TECHNICAL NOTE

ETHANOL SUPPLY SCENARIOS AND OTTO CYCLE DEMAND: 2026 - 2035

MINISTÉRIO DE MINAS E ENERGIA

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EPE conducts studies and research to subsidize the formulation, implementation, and evaluation of Brazilian energy policy and planning.

With this document, EPE brings transparency and reduces information asymmetry by presenting data and facts that can assist in debates regarding energy transition efforts in Brazil. This Technical Note presents scenarios for sugarcane and corn ethanol supply and their developments for Otto cycle fuel demand and on the national balance of gasoline A.

The document also addresses sugarcane bioelectricity, biomethane production, emissions avoided by the use of biofuels, as well as the allocation of ethanol for the production of sustainable aviation fuels and for waterway use.

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Introduction

The Energy Research Office (Empresa de Pesquisa Energética - EPE) releases its tenth 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 national supply of Otto cycle light vehicles (ethanol and automotive gasoline). Considering EPE's reference transport demand, scenarios for sugarcane and corn[1] ethanol supply and their developments for fuel demand and on the national balance of gasoline A are presented up to the 2035 horizon. The study also contemplates the supply of sugarcane bioelectricity exported to the National Interconnected System, the potential for biomethane production from sugarcane residues, with expansion trajectories of production capacity, and an evaluation of the investments associated with each scenario. Furthermore, the contribution of the sugar-energy sector and corn ethanol to the reduction of greenhouse gas (GHG) emissions is estimated. The projections presented also encompass the portion of this biofuel that is destined for the production of Sustainable Aviation Fuel (SAF) via the ATJ (Alcohol to Jet) route and for waterway use.

1. Contextualization

Brazil is one of the main producers of renewable fuels in the world, and this position is the result of various actions and public policies developed over time to encourage the increase of their participation in the energy matrix. Among these are the mandates for the mandatory addition of biofuels (ethanol and biodiesel) to petroleum derivatives, tax differentiation mechanisms between renewables and fossils, specific financing lines, and, more recently, the National Biofuels Policy (RenovaBio) and the Fuel of the Future Law (BRASIL, 2017, 2024; EPE, 2016, 2025a). Biofuels constitute a sustainable and renewable alternative for the energy transition and place Brazil in a prominent position with the challenge of stimulating actions in a fair and balanced manner, considering social inclusion and the fight against poverty.

Given its experience, Brazil can contribute to achieving the Sustainable Development Goals of the UN 2030 Agenda, which involves the production of raw materials for obtaining biofuel and its interrelation with the promotion and development of family farming. In addition to its role in food supply and its importance as a source of job generation in rural areas, income increase, and improvement of quality of life, family farming constitutes one of the social protection network policies that can cooperate in the fight to eradicate hunger and food insecurity on the planet. In this way, biofuel production directed by Brazilian energy policy can, in addition to collaborating with the renewability of the national matrix and mitigation of climate change, contribute to the eradication of poverty and the promotion of a dignified life for all (ONU, 2021). EPE has developed some studies in this regard, such as the article “Potential for expansion of biofuel production and associated impacts”, from the Biofuels Conjuncture Analysis: year 2024, and the Fact Sheet “Family Farming, PNPB and Agenda 2030: A Commitment to a Sustainable Future” (EPE, 2025a, 2025b).

Among national biofuels, ethanol stands out, whose production comes mostly from sugarcane and, in recent years, from corn, which has shown relevant growth. Ethanol is marketed in hydrous and anhydrous forms, the latter in a mixture with gasoline A, composing gasoline C. In 2025, the anhydrous content in gasoline C went from 27% to 30%, starting in August, according to CNPE Resolution No. 9/2025 (CNPE, 2025).

Regarding sugarcane, the reflection of the appreciation of sugar prices in the international market is observed, with the sugar-energy sector adjusting to these fluctuations to maximize revenues or minimize losses. Bioelectricity is a third asset of this segment, contributing to the increase of its revenue. The production of biomethane using vinasse and filter cake has shown significant advances, with 6 units in operation in December 2025, out of a total of 17 authorized units, including other inputs.

[1] Under the denomination corn ethanol, those from soy, wheat, sorghum, and other cereals are also included.

Ethanol production from corn has been showing expressive growth, mainly in the Midwest region, and reached 7.6 billion liters in 2024, about 20% of national production (MAPA, 2025; UNICA, 2025). Between January and November 2025, its production reached about 9 billion liters, which corresponds to 25% of the total ethanol (35 billion liters). This sector has been favored by the increase in cereal production, which, unlike sugarcane, is a crop from which a second annual harvest or even, occasionally, a third can be obtained, in combination with other crops, notably soy. Furthermore, it benefits from the generation of co-products such as corn oil, intended for human consumption, and DDGS (distiller's dried grains with solubles) for animal nutrition, thus adding two more assets to the mills' revenue pool (IMEA, 2017; MILANEZ et al., 2014). In recent years, the Country has been expanding markets for DDGS export, such as the recent authorization of establishments by China (the main importer of Brazilian grains). There is also the possibility of chain integration, with the supply of this co-product for intensive livestock farming.

Additionally, corn has the advantage of the possibility of cereal storage, enabling mills to operate throughout the year. Regarding the expansion of the corn production area, sequential cultivation to soy (second crop) already represents approximately 80% of total production and still has the potential to double, thus favoring an increase in ethanol supply without the need for conversion of new agricultural areas (EPE, 2024a). Furthermore, the productivity of this grain in Brazil has been growing significantly, with an expectation of maintaining this gain rate in the coming years. The challenges for the corn ethanol sector lie in the availability of biomass for energy generation and distribution logistics, given the location of these units.

Another source of revenue for the biofuels segment is the CBIOs[2], for units that met the requirements and adhered to RenovaBio. Currently, most certified mills are E1G sugarcane, as corn mills face some challenges related to the grain chain of custody (EPE, 2025a).

Otto cycle consumption (except CNG) again surpassed the annual historical maximum, reflecting a favorable economic conjuncture, with an increase in GDP per capita, record formal employment and real income mass, as well as the lowest unemployment level in the historical series (EPE, 2025i). In this context, Otto cycle demand reached 61.1 billion liters of gasoline equivalent in 2025, with hydrous ethanol significantly expanding its share (EPE, 2025a, 2025c). The 2025/26 sugarcane harvest has been exhibiting good performance in productivity and milling, although lower than the previous period. The price of sugar[3] in the international market reduced throughout this year and approached parity with ethanol; however, the mix for the sweetener remains high, due to commercial agreements already signed. As mentioned, corn ethanol production continues with a consistent increase. The price relationship between ethanol and gasoline remained favorable to the biofuel in some Brazilian states throughout this year (CONAB, 2025a; EPE, 2025a, 2025d; MAPA, 2025; USDA, 2025). Until October 2025, hydrous ethanol consumption was 19.2 billion liters, a reduction of 1.4% compared to 2024, while for gasoline C, there was an increase of 4.1% (ANP, 2025a; MAPA, 2025).

2. Scenario Assumptions

This study will present three ethanol supply scenarios, whose names were chosen based on the growth of ethanol production from sugarcane and corn. They are: High Growth, Medium Growth, and Low Growth.

First, the common assumptions for these scenarios will be described, followed by the specific assumptions.

[2] Instrument of the National Biofuels Policy – RenovaBio, registered in book-entry form, for the purpose of proving the individual target of the fuel distributor addressed in art. 7 of Law No. 13.576/2017 (BRASIL, 2017).

[3] From January to October 2025, national sugar production was 40.3 million tons, 0.6% lower than the same period in 2024 (MAPA, 2025).

2.1. Common Assumptions for All Scenarios (Conditioning Factors)

Adjustments to Base Year Factors

For the years 2024 and 2025, the area and agricultural and industrial yields related to sugarcane cultivation were adjusted according to the second survey of the 2025/26 sugarcane harvest by CONAB (2025a). The values for the year 2026 are the same for all scenarios and were represented uniquely.

Current Installed Capacity

For units using exclusively sugarcane, the milling and ethanol production capacity factor was 90%. For corn processing, this value is 96%. The biofuel production plants in operation and with authorizations for expansion and construction by the ANP have the position of March 28 as a reference, except for the high scenario, whose base date[4] is October 3, 2025 (ANP, 2025b).

a) Cane

- The nominal installed milling capacity stands at around 840 million tons of cane[5] (corresponding to 750 Mtc in effective capacity), with 337[6] operating units. The production capacity for anhydrous and hydrous ethanol is 48.3 billion liters (200 harvest days) (ANP, 2025b; MAPA, 2025).
- Expansion[7] of ethanol production capacity in 42 operating mills, totaling 2.5 billion liters (200 harvest days), for the medium and low scenarios. For the high scenario, the total is 2.6 billion liters (44 units) (ANP, 2025b).
- Implementation of one sugarcane ethanol production unit in the short term, with an authorization process underway with the ANP as of 03/28/2025 (low and medium scenarios). For the high scenario, there is also the entry of another unit in the medium term, also indicated by the ANP. There are also two units at the Agency that are producers of aguardiente (spirits) and have an authorization process underway for the production of ethanol for fuel purposes (ANP, 2025b). All these mills were included in the projections.

b) Corn and others

- Corn processing capacity is 21.9 million tons and ethanol production capacity stands at 11.6 billion liters, from 30 units (11 flex and 19 full). There are also three ethanol production units using soy/cereals[8] with a capacity of 31.4 million liters (ANP, 2025b; MAPA, 2025).
- Capacity expansion of three operating mills (2 full and 1 flex) by 72.3 million liters (ANP, 2025b).
- Implementation of 16 corn ethanol units, plus one corn/soy, one wheat, and one cereals unit, for the low and medium scenarios. In the case of the high scenario, a total of 18[9] full mills are considered (including those three using other grains/cereals) (ANP, 2025b).

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[4] This change was necessary due to the entry of new projects related to corn ethanol, both in the ANP (2025b) and in company disclosures.

[5] The analysis considered the closure, reactivation, and expansions in existing units that occurred up to the indicated period.

[6] This total includes four producers of aguardiente and/or ethanol for other uses, and 11 flex corn ethanol units whose corn processing and ethanol production capacities will be counted together with the full corn ones. Flex units are those that produce ethanol from sugarcane and corn. Full units use only the grain/cereal. A harvest of 155 days is considered for flex units when using grain.

[7] It was assumed that the volume to be expanded will be available by 2029.

[8] To simplify the analyses conducted in this study, for now, ethanol production from soy and cereals is counted together with corn.

[9] Although the total is lower, the ethanol production capacity is higher. In the ANP report of 10/03/2025, some units were no longer listed as under construction when compared to what was indicated on 03/28/2025.

Yield

Industrial yield (cane quality) is defined by the amount of TRS (Total Recoverable Sugars) per ton of cane and is related to its variety (richer in sugar or fiber), its suitability to the production environment and mechanized harvesting, cane field age (renewal at optimal time), vegetable and mineral impurities, cultural treatments, and climatic aspects (EPE, 2025a).

This indicator has been fluctuating over past harvests (EPE, 2025a) and, for the horizon of this study, it is considered that the average cane yield will be about 142 kg TRS/tc.

Ethanol Export and Import

Currently, there is a global trend toward migration to sustainable and low-carbon emission economies as one of the ways to mitigate the adverse effects of human action on the climate and protect the quality of life on the planet. There are alternatives to achieve these goals, such as the use of biofuels and electrification (more disseminated internationally), provided that electricity comes from renewable sources, each being more suitable to the specificities of each country.

Traditionally ethanol-importing countries are generally seeking their decarbonization through the electrification of the transport sector.

Despite the trend of increasing use of biofuels as one of the forms of decarbonization, the international market is expected to maintain its current characteristics, with low volumes of biofuels traded until the end of the period. The main reasons for this scenario are: the prospect of increased vehicle energy efficiency; the generalized search for energy independence; and the imposition of barriers on major producing countries.

As a result, it is estimated that Brazilian ethanol exports will be 2.3 billion liters in 2035. The export projection considers, mainly, the participation of sugarcane ethanol in meeting the United States RFS (Renewable Fuel Standard)[10] targets (EPA, 2023), with the markets of South Korea, USA, and the Netherlands being the main importers of ethanol from Brazil, as described in EPE (2025a).

Por On the other hand, there is the possibility of increasing these exported volumes if ethanol is allocated, as a product or input, for use in sectors that are difficult to decarbonize, such as aviation, for the production of sustainable fuels via the Alcohol to Jet (ATJ) route, and the waterway sector.

It was estimated that imported volumes of ethanol will average 500 million liters per year throughout the period.

Ethanol for Other Uses (Non-Energy)

In Brazil, the demand for ethanol for non-energy use, concentrated basically in the production of beverages, cosmetics, pharmaceutical products, petrochemicals, and oxygenated compounds (acetic acid, ethyl acetate, and butanol), is projected to be 1.0 billion liters in 2035.

[10] According to this program, biofuels are classified based on the amount of GHG emitted in the life cycle: renewable (corn ethanol and biobutanol), advanced (sugarcane ethanol), biomass diesel (ester or HVO – hydrated vegetable oil), and cellulosic (cellulosic ethanol and bioethanol) (EPA, 2023).

