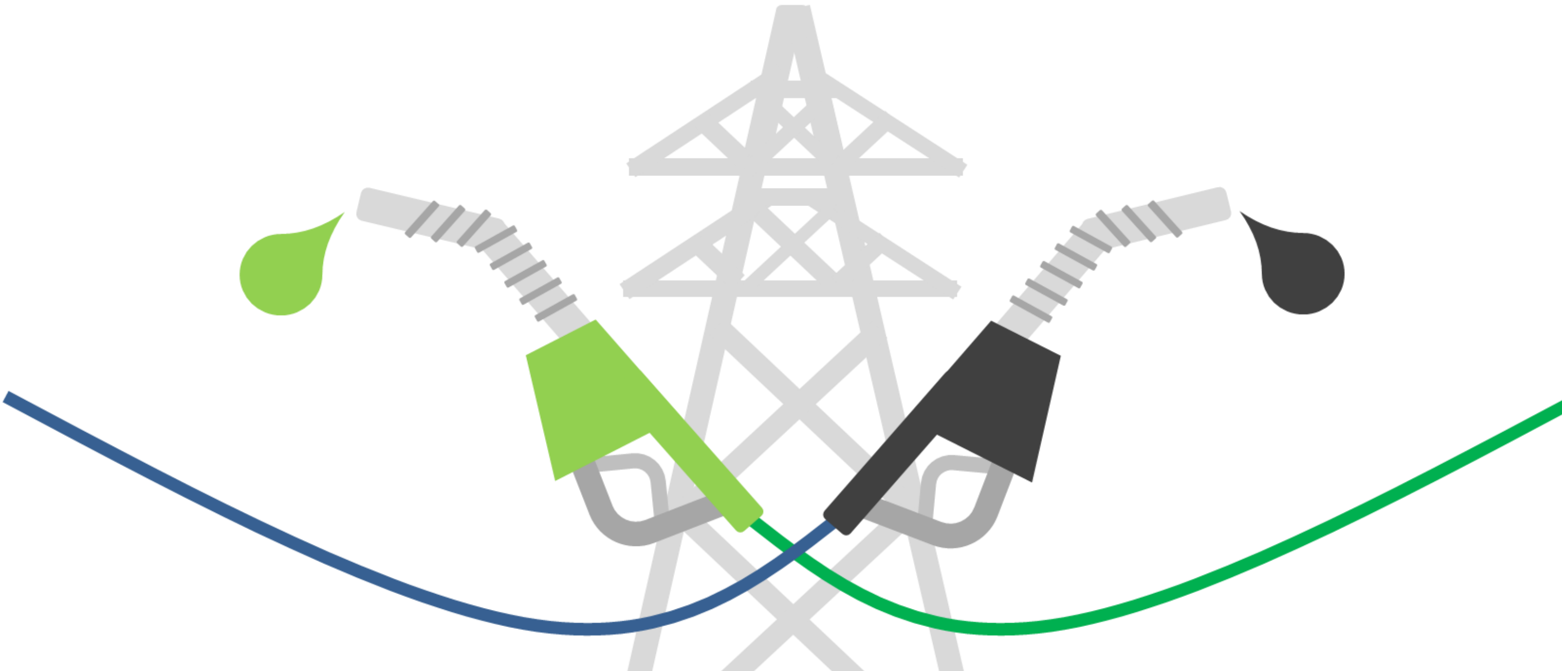
MINISTRY OF MINES AND ENERGY

ETHANOL SUPPLY SCENARIOS AND OTTO CYCLE DEMAND 2018-2030



Rio de Janeiro, May 2018

Empresa de Pesquisa Energética

MINISTÉRIO DE MINAS E ENERGIA

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Ministry of Mines and Energy

Ethanol Supply Scenarios and Otto Cycle Demand 2018–2030

Empresa de Pesquisa Energética

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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Ethanol Supply Scenarios and Otto Cycle Demand

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1. Introduction

The Energy Research Company presents its third edition of the ethanol supply scenarios and Otto cycle demand. With this study, EPE aims to contribute to the identification of opportunities and threats to the domestic supply of Otto cycle light-duty vehicles (ethanol and automotive gasoline). To this end, the document presents **ethanol supply scenarios** and its consequences for the Otto cycle demand and for the **national balance of gasoline type A** up to the horizon of 2030. In this edition, the assumptions made in the studies for second generation ethanol, corn ethanol and sugarcane insertion were explained. The presentation of a second trajectory is also included, associated with the scenario of high ethanol supply growth for some selected variables (sugar, corn ethanol and sugar cane). The construction of this trajectory was required as a result of the fast, successful and promising process of RenovaBio, which culminated in the National Biofuels Policy Act enacted in December 2017, indicating the pertinence of evaluating the effects of exceeding expectations, which generate additional stimulus on the selected factors. Additionally, the document included the presentation of the supply of sugarcane bioelectricity exported to the National Interconnected System and the biogas production potential for each of the scenarios elaborated, as well as an estimate of the contribution of the sugar-energy sector to the reduction of greenhouse gases (GHG) emission in the Energy Sector and an assessment of the associated investments.

2. Contextualization

Brazil stands out in the world for its leadership in the production and use of biofuels. The space occupied by these renewable sources in the national energy matrix is, to a large extent, the result of public policies that integrated actions by government, energy-sector agents and civil society, as pointed out by EPE (2016). To stimulate the market, Brazilian government has been using public policies, such as Proálcool (National Alcohol Program) and PNPB (National Program for the Production and Use of Biodiesel), and mandates of mandatory addition to petroleum derivatives. Several economic instruments have also resulted in incentives for biofuels (EPE, 2016).

It is in this context that the establishment of the National Biofuels Policy, through Law No. 13,576, enacted in December 26, 2017, opens up other great opportunities for Brazil (BRAZIL, 2017a).

RenovaBio lists among its main objectives to promote the proper expansion of biofuel production and use in the national energy matrix, with emphasis on the regularity of fuel supply, and also to contribute with predictability for the competitive participation of these energy sources in Brazilian fuel market. The National Biofuels Policy also aims to cooperate to meet Brazilian commitments with the Paris Agreement under the United Nations Framework Convention on Climate Change, valuing its role in mitigating GHG emissions.

It is important to note that the program aims to increase the participation of several biofuels in the Brazilian energy matrix, such as ethanol, biodiesel, biogas and aviation biokerosene. It should be noted that, specifically for ethanol, since 2013, several direct or indirect governmental actions have been seeking to provide favorable conditions for the sugar-energy sector to resume growth, such as:

- Increases in the percentage of anhydrous ethanol in gasoline: from 20% to 25% in March 2013 and to 27% since March 2015 (MAPA, 2013, 2015);
- Recomposition of the Economic Intervention Contribution (CIDE) rate on gasoline to R$0.10/liter since 2015, while on hydrous ethanol has been kept at zero since 2004 (BRAZIL, 2015);
- Increase of PIS and COFINS tax rate for gasoline from zero to R$0.12/liter, as of February 2015 (BRAZIL, 2015) [5]. Since July 2017, this has been raised to R$0.7925/liter (BRAZIL, 2017b).
- Maintenance of zero PIS and COFINS tax rates for ethanol until December 2016 (BRAZIL, 2013). In January 2017, the rate became R$0.12/liter and in July it was raised to R$0.1964/liter (BRAZIL, 2017b).

At the same time, BNDES has maintained several financing lines related to the sugar-energy activity. PRORENOVA (Support Program for the Renewal and Implementation of New Sugarcane) and the PAISS (Support Plan for the Industrial Technological Innovation of the Sugar and Energy Sector)[1,2] (BNDES, 2018a, 2018b).

The government actions described sought to resume the growth of the sugar-energy sector, seriously impacted by the global economic crisis of 2008, as the period of large investments in new units resulted in a high degree of indebtedness of the segment. To get out of financial difficulties, some groups were forced to sell their assets and others went into judicial recovery process or had bankrupted (EPE, 2017a, 2017b). It should be noted that the depreciation of the real against the dollar was a determining factor for many companies to file for judicial recovery, as their debts are predominantly based on this currency, while their revenues are denominated primarily in Brazilian reais.

In this context, companies had to reduce their investments and expenses. As a result, they did not renew the sugarcane fields and the appropriate cultural treatments, nor did the insertion of new varieties, among other factors, which caused a drop in productivity. Climate factors (excessive rainfall or atypical droughts), rising of land-leasing prices, and gasoline prices not always on par with the international market also contributed to aggravate the situation.

In addition, it is notorious that ethanol production is strongly impacted by international sugar prices. Between 2009 and 2012, the impact was negative for ethanol, because the sugar yield per kg of TRS[3] was higher than that of anhydrous and hydrous. However, due to continued world surpluses of the *commodity*, their remuneration was lower than the same between 2013 and 2015. From the end of 2015 until the beginning of 2017, the sugarcane industry has been taking advantage of the high in international sugar prices to increase its revenues and pay off part of these debts and is undergoing a period of adjustments in which they seek to balance their financial situation. In this context, actions are taken to improve production factors, which lead to cost reduction and margin increase, raising its financial sustainability. It should be noted that the return to the import parity of gasoline prices in

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[1] Between 2013 and 2017, the amounts made available to the sector through PRORENOVA and PAISS were, respectively, R$8 billion and R$3 billion, while the amounts contracted during this period totaled R$4.1 billion and R$1.8 billion, respectively (BNDES, 2018c).

[2] The Sugar and Alcohol Sector Support Program – PASS, another BNDES financing line, directed to ethanol storage, was discontinued by the Bank in 2016. Through 2009 and 2015, R$3.5 billion were contracted (BNDES 2018c).

[3] TRS – Total Recoverable Sugar

the country and the recent rise in international oil prices have also contributed to the business profitability improvement.

3. Scenario Assumptions

Considering the estimated nominal installed grinding capacity of 827 million tons of sugarcane[4] (corresponding to 744 Mtc in effective capacity), three scenarios of ethanol supply were traced, whose names were chosen based on production growth. These are: **High Growth, Medium Growth and Low Growth**. The assumptions corresponding to the scenarios are given below.

3.1. Common assumptions

Adjustments to base year factors:

The area and agricultural and industrial productivity of 2017 were adjusted according to the fourth survey of the 2017/18 CONAB sugarcane crop (2018a).

Current installed capacity:

- Implementation of two units: one has been sold at energy auctions, and another already owns part of the works carried out;
- Grinding capacity factor of 90% for processing plants (depending on climatic aspects during each harvest, this percentage may be higher);
- Expansion of the grinding capacity of 23 existing units by 32 million tons of sugarcane (currently mapped projects).

Second Generation Ethanol

Brazil has two commercial second-generation ethanol (E2G) plants (Granbio and Raízen) and one experimental (Sugarcane Technology Center – CTC), with nominal production capacity of 82, 42 and 3 million liters per year, respectively. Currently, the commercial units still operate below nominal capacity due to some technical problems, such as the pre-treatment and lignin filtration stage, which have already been addressed.

The second-generation ethanol production projection considered the announced investments, as well as the higher valuation of this advanced biofuel in the international market. E2G production is estimated to reach 2.0 billion liters by 2030.

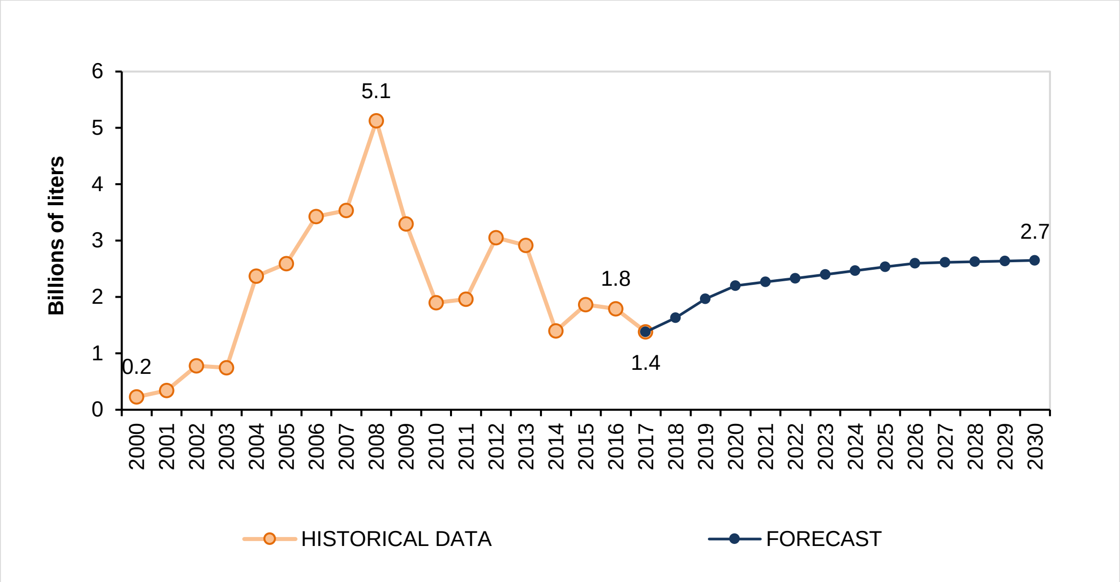
Ethanol Exports

The volume of ethanol exported by Brazil fluctuates significantly over time, as can be observed in Chart 1. It is estimated that the international biofuels market should maintain its current characteristics, with low volumes traded until the end of the period. The main reasons for maintaining the current trend are the prospect of reducing world energy consumption per vehicle, the widespread pursuit of energy independence, the adoption of more efficient technologies and the maintenance of some degree of protectionism by the main consuming countries.

