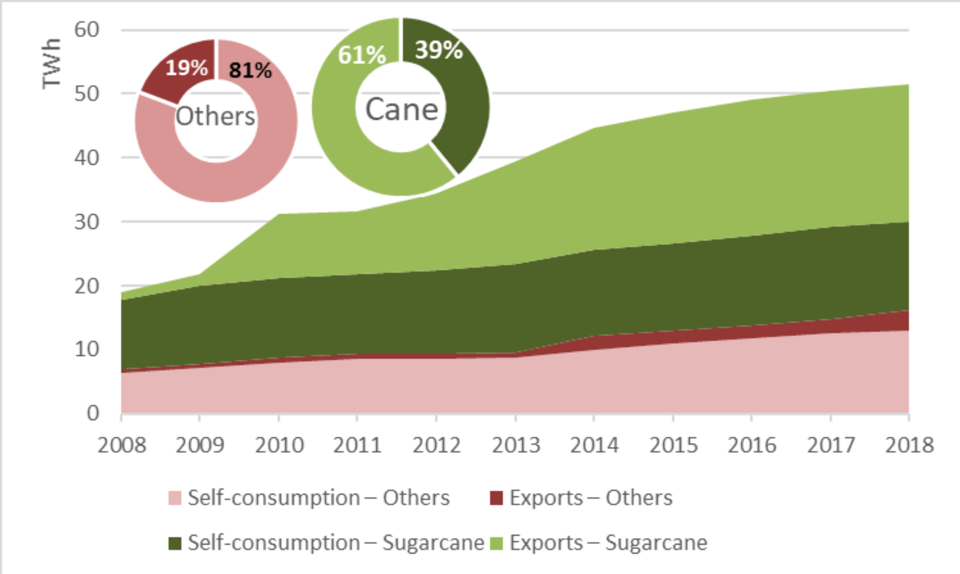
As a way of supplying this *gap*, thermal plants now play an important role in contributing to energy security and increasing the reliability of the electrical system. Among the thermal ones, those that use natural gas acted the most expressively. Initially, this solution was promoted based on the market development policy for Bolivian gas related to the construction of GASBOL (whose northern section was commissioned in 1999 and southern section, in 2000) and the Thermoelectric Priority Program (PPT) in the 2000s (EPE, 2017c). Subsequently, based on the competitiveness of the GTW business models (*Gas to Wire*) at the wellhead or integrated with LNG (Liquefied Natural Gas) regasification terminals, they were the winner bidders in energy auctions.

However, bioelectricity has also been increasing since the introduction of the new regulatory framework for the electricity sector through Law No. 10,848 (BRASIL, 2004). Through this public policy, measures were taken with the objective of fostering the adoption of a competitive market and guaranteeing the electric supply, such as the execution of auctions to contract electricity in the regulated market, when the criterion of lower tariff was adopted.

Due to the significant amount of sugarcane biomass available for generation, these thermal plants may represent an even greater highlight in the Brazilian electric scenario, because they are complementary to hydroelectric plants, as their period of greatest generation occurs in the months of greatest water stress, as described by EPE (EPE, 2015).

As illustrated by Chart 44 in this document, the electrical share of the ethanol and sugar producing units was initially limited to self-production. Faced with measures that value bioelectricity, either through public policies, or by the fusion movements that occurred in the sector and its internationalization, the segment has been presenting a more exporting profile in recent years. The growth of other sources in biomass generation is also observed. Lixivium (black liquor, originating from the pulp and paper industry) showed a significant increase in the injection of electricity to SIN, as pointed out in item 5.2 of the Conjuncture Analysis.

Chart 44 – Share of sugarcane biomass in bioelectricity generation



Source: (EPE, 2019a)

From 2008 to 2018 bioelectricity generated around 420 TWh, of which 170 TWh were exported to the National Interconnected System, contributing to the Brazilian electricity matrix.

11.5. Biogas

The share of biogas in the domestic energy supply has increased dramatically in recent years (EPE, 2019a)but still modest in view of its expressive potential and small compared to other energy sources. It is important to highlight that the public policy of fomenting the distributed generation, through the promulgation of ANEEL Normative Resolutions 482/2012 and 687/2015, was essential to stimulate the greater penetration of this input in the power generation (ANEEL, 2012) (ANEEL, 2015).

The Decennial Plans for Energy Expansion have been signaling that the sugar-energy industry can contribute strongly to the supply of biogas from the digestion of vinasse and filter cake. (EPE, 2017a) (EPE, 2018b). It can also contribute to the dissemination of this renewable source the large availability of inputs dispersed in various regions of the country, such as waste from sanitation units and pig farming. In this context, it is estimated that the use of biogas will be considerably expanded in Brazil in the coming years. In addition to the positive development resulting from the greater supply of an energy source, the solution to an environmental problem is obtained by directing these residues to biogas production.