2.2. Specific Assumptions for Each Scenario

The scenarios developed differ basically regarding the degree of economic attractiveness of ethanol production and the competitiveness of hydrous ethanol against gasoline C. To this end, the sector's efforts directed both at improving production factors (productivity and cane yield, among others) and expanding capacity are distinguished, as well as the intensity of government incentives, including the commitment to expanding biofuel production and contributions to meeting the goals of the 21st Conference of the Parties (COP 21), through the Paris Agreement and, more recently, at COP 30, with the approval of the Belém Consensus, which included advances in themes such as just transition, adaptation financing, trade, gender, and technology. At this same event, the global commitment Belém 4x Pledge was also launched, to quadruple the use of sustainable fuels by 2035, based on 2024 levels. This initiative, led by Brazil, Italy, and Japan, with initial support from India, aims to accelerate the energy transition and the decarbonization of hard-to-electrify sectors, such as transport and industry, reducing greenhouse gas emissions (BRASIL, 2009; COP 30 BRASIL AMAZÔNIA, 2025). Additionally, with the aim of expanding the use of biofuels and contributing to the energy transition with the reduction of GHG emissions, the National Biofuels Policy (RenovaBio) was approved in 2017, and in 2024, the Fuel of the Future Law (Law No. 14.993/2024) was promulgated (BRASIL, 2017, 2024).

Specifically for RenovaBio (BRASIL, 2017), with the definition of decarbonization targets, it is expected that mills will feel driven to produce more biofuels and more efficiently, increasing the supply of CBIO (Decarbonization Credit) and reflecting on its price in the market where it will be traded. This mechanism should contribute to ensuring the necessary security for new investments. On the other hand, the Fuel of the Future Law (BRASIL, 2024), sanctioned by President Luís Inácio Lula da Silva on October 8, 2024, expanded the range of the mandatory addition percentage of anhydrous ethanol in gasoline C to 30% (in force) with the possibility of reaching 35%. Furthermore, this Law established emission reduction targets through the use of renewable fuels, offering other possibilities for ethanol, such as: carbon capture, production of biogas, sustainable aviation fuels (SAF) via the ATJ route, fuels for use in the waterway sector, and hydrogen (BRASIL, 2024). Thus, the intention is to develop a favorable environment to expand the participation of biofuels in the national energy matrix.

It is of national interest to penetrate ethanol into the consumption of the flex-fuel fleet, expanding its share in consolidated markets, such as the producing states of the Center-South, and mainly the expansion to other Brazilian regions (North, Northeast, and South). In this aspect, greater clarification of the technical attributes and advantages of this biofuel becomes important.

Therefore, each of the scenarios will present greater or lesser attractiveness for ethanol, which will be reflected in the variation of its production capacity, in the different production factors, and in technological innovations for this sector. It was assumed that the current policies encouraging ethanol will remain throughout the period, such as, for example, differentiations in CIDE, PIS/COFINS, and ICMS[11]levied on ethanol and gasoline in some states, as well as the availability of financing lines.

In all scenarios, the alignment of the realization price of gasoline with international quotations was considered, emphasizing that, despite fluctuations in recent history, it is estimated that it will follow a trajectory with a small increase during most of the period and with a small reduction at the end of the decade, according to the International Oil and Derivatives Prices Notebook of the PDE 2035 (EPE, 2025e). As indicated previously, the mandatory percentage of anhydrous ethanol addition in gasoline C increased from 27% to 30% in August 2025 (CNPE, 2025). Sensitivity analyses will be performed, with anhydrous content evolving up to 35%.

[11] In 2024, 26 federation units presented tax differentiation between hydrous ethanol and gasoline C (CONFAZ/MF, 2025; EPE, 2025a).

Below, the differentials between the scenarios are presented, which were built taking into account the various factors mentioned above, and which materialize in the expansion and/or reduction of ethanol production capacity and in the trajectories of sugar production and ethanol allocation for SAF production via the ATJ route.

Cane and Corn Ethanol Production Capacity

In the early 2000s, there was the entry of several sugarcane production units, due to the growth in ethanol demand by flex-fuel vehicles and sugar in the international market. In the following years, groups in the sector presented high indebtedness, investments were reduced, and several units paralyzed their activities. More recently, the reactivation of some mills and few greenfield projects have been observed (EPE, 2025a).

Regarding ethanol from corn, since 2018, several units have come into operation and capacity expansions of existing ones have occurred, with production showing expressive growth (MAPA, 2025; UNICA, 2025). The time required for the implementation of this type of unit is about two years, which is relatively shorter than estimated for cane units. Furthermore, the raw material is acquired directly from grain producers, without the need for the mill to own land. Unlike sugarcane culture, corn has up to three annual harvests, in rotation with soy and/or other grains and cereals. Considering the rapid expansion of corn processing for ethanol, a point of attention for the coming years lies in the need for biomass for energy generation and in the logistics of moving products and raw materials, given the location of the mills in the Midwest region. The Annex presents the history regarding cane and corn units.

Cane mills are adjusting their financial conditions and were driven by the attractiveness of sugar in the international market, observed in recent years (CONAB, 2025a; MAPA, 2025; USDA, 2025). Investments to be made may aim at expanding crystallization capacity, improvements in cane fields, reduction of cultivation costs, irrigation, cogeneration, use of straw and tops, yeast production, biogas, second-generation ethanol, among others. It is understood that the opportunities observed for mills already in operation will involve relatively low risks and CAPEX and may compete, in terms of investment priority of sector groups, with greenfield projects.

Regarding second-generation ethanol (E2G)[12], commercial plants exist in Brazil: Granbio's Exygen-I[13] in São Miguel dos Campos, with a nominal capacity of 30 million liters/year, and Raízen's, in Guariba, with 82 million liters/year and Piracicaba[14] (SP) with 42 million liters/year. The company has already announced the construction of seven more projects, all with a capacity of 82 million liters, with four of them expected to enter by 2027. The company communicated sales agreements for 460 million liters of E2G, over nine years, and has plans to build other units and license the technology[15] (GRANBIO, 2025; RAÍZEN, 2023, 2024a).

For each scenario, a variation in ethanol production capacity was considered, based on actions by sector agents and government incentives. The charts and tables below summarize the adopted ethanol production capacity expansion hypotheses, based on March 28 (low and medium) and October 3 (high) of 2025, as described previously. As stated in item 2.1, for all scenarios, there is the entry of units with an authorization process underway for the operation of new facilities and expansion of existing facilities registered by the ANP (2025b).

[12] There is an experimental plant at the Sugarcane Technology Center (CTC), with a capacity of 3 million liters/year.

[13] The Granbio plant has not produced lignocellulosic ethanol since the 2021/22 harvest. In 2025, it was renamed with the prospect of becoming a biorefinery, producing ethanol (1G and 2G), biomethane, biofertilizers and e-ethanol (ALAGOAS, 2025).

[14] In 2025, it was announced that 2G ethanol production at the Costa Pinto (Piracicaba) plant would be discontinued, with the plant being used for testing and development of future biofuels (JORNALCANA, 2025).

[15] In 2025, Raízen announced that it is reviewing its asset portfolio and conducting divestments. (AGFeed, 2025).

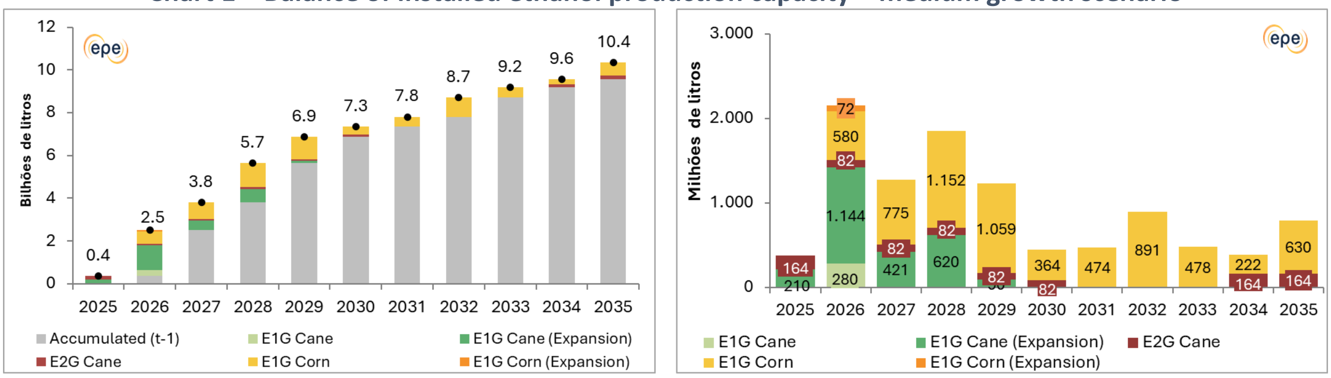
New indicative sugarcane units (greenfields) were estimated only for the high scenario, based on an announced investment and another with an average profile of nominal milling capacity of 4.0 Mtc. The reactivation of mills belonging to groups with relevant participation in this market was also considered. For E2G, based on its valuation in the international market, the entry of units with an average specific capacity of 82 million liters is projected, according to the conditions of the different scenarios.

In the case of corn ethanol, announced projects were considered, including expansions, which are not yet listed at the ANP, for both the medium and high scenarios, according to the attractiveness assumptions of each.

Medium Growth Scenario (Reference)

The medium growth scenario considers the entry of one cane unit, under construction with an authorization process underway[16], which increases the nominal milling capacity by 3.0 million tons (280 million liters for ethanol production). Ethanol production expansions total 2.5 billion liters. For corn, expansions and implementations in the authorization process result in a capacity increase of 4.5 billion liters (ANP, 2025b)[17], in addition to an indicative (new units) of 2.2 billion liters, with all being of the full type. Processing capacity increases by 16 million tons. The increase in E2G production capacity will be 0.9 billion liters in 2035, from 11 production units. The balance of cane and corn ethanol production units[18]in terms of installed production capacity can be observed in Chart 1.

Chart 1 – Balance of installed ethanol production capacity – medium growth scenario



Note: The chart on the right details the volume added to ethanol production capacity (expansions and new units).
Source: EPE (Own elaboration)

High Growth Scenario

The high growth scenario considers the entry of cane units under construction with an authorization process underway at the ANP (as of 10/03/2025) and two indicative ones, which in total increase the nominal milling capacity by 9.9 million tons (673 million liters of ethanol production). The balance of reactivations will be 4.4 million tons (174 million liters). Ethanol production expansions total 2.6 billion liters. For corn, expansions and implementations with an authorization process underway at the ANP result in a capacity increase of 4.9 billion liters (ANP, 2025b), in addition to an indicative (new units and/or expansions) of 9.4 billion liters, with the majority being of the full type. Processing capacity increases by 33 million tons. The increase in E2G production capacity will be 1.0 billion liters in 2035, from 12 production units.

The balance of cane and corn ethanol production units in terms of installed production capacity is presented in Chart 2.

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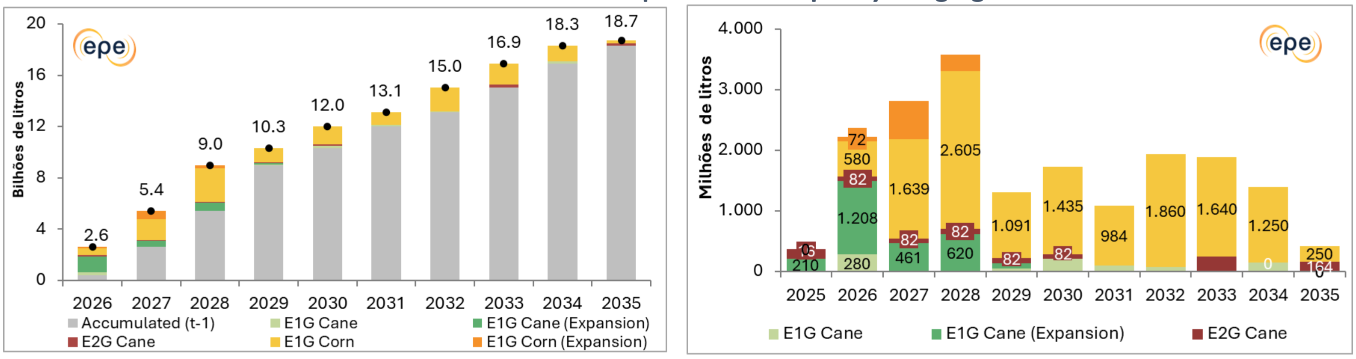
[16] The authorization to operate this unit was already granted by the ANP in July 2025, however, in all scenarios, the start-up occurs in 2026.

[17] The authorization and expansion processes were based on data from the ANP.

[18] For all scenarios, it is considered that 210 million liters related to expansions of sugarcane mills and 164 million liters of E2G will come into operation in 2025.

Chart 2 –Balance of installed ethanol production capacity – high growth scenario



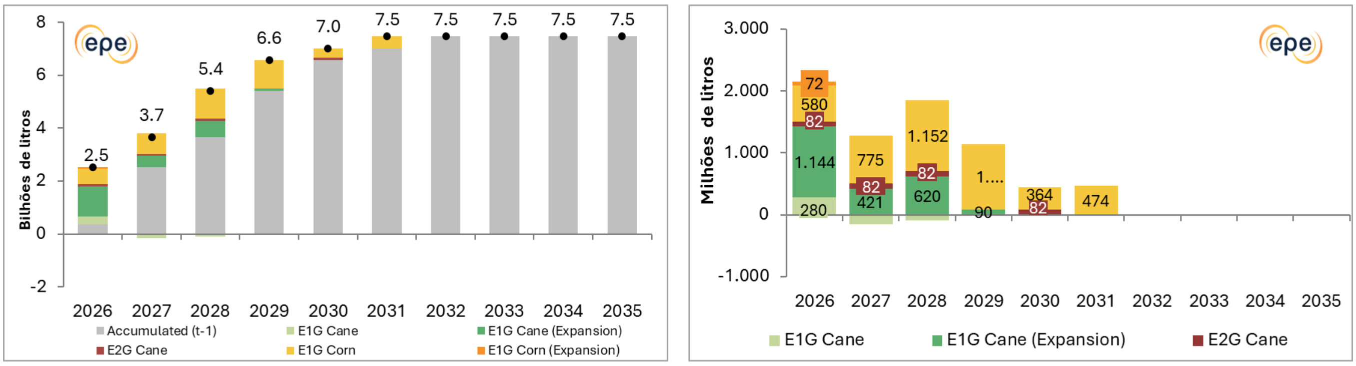
Note: The chart on the right details the volume added to ethanol production capacity (expansions and new units).