[4] Data as of December 2017. The analysis considered the shut down, reactivation and expansions in existing units that took place in 2017.

As a result, Brazilian ethanol exports are projected to grow from 1.4 billion liters in 2017 to 2.7 billion liters in 2030. Note that this value is similar to the average observed in the 2007-2017 period, corresponding to about half of the historical maximum. The exports projection considers mainly the participation of sugarcane ethanol in meeting the RFS goals (*Renewable Fuel Standard*)[5] from United States.

Chart 1 – Ethanol Exports



Source: EPE based on MDIC (2018)

Despite the expectation of reduced international trade, the United States, the European Union and Asia (South Korea and Japan) have the highest biofuel consumption potential, as described in EPE (2017b).

In 2017, Brazil experienced the first negative trade balance of ethanol in the last 20 years, with imports totaling 1.8 billion liters, compared to exports of 1.3 billion liters (MDIC, 2018).

Yield

Industrial yield (sugarcane quality) is defined by the amount of TRS per ton of sugarcane and is related to the sugarcane variety (richest in sugar or fiber), its suitability to the production environment and mechanized cutting, age of sugarcane (renewal at the right time), cultural treatment and climatic aspects.

This indicator, which had been on an increasing path between 2000 and 2007 (rate of 0.7% per year), decreased at a rate of 0.6% between 2007 and 2017, falling to values below those shown in 2000. (CONAB, 2018a, 2018b). This trend is due to mechanization and non-renewal of sugarcane, as well as climatic aspects, which were detrimental in specific years.

Mechanized harvesting was implemented mainly to achieve the goals imposed by environmental laws and agreements to reduce wildfires, however, it is observed that there was a mismatch between mechanization of harvesting and planting. The insertion of

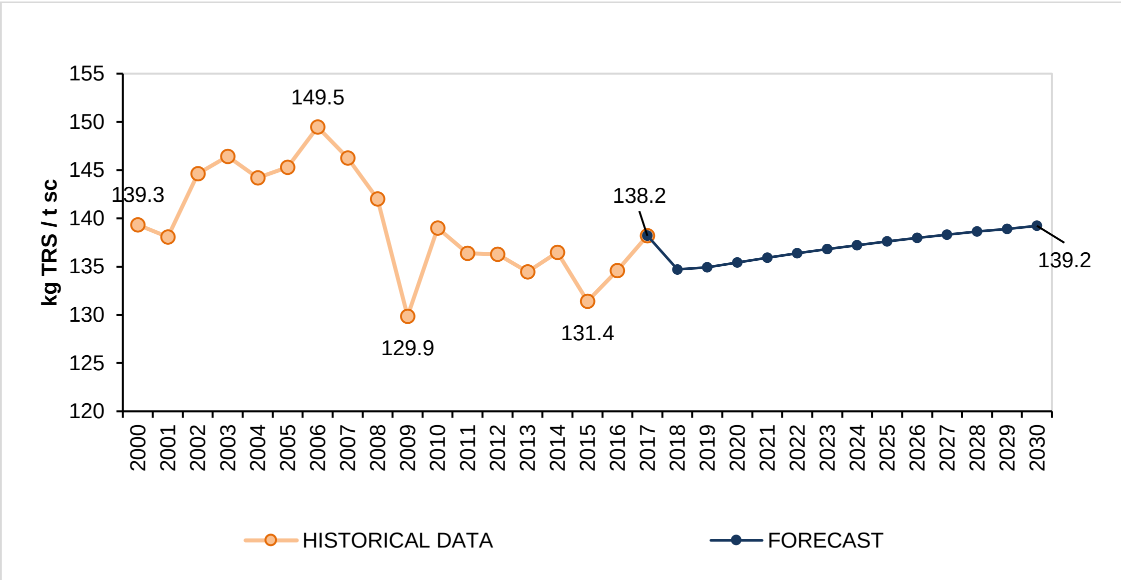
[5] Under this program, biofuels are classified according to the amount of GHG emitted in the life cycle: renewable (corn ethanol and biobutanol), advanced (sugarcane ethanol), biomass diesel (biodiesel or HVO, hydrated vegetable oil) and cellulosic (ethanol and cellulosic bioethanol) (EPA 2018).

mechanized planting techniques and practices is slower, as it occurs only in areas of reformation, already amortized (EPE, 2017a, 2017b). It should be noted that mechanization caused an increase in plant (8–11%) and mineral (1.0–1.5%) impurities, which compromises the quality of the raw material entering the processing plant (CTC, 2014, 2017, 2018; EPE, 2017b).

Another important point is that mechanization of the sugarcane harvesting requires the use of more favorable varieties, as well as proper agricultural management, with adequate spacing between sugarcane field rows, field sizing (to avoid trampling during harvester maneuvers), grouping of varieties and height of the plough grooves to make the cut closest to the ground – the part where the sugarcane has the highest sucrose content (EPE, 2017a, 2017b). However, the sector's level of indebtedness has been an impediment to the adoption of these practices by all groups.

Considering that part of the sector, which has a controllable level of indebtedness, will seek the implementation of good practices and technologies, sugarcane yields will reach about 139 kg TRS /tc in 2030, slightly higher than in 2017 and 10 points below the record achieved in 2006, as can be observed in Chart 2. The rate between 2017 and 2030 will be 0.1% per year.

Chart 2 – Industrial Yield (Sugarcane Quality)



Source: EPE based on CONAB (2018a, 2018b) and MAPA (2016)

Ethanol for Other Uses

In Brazil, it is estimated that the non-fuel ethanol demand, mainly concentrated in the production of beverages, cosmetics, pharmaceuticals, petrochemicals and oxygenated compounds (acetic acid, ethyl acetate and butanol), will increase from 1.1 billion liters in 2017 to 1.4 billion liters in 2030, which represents a growth rate of 2.3% per year.

3.2. Specific Assumptions

The scenarios elaborated differ basically as to the degree of economic attractiveness of ethanol production and the competitiveness of hydrous ethanol against gasoline type C. To this end, the sugar-energy sector is striving to improve production factors and Brazilian government is offering incentives for the sector, including a commitment to expanding biofuel production and ensuring 21st Conference of the Parties (COP-21).

It is important to highlight that RenovaBio consists of a modern public policy of internalizing the positive environmental externalities of biofuels, in which the environmental benefit will be valued by society itself. Such valuation will be set in markets organized to trade Decarbonization Credits (CBIO) issued on the basis of Certificates of Efficient Biofuel Production.

The CBIO is the instrument created for commercialization between biofuel producers and distributors, which must meet the carbon reduction targets. The amount of CBIO will vary according to the production and Energy Efficiency Rating of each primary issuer. Thus, the lower the carbon emission for biofuel production, the better qualified the unit and the higher its grade. Thus, with the decarbonization targets set, there will be a stimulus for biofuels production, which will increase the search for CBIO. With such economic signaling, it is expected that the processing plants will feel motivated to produce more biofuels and to do this more efficiently, increasing the offer of this certificate and regulating its price in the market, where it will be traded. This mechanism should ensure the necessary security for investments in new processing plants, as CBIOs will offer more revenue to producers.

In this sense, it is estimated that the price of CBIO will be one of the distinguishing factors of the scenarios, contributing, to a greater or lesser extent, to the expansion of ethanol production. Then, the document addresses the main qualitative assumptions adopted in the achievement of the scenarios.

Medium Growth Scenario

In the medium growth scenario, it was considered that there will be a price relation, among the fuels, more favorable to ethanol. Alignment of **ex-refinery gasoline price** to international prices is supposed to happen, noting that it has presented a higher level of oscillation. It was also considered the continuity of **ethanol incentive policies as,** for example, **differences in CIDE, PIS/COFINS and ICMS[6] incidents on ethanol and gasoline in some states,** as well as the provision of financing lines for the sector.

Another key factor in shaping this scenario is RenovaBio's success, resulting in CBIO prices that enhance the economic attractiveness of ethanol production. In this way, the sugar-energy sector now has an additional revenue, generating the progressive recomposition of its margins and creating a business environment favorable to the resumption of investments. It should be noted that this additional financial income from the subscription and sale of CBIO would occur in an already more favorable ethanol price scenario, due to the higher level of international oil prices.

It was also considered that the sector will carry out actions to reduce costs, such as: sugarcane renewal and adequate cultural treatment. Note that these actions are reinforced by the search for greater efficiency in ethanol production induced by RenovaBio

[6] In 2017, 15 states presented tax differentiation between hydrous ethanol and gasoline type C (CONFAZ, 2018; EPE, 2018).

instruments, in particular, the Energy-Environmental Efficiency Score of each CBIO primary issuer.

Other assumptions are the introduction of new varieties adapted to the new production environments and the mechanized planting, and the adoption of new harvesting methods. These varieties provide higher productivity and higher yield (quality) in addition to reduced losses and impurities in the harvesting process. In this same aspect, agricultural management was considered for the appropriate development of sugarcane crop (row height and spacing, and georeferencing of the sugarcane fields).

With this, it is estimated that the margins of the sector will be higher than the current ones, which will provide return on investments in new units from 2022. The projection for the medium growth scenario considers a partial resumption of investments from that year onwards, since the insertion of new agricultural and industrial technologies promotes the reduction of production costs, as well as the increase in demand raises the demand for fuels and, consequently, their prices.

It should be emphasized that this scenario is compatible with the ethanol supply projections presented in PDE 2026, as well as with the increase in international oil prices. The final features of the scenario are slightly different as the RenovaBio′s contours were not yet known at the time, but the outline is basically the same. This is why no significant changes in this scenario are considered in relation to the PDE 2026 projections, since the events of 2017 and 2018 only made the traces of this scenario clearer and more credible.

High Growth Scenario

The high growth scenario considered that the assumptions adopted for the medium growth scenario will occur with a higher intensity. Thus, it has been estimated that, in the mid term, the number of greenfields (projects) will be higher, as will agricultural productivity, resulting from a greater insertion of new, more productive varieties, as described below.

In this scenario, RenovaBio′s success is more vigorous, resulting in higher CBIO prices, substantially increasing the economic attractiveness of ethanol production as well as the energy-environmental efficiency of production. It is noteworthy that this higher additional financial income would induce a larger increase in ethanol production.

As in the scenario of slow growth, it is assumed that an alignment of ex-refinery gasoline price with international prices will occur. It was also considered a higher intensity of ethanol incentive policies *vis-à-vis* current ones. In this context, for example, there would be additional differences in taxes and contributions on ethanol and gasoline, especially in some states, as well as greater availability of financing lines for the sector.

Low Growth Scenario

In the low growth scenario, despite the alignment of ex-refinery gasoline price with international prices, it was admitted that there will be no dissemination throughout the sector of good agricultural practices (agricultural and varietal management, as well as renewal in the appropriate period) and of technological innovations. In addition, it was considered that there will be less intensive ethanol incentive policies *vis-à-vis* the average growth scenario. Therefore, it was considered that, in the mid term, the number of units greenfields (projects) will be lower than the average growth scenario, as will agricultural productivity.