Observing the historical sharing of the sources used for electricity generation, it is notorious the largest increase in natural gas, which increased from 28.7 TWh to 54.6 TWh, from 2008 to 2018. (EPE, 2019a). Note that there was an increase of 26 TWh, almost double, although its percentage share in the period remained at the same level, increasing from 31% to 34% in electric generation by thermal plants. This increase represented approximately 20% of the increase in electricity generation over the evaluated horizon. In addition to the reduction in hydro share, one of the factors that justify the increase in natural gas is the increase in the share of high variability energy sources, which demand that there be flexible thermal backup so that its generation occurs to minimize the risks inherent to its use. Wind energy registered a share of 86,000 tep in 2008 and 4,168,000 tep in 2018 in the electricity matrix. The solar matrix had no records until 2012, and reached 298,000 tep in the last year. Biogas will be included in the matrix as of 2010, with 15,000 tep, ending 2018 with 204,000 tep.

The purification of biogas gives rise to biomethane, whose energy content is similar to that of natural gas. If the minimum requirements determined by the specific regulation are met, it can be applied in the production of electricity, in exclusive use or in bagasse co-burning in hybrid plants, in joint use or in replacement of diesel in agricultural machinery and heavy vehicles. be injected into the pipeline network of natural gas of fossil origin.

In this sense, it is important to highlight the opportunity created in the context of New Gas Market. The production and use of biogas can serve to increase the supply of natural gas as well as to reduce its carbon footprint, showing a positive synergy between fossil fuel and renewable. In this respect, biogas production increases both the capacity to meet demand and the scope of supply.

11.6. Energy Matrix Perspectives

There are several elements that point out that the world is going through a new energy transition based on conditions such as sustainable development, climate change and technological innovations associated with electronics and entering the digital age.

The new energy transition consists of a process of transformation towards a low carbon economy and a lower environmental footprint, increasing the efficiency of the use of different energy sources and progressively replacing more carbon intensive energy resources with those of lower environment GHG emissions and environmental impacts.

It should be noted that the pace of changes in primary and final energy matrices around the world is quite geographically distinct. Brazil already has a high degree of renewability of its matrix, which is equivalent to almost three times the reality experienced in the world. (EPE, 2019a) (IEA, 2019). Thus, at the national level, the greater share of biofuels will contribute to this transition with less use of fossil resources. With regard to transportation, internal combustion engines should continue to be present in the Brazilian matrix in the coming decades, and their replacement by technologies that use other forms of propulsion, such as hybrid and electric vehicles, should be slower than the growing presence of liquid biofuels. In the medium to long term, the Rota 2030 should contribute to harmonizing biofuels and alternative automotive technologies.

In this sense, the 2027 Decennial Energy Expansion Plan estimates the increase in the share of renewable sources in the national energy matrix, from 45.3% in 2018 to 48.8% in 2025, as illustrated by Chart 45. We highlight the growth of wind and solar energy, as well as the evolution of sugarcane derivatives. In the view of the International Energy Agency (IEA, 2019), the share of non-renewable energy in the global energy matrix will continue to large in 2025, around 82.7%, even in the most favorable scenario for the entry of renewables (*Sustainable Development Scenario*). Comparing the years 2017 and 2025, although oil falls from 32% to 31% and coal from 27% to 22%, natural gas increases its contribution from 22% to 24%, while the sum of renewables and solid biomass increases from 14% to 17%. When considering the current policy maintenance scenario (*Current Policies*), non-renewable sources show a small reduction from 85.7% in 2017 to 84.4% in 2025.

Chart 45 – Domestic energy supply – Brazil and world (2025)

Source: (EPE, 2018b) and (IEA, 2019)

It is evident, then, that by the year 2025, most countries will still be far from the current position of Brazil in terms of renewable energy matrix (item 11.1.1).

The world's energy needs will continue to grow, and the pursuit of a low carbon economy will guide the future towards the efficient use of energy and the use of lower carbon sources, including renewables. Brazil is already in a prominent position and should further strengthen this scenario, given the National Biofuels Policy, which opened a new horizon for the expansion of biofuels share in the Brazilian energy matrix.

11.7. Benefits

The insertion of biofuels in the Brazilian energy matrix occurred massively in the 1970s, as a reaction to the oil crises. Since the 1990s there have been new advances, adding the environmental aspect to the motivation of supply security (reduction of dependence on oil).