Source: EPE (Own elaboration)

Low Growth Scenario

The low growth scenario considers the entry of one cane unit under construction with an authorization process underway at the ANP, which increases the nominal milling capacity by 3.0 million tons (280 million liters for ethanol production). The balance of closures will cause a decrease of 3 million tons (240 million liters for ethanol). Expansions (ANP) of ethanol production total 2.5 billion liters. In the case of corn, expansions and implementations with an authorization process underway at the ANP result in a capacity increase of 4.5 billion liters (ANP, 2025b), with the majority being of the full type. Processing capacity increases by 11 million tons. The increase in E2G production capacity will be 0.5 billion liters in 2035, from 6 production units. The balance of cane and corn ethanol production units in terms of installed production capacity is illustrated in Chart 3.

Chart 3 - Balance[19] of installed ethanol production capacity – low growth scenario



Note: The chart on the right details the volume added to ethanol production capacity (expansions and new units).

Source: EPE (Own elaboration)

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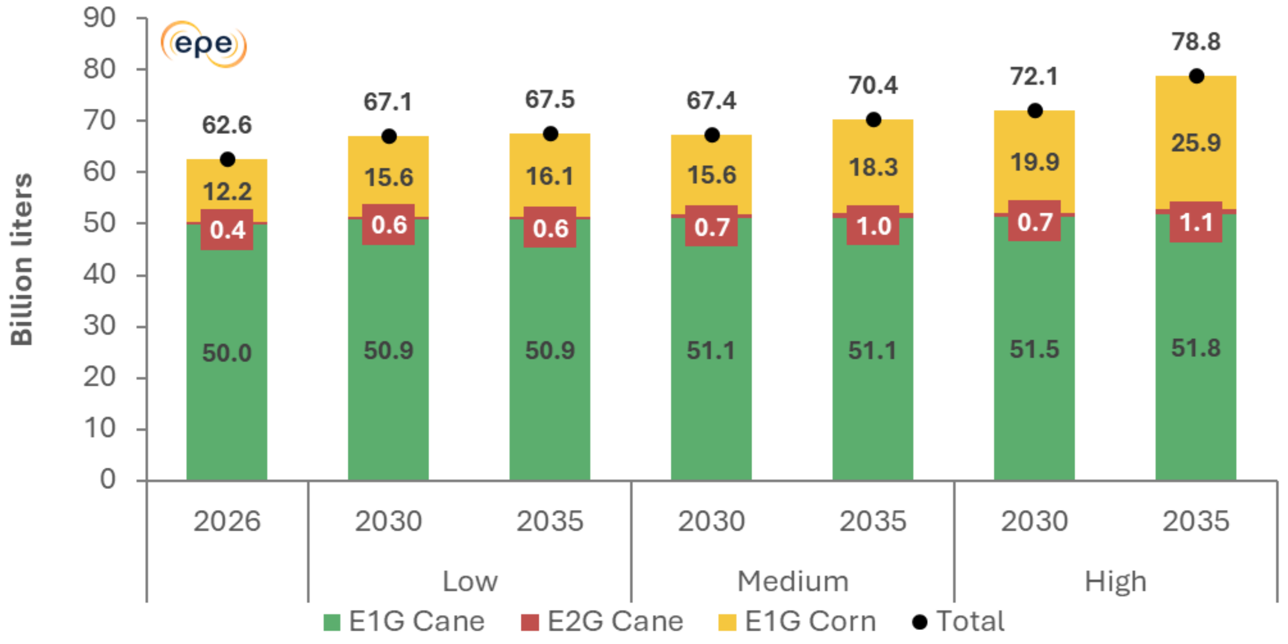
19 In the case of the low scenario, for simplification, the designation E1G Cane encompasses the units under construction with an authorization process underway at the ANP together with the shutdowns, projected to occur in 2027 and 2028 (chart on the right).

O Chart 4 presents the nominal production capacities of cane ethanol (1G and 2G) and corn ethanol, based on the considerations made previously, for the low, medium, and high growth scenarios.

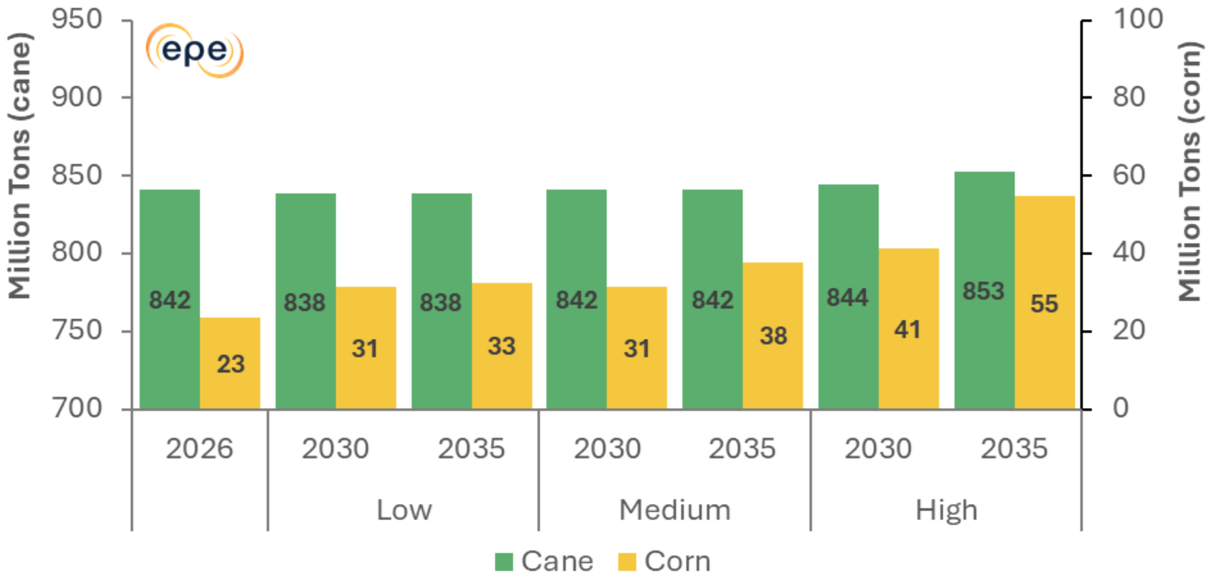
Chart 4 - Ethanol production capacity (cane and corn)



Source: EPE (Own elaboration)

Finally, Chart 5 presents the nominal processing capacities of cane and corn, based on the considerations made previously, for the low, medium, and high.

Chart 5 - Nominal processing capacities (cane and corn)



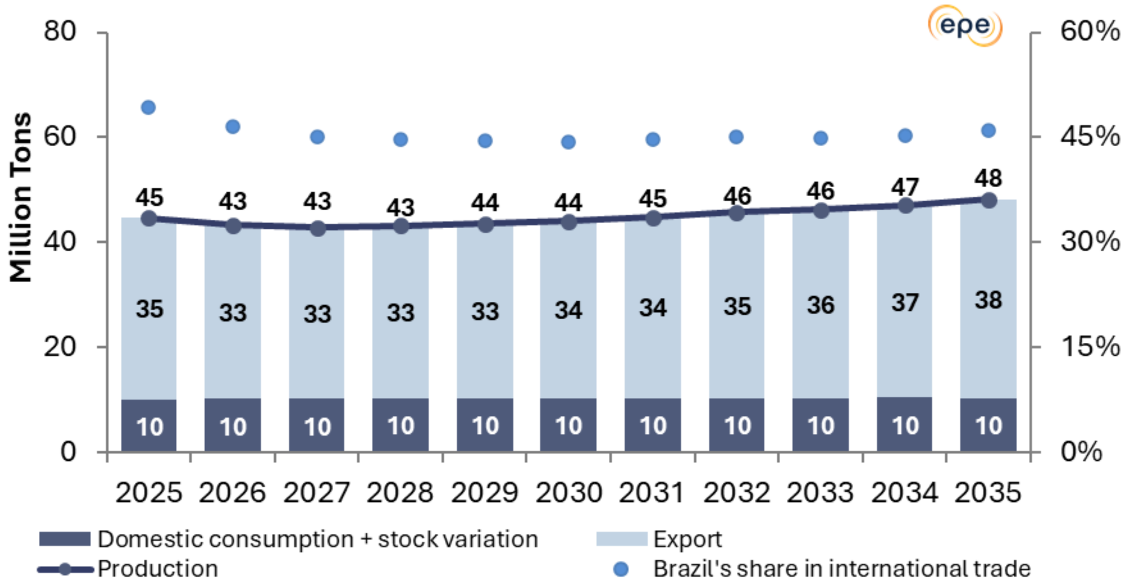
Source: EPE (Own elaboration)

Sugar

The projection of Brazilian sugar production comprises two components: domestic consumption and export. Domestic consumption considers the evolution of Brazilian per capita consumption (kg/inhab./year) and is related to aspects of income, population aging, and changes in eating habits. Regarding the international market, Brazil figures as the main player, responsible for about 50%[20] of the international market for this commodity, followed by India, Thailand, and the EU (FAO, 2012, 2024; ISO, 2024).

For the medium and low growth scenarios, the projection considered that domestic per capita sugar consumption will remain around 47 kg/inhab/year throughout the period (FAO, 2012, 2024; ISO, 2024, MAPA, 2025). The commodity export projection was estimated based on the assumption that Brazil's participation in the world trade flow will remain high, with an estimate of representing 46% in 2035 (FAO, 2024). As a result, for the reference sugar production projection, the growth rate in the 2024-2035 period is 0.8% p.a., reaching 48.2 million tons in 2035, as per Chart 6 below.

Chart 6 - Sugar production (reference scenario)



Source: EPE (Own elaboration)

For the high growth scenario, the estimated sugar production reaches 52.3 million tons in 2035, with Brazil's participation in the world trade flow reaching 50%.

Ethanol for Other Energy Uses

Given the versatility of ethanol for other applications, such as in the waterway sector and for SAF production via the ATJ route, this study conducted estimates regarding these possibilities.

The volumetric demand for SAF to meet the targets established by CORSIA[21] and ProBioQAV[22] will depend on the carbon intensity of each technological route and raw material used. In this sense, EPE

[20] In recent years, Brazil's market share was even more relevant.

[21] CORSIA: Carbon Offsetting and Reduction Scheme for International Aviation. Program established by ICAO (International Civil Aviation Organization) to reduce global civil aviation emissions.

[22] Program established under the Fuel of the Future Law with emission reduction targets in national aviation.

(2024b, 2025f)[23] evaluated criteria for the production of this fuel in Brazil and indicated a possible composition of routes and raw materials to meet emission reduction targets.

In the first analysis[24], adopted for the medium and low growth scenarios, SAF production via the ATJ route would represent about 420 million liters, 24% of the total in 2035. This volume corresponds to a demand of 0.9 billion liters of ethanol, considering an average conversion yield (0.46 liters SAF / liters ethanol, according to ICS (2024)). For the high scenario, the estimate considered the entry of a new ATJ project, recently indicated, and the prioritization of routes with cane and corn 1G, which have higher carbon intensities and thus would require larger volumes of biofuel. In this case, the demand for ethanol would be 3.9 billion liters for the production of 1.8 billion liters of SAF.

Regarding ethanol for use in the waterway sector, the projection considers that it starts in 2034, reaching 65 million liters in 2035, for all scenarios indicated in this study.

Relationship between ethanol supply increase and land use

The projected increase in ethanol supply in Brazil over the coming decade does not necessarily imply a proportional expansion of the agricultural area destined for energy crops. The expected dynamics differ from previous cycles, since a large part of production growth is expected to occur through land-saving techniques, which allow supply to be increased from the existing agricultural base (EPE, 2024a, 2025a, 2025b). Standing out in this context are the expansion of second-crop corn ethanol, continuous productivity gains in sugarcane and corn, and the increasing incorporation of agro-industrial residues in the production of second-generation ethanol (E2G), reducing the pressure for new areas and the risk of land-use changes.

In this context, the relationship between ethanol production growth and land use tends to become progressively more dissociated. Second-crop corn, cultivated mostly after the soy harvest in already consolidated areas, exemplifies a process of agricultural intensification without territorial expansion. Complementarily, agricultural and industrial productivity gains expand the volume of ethanol produced per hectare, while E2G reinforces system efficiency by converting residues such as bagasse and straw into fuel. These vectors consolidate an ethanol supply expansion model compatible with environmental, climatic, and sustainable land use objectives.

The results of these actions were introduced into each scenario proportionally, based on the described assumptions.

3. Results – Supply Expansion Studies

The results of the projections for harvested area, productivity, processed cane and corn, total TRS produced, DDGS and corn oil, ethanol supply (cane and corn), bioelectricity, biomethane, GHG emissions reduction, and investments for each of the scenarios are presented below.

Processed cane area

Based on the assumptions of installed capacity and implementation of new units, the projections for the processed cane area present the growth rates indicated in Table 1 and Chart 7.

[23] For more information, it is suggested to consult the studies Sustainable Aviation Fuels in Brazil (EPE, 2024b) and Sustainable Aviation Fuels in Brazil and synergy with green diesel (EPE, 2025f).