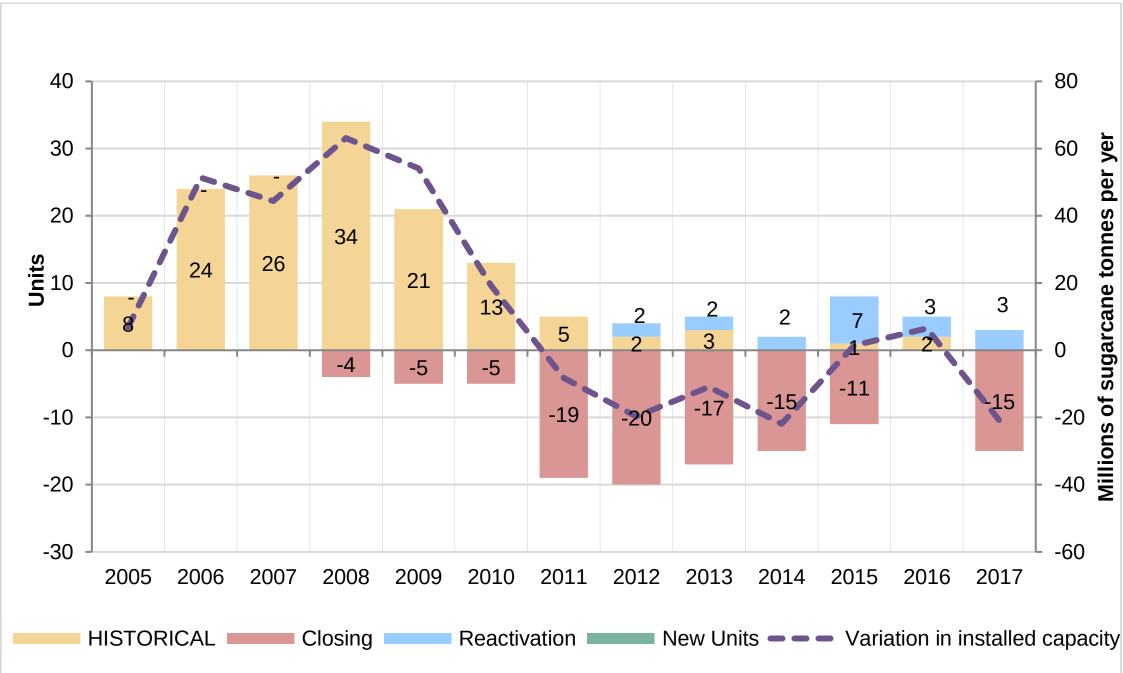
In this scenario, RenovaBio's success is more modest, resulting in lower CBIO prices, which implies little economic attractiveness of ethanol production as well as the energy-environmental efficiency of production.

The following describes the three scenarios of varying input and output flow of units, as presented in the last issue. However, in this cycle of studies, the rapid implementation of RenovaBio (the launch of the program took place on 12/13/2016 and the enactment of Law 13,576, on 12/25/2017, in just twelve months) required for the high-growth scenario the construction of a second trajectory for the following variables: sugar, corn ethanol and sugar cane. It is worth to note that the medium and low growth scenarios used the same trajectory for such factors, except for corn ethanol.

3.2.1. Production Unit Flow of Sugarcane

The history of new units deployed each year showed very high numbers between 2006 and 2010 (average of 24 units per year), as illustrated by Chart3. This was due to the growing demand for ethanol by vehicles flex fuel as well as for sugar. However, after this period, the sector reduced investment in new units, driven by high indebtedness and reduced expenses of production to balance their budgets, in addition to climatic aspects (MAPA, 2018b).

Chart3 – Historical flow of sugarcane producing units



Source: EPE based on MAPA (2018b) and UNICA (2014)

In the period from 2005 to 2017, there was the implementation of 139 units. On the other hand, 111 production units closed their activities[7]. The balance of this flow is estimated to have increased about 165 million tons of nominal installed sugarcane processing capacity. It is assumed that a more detailed analysis of the deployment and shut down flow of units in this period indicates that the number of new units deployed has fallen significantly since 2011 (full assessment in the Biofuel Conjuncture Analysis – Base Year 2017 document (EPE, 2018a)).

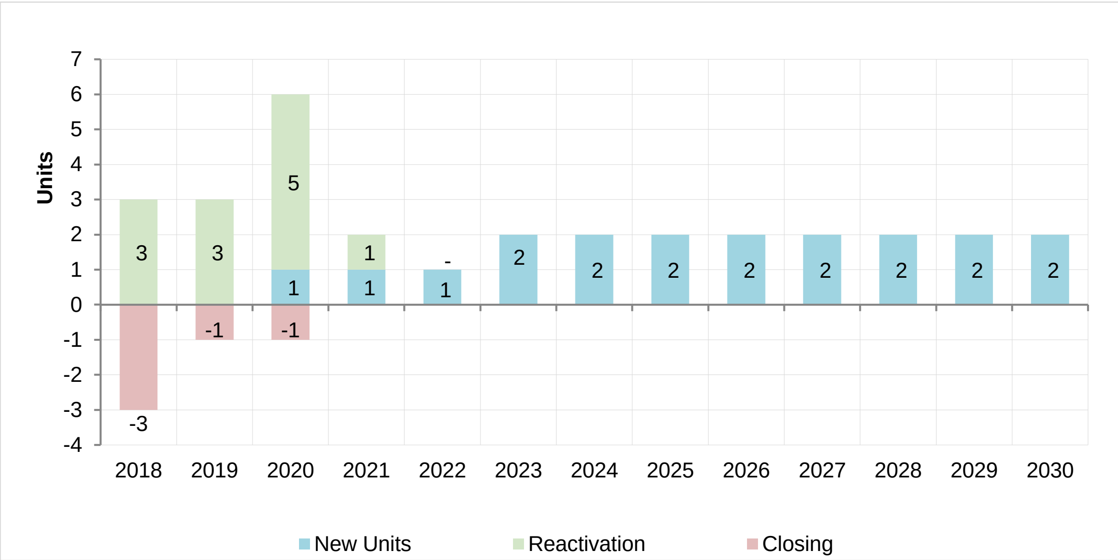
[7] They went bankrupt or paralyzed their activities for a few years and returned to the operation later.

For each scenario, we considered the variation in the inflow and outflow of units, according to the specific assumptions of government incentives and actions of sector agents. Given this context, the following charts summarize the assumptions of expansion of production capacity adopted for each of the scenarios, considering input[8], reactivation and shut down of production units. The average profile considered for the new units (projects) is around 3.5 Mtc/plant. As mentioned in item 3.1, in all scenarios, it was adopted the expansion of the grinding capacity of the existing units by about 32 million tons of sugarcane (as of December 2017).

Medium Growth Scenario

The medium growth scenario considers the entry of 19 new units that increase the nominal sugarcane grinding capacity by about 67 million tonnes. The flow of sugarcane producing units can be observed in Chart 4. It is noteworthy that the balance of reactivations and shut downs will add about 16 million tons of sugarcane to the installed grinding capacity of the sector. In addition, existing units are expected to undertake additional expansions of 26 million tonnes (nominal) to process all available sugarcane.

Chart 4 – Flow of production units – Medium Growth Scenario



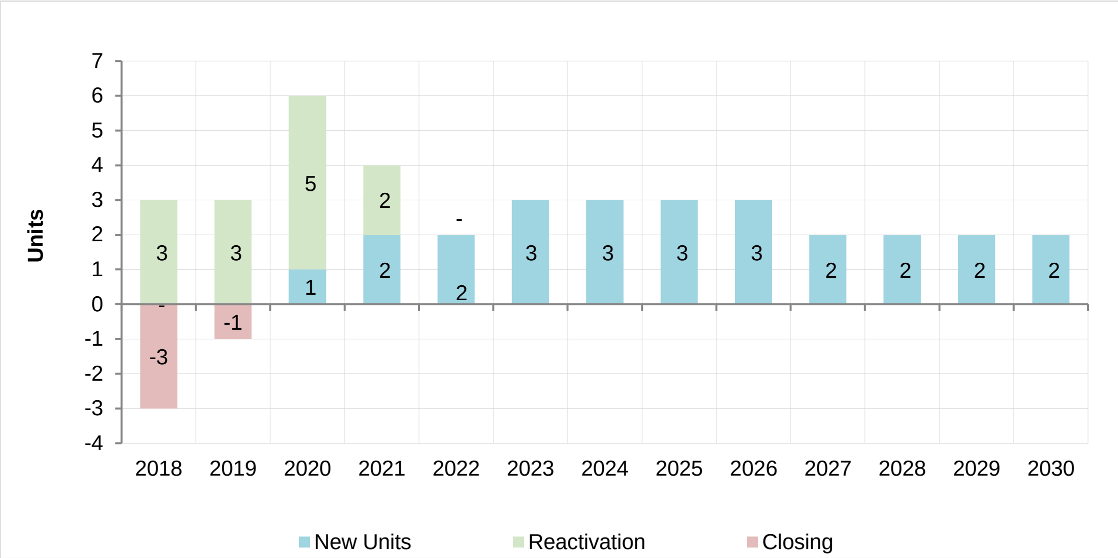
Source: EPE

High Growth Scenario

The high growth scenario considers the entry of 25 new units that would increase the nominal sugarcane grinding capacity by about 85 million tons. The flow of sugarcane producing units is presented in the table Chart 5 below. In this scenario, the balance of reactivations and closings will be the addition of 19 million tons of sugarcane in the installed grinding capacity of the sector. In addition, existing units are expected to increase the processing of all available sugarcane in 82 million tons (nominal).

[8] The units were selected from a portfolio of projects announced but not yet made feasible.

Chart 5 – Flow of producing units – High Growth Scenario



Source: EPE

Low Growth Scenario

The low growth scenario considers the entry of 10 new units that increase the nominal sugarcane grinding capacity by 31 million tons. The flow of sugarcane producing units is illustrated in Chart 6. It is noteworthy that the balance of reactivations and shutdowns will provide an increase of about 6 million tons of sugarcane in the installed grinding capacity of the sector.

Chart 6 – Flow of production units – Low Growth Scenario

Source: EPE

Table 1 presents the balance of the units flow, the installed sugarcane grinding capacity and its variation in relation to December 2017, corresponding to the new units, the reactivations, those in operation that shutdown their activities, as well as the expansions.

Table 1: Unit flow balance and nominal installed capacity[9] of sugarcane grinding

Scenarios	Unit flow		Capacity (Mtc)		Variation (Mtc)	
	2025	2030	2025	2030	2025	2030
Low growth	7	12	888	906	62	80
Average growth	16	26	916	977	89	151
High growth	23	34	967	1050	141	224

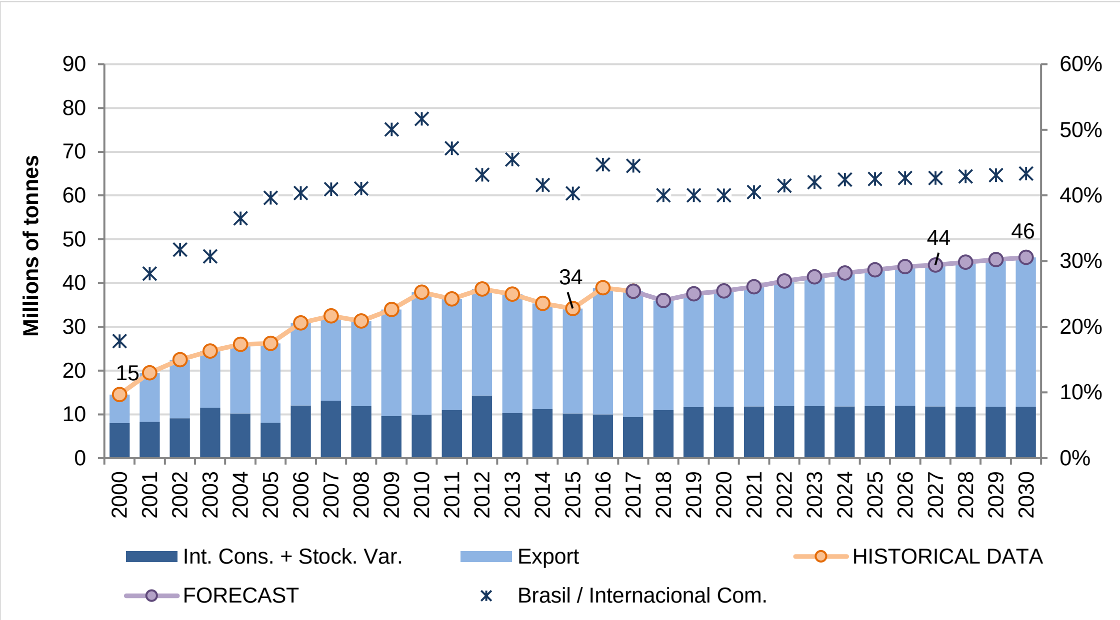
Source: EPE

3.2.2. Sugar

National sugar production is destined to domestic consumption and exportation. Between 2000 and 2017, the production growth rate was 5.8% per year. (between 2007 and 2017, this amount was 1.6%) (MAPA, 2018a).