There are several benefits from the use of biofuels in the national matrix, which can be observed in the economic, social and environmental spheres. Considering liquid biofuels, since Brazilian production of petroleum, gasoline and diesel derivatives is not sufficient to meet domestic demand, the consumption of ethanol and biodiesel acts favorably to reduce the risks related to the instability of the world oil market, and of increase the security of energy supply. The absence of these biofuels could result in increased imports of fossil analogs, impacting Brazil's trade balance.

The most evident social impacts of biofuel use are related to job and income creation, either in the agrarian phase of its production or in the industrial phase. In the case of biodiesel, we highlight the existence of the Social Fuel Seal, which benefited small farmers from the inclusion of family farming in the biofuel production process.

The environmental benefits of biofuels result from the lower generation of air pollutants, liquid effluents and solid waste compared to fossil fuels. It is important to highlight that the burning of fossil fuels emits several contaminants that cause environmental impacts, both local and regional as well as global, with emphasis to acid rain, *smog* photochemical and global warming. In addition to contributing to the mitigation of greenhouse gases (GHG), the use of these renewable sources causes a lower emission of some local contaminants (e.g., total hydrocarbons, particulate matter, SO_x and CO). It should be noted that there is an increase in NO_x in the case of biodiesel, and aldehydes in the case of ethanol. Thus, the use of biofuels is resulting in a favorable environmental balance for Brazil, both in terms of local and regional pollution, with impacts on health, and in terms of the reflexes on climate change. In addition, through specific regulation for distributed generation, there is a stimulus for using waste as an energy source, originating inputs for electric generation, vehicular use, among others.

Brazil has been a protagonist in international discussions on climate change. It was a signatory to the Kyoto Protocol (ratified in 1999) and, more recently, has committed itself to the Paris Agreement, concluded at the 21st Conference of the Parties of the United Nations Framework Convention on Climate Change (UNFCCC) held in that city, in December 2015. The Paris Agreement represented an important worldwide articulation to address the anthropogenic causes of global climate change and to adapt to its effects, and Brazil presented its Nationally Determined Contribution (NDC) on this occasion (EPE, 2016a).

In the Brazilian NDC, Brazil committed to reduce 37% of GHG emissions by 2025, and indicated that it could reduce by 43% by 2030, with 2005 as its benchmark. It is crucial to note that Brazil's NDC applies to the economy as a whole and is therefore based on flexible paths to achieve the 2025 and 2030 objectives. Although Brazil's NDC does not set sectoral targets, in addition to the Brazilian commitment presented at COP 21, additional information is provided on measures that can be taken to achieve the targets, including the energy sector: "i) increase the share of sustainable bioenergy in the Brazilian energy matrix to approximately 18% by 2030, expanding biofuel consumption, increasing ethanol supply, inclusive by increasing the share of advanced biofuels (second generation), and increasing portion of biodiesel in the diesel blend".

By promoting vehicular consumption of ethanol and biodiesel and the increased share of bioelectricity and biogas in the energy matrix (replacing its fossil channels), while at the same time strengthening the security of national energy supply, Brazil is also decreasing the intensity of GHG configurations in the energy sector, as well as the emission of local pollutants.

Considering the last ten years, total demand for the Otto cycle amounted to 525 billion liters of gasoline equivalent (excluding CNG), of which 218 billion liters of ethanol (gasoline equivalent). In this same period, the net importation of gasoline was 15 billion liters. Thus, the use of ethanol contributed to this value not being even higher and had the environmental benefit of reducing GHG emissions, which reached 446 $MtCO_2eq$.

Biodiesel, in turn, participates with a mandatory percentage of addition to fossil diesel. Evaluating the period from 2008 to 2018, the total biodiesel consumed, considering the various percentage changes over this time, was about 34 billion liters. Considering that soy and animal fats account for more than 90% of the raw material used for the production of this biofuel, emissions avoided by its use exceed 88 $MtCO_2$ eq.

The benefits from bioelectricity are also related to the mitigation of GHG emissions, as well as their complementarity with hydro generation, located near the load center. The share of sugarcane bioelectricity is estimated to have generated 300 TWh from 2008 to 2018, of which 150 TWh were injected into the National Interconnected System. Calculations of avoided emissions from the use of this input as an electrical source amount to 25 $MtCO_2$.

In this regard, considering the use of ethanol and biodiesel and bioelectricity, the use of these biofuels accounted for the mitigation of 560 $MtCO_2$.

Thus, the strategic role of biofuels in the Brazilian energy matrix is evident, with emphasis on the supply security and the mitigation of greenhouse gas emissions.