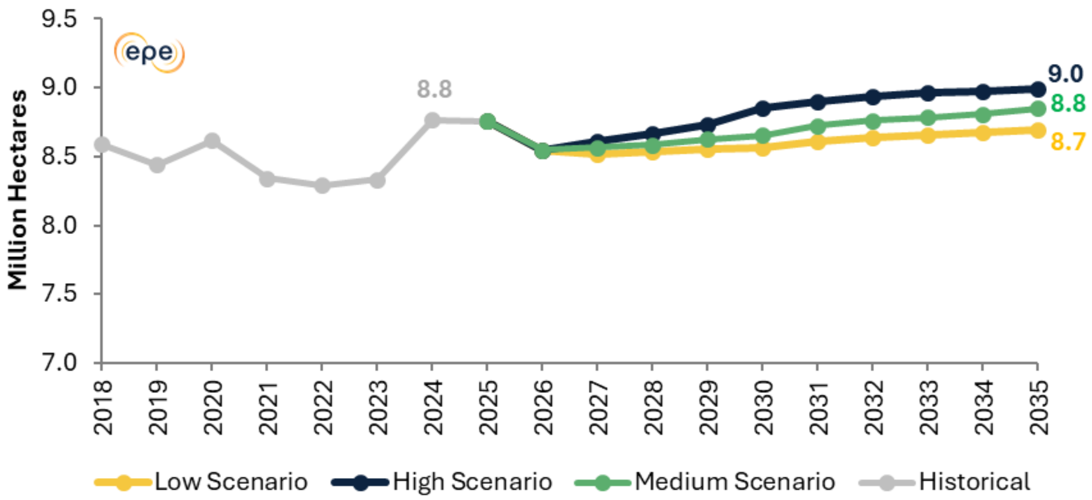
[24] The low and medium growth scenarios follow the SAF projection indicated for the PDE 2035 (EPE, 2025e). Recently, there was the announcement of a new ATJ project, which was included only in the high scenario.

Table 1 - Growth rate and variation of processed cane area

	2024 - 2030		2024 – 2035	
Scenarios	Rate (%)	Variation (Mha)	Rate (%)	Variation (Mha)
Low Growth	-0.4	-0.2	-0.1	-0.1
Medium Growth	-0.2	-0.1	0.1	0.1
High Growth	0.2	0.1	0.2	0.2

Source: EPE (projections) and CONAB (2025a, 2025b) (historical)

Chart 7 - Processed cane area.



Source: EPE (projections) and CONAB (2025a, 2025b) (historical)

Cane productivity

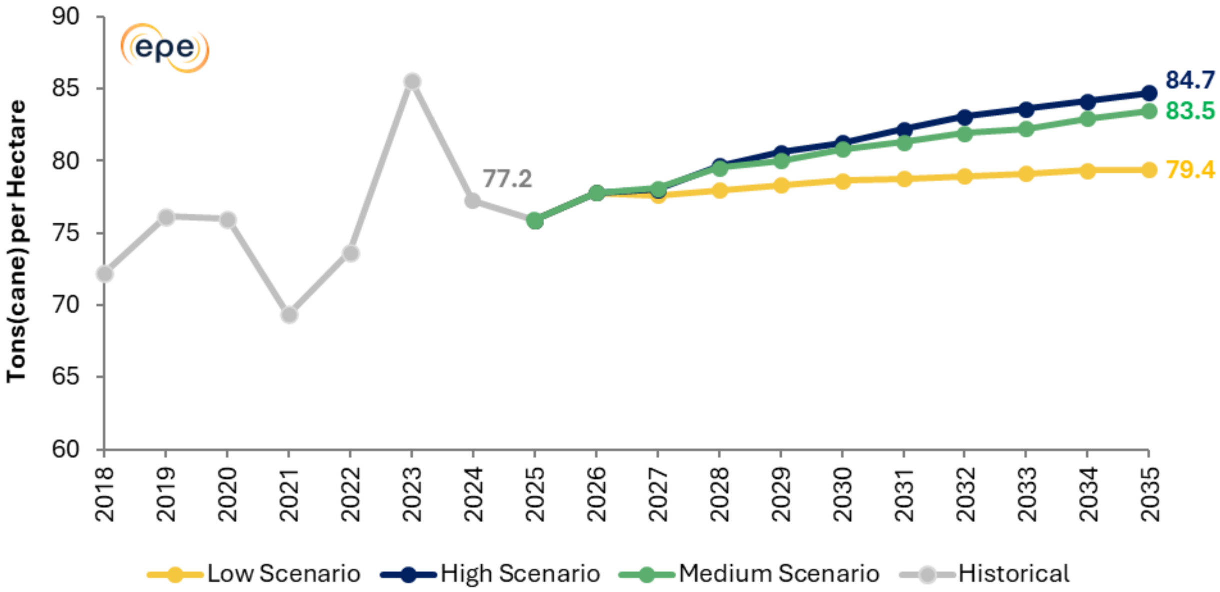
For the projection, according to the qualitative assumptions described for each scenario, the productivity variations (in tons of cane per hectare – TCH) obtained are presented in Table 2 and Chart 8 below:

Table 2 - Growth rate and variation of productivity

	2024 - 2030		2024 – 2035	
Scenarios	Rate (%)	Variation (Mha)	Rate (%)	Variation (Mha)
Low Growth	0.3	1.4	0.3	2.2
Medium Growth	0.8	3.6	0.7	6.3
High Growth	0.9	4.0	0.8	7.5

Source: EPE (projections) and CONAB (2025a, 2025b) (historical)

Chart 8 - Cane productivity



Source: EPE (projections) and CONAB (2025a, 2025b) (historical)

Processed cane

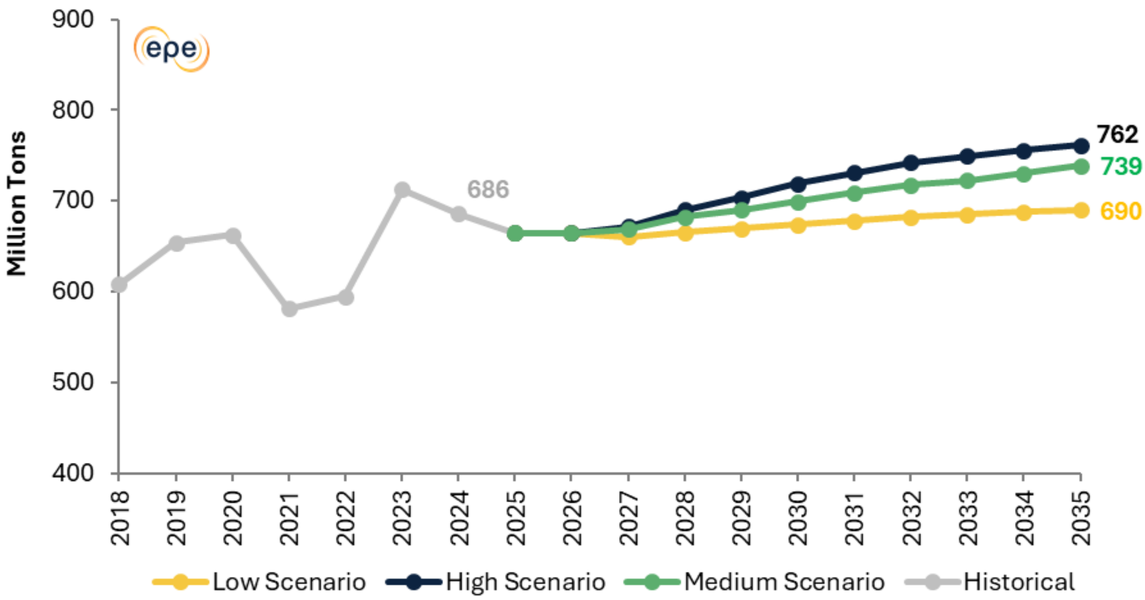
From the area and productivity estimates, the projection of processed cane in the study horizon is obtained. The projections for each of the scenarios are presented Table 3 and Chart 9.

Table 3 - Growth rate and variation of processed cane

	2024 – 2030		2024 – 2035	
Scenarios	**Rate (%)**	**Variation (Mha)**	**Rate (%)**	**Variation (Mha)**
Low Growth	-0.3	-12	0.1	4
Medium Growth	0.3	13	0.7	53
High Growth	0.8	33	1.0	75

Source: EPE (projections) and MAPA (2025) (historical)

Chart 9 - Processed cane



Source: EPE (projections) and MAPA (2025) (historical)

In 2035, it is estimated that 384 million tons of sugarcane will be destined for ethanol in the medium scenario (52%), 336 million in the low scenario (49%), and 377 million in the high scenario (50% - higher sugar production).

Total TRS

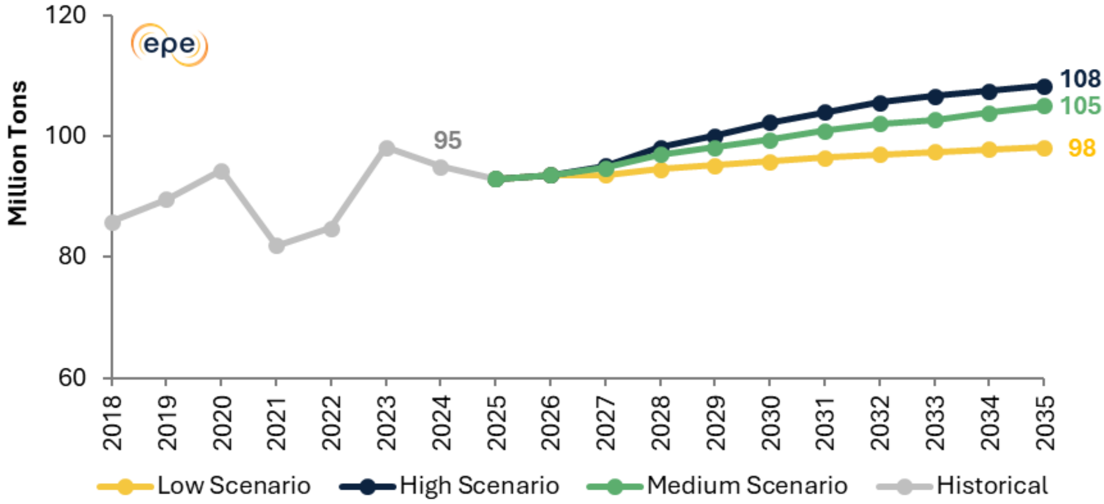
As a result of the composition of area, productivity, and yield, the ATR (Total Recoverable Sugars) produced is obtained, which will vary for each scenario according to the assumptions of these production factors. Table 4 and Chart 10 below present the growth rate and variation of total TRS between 2024 and 2035.

Table 4 - Growth rate and variation of TRS

	2024 - 2030		2024 – 2035	
Scenarios	Rate (%)	Variation (Mha)	Rate (%)	Variation (Mha)
Low Growth	0.1	0.8	0.3	3.2
Medium Growth	0.8	4.5	0.9	10.2
High Growth	1.2	7.3	1.2	13.5

Source: EPE (projections) and CONAB (2025a, 2025b), MAPA (2025) (historical)

Chart 10 - Amount of total recoverable sugars (TRS)



Source: EPE (projections) and CONAB (2025a, 2025b), MAPA (2025) (historical)

Corn Processing

The projection of corn processing[25] for ethanol production is summarized in Table 5 and Chart 11.

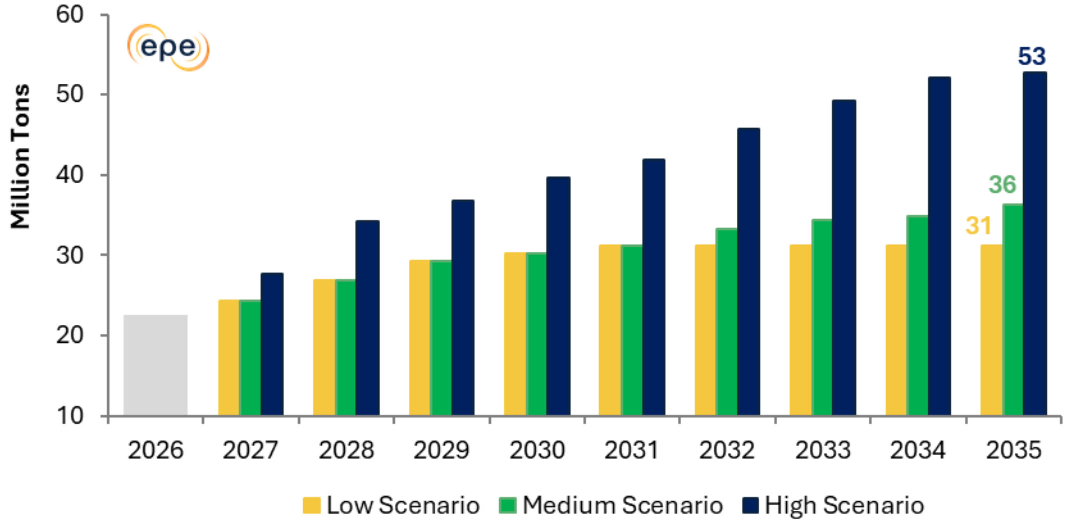
[25] Corn processing for ethanol production is estimated based on 420 liters of ethanol/ton of corn and a utilization factor of 96%.

Table 5 - Growth rate and variation of corn processing for ethanol production

	2024 - 2030		2024 – 2035	
Scenarios	**Rate (%)**	**Variation (Mha)**	**Rate (%)**	**Variation (Mha)**
Low Growth	9.7	12.9	5.5	14.0
Medium Growth	9.7	12.9	7.0	19.0
High Growth	14.8	22.4	10.7	35.4

Source: EPE (projections) and ANP (2025c), MAPA (2025) and UNICA (2025) (historical).