For the medium and low growth scenario, the projection of domestic sugar consumption considered that *per capita* (kg/inhab/year) will remain around 55 kg/inhab/year over the period, based on income, population aging and change of alimentary habits (FAO, 2012; ISO, 2017, MAPA, 2016, 2018a). The exports projection of commodity was estimated from the premise that Brazil's share of the world trade flow will reach about 43% by 2030 (FAO, 2006, 2012, 2016). As a result, the sugar production growth rate in the 2017-2030 period is 1.4% per year, reaching 45.8 million tons in 2030, as Chart 7 Next.

Chart 7 – Sugar Production



Source: EPE based on FAO (2006, 2012, 2016), ISO (2017) and MAPA (2016, 2018a)

For the high growth scenario, sugar production reaches 48.8 million tons in 2030, with a 45% participation of Brazil in the world trade flow.

[9] To estimate effective capacity, a grinding capacity factor should be applied to consider any unscheduled downtime for technical or climatic operational reasons. In this study, it is considered 90%.

3.2.3. Corn Ethanol

It was admitted that the largest number of corn ethanol production units will be of flex type, similar to most of those currently in operation. Thus, it may be possible to take advantage of low prices of corn, as the logistics costs of outflow from the Center-West region significantly impact the competitiveness of the product in the international market. It is important to note that there is a large-scale dedicated unit installed in 2017 that has expansion plans. By 2030, corn ethanol production is projected to reach 1.5 billion, 2.3 billion and 3.4 billion liters for low, medium and high growth scenarios, respectively. It is estimated that there will be the entry of nine units in the period.

3.2.4. Energy Cane

It is estimated that the insertion of energy cane (EC) will occur gradually, so that this variety will represent, in 2030, only a small portion of the total sugarcane production area (approximately 260 thousand ha in medium and low growth scenarios) and 500 thousand ha in the high growth scenario). It was further evaluated that EC should preferably be employed in ethanol production.

4. Results – Supply Expansion Studies

The results of the projected area harvested, productivity, processed sugarcane, total produced TRS, ethanol supply, bioelectricity, biogas, GHG emission reduction and investments, for each scenario, are presented below, considering the assumptions already exposed.

Sugarcane Area Processed

The area destined to the sugar and alcohol sector has shown significant growth in recent period, mainly due to the growth of ethanol demand for full-flex vehicles but also by the growing demand for sugar. From 2000 to 2017, the area under cultivation expanded 3.9 million hectares at a rate of 3.6% per year. (CONAB, 2018a, 2018b).

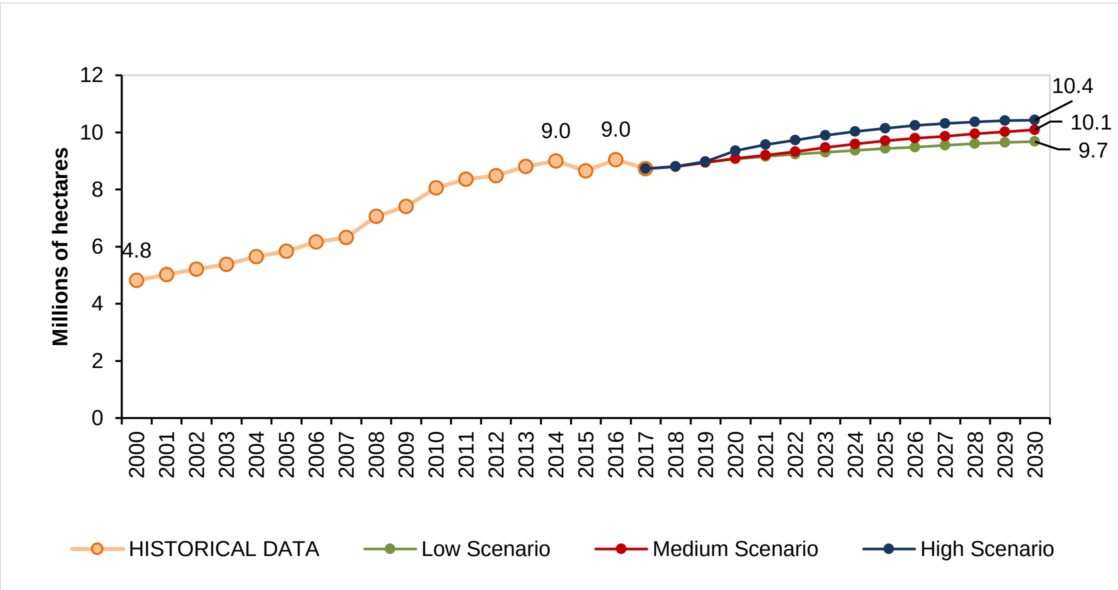
Considering the assumptions of installed capacity and implementation of new units, the projected sugarcane area projections show the growth rates indicated in Table 2 and in Chart 8

Table 2: Growth rate and variation of processed sugarcane area

	2017 - 2025		2017 - 2030	
Scenarios	Rate (%)	Variation (Mha)	Rate (%)	Variation (Mha)
Low growth	1.0	0.7	0.8	0.9
Average growth	1.3	1.0	1.1	1.4
High growth	1.9	1.4	1.4	1.7

Source: CONAB based EPE (2018a)

Chart 8 – Sugarcane Area Processed



Source: CONAB based EPE (2018a, 2018b)

Productivity

The productivity growth rate between 2000 and 2009 was 2.1% pa, when it reached its peak, 81.6 tc/ha. From this year on, previously mentioned issues — as the mismatch between the mechanization of the harvest and the planting, with consequent inadequate agricultural management, and climate issues and debt problems after the 2008 crisis — reduced this level, which oscillated around 70 tc/ha, with a minimum of 67.1 tc/ha in 2011 (CONAB, 2018a, 2018b). From 2012 onwards, this indicator started to recover, reaching 72.5 tc/ha in 2017, corresponding to a rate of 1.3% pa, when considering the base year 2011.

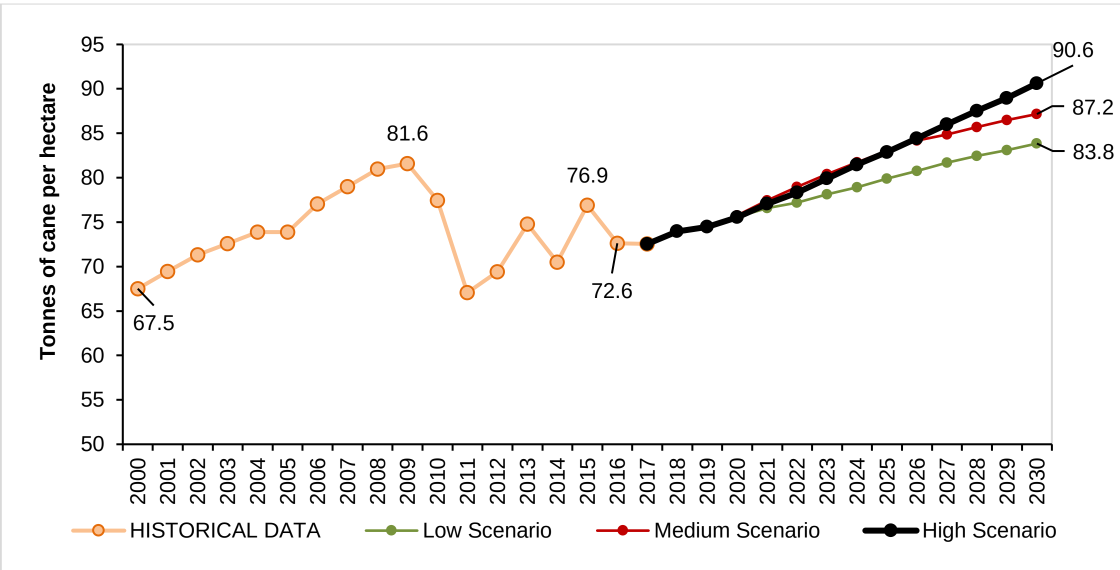
For the projection, between 2017 and 2030, according to the qualitative assumptions described for each scenario, the productivity gains obtained are presented in Table 3 and in Chart 9 Next:

Table 3: Growth rate and productivity change

	2017 - 2025		2017 - 2030	
Scenarios	Rate (%)	Variation (tc/ha)	Rate (%)	Variation (tc/ha)
Low growth	1.2	7.4	1.1	11.3
Average growth	1.7	10.5	1.4	14.6
High growth	1.7	10.3	1.7	18.1

Source: CONAB based EPE (2018a)

Chart 9 – Sugarcane Productivity



Source: CONAB based EPE (2018a and 2018b)

Cane Processed

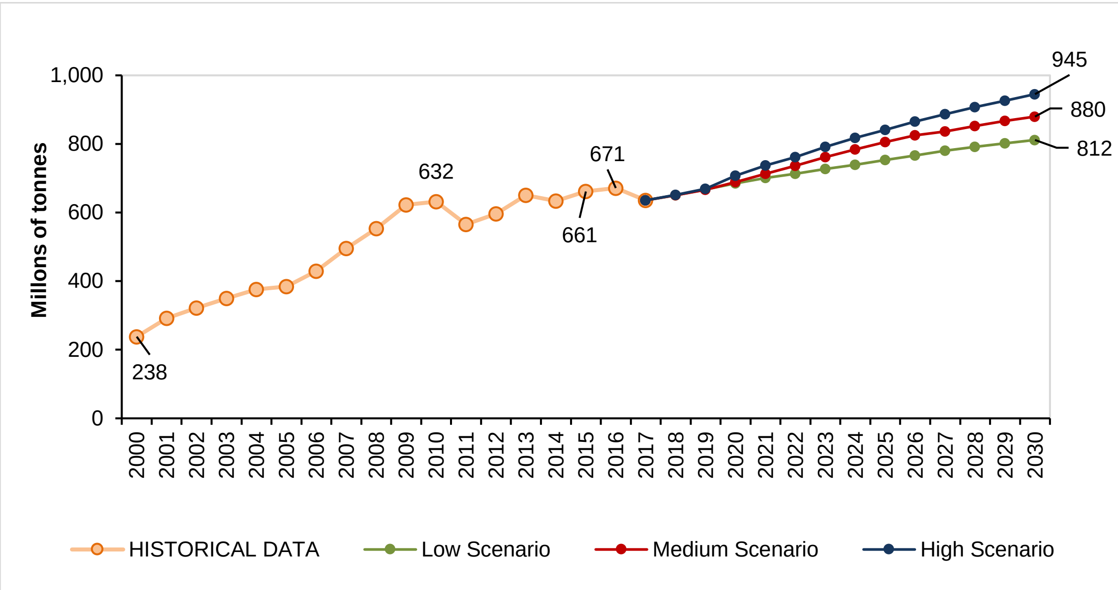
From the area and productivity estimates, the projection of the processed sugarcane on the study horizon is obtained. Its expansion between 2000 and 2017 was 398 million tons of sugarcane, at a rate of 6.0% per year, even considering periods of oscillation between 2010 and 2017, for the reasons mentioned above (MAPA, 2018a). The processed sugarcane projections for each of the scenarios are presented in Table 4 and in Chart 10.

Table 4: Processed sugarcane growth rate and variation

Scenarios	2017 - 2025		2017 - 2030	
	Rate (%)	Variation (Mtc)	Rate	Variation (Mtc)
Low growth	2.1	118	1.9	176
Average growth	3.0	170	2.5	244
High growth	3.6	205	3.1	309

Source: MAP-based EPE (2018a)

Chart 10 – Processed Cane



Source: EPE based on MAPA (2018a)

Total Recoverable Sugars (TRS)

As a result of the area composition, productivity and yield, the total produced TRS is obtained, which will vary for each scenario, according to the assumptions for each of these factors of production.

It is noteworthy that the history in the 2000-2017 period presented a rate of 3.9% per year and an increase of 42.2 million tons (CONAB, 2018a, 2018b; MAPA, 2018a).