11.8. Final considerations

Historically, Brazil has had a prominent position in the production and use of biofuels, with a high share of renewable sources in its energy matrix. This is the result of continuous public policies that combined actions of the federal government, private agents and civil society in taking advantage of national edaphoclimatic characteristics.

Throughout the ten years of the Biofuels Conjuncture Analysis, such public policies have guaranteed renewable sources to maintain a percentage above 40% in the domestic energy supply, even with a 17% growth of the latter. For the transportation sector, the share of renewable sources increased from 18.7% to 23.1%, an increase of 8Mtep between 2008 and 2018.

Ethanol plays a key role in this growth, adding about 10 billion liters of gasoline equivalent to the Otto cycle fuel consumption when compared to 2008 and 2018. Much was motivated by the successful introduction of flex fuel vehicles, which represents the majority of total light-duty vehicle fleet in 2018, as well as by the mandate of adding anhydrous ethanol to gasoline type A. The accumulated consumption of fuel ethanol in the period 2008-2018 was 218 billion liters.

The PNPB introduced biodiesel into the Brazilian energy matrix, establishing the mandatory mixture with fossil diesel from 2008, aiming at the promotion of national industry, energy security, foreign exchange economy and social inclusion through family farming. In the period 2008-2018, total accumulated consumption was approximately 34 billion liters. However, efforts are still needed to diversify the raw materials and the producing regions, one of the initial purposes of the PNPB, since its production is mostly concentrated in soybean and animal fat, about 90% of total inputs, and in Central-West and South regions.

A waste from ethanol and sugar production, bagasse is a source for bioelectricity generation. Over the last decade, the exportation of the energy from the sugar-energy industry to the SIN has been growing and preponderant, totaling about 150 TWh in this period. It is important to emphasize the seasonal characteristic of bagasse, which presents the largest generation during the sugarcane harvest, concomitant to the time of greater water stress. More recently, it is also possible to observe the greater share of lixivium in biomass generation.

Throughout the publication period of the Biofuels Conjuncture Analysis it was possible to notice the introduction of biogas in the energy matrix, which, although incipient, presents a strong growth, indicating a promising future in the national matrix.

Brazil stands out in the world energy scenario for the renewable nature of its matrix, a result of its enormous potential, and, above all, of public policies aimed at strengthening national security and making better use of renewable resources. So, the current uniqueness of the Brazilian energy matrix is the future purpose of many nations, given the significant presence of low carbon sources. As stated in this article, the 2027 Ten Year Energy Expansion Plan indicates that the growing national energy demand will continue to be met in a sustainable manner.

In addition to the numerous positive developments already mentioned, it is also worth mentioning that there are other benefits associated with the growing use of biofuels in the economic, social and environmental spheres. The promotion of domestic industry to produce equipment and deliver services in order to meet the demand, and the positive trade balance generated by the exports are some of the positive effects of biofuels investments. Socially, the employment generation and income growth stand out, both in the agrarian phase and in the industrial phase of its production. In the environmental sphere, the reduction of greenhouse gas emissions associated with the increased use of biofuels is aligned with the Brazilian commitment with reduction of the impacts of climate change and endorses Brazil's leading role in discussions on the topic.

The EPE Biofuels Conjuncture Analysis sought to understand more deeply some of the main biofuel market movements in the country in its articles, such as the concentration and internationalization of the sugar-energy sector, the analysis of ethanol production costs and the insertion of bioelectricity in the national energy matrix (EPE, 2013) (EPE, 2014) (EPE, 2015).

In the most recent editions, we analyzed the public policies to encourage the production and use of biofuels in Brazil, the impacts of tax differentiation between gasoline and hydrate for Minas Gerais (a subject of state policy), and the objectives and possible consequences of the Biofuels National Policy – the RenovaBio (EPE, 2016b) (EPE, 2017b) (EPE, 2018a).

Therefore, it is considered that the studies have moved towards a better understanding of public policies, as well as their importance for the promotion of the biofuels market in Brazil.

Completing the first decade of the Conjuncture Analysis, this edition highlights the important role of biofuels in the Brazilian energy matrix, largely guided by such policies, properly directed to the exploitation of our national wealth through sustainable development, aiming at the social optimum.

Many challenges have been overcome and the Brazilian state has over the years been able to develop mechanisms to leverage the opportunities offered by the country's edafoclimatic conditions. The National Biofuels Policy has focused on improving public policies and regulatory aspects that are necessary for expansion of national production of these renewable sources and for their use. In addition to these efforts, preparing the fertile soil where RenovaBio can sprout, hopefully the biofuel industry will act to expand biofuel production in Brazil, based on predictability and environmental, economic and social sustainability.

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