Chart 11 – Corn processing for ethanol production

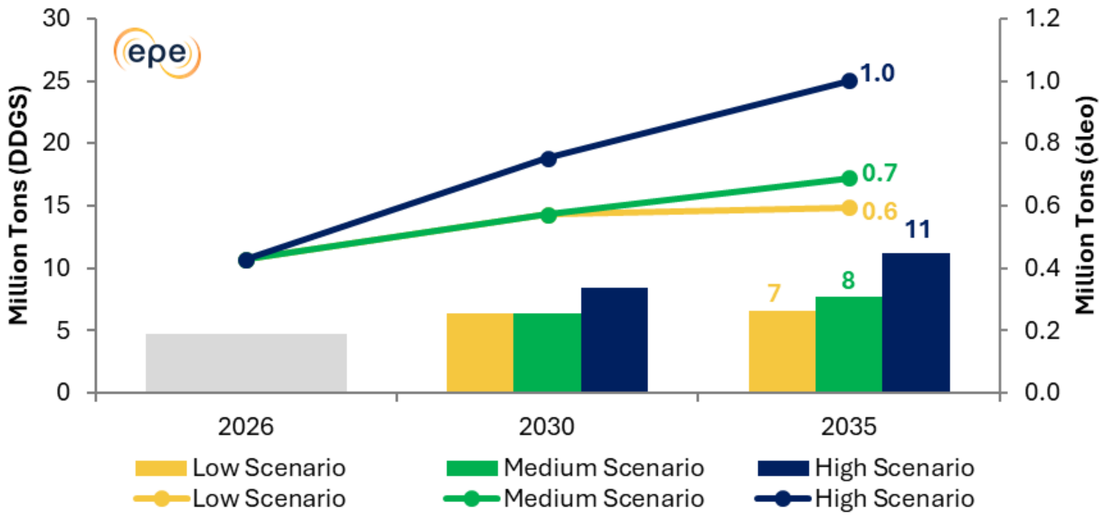


Source: EPE (Own elaboration)

DDGS and Corn Oil Production

Chart 12 presents the estimated production of co-products[26] originating from corn ethanol, which would be DDGS and oil.

Chart 12 – DDGS and corn oil production



Note: The columns refer to DDGS and the lines to corn oil.

[26] For the determination of DDGS and corn oil production, 212 kg DDGS/ton corn and 19 kg/ton corn were considered, respectively, according to UNEM (2025).

Source: EPE (Own elaboration)

Total ethanol supply

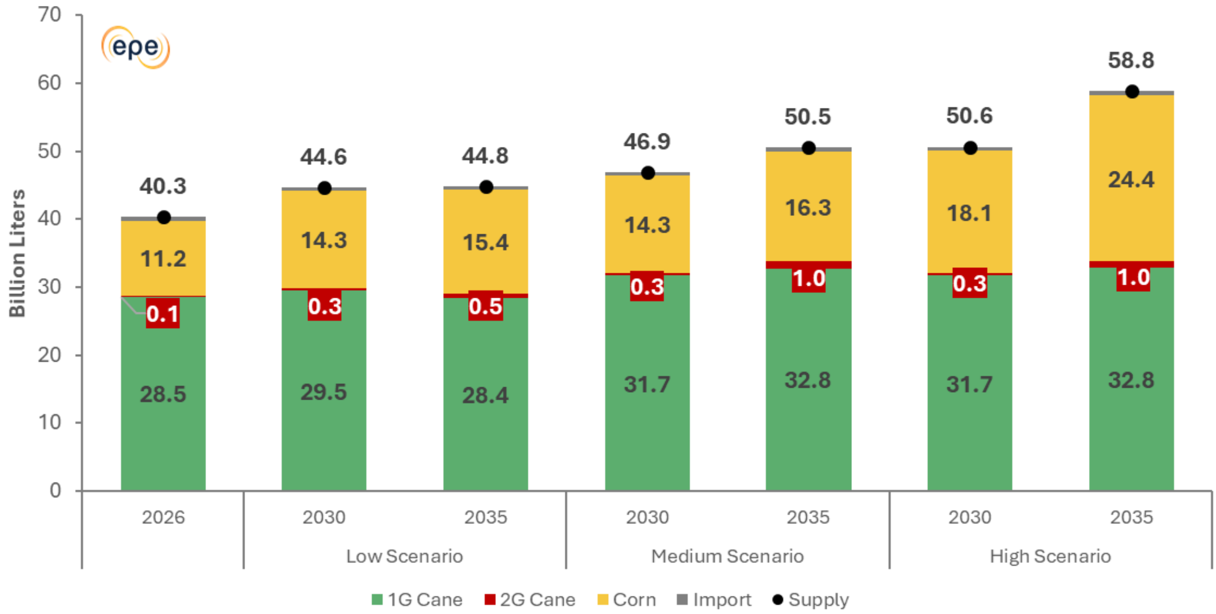
Finally, from the produced TRS, the portion destined for sugar is deducted, presented in Item 2.2, and ethanol production from corn and second-generation cane is included, obtaining the national ethanol production. From this total, with the sum of imported ethanol, results the total ethanol supply. A Table 6 and Chart 13 present the growth rates and variation of ethanol supply.

Table 6 – Growth rate and variation of total ethanol supply

	2024 - 2030		2024 – 2035	
Scenarios	**Rate (%)**	**Variation (Mha)**	**Rate (%)**	**Variation (Mha)**
Low Growth	2.9	7.1	1.6	7.3
Medium Growth	3.8	9.3	2.7	13.0
High Growth	5.1	13.1	4.2	21.3

Source: EPE (projections) and CONAB (2025a, 2025b), MAPA (2025), ME (2025) (historical)

Chart 13– Total ethanol supply by raw material



Source: EPE (Own elaboration)

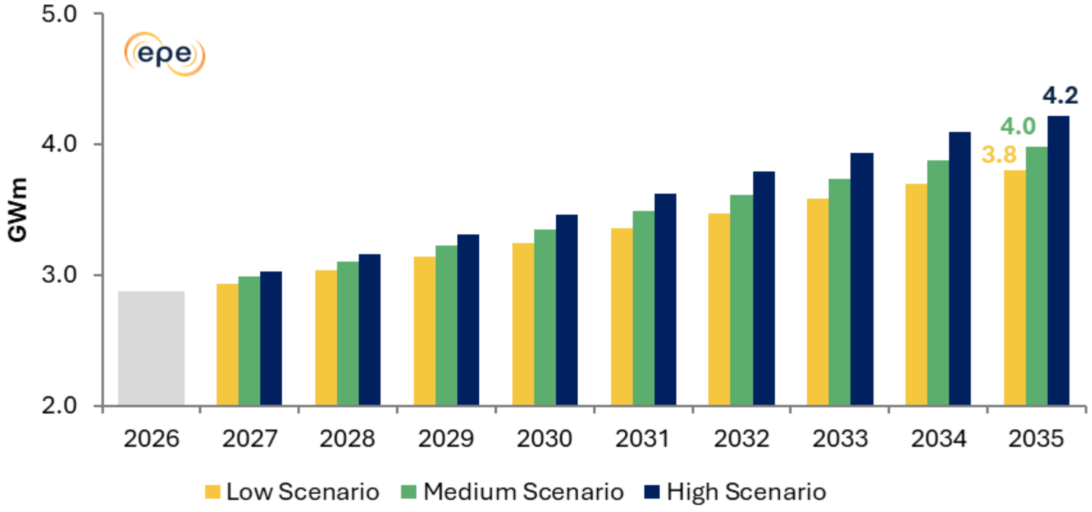
Bioelectricity

From the sugarcane biomass supply projection, the study performed two estimates of bioelectricity supply to the grid: (1) the bioelectricity export curve based on the sector's historical behavior[27] and (2) the calculation of technical potential, based on data from mills winning energy auctions (CCEE, 2025).

Based on the historical behavior of the sugar-energy sector, the amount injected into the SIN (National Interconnected System) in the year 2035 is 4.2 GWm, 4.0 GWm, and 3.8 GWm, respectively, for the high, medium, and low growth scenarios, according to Chart 14 below.

[27] This methodology accounts for the entire national sugar-energy park, including all cane processed in the Country and all energy exported by the sector. The export factors used were 69.86 kWh/tc for the technical potential and a variation from 36.94 kWh/tc to 47.65 kWh/tc, between 2025 and 2035 respectively, for the bioelectricity export curve based on historical behavior.

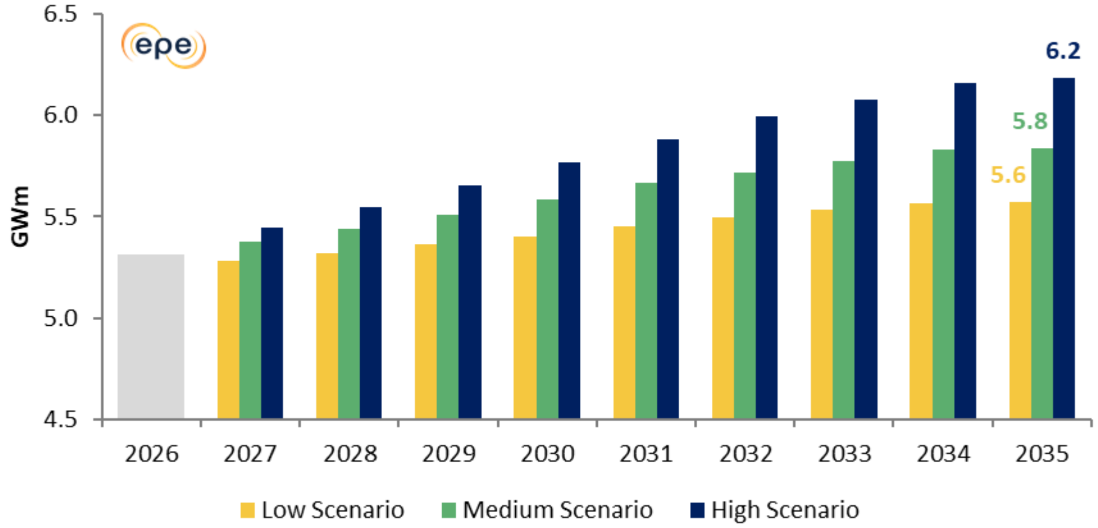
Chart 14 – Bioelectricity projection from history (conversion curve)



Source: EPE (Own elaboration)

The technical potential projections presented in Chart 15 illustrate that the total energy coming from cane bioelectricity injected into the grid in the year 2035 could vary from 5.6 GWm to 6.2 GWm, representing the low and high growth scenarios, respectively.

Chart 15 – Bioelectricity projection from technical potential



Source: EPE (Own elaboration)

Regarding corn ethanol, with the consistent and expressive growth observed in recent years, the need for biomass for energy generation for ethanol production becomes a point of attention. In this context, an estimate was made of the biomass demand needed to supply this sector, considering the corn ethanol supply projected for 2035 of 15.3; 16.2 and 24.4 billion liters in the low, medium, and high scenarios, respectively. Simply put, biomass was considered to be only firewood[28] coming from eucalyptus, whose consumption projection for ethanol production in each scenario is 12.2; 12.9 and 19.4 million tons, respectively[29].

The ideal age for eucalyptus harvest is between 5 and 6 years. However, in corn ethanol producing regions, the age of their forests is in the range of 4 years (MAPA, 2025). This point presents a logistical

[28] Among the biomasses used for this purpose, besides firewood, the following stand out: bamboo, cotton seed, rice husk, and sawmill dust.

[29] A factor of 350kg of biomass for the production of 440 Liters of corn ethanol was adopted (UNEM, 2025).

challenge for the sector; the creation of new forests for energy purposes is crucial for the viability of corn ethanol expansion, considering the Midwest as the largest producing region.

Biomethane from sugarcane biomass

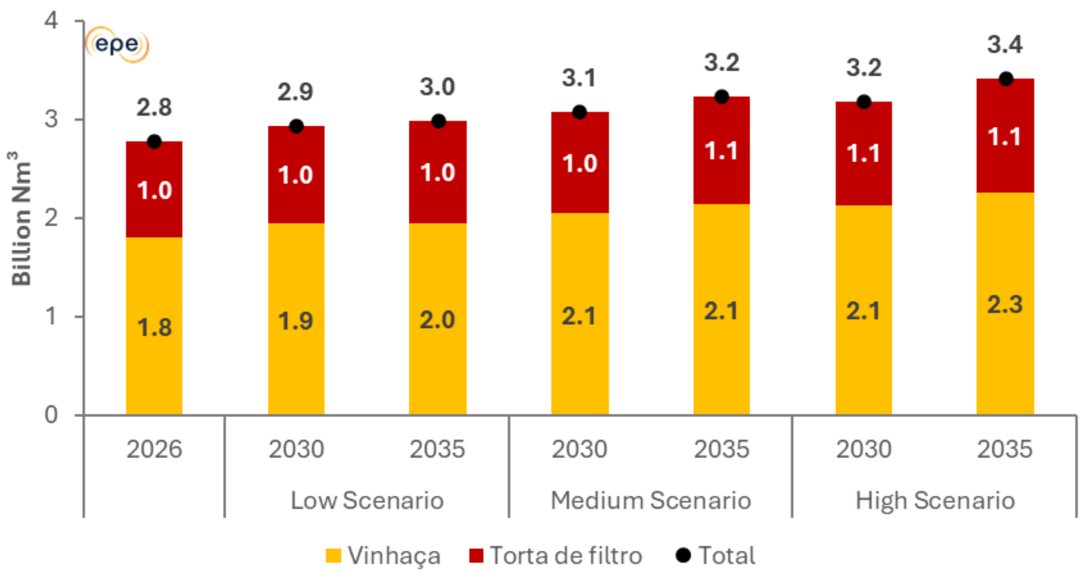
The cultivation of sugarcane and its processing for ethanol and sugar production generates a large amount of organic residues in the form of vinasse, filter cake, and straw and tops, whose utilization allows optimizing the energy content of the cane. The fermentation of these residues originates biogas[30], which is composed mostly of methane gas (CH4, 55 – 70% v/v) and carbon dioxide (CO2, 30 – 45% v/v). Vinasse biogas, in particular, is also characterized by the relatively high presence of hydrogen sulfide (H2S, 200 – 4000 ppm/v), an impurity with damaging potential to equipment.