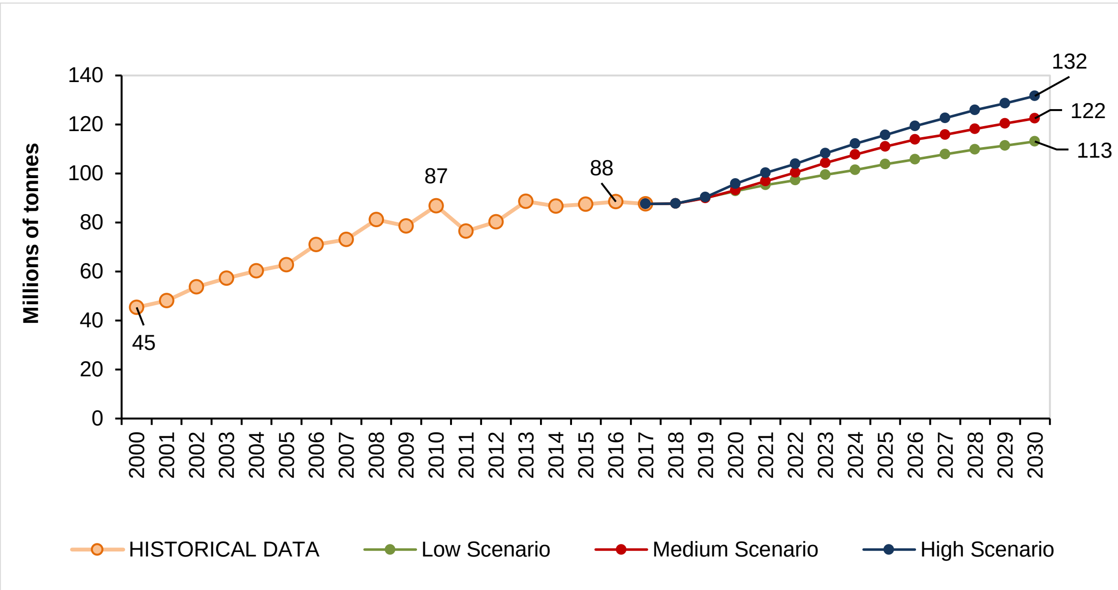
Table 5 and Chart 11 bellow shows the growth rate and TRS variation between 2017 and 2030.

Table 5: TRS growth rate and change

	2017 - 2025		2017 - 2030	
Scenarios	Rate (%)	Variation (M ton)	Rate (%)	Variation (M ton)
Low growth	2.1	16.2	2.0	25.5
Average growth	3.0	23.4	2.6	35.0
High growth	3.6	28.2	3.2	44.1

Source: EPE based on CONAB (2018a) and MAPA (2018a)

Chart 11 – Total Recoverable Sugars (TRS)



Source: EPE from CONAB (2018a, 2018b) and MAPA (2018a)

Total Ethanol Supply

Finally, the portion destined to sugar, showed in Item 3.2.2, is deduced from TRS produced, and the national production of ethanol is obtained, which, added to the imported ethanol, results in the total supply of ethanol.

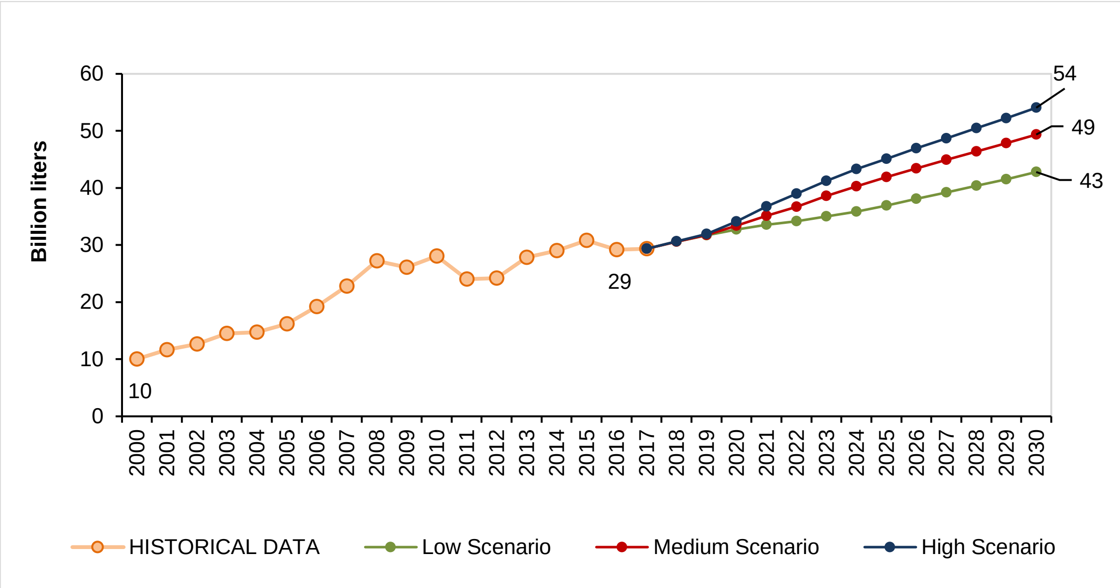
The expansion of ethanol supply between 2000 and 2017 was 19.4 billion liters, with a rate of 6.5% per year, even considering a period of oscillation between 2009 and 2013, for the reasons mentioned above (CONAB, 2018a, 2018b; MAP, 2018a). Table 6 and Chart 12 show the growth rates and variation of ethanol supply for each scenario.

Table 6: Growth rate and variation of total ethanol supply

	2017 - 2025		2017 - 2030	
Scenarios	Rate (%)	Variation (Bi liters)	Rate (%)	Variation (Bi liters)
Low growth	2.9	7.6	2.9	13.4
Average growth	4.5	12.6	4.1	20.0
High growth	5.5	15.7	4.8	24.7

Source: EPE based on CONAB (2018a) and MAPA (2018a)

Chart 12 – Total ethanol supply



Scenario (Bi ℓ)	2020	2025	2030
Low growth	**32.7**	**36.9**	**42.8**
Average growth	**33.4**	**41.9**	**49.4**
High growth	**34.1**	**45.1**	**54.0**

Source: EPE based on CONAB (2018a, 2018b) and MAPA (2018a)

Bioelectricity

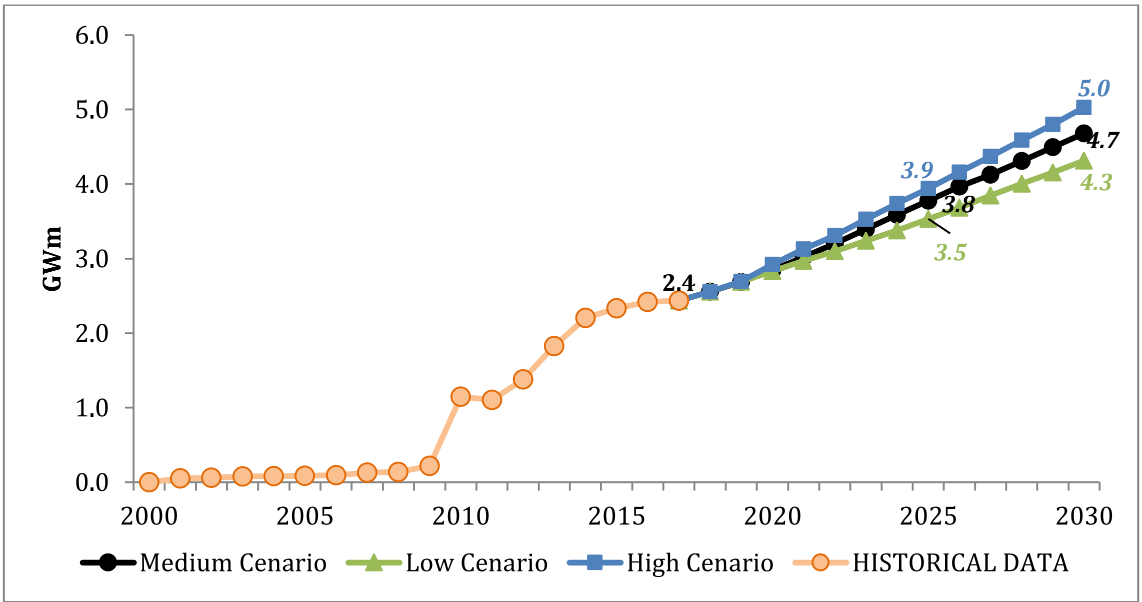
The energy use of the residual biomass generated in the industrial processing of sugarcane, both in heat and electricity production, is intended for self-consumption and the production of surplus electricity, exported to the National Interconnected System (SIN).

Its sharing in the electric matrix is important because it occurs near large consumption centers and in periods of greater water scarcity, reducing the demand for fossil fuels. In 2016, bioelectricity accounted for 8.2% of the national electricity matrix, and over 85% of this production used as input the residues of the sugar-energy industry (EPE, 2018d).

From the projection of sugarcane biomass supply, the study made two estimates of bioelectricity supply to the grid: (1) the construction of the bioelectricity exports curve, based on the historical behavior of the sector[10] and (2) the calculation of the technical potential, based on data from the winning plants of the energy auctions.

Based on the historical behavior of the sugar-energy sector, the amount injected to the SIN in the year 2030 is 5.0 GWm, 4.7 GWm and 4.3 GWm, respectively, for the high, medium and low growth scenarios, as showed Chart 13 bellow.

Chart 13 – Bioelectricity projection from history (conversion curve)

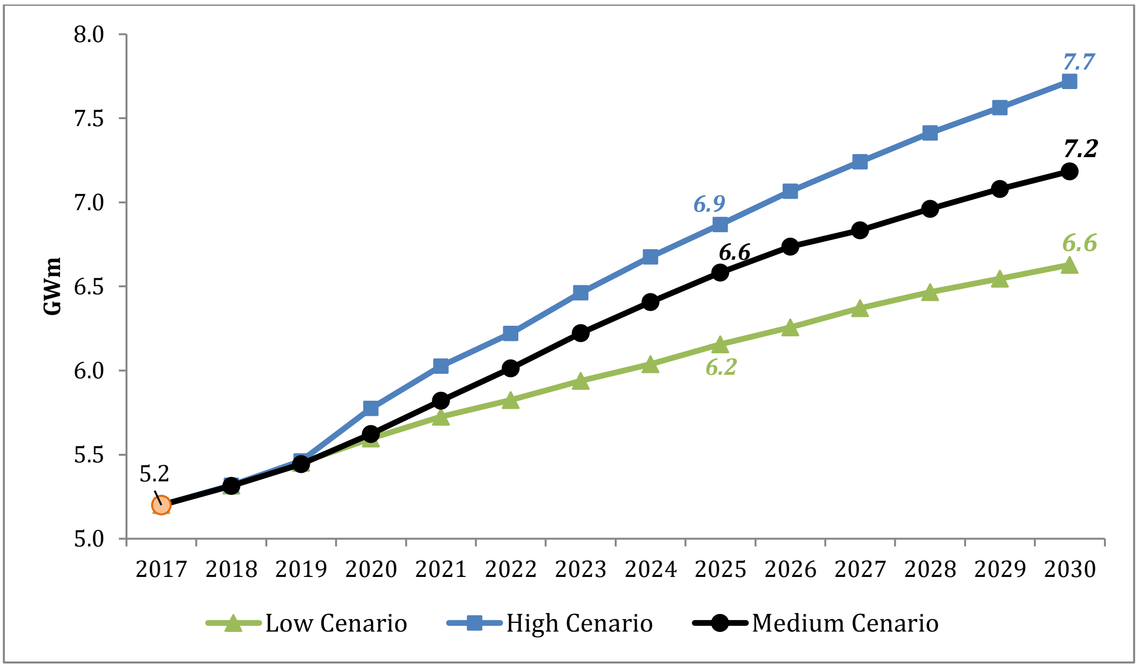


Source: EPE based on CCEE (2018)

The projections of the technical potential showed in Chart 14 illustrate that the total energy from the injected sugarcane bioelectricity in the year 2030 could range from 6.6 GWm to 7.7 GWm, representing the low and high growth scenarios, respectively.

[10] This methodology accounts for the entire national sugarcane park, including all sugarcane processed in the country and all the energy exported by the sector, and not only the data related to the auctions winners.

Chart 14 – Bioelectricity projection from technical potential



Source: EPE based on CCEE (2018)

Biogas

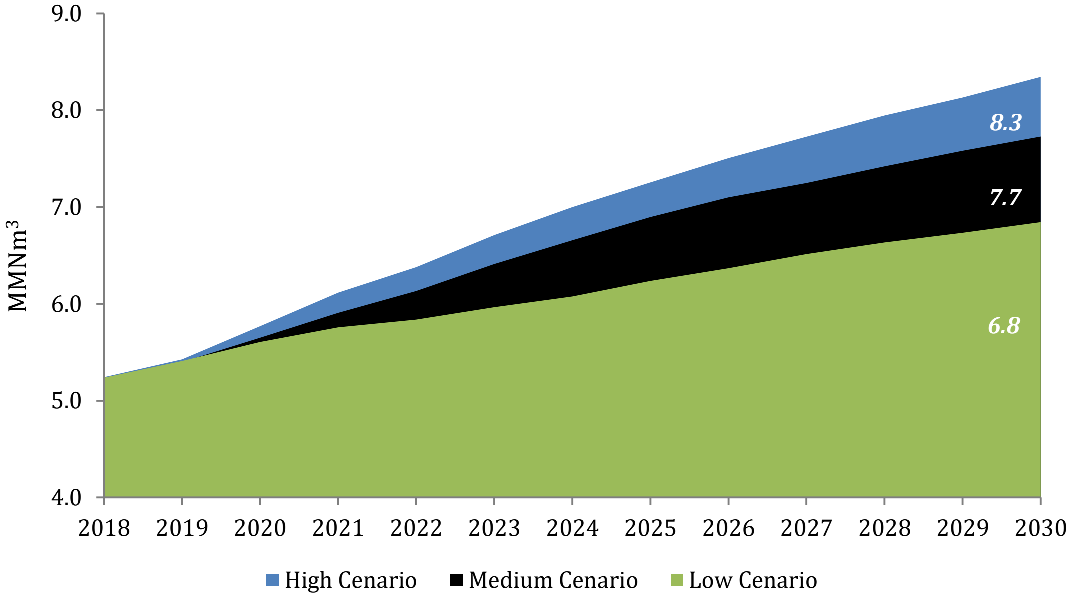
The potential for biogas production in the sugarcane segment is very high. In the present study, an estimate was made of the energy utilization potential of the main byproducts of the ethanol and sugar production processes: vinasse and filter cake.

In current ethanol production technologies, each liter of biofuel generates about 10 liters of vinasse, a significant amount. This waste is widely used in irrigation of sugarcane fields. However, recent data indicate soil fatigue closer to the processing plants due to the excessive presence of some chemical compounds present in the vinasse. Filter cake is another residue of the sugarcane industry, obtained from the filtering of sugarcane juice, and is therefore inherent to both ethanol and sugar production. As this waste is made available on the same industrial site, there are a number of logistical facilities for its use.

Still little used for energy generation in sugarcane plants, the fermentation of vinasse and filter cake gives rise to biogas, a destination of these inputs that is a better than the current one. In general, biogas is mostly composed of methane gas (55-70% v/v), carbon dioxide (30-45% v/v), and small amount of hydrogen sulfide (H_2S–200–4000 ppm/v)

Due to the presence of methane, this energy input can be used as a source of electricity generation or as a substitute for diesel in engines of agricultural machinery. As illustrated in Chart 15, considering that all vinasse and filter cake are directed to biogas production, the total volume generated may vary between 8.3 MMNm^3 for the high growth scenario and 6.8 MMNm^3 for the low.

Chart 15 – Biogas production potential



Source: EPE (2018b)

Greenhouse Gas Emissions Avoided

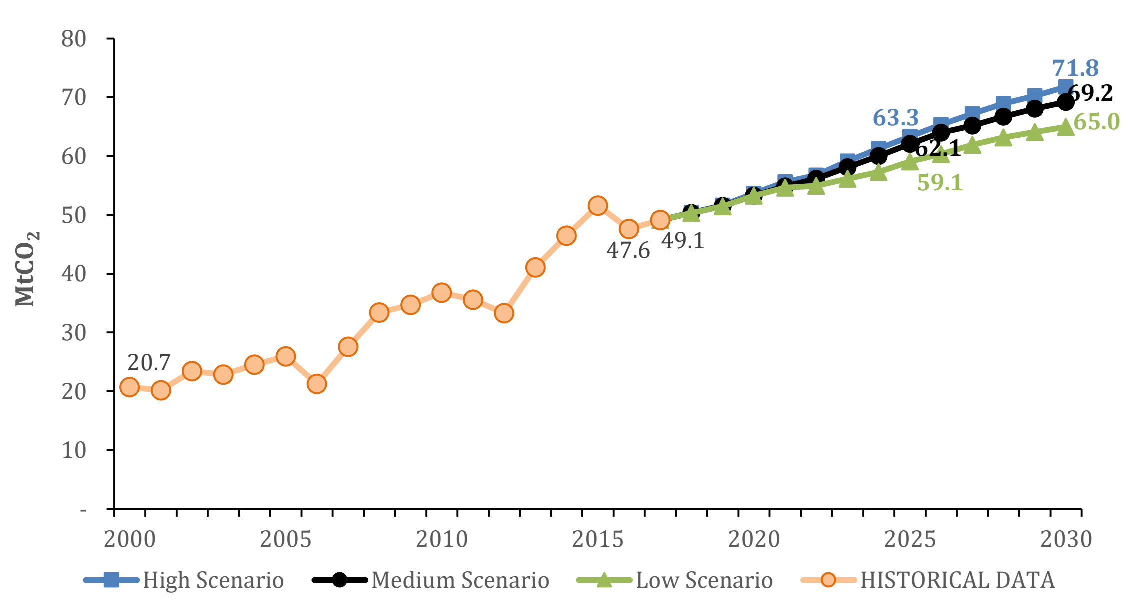
The use of fuel ethanol, either by mandatory (anhydrous) or by the free choice of the consumer in his flex-fuel (hydrated) vehicle, contributes to lower consumption of its fossil substitute (gasoline) and, consequently, to the reduction of GHG emissions.

In addition to liquid biofuels, sugarcane bioelectricity also contributes to the mitigation of CO_2, considering both the self-consumption by sugarcane units and the energy exported to SIN. To estimate the avoided emissions, the tCO_2 emission factor per MWh generated was used, calculated by the Ministry of Science, Technology, Innovation and Communication (MCTIC, 2018). 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 energy. In 2017, contrary to the movement observed in 2015 and 2016, this emission factor increased by 13.5%, from 0.0817 tCO_2/MWh to 0.0927 tCO_2/MWh.

Based on the above exposition, it was possible to estimate the avoided CO_2 emissions due to the consumption of ethanol, anhydrous and hydrated, and the generation of bioelectricity for each of the studied scenarios. Taking the most conservative approach to bioelectricity[11] (Chart 13) and considering the fuel demand for ethanol, up to 72 $MtCO_2$ could be avoided with the high Scenario and 65 $MtCO_2$ with the low scenario as illustrated in Chart 16 below.

[11] For projections of emissions avoided with bioelectricity the factor used corresponds to the annual average of the last ten years.

Chart 16 – Avoided GHG emissions from ethanol use and bioelectricity



Source: EPE based on EPE (2009) and MCTIC (2018)

Scenario ($MtCO_2$)	2020	2025	2030
Low growth	**53.3**	**59.1**	**65.0**
Average growth	**53.3**	**62.1**	**69.2**
High growth	**53.7**	**63.3**	**71.8**

Investments

For the evaluation of the necessary investments, we considered first generation sugar-energy units (greenfields) – mixed or distilleries[12] – with optimized technological profile and average size of four million tons of nominal cane processing capacity. It is estimated that *capex* average for this profile is R$359.80/tc (CTBE, 2018), as detailed in Table 7 below. It was adopted as the specific investment value for the expansion of existing units in the order of R$260/tc.

Table 7: Average investment for new units and expansion of existing ones

CAPEX	R$ (DEZ. 2017) / tc
Expansion of existing units (*Brownfield*)	**256.0**
New units (*Greenfield*)	**359.8**
Industrial (includes optimized cogeneration)	287.6
Agricultural machinery (includes trucks)	67.9
Land leasing (Center-West region)	4.3

Source: CTBE based EPE (2018)

The estimated investments in new lignocellulosic-ethanol processing plants took into account the values of the commercial units operating in Brazil, estimated at R$5.6/liter. It is emphasized that this value should be smaller, due to the learning curve of the sector. For

[12] Substitutions for industrial equipment for ethanol and/or sugar production are considered.

corn ethanol it is estimated that the *capex* for the implementation of a plant flex R$0.75/liter, while for a processing plant full, the value is R$1.50/liter (CTBE, 2018 and UNEM, 2018).

Thereby, an estimate was made of the investments required in new units for the scenarios considered, as Table 8.

Table 8: Estimated investment for new projects and expansions

Capex (Billion R$)	Low	Average	High
Greenfields	**25.2**	**39.7**	**46.4**
Brownfields	**8.0**	**14.0**	**40.0**
Total	**33.2**	**53.7**	**86.4**

Source: EPE based on CTBE (2018) and UNEM (2018)

5. Results – Fuel Demand

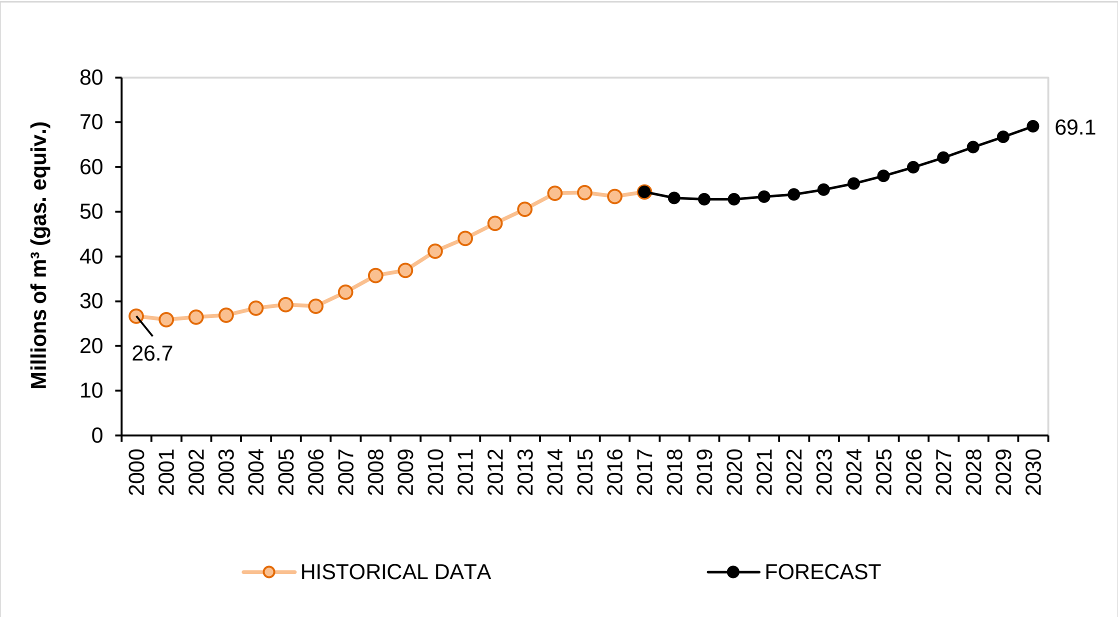
In this item, the evolution of global fuel demand for the light-duty vehicle fleet (automobiles and light-duty commercial vehicles) of the Otto cycle will be presented, for the three scenarios of ethanol supply elaborated here, considering a percentage of anhydrous ethanol mixture in gasoline type C of 27% throughout the period.

Global fuel demand is projected through an accounting model developed by EPE (2010), which considers, besides the economic scenario (EPE, 2018c), several other aspects, such as the licensing of light-duty vehicles, the domestic supply of ethanol, the domestic price of gasoline and consumer preference between gasoline and ethanol, when supplying flex-fuel vehicles.

The licensing trajectory considered results in an increase of the national Otto-cycle fleet, which grows from 2017 to 2030, at an average annual rate of 3.1%, reaching 54.4 million units in 2030. At the end of this period, flex-fuel vehicles with internal combustion will account for 90% of this fleet.

Thus, for the period from 2017 to 2030, the estimated growth rate for fuel demand of the total Otto cycle light vehicle fleet (without CNG) is 1.9% per year. Chart 17 presents this evolution, expressed in millions m³ of gasoline equivalent.

Chart 17 – Otto-cycle demand*



Source: EPE from EPE (2018d)

Fuel Ethanol

The demand for fuel ethanol is obtained from the total ethanol supply, removing the portions of exported biofuel and those destined for other purposes, presented in the Common Assumptions item (3.1). From this amount, it was estimated the demand of dedicated fleets, powered by gasoline type C and hydrous ethanol, as well as the share of flex-fuel vehicle demand which will be met by hydrous ethanol and gasoline type C (gasoline type A + anhydrous ethanol).