The cleaning of contaminants and purification (upgrading) of biogas give rise to biomethane, a standardized biofuel that is considered interchangeable with natural gas if it meets the requirements of ANP regulations[31], capable of being used in combustion engines adapted or originally designed for gas operation in trucks and agricultural machinery, being marketed via compressed or liquefied gas (CNG/LNG), as well as being injected into natural gas grids.

Initially, this study presents the biomethane production potential[32]. The estimates consider that all vinasse[33] and filter cake will be directed to biogas production, following the availability of residues derived from the presented ethanol production scenarios.

Under these assumptions, it is calculated that the potential volume of biomethane in 2035 would represent between 3.4 billion Nm³ and 3.0 billion Nm³ per year, for the high and low scenarios, respectively, as illustrated in Chart 16.

Chart 16 – Biomethane production potential



Source: EPE (Own elaboration)

[30] Parameters: 1 t filter cake = 90-120 Nm³ biogas; 1 m³ vinasse = 12-25 Nm³ biogas and 1 t straw and tops = 240 Nm³ biogas (ABIOGÁS, 2017).

[31] The minimum permitted concentration of CH4 is 90%. For the sugar-energy sector, ANP Resolution No. 906/2022 is applicable, valid for biomethane originating from agro-silvopastoral and commercial organic products and residues (ANP, 2022).

[32] Biomethane production potential is considered in EPE studies that contemplate the integration of biomethane with natural gas (EPE, 2025h).

[33] Only residual vinasse from first-generation cane ethanol production is adopted.

If the harvest of straw and tops from the sugar-energy sector is economically viable, with a fraction of 20% of the total being used, the biomethane potential would represent between 6.6 billion Nm^3 and 5.8 billion Nm^3 per year, for the high and low scenarios, respectively.

One can also observe the potential relative to the mills that are part of the sector's most economically efficient group[34] (ITAUBBA, 2019; NOVACANA, 2020), which would be able to make investments in biomethane production more quickly, utilizing residues from the sugar-energy sector mills (vinasse and filter cake). In this case, the potential in 2035 varies from 1.4 billion Nm^3 to 1.6 billion Nm^3, according to Table 7.

Table 7 - Biomethane potential of the most efficient mills [billion Nm^3]

Scenarios	2025	2030	2035
Low Growth	1.3	1.4	1.4
Medium Growth	1.3	1.5	1.5
High Growth	1.3	1.5	1.6

Fonte: EPE (Own elaboration)

Conditions for the expansion of sugar-energy biomethane

In recent years, the successful implementation and announcement of a series of biogas and biomethane production projects from sugarcane residues have been verified. The diversity of mills with investments in biomethane, not restricted to one or a few economic groups, points to the maturity of this technology – which indicates the possibility of dissemination to new units.

The viability of biomethane production businesses receives the contribution of the advancement of public policies. Establishing itself as the biofuel with the lowest carbon intensity in RenovaBio, the additional revenue in certified commercialization is significant. In turn, the inclusion of biomethane in REIDI[35] allows for the reduction of the investment amount in project installation (EPE, 2023).

The Fuel of the Future Law (Law No. 14.993/2024) created the National Program for Decarbonization of the Natural Gas Producer and Importer and Incentive for Biomethane (BRASIL, 2024). The initiative aims to stimulate research, production, commercialization, and use of biomethane and biogas in the Brazilian energy matrix. The legal text determines that the CNPE will define annual targets for the reduction of greenhouse gas emissions by the natural gas sector, to be met by natural gas producers and importers through the acquisition of biomethane or through obtaining biomethane guarantee of origin certificates (CGOB). The Program will begin in January 2026 with a pre-established target of 1%, a value that cannot exceed the limit of 10%[36].

With technological maturity and increasing support from public policies, a favorable environment is identified for the expansion of biomethane in sugarcane mills in the coming years.

Scenarios for the installation of biomethane production units in sugar-energy mills

For the construction of biomethane plant scenarios, ANP data recording plants authorized to operate and those in the authorization process are taken as a reference[37].

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[34] Financial institutions have been reporting significant improvement in the economic situation of companies in the sugar-energy sector. In order to perform a more conservative analysis that reflects the capacity to make new investments, it was decided to maintain the proportion of mills in this group observed in previous studies.

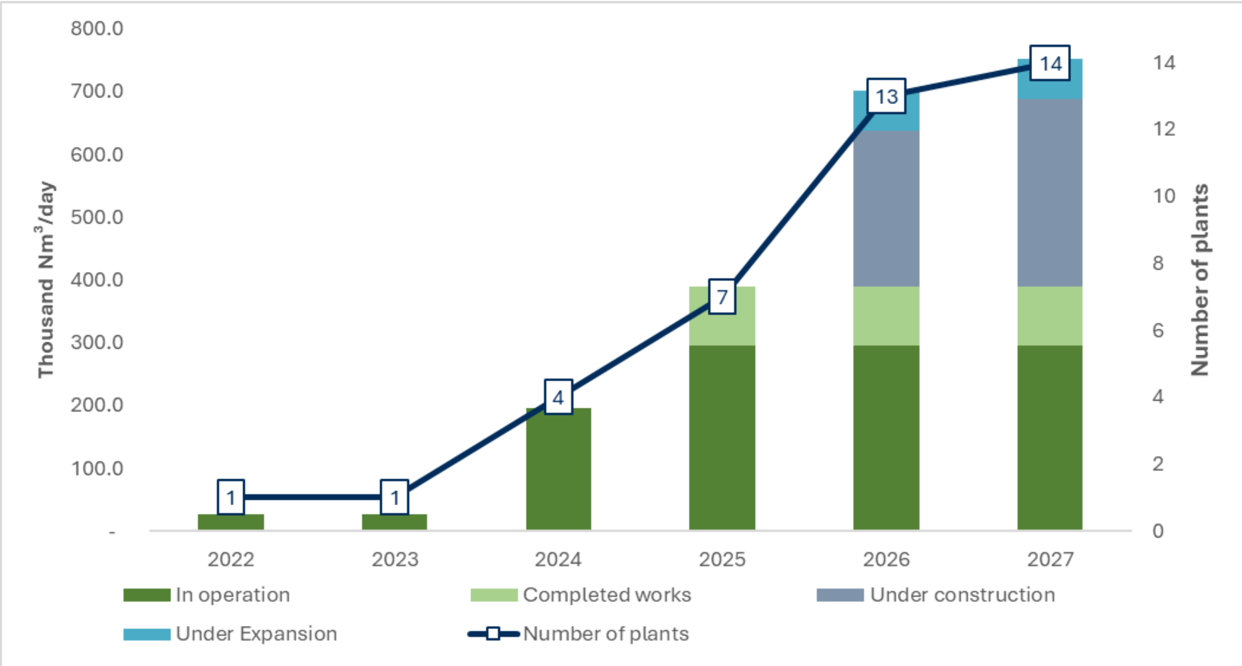
[35] The Special Regime of Incentives for Infrastructure Development suspends the requirement of PIS/PASEP and Cofins on the sale or import of goods and services destined for works.

[36] By the completion date of this study, the minimum value of biomethane for the first year of compliance with the Fuel of the Future Law had not yet been established, whose decree defining this value was not yet concluded.

[37] According to CIBiogás (2024), there is a series of biomethane producing units in "non-commercial" operation, without ANP authorization. These units are not considered in the study.

In early December 2025, there were 17 units in operation, 5 being from the sugar-energy sector. Additionally, 41 installations were in the authorization process and, from cross-referencing with other information, there is an indication that 10 of them would be from sugarcane[38], with the evolution depicted in Chart 17.

Chart 17 – Evolution of biomethane installations in the sugar-energy sector registered with ANP



Source: EPE based on ANP (2025b)

With the ANP registry counting mills with construction completion expected by the end of 2027, it was adopted as an assumption for all scenarios that the plants installed by that year will be exclusively those already identified in this database. All scenarios include in their projections the positive developments of the legal frameworks established by the Fuel of the Future Law, which provokes growth perspectives for this biofuel market.

Based on recent sector developments, three scenarios for the implementation of projects in sugarcane mills are proposed for the 2028-2035 horizon, according to Table 8.

[38] ANP records do not inform the raw material of the mills in the authorization process.

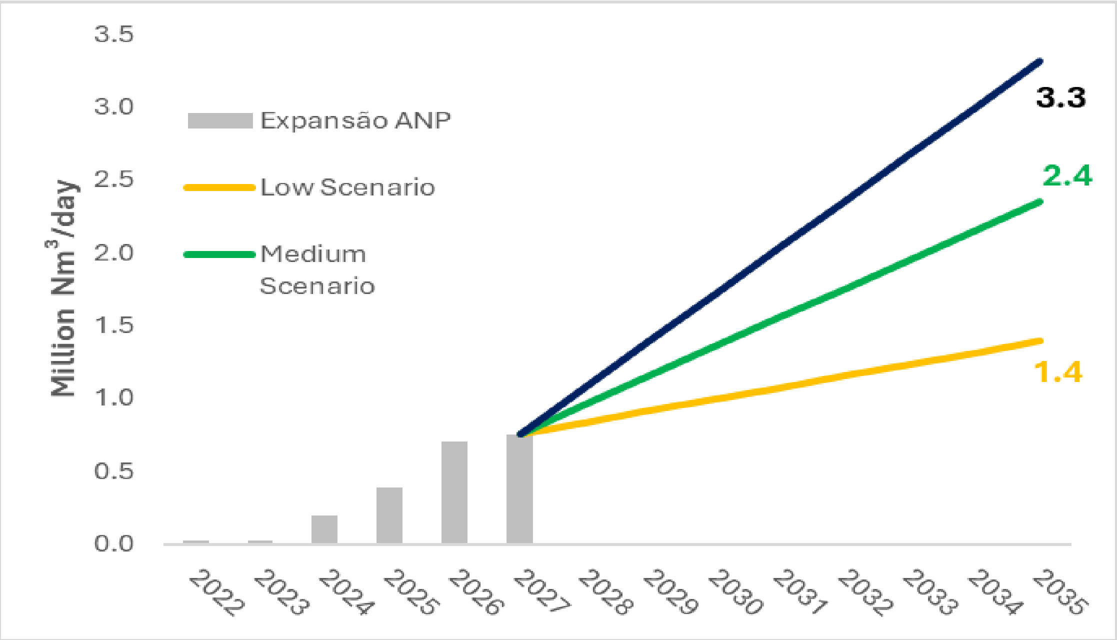
Table 8 - Detailing of scenarios for the entry of biomethane mills

Scenario	Justification
Low Scenario - Paced expansion	Investments impeded by eventual barriers, such as: • 2 plants per year • supply chain restrictions; • option for other projects in the mills; • timid demand; • caution of producers, awaiting advanced biogas utilization solutions, access to infrastructure, or wide availability of gas equipment.
Medium Scenario - Accelerated expansion	Continuation of the rhythm of new projects observed in 2025, including mills with completed works and/or expected completion by the end of the year, based on ANP records. • 5 plants per year
High Scenario – Towards the standard mill	• Investment in biomethane becoming an unavoidable decision in all mills, in a virtuous cycle driven by public policies. Conditions: • 8 new plants per year • successful experiences being disseminated with optimal use of their resources; • advancement in the learning curve with cost reduction and productivity increase; • maintenance of incentives in force.

Source: EPE (Own elaboration)

As an estimate of the scale of new plants, an average value of 40,000 Nm³ of biomethane per day was adopted, close to the average capacity of mills in the authorization process at ANP. The consolidated result of the scenarios is presented in Chart 18.

Chart 18 - Scenarios of installed biomethane capacity in the sugar-energy sector



Source: EPE (Own elaboration)

In the paced expansion scenario, the number of biomethane plants in the sugar-energy sector reaches 30 in 2035, while accelerated expansion leads to 54. In the scenario that understands biomethane as a new product in the portfolio of the country's standard cane mills, there would be 78 units at the end of the period. The installed capacity varies from 1.4 to 3.3 million Nm³ per day in the study horizon.

Biomethane production by the sugar-energy sector will be a significant expansion agent for this biofuel in the country, in combination with biomethane from other raw materials. The contribution of cane mills to meeting the targets that will be established by the CNPE under the scope of the Fuel of the Future will be the subject of a specific study to be published by EPE.

Avoided greenhouse gas emissions

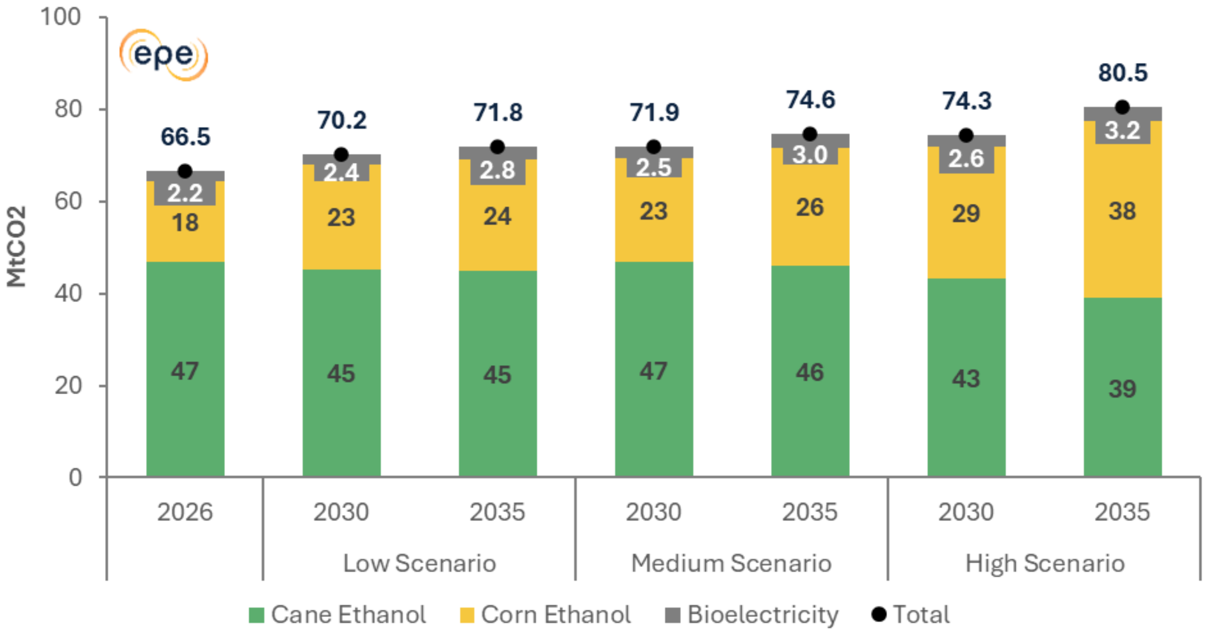
To estimate the emissions avoided by the use of cane and corn ethanol (hydrous and anhydrous) and sugarcane bioelectricity, replacing fossil fuels, parameters determined by the IPCC (2006), RenovaBio (ANP, 2025d), and MCTI (2023) were used.

For cane ethanol, anhydrous and hydrous, avoided emissions were estimated at 2.56 kgCO2eq/liter and 1.08 kgCO2eq/liter, respectively. In the case of corn ethanol, data available in RenovaBio were the basis for calculating the substitution of gasoline A (anhydrous) and C (hydrous). The avoided emission factors for this biofuel were 2.33 kgCO2eq/liter (anhydrous) and 1.16 kgCO2eq/liter (hydrous).

In the case of bioelectricity, it is considered that its generation occurs in substitution for electricity generated by the SIN (National Interconnected System), whose emission factor varies according to the use of the various sources that make up the national electric matrix each year. A 42% increase in this factor was observed in 2024, compared to that registered in 2023, reaching 0.0545 tCO2/MWh, about 40% of that observed in 2021, a year of severe water stress, when the value was 0.1264 tCO2/MWh.

Adopting the most conservative approach for bioelectricity[39] (Chart 14) and considering the fuel demand for ethanol, both cane and corn, up to 80.5 MtCO2 could be avoided with the high scenario and 71.8 MtCO2 with the low scenario, as illustrated in Chart 19.

Chart 19 – Avoided GHG emissions by the use of ethanol and bioelectricity*



Source: EPE (Own elaboration) based on IPCC (2006) and MCTI (2023)

(*) projection based on the factor of processed cane ton/kWh based on history*

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

Investments

For the evaluation of necessary investments (indicative), mixed sugar-energy first-generation units (greenfields) were considered, with an optimized technological profile and average size of 4 million tons of nominal processing capacity. It is estimated that the average CAPEX for this profile is R$ 730.1 / tc (IBGE, 2025; LNBR, 2022; FGV, 2025). The specific investment value adopted for the expansion of existing units was R$ 293.0 / tc (IBGE 2025a; LNBR, 2022; FGV, 2025).

The estimate of investments in new lignocellulosic ethanol plants considered the values referring to projects recently announced in Brazil, estimated at R$ 16.92 / liter (RAÍZEN, 2024b, 2024c; IBGE, 2025).

For corn ethanol, it is estimated that the CAPEX for the implementation of a flex plant will be R$ 1.54 / liter, while for a full plant, the value is R$ 2.66 / liter (IBGE, 2025a; LNBR, 2022, NOVACANA, 2025).

Thus, an estimate of the necessary investments in new units was performed for the considered scenarios, according to Table 9.

Table 9 - Estimated investment for new projects and expansions

CAPEX (R$ bilhões)	Low	Medium	High
E1G Cane	10.2	10.2	15.6
E2G Cane	5.6	12.5	13.9
Corn	11.9	17.8	37.7
Total	**27.7**	**40.5**	**67.2**

Source: EPE based on LNBR (2022); FGV (2025), IBGE (2025a); NOVACANA (2025) and RAÍZEN (2024b, 2024c)

It is highlighted that investments associated with the formation of sugarcane fields will be R$ 47 billion, R$ 48.7 billion, and R$ 50 billion in the low, medium, and high scenarios, respectively, with about 50% divided between sugar and ethanol.

For further details, access the publication Technical Note on Investments and Operational and Maintenance Costs in the Biofuels Sector (EPE, 2025g).

4. Results – Supply Expansion Studies

In this item, the evolution of the total demand for liquid fuels for the light vehicle fleet (automobiles and light commercial vehicles) of the Otto cycle will be presented, for the three ethanol supply scenarios developed, considering a mixture percentage of anhydrous ethanol in gasoline C of 30%. A sensitivity analysis considering that the anhydrous content reaches 35% in 2035[40], will also be presented in Item 5.

The total fuel demand is projected through an accounting model developed by EPE (2010), which considers, besides the economic scenario (EPE, 2025e), various aspects such as the licensing of light vehicles, the entry of new vehicle technologies such as hybrids and electrics, the domestic supply of ethanol, the domestic price of gasoline, and consumer preference between gasoline and ethanol in the fueling of flex-fuel vehicles. Further details can be found in the Technical Note on Light Vehicle Energy Demand (EPE, 2024c).

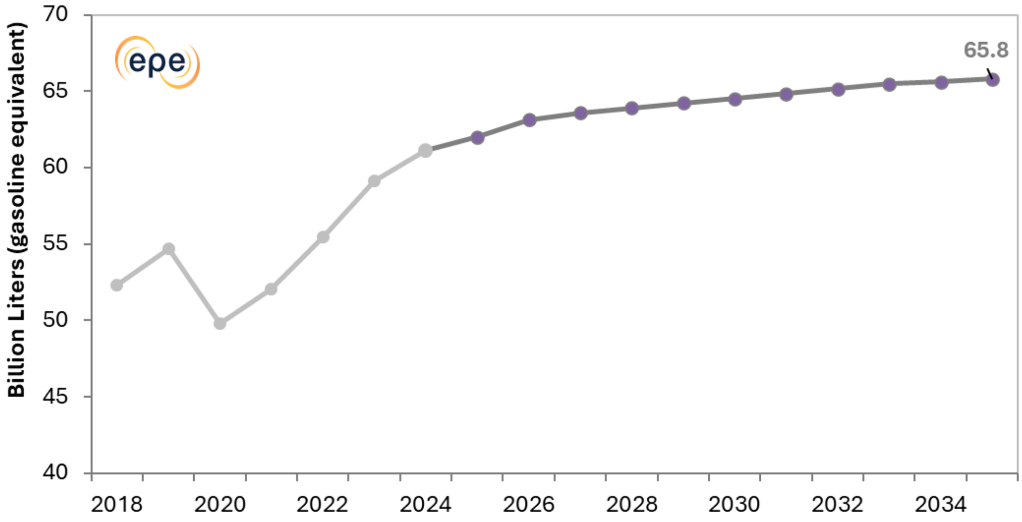
The considered licensing trajectory, added to the vehicle scrappage rate, results in an increase in the national circulating fleet, which grows from 2024 to 2035 at an average annual rate of 1.3%, reaching the mark of 42.9 million units in 2035. At the end of this period, internal combustion flex-fuel vehicles will represent 83% of this fleet; those dedicated to gasoline, 6.5%; electrified ones, 8.7%; and those dedicated to ethanol, the residual value.

For the period from 2024 to 2035, the estimated growth rate for fuel demand of the total light vehicle fleet of the Otto cycle (except CNG[41]) is 0.7% p.a. and will reach 65.8 billion liters of gasoline equivalent, according to Chart 20.

It is observed that the Otto cycle fuel consumption has been maintaining an expressive growth trend in recent years. Such fact may be related to the increase in the licensing of light vehicles and motorcycles. Furthermore, this perspective reflects a quite favorable economic conjuncture, with an increase in GDP per capita, observed since 2024. Formal occupation has reached successive records, as has the unemployment rate, continuously reaching the lowest value in the historical series (IBGE, 2025b). The reduction of social inequalities (AGÊNCIA GOV), the real increase in the minimum wage, and the record of the real income mass also contributed to this panorama (IBGE, 2025b).

[40] It was adopted that the percentage evolves by 1% per year, until reaching 35% at the end in the last year of the study period.
[41] It is estimated that CNG demand evolves from 2.2 billion to 5.0 billion liters of gasoline equiv. between 2024 and 2035.

Chart 20 – Otto cycle demand (without CNG)



Source: EPE (Own elaboration)

Fuel ethanol

Fuel ethanol demand is obtained from the total ethanol supply, removing the portions of the biofuel destined for other energy uses (ethanol for waterway and SAF production), export, and non-energy (other purposes), according to Chart 21. From this amount, the demand of dedicated fleets, powered by gasoline C and hydrous ethanol, was estimated, as well as the portion of the demand of flex-fuel vehicles that will be met by hydrous ethanol and gasoline C (gasoline A + anhydrous ethanol).

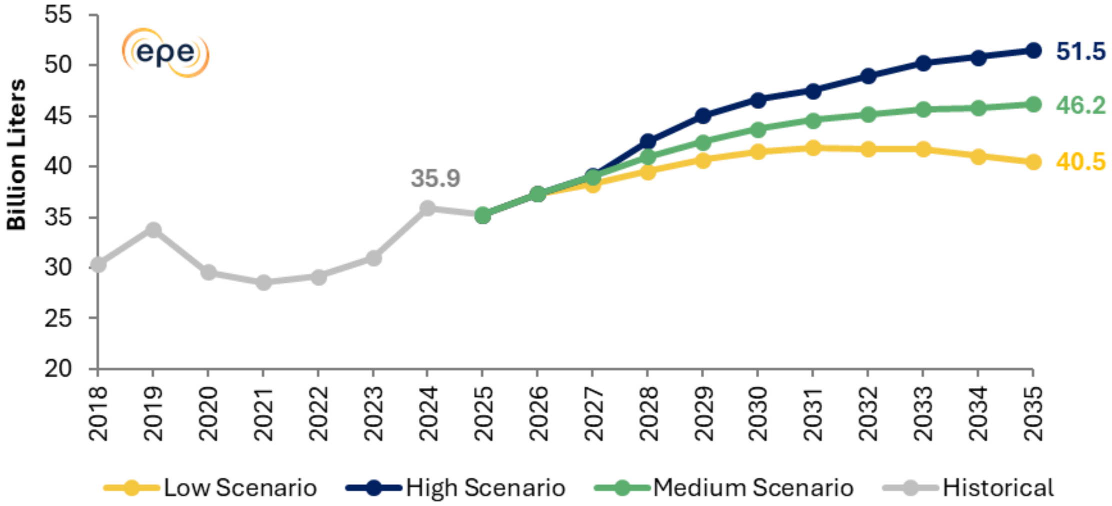
A Table 10 and Chart 21 present the growth rates and variations of fuel ethanol demand between 2024 and 2035.

Table 10 - Growth rate and variation of fuel ethanol demand

	2024 - 2030		2024 – 2035	
Scenarios	**Rate (%)**	**Variation (Bn liters)**	**Rate (%)**	**Variation (Bn liters)**
Low Growth	2.4	5.5	1.1	4.6
Medium Growth	3.3	7.8	2.3	10.3
High Growth	4.4	10.7	3.3	15.6

Source: EPE (projections) and EPE (2025c) (historical)

Chart 21 – Fuel ethanol demand



Source: EPE (projections) and EPE (2025c) (historical)

Gasoline A

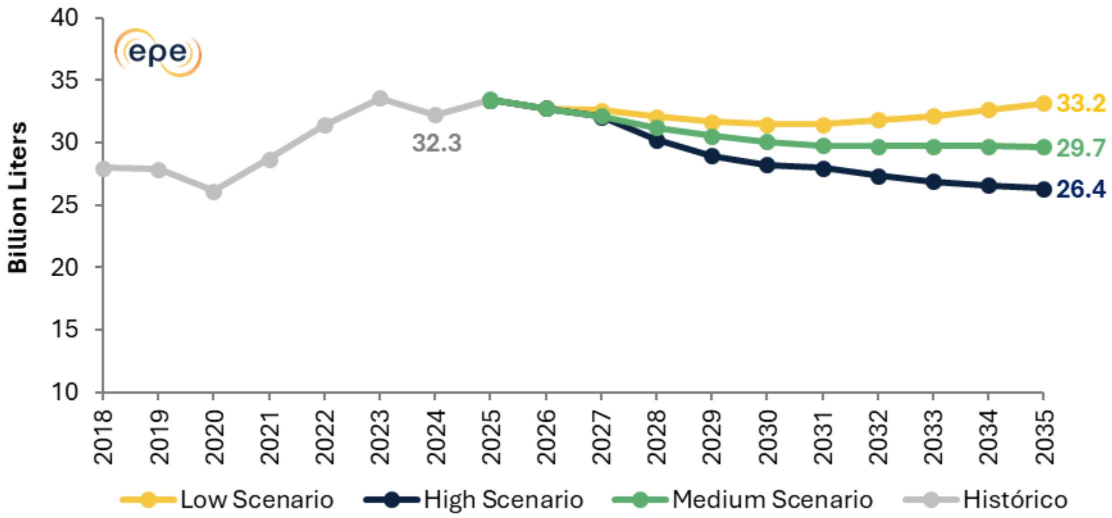
Gasoline A added to anhydrous ethanol originates gasoline C and is destined both to meet the dedicated fleet and a portion of the flex-fuel fleet. It is estimated that, in 2035, the volume of fossil fuel will reach 29.7 billion liters, for the medium growth scenario. Table 11 and Chart 22 present the growth rates and variations of gasoline A demand between 2024 and the years 2030 and 2035.