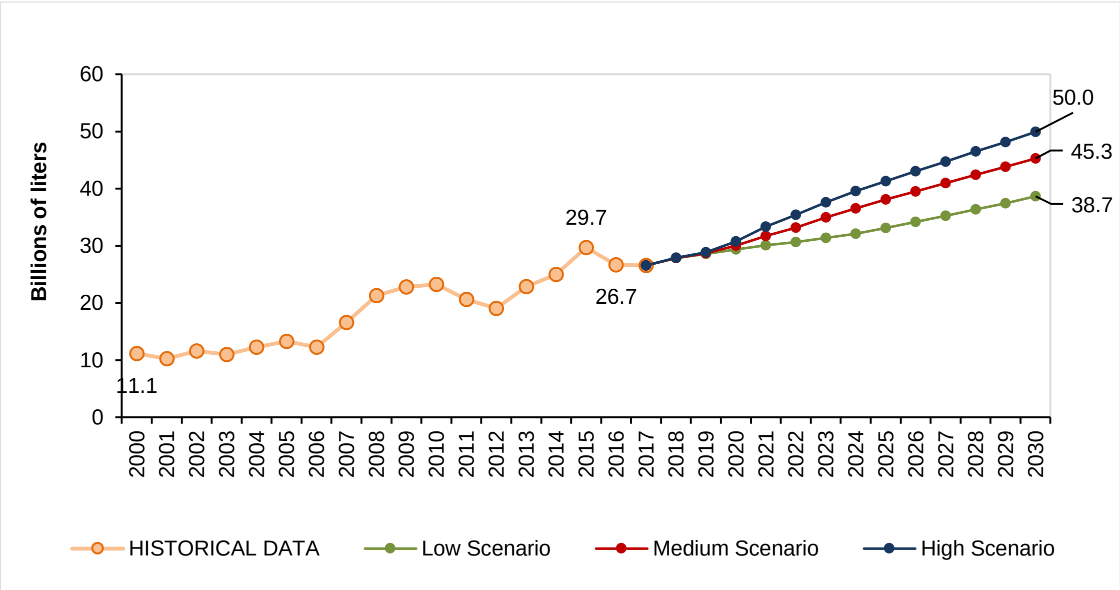
It should be noted that between 2000 and 2017, fuel ethanol demand grew by 15.4 billion liters at a rate of 5.3% per year, even considering the period of fluctuation in ethanol supply between 2009 and 2013 (MAPA, 2018a ; EPE, 2018d), cited above. Table 9 and Chart 18 present growth rates and variations in fuel ethanol demand between 2017 and 2030.

Table 9: Growth rate and variation of fuel ethanol demand

	2017 - 2025		2017 - 2030	
Scenarios	Rate (%)	Variation (Bi liters)	Rate (%)	Variation (Bi liters)
Low growth	2.8	6.5	2.9	12.1
Average growth	4.6	11.5	4.2	18.7
High growth	5.7	14.7	5.0	23.4

Source: EPE from EPE (2018d)

Chart 18 – Fuel ethanol demand



Source: EPE from EPE (2018d)

Gasoline type A

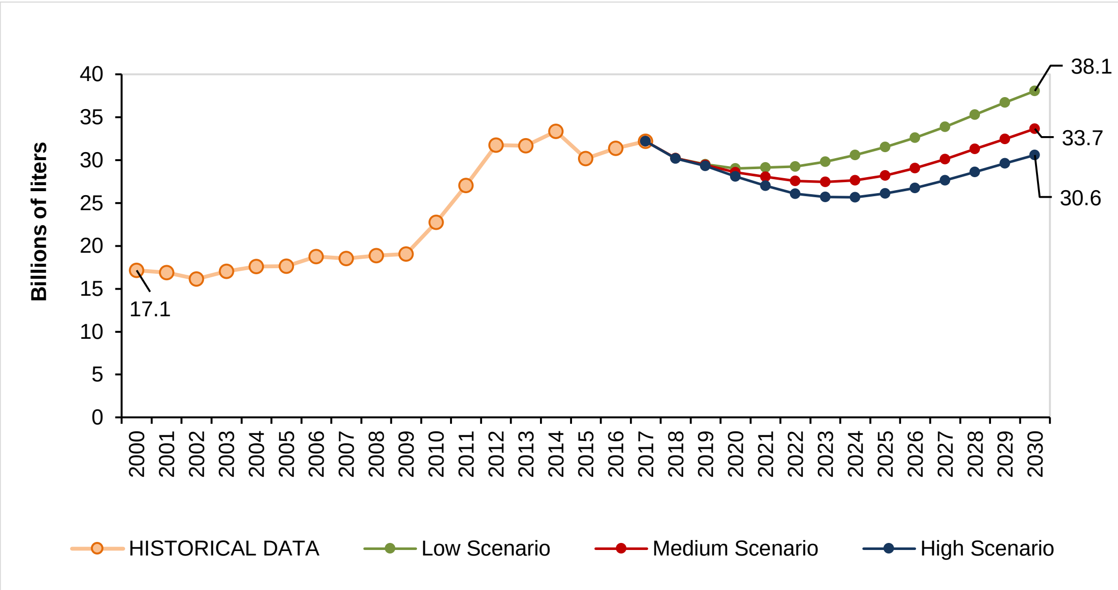
The demand for gasoline type A is intended to serve both the dedicated gasoline fleet and the flex-fuel fleet that consumes this fuel. It is estimated that by 2030 the volume of this fuel will reach 33.7 billion liters for the medium growth scenario. Table 10 and Chart 19 present growth rates and changes in demand for gasoline type A between 2017 and the years 2025 and 2030.

Table 10: Gasoline type A demand growth rate and change

	2017 - 2025		2017 - 2030	
Scenarios	Rate (%)	Variation (Bi liters)	Rate (%)	Variation (Bi liters)
Low growth	- 0.3	- 0.7	1.3	5.8
Average growth	- 1.7	- 4.0	0.3	1.4
High growth	- 2.6	- 6.1	-0.4	-1.6

Source: EPE from EPE (2018d)

Chart 19 – Gasoline type A demand

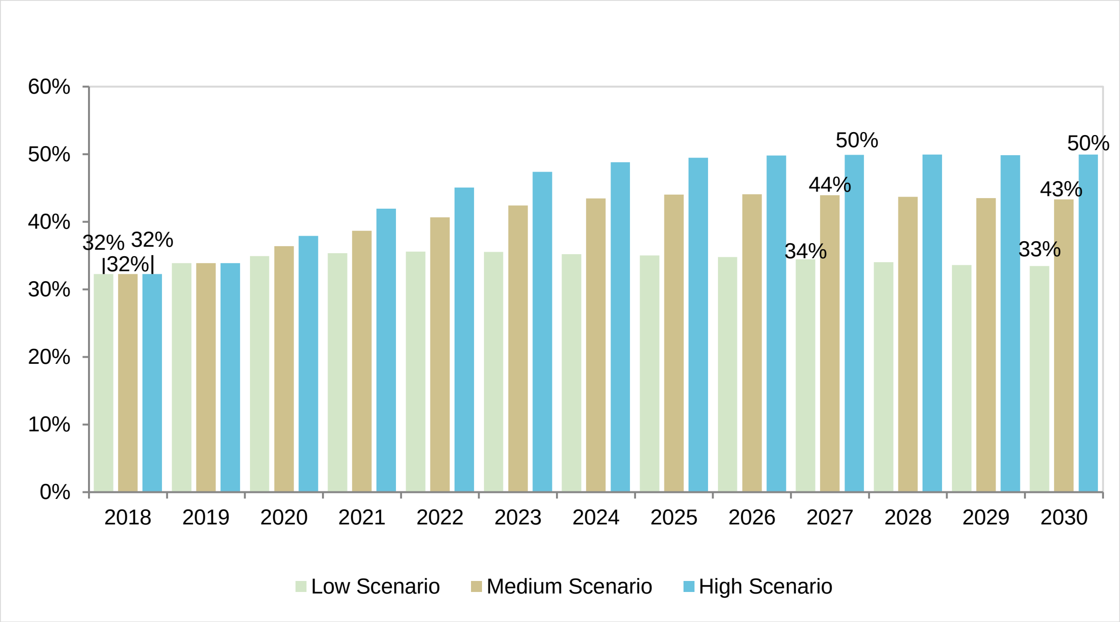


Source: EPE from EPE (2018d)

Market share of hydrated in flex fuel

From the availability of hydrated fuel ethanol, it is verified the trajectory of its participation in the demand of the Otto cycle. In Chart 20, it is noted that this amount will result in an increase of market share of hydrous ethanol in fleet flex. This share goes from 32% in 2018 to reaches in 2030, 33%, 43% and 50% in the low growth, medium growth and high growth scenarios, respectively. These percentages are lower than those observed in the 2007-2010 period, which ranged from 53% to 71%.

Chart 20 – *Market share* hydrous ethanol in the flex fuel (by volume)



Source: EPE

National Balance of Gasoline Type A

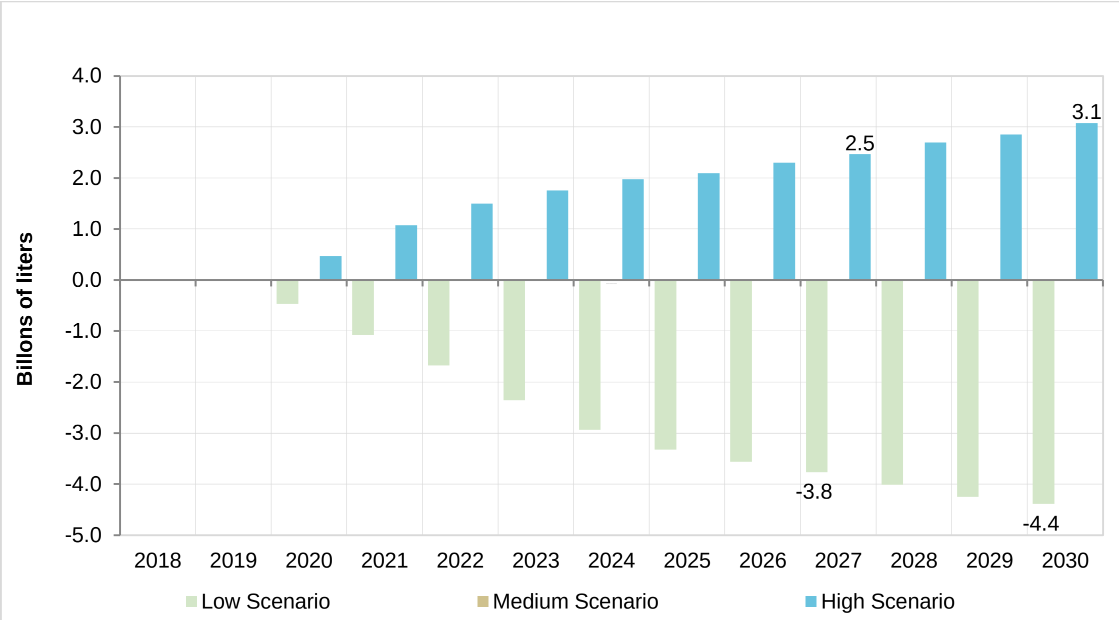
To assess the gasoline type A balance over the study horizon, we considered the scenarios of ethanol supply consolidated in this study, the historical data of national production of this fuel (EPE, 2018d), and its production projection, as published in PDE 2026.

Since gasoline and naphtha fractions are obtained from similar oil cuts, the supply of gasoline ultimately results from the demand analysis, prices and logistic flows of these derivatives. However, there are other factors that also influence this market flow, such as the opportunity cost of ethanol and sugar, and crop conditions. Thus, although there is a set of indications for domestic production of gasoline, it may be influenced by the factors mentioned above, resulting, for example, in minimum import volumes.

The resulting demand of gasoline type A from the scenario of average ethanol supply growth resides, until 2028, in a range lower than the record national production of this derivative, equivalent to 31 billion liters in 2014 (EPE, 2018d). Since then, this level is exceeded, reaching 33.7 billion liters in 2030. Given the projections of the demand for the Otto cycle and for anhydrous and hydrated ethanol, it was considered that its national production will follow the demand of the medium growth scenario, in which case there would be no need to import gasoline throughout the horizon of study.

For the high growth scenario, since ethanol production is higher than in other scenarios, the excess volumes allow the refining park to meet the demand for other light derivatives that use fractions similar to gasoline. Adopting gasoline production throughout the study horizon A resulting from the medium growth scenario, it is observed that, in the scenario of low ethanol supply growth, it would be necessary to increase the production of gasoline and/or carry out imports from 2020. In this case, the imported volume would reach 4.4 billion liters in 2030, slightly lower than in 2017 (4.5 billion liters) (EPE, 2018d). Chart 21 illustrates the evolution of the gasoline type A balance in Brazil for the three elaborated ethanol supply scenarios.

Chart 21 – National balance of type A gasoline (by volume)



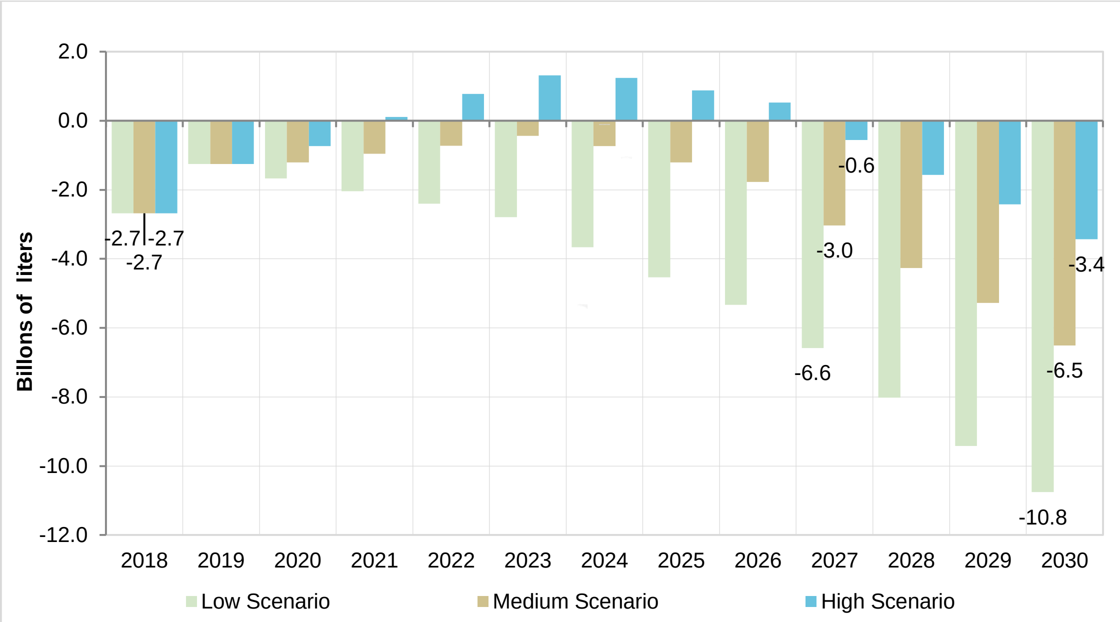
Source: EPE

In order to estimate the impact on the domestic supply of Otto-cycle light-duty vehicles, the present study performed a sensitivity analysis considering that the production of gasoline type A will correspond to that presented in the 2026 Ten Year Energy Expansion Plan (EPE, 2017b), in which it reaches 27.2 billion liters in 2030, remaining below historical maximum production (EPE 2018d).

This exercise showed that, for all scenarios, import volumes of gasoline type A will be required throughout the horizon, except for the high growth scenario, as can be seen in Chart 22. In this superior trajectory, only in the interval between 2021 and 2026, the demand for gasoline type A will be lower than its production, allowing the refining park to meet the demand for other light derivatives that use fractions similar to gasoline. However, thereafter, a deficit of the fossil derivative, 600 million liters in 2027, again comes to an import demand of 3.4 billion liters in 2030.

For the medium growth scenario, imports of gasoline type A will be 1.2 billion liters by 2025 (well below the historical high of 4.5 billion liters in 2017) and will reach 6.5 billion liters by 2030. Already in the scenario of low growth, imports reach the value of 10.8 billion liters in 2030.

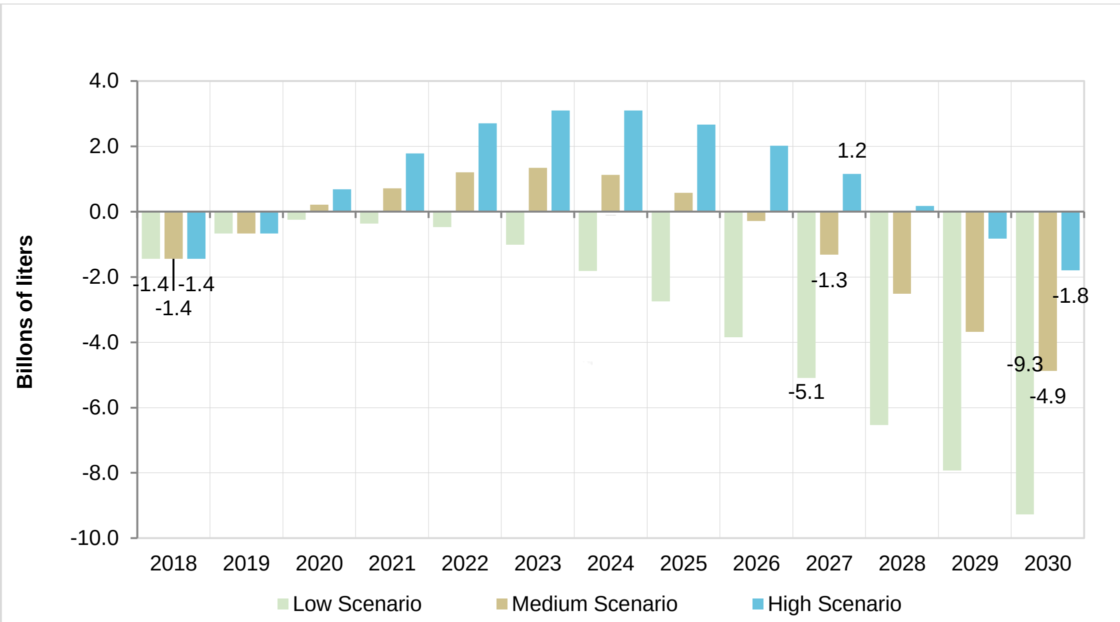
Chart 22 – National balance of gasoline A – PDE production 2026 (in volume)



Source: EPE

Finally, another sensitivity analysis was performed, considering that the production of gasoline A will correspond to the average of the last five years (28.8 billion liters) (EPE, 2018d). In Graph 23, assessing the gasoline type A balance, it is observed that the medium growth scenario requires imports in 2018 and 2019, and from 2026, reaching 4.9 billion liters in 2030. Already low growth needs import volumes throughout the period, reaching 9.3 billion liters in 2030. For the high growth scenario, there would be a need for imports in 2018 and 2019, and in 2029 and 2030 (when it reaches 1.8 billion liters).

Chart 23 – National balance of gasoline type A – average last five years (in volume)



Source: EPE

BOX – Sensitivity analysis

This Box aims to present a sensitivity analysis for ethanol supply and Otto cycle demand, considering an even more unfavorable scenario for the biofuel sector, regarding public policies, companies' actions to reduce production costs and financial restructuring of indebted groups. In addition, international oil prices will remain at moderate levels. Thus, despite RenovaBio, the economic attractiveness of the sugar-energy sector would not be sufficient to induce relevant investments.

In this sense, it was considered that there will be no greenfield unit project in the mid term and that production indicators will be lower than those presented in the Low Growth scenario.

In terms of sugarcane grinding production capacity, only one unit is considered (already in implementation in 2018). Additionally, the balance of reactivations and shutdowns will lead to a reduction of 3 production units, resulting in a small loss of processing capacity, less than 1 million tons of sugarcane.

In this scenario, yield, exports, ethanol for other uses, sugarcane area and national sugar production were considered the same as those presented for the average growth scenario. Second-generation ethanol production will be 1.0 billion liters in 2030, half of the average growth scenario, while corn ethanol will reach 0.9 billion liters at the end of the period.

Installed capacity will remain broadly stable in 2030 at 828 Mtc (nominal) and 745 Mtc (effective). The processed sugarcane area is 9.3 Mha and agricultural productivity will reach 79.8 tc/ha by 2030 (similar to that shown in 2007). As a result, an estimated 745 million tons of ground cane at the end of the period. Ethanol supply will reach about 34 billion by 2030, just 4.6 billion liters higher than in 2017.

Of this volume, discounting the ethanol installments for other purposes and for exportation (Item 3.1), the available ethanol is balanced against the demand of the Otto cycle, so that the volumes of 33.7 billion liters of gasoline type A and 29.9 billion liters of fuel ethanol are obtained in 2025. By 2030, these figures would reach 43.0 billion liters of gasoline type A and 31.3 billion of ethanol. With that, the market share hydrated ethanol in the flex fuel will be on the order of 22% by 2030.

Finally, when analyzing the national balance of gasoline type A, assuming the demand of the scenario of average growth of this fuel, as well as the reference production, it is estimated that it would be necessary to increase the production of gasoline and/or to carry out imports throughout the period. This figure would reach 9.4 billion liters in 2030, 22% of the forecast demand for those years, exceeding the imported historical maximum of 4.5 billion in 2017 (EPE 2018d).

Adopting the production of gasoline type A presented in PDE 2026 (EPE, 2017b), it is necessary to import 15.7 billion liters in 2030, which corresponds to 37% of the fossil fuel demand.

When considering the average volume of gasoline type A production of the last five years (28.8 billion liters) (EPE, 2018d), the import requirement in 2030 would be 14.3 billion liters, corresponding to 33% of the forecasted demand for that year.

6. Conclusion

This document aimed to present the ethanol supply scenarios considered for the 2017-2030 period and their respective reflexes in the Otto cycle demand and in the national balance of gasoline A.

The scenarios elaborated indicate variations in the fuel ethanol supply, considering the assumption of alignment of ex-refinery gasoline price with international quotations, actions in the sector aimed at reducing costs (sugarcane renewal, adequate cultural treatment, etc.) and policies to encourage ethanol (tax and contributory differentiations, provision of financing lines for the sector, among others). That is, different assumptions about the degree of economic attractiveness for investments in the sugar-energy sector.

As a result of these projections, ethanol supply volumes could reach 43 to 54 billion liters by 2030. Based on the estimated Otto cycle demand and fuel production corresponding to the medium growth scenario, it would only be necessary to increase production of gasoline type A and/or import from 2020 onwards in the low growth scenario.

However, when a sensitivity analysis is performed, in which gasoline type A production corresponds to that presented in the 2026 Ten Year Energy Expansion Plan, imports of this derivative would be required for all scenarios over the entire horizon, except for the range 2021-2026, for the high growth. In 2030, these imports would reach 6.5 billion liters in the medium growth scenario, below the historical maximum already imported (4.5 billion in 2017) and 10.8 billion liters in the low growth scenario. In the scenario of high growth there would be a need for imports of 3.4 billion liters in 2030.

Considering a sensitivity analysis, where gasoline type A production will correspond, over the entire period, to the average of the last five years (28.8 billion liters), imports of this derivative would be necessary in 2018 and 2019 for all scenarios. In relation to the scenario of low ethanol supply growth, the deficit would remain throughout the period. For the average growth scenario, this behavior is observed from 2026. Imports would reach, in 2030, 5.0 billion liters in the medium growth scenario, close to the historical high already imported (4.5 billion in 2017) and 9.4 billion liters in the low growth scenario. In the scenario of high growth, there would be a need for imports, beginning in 2029, and reaching 1.9 billion liters in 2030.

The document showed that the contribution of sugarcane biomass to the national energy scenario could become even more relevant. The share of bioelectricity in the most conservative assessment could inject by 2030 up to 5.0 GWm in the high growth scenario and 4.3 GWm in the low growth scenario. In addition, the use of vinasse and filter cake for biogas production, for this same horizon, would enable the generation of 8.3 MMNm^3 and 6.8MMNm^3 for the mentioned scenarios, respectively.

On the other hand, aware of the international commitments made by Brazil, avoided GHG emissions from the use of sugarcane products are very relevant in the national scenario. Considering the demand for ethanol for fuel purposes and the participation of bioelectricity in the most conservative analysis, the avoided values may vary, in 2030, between 72 $MtCO_2$ and 65 $MtCO_2$, for the high and low growth scenarios, respectively.

The implementation of RenovaBio and the degree of effectiveness of the agents' decisions regarding their stimuli will define the ethanol supply trajectory until 2030.

The analysis of the consequences of this study is relevant to determine the magnitude and scope of public policies aimed at supplying the Otto-cycle vehicle market and meeting the international commitments of Brazil under the Paris Agreement, contributing to energy planning. in the mid and long term.

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