Table 11 - Growth rate and variation of gasoline A demand

	2024 - 2030		2024 – 2035	
Scenarios	Rate (%)	Variation (Bn liters)	Rate (%)	Variation (Bn liters)
Low Growth	-0.4	-0.8	0.3	0.9
Medium Growth	-1.2	-2.2	-0.8	-2.6
High Growth	-2.2	-4.0	-1.8	-5.9

Source: EPE (projections) and EPE (2025c) (historical)

Chart 22 – Gasoline A demand

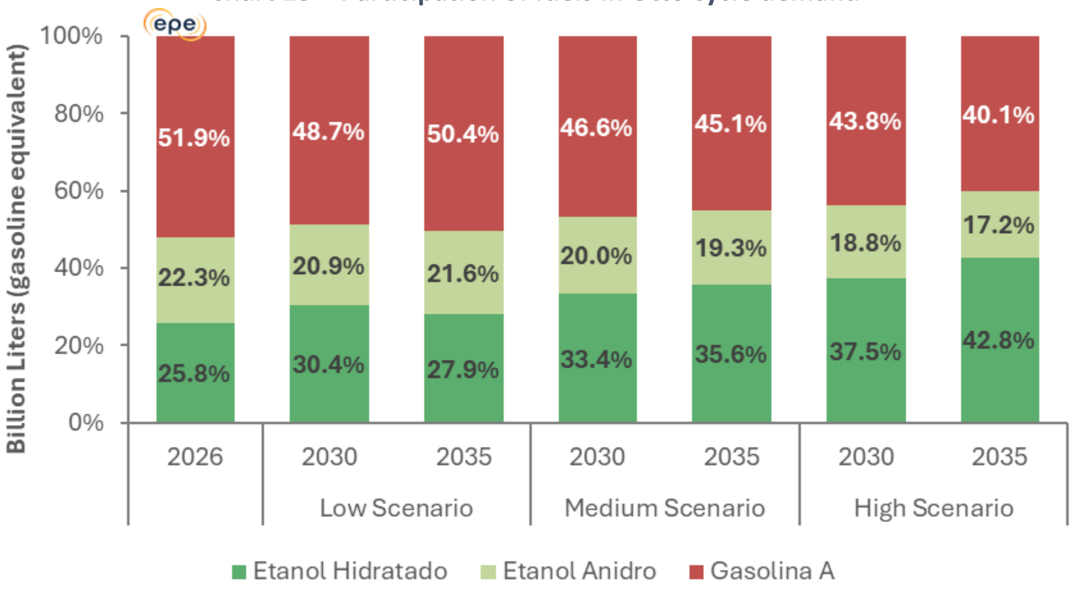


Source: EPE (projections) and EPE (2025c) (historical)

Fuel participation in the Otto cycle

The participation of hydrous and anhydrous ethanol and gasoline A in the Otto cycle in each scenario is indicated in Chart 23. The participation of biofuels varies from 50%, 55%, and 60% in 2035, for the low, medium, and high growth scenarios, respectively.

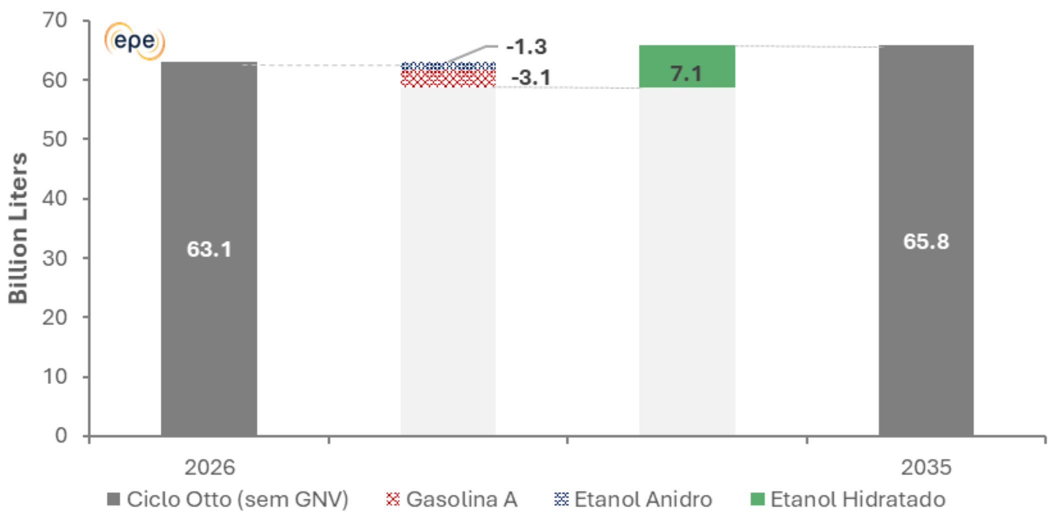
Chart 23 – Participation of fuels in Otto cycle demand



Source: EPE (Own elaboration)

Chart 24 presents the evolution of Otto cycle demand segmented by fuel between 2026 and 2035, for the medium scenario, in which gasoline C decreases by 4.4 billion liters, while demand for hydrous ethanol grows by about 7.1 billion liters.

Chart 24– Evolution of Otto cycle demand segmented by fuel

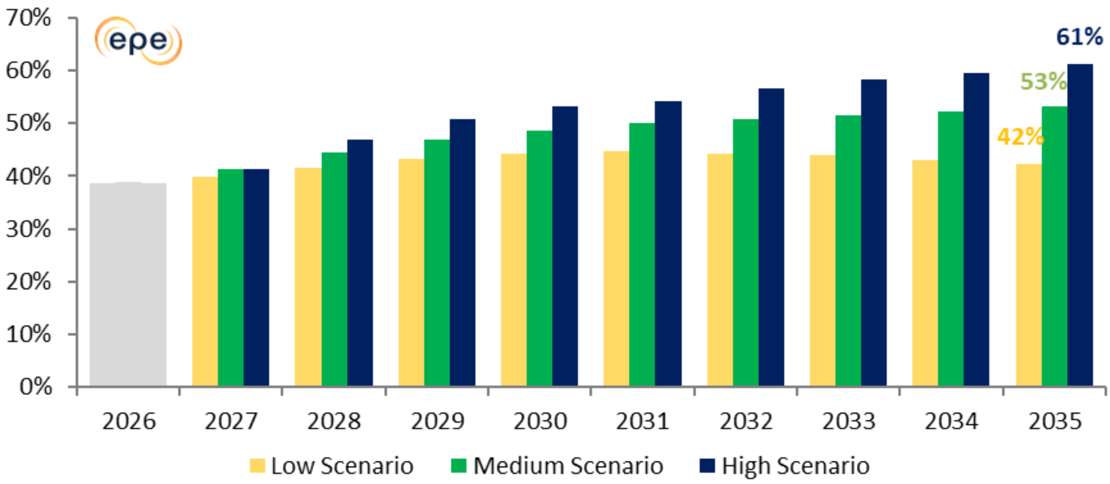


Source: EPE (Own elaboration)

Hydrous market share in flex fuel

Based on the availability of hydrous fuel ethanol, the trajectory of its participation in the demand of flex-fuel vehicles is verified. In Chart 25, it is observed that this amount will result in an increase in the market share of hydrous ethanol in the flex fleet. This participation represents, in 2035, 42% in the low growth scenario of ethanol supply. For the medium and high growth scenarios, it reaches 52% and 61%, respectively.

Chart 25 – Hydrous ethanol market share in flex fuel (in volume)



Source: EPE (Own elaboration)

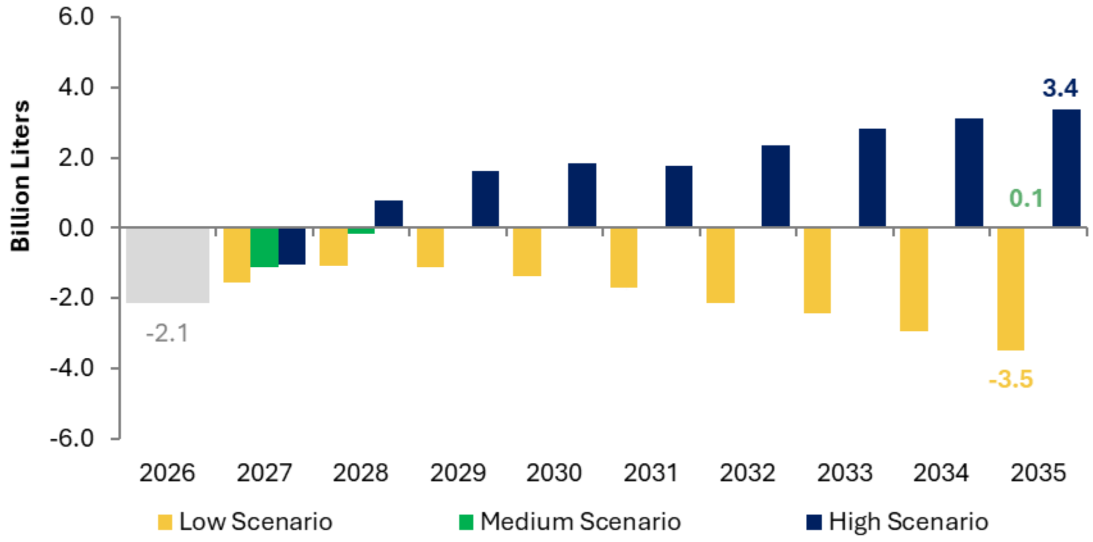
National Gasoline A Balance

The evaluation of the gasoline A balance in the study horizon considered the production projection from the PDE 2035, which reaches 29.7 billion liters in 2035 (EPE, 2025e) and the average value between 2018 and 2022, 26.3 billion liters, a period in which the production of this fossil fuel by refineries presented the lowest values (since 2014). In 2024, gasoline A production reached 31.9 billion liters, the highest value in the historical series, surpassing the year 2014 (31.0 billion liters).

Since gasoline and naphtha fractions are obtained from similar oil cuts, gasoline supply ends up resulting, basically, from the analysis of demand, prices, and logistical flows of these derivatives. However, there are other elements that also influence this market flow, such as the opportunity cost of ethanol and sugar and crop conditions. Thus, even if there is a set of indications for domestic gasoline production, it may suffer influences from the factors cited previously, resulting, for example, in lower import volumes.

As can be observed in Chart 26, such exercise evidenced that there will be a need for importation for the years 2026 and 2027 for all scenarios. In subsequent years, for the medium scenario, it will practically not be necessary to import gasoline, while for the low scenario the deficit is growing and reaches 3.5 billion in 2035. For the high scenario, a surplus is observed, reaching 3.4 billion at the end of the period.

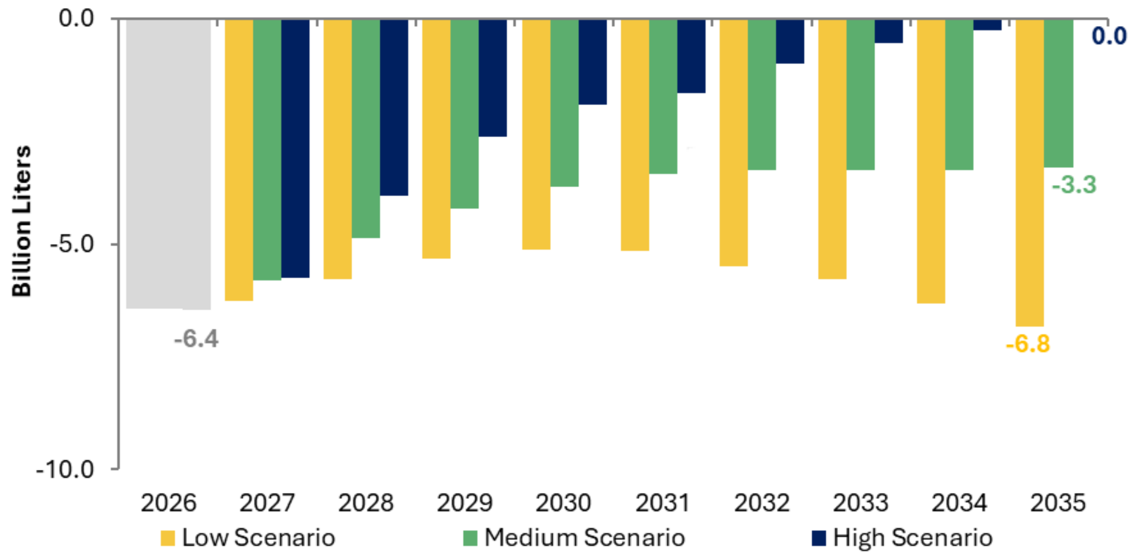
Chart 26 – National Gasoline A Balance - PDE 2035 Production



Source: EPE (Own elaboration)

The second sensitivity analysis, which aims to evaluate the reflections on the national gasoline balance in a scenario of lower supply of this derivative - production of 26.3 billion liters, average between 2018 and 2022 - indicates that there will be a need for importation throughout the period for the low and medium scenarios, reaching 6.8 and 3.3 billion liters, respectively. In the high growth scenario, imports occur until 2034, according to Chart 27.

Chart 27 - National Gasoline A Balance – average of volumes produced between 2018 and 2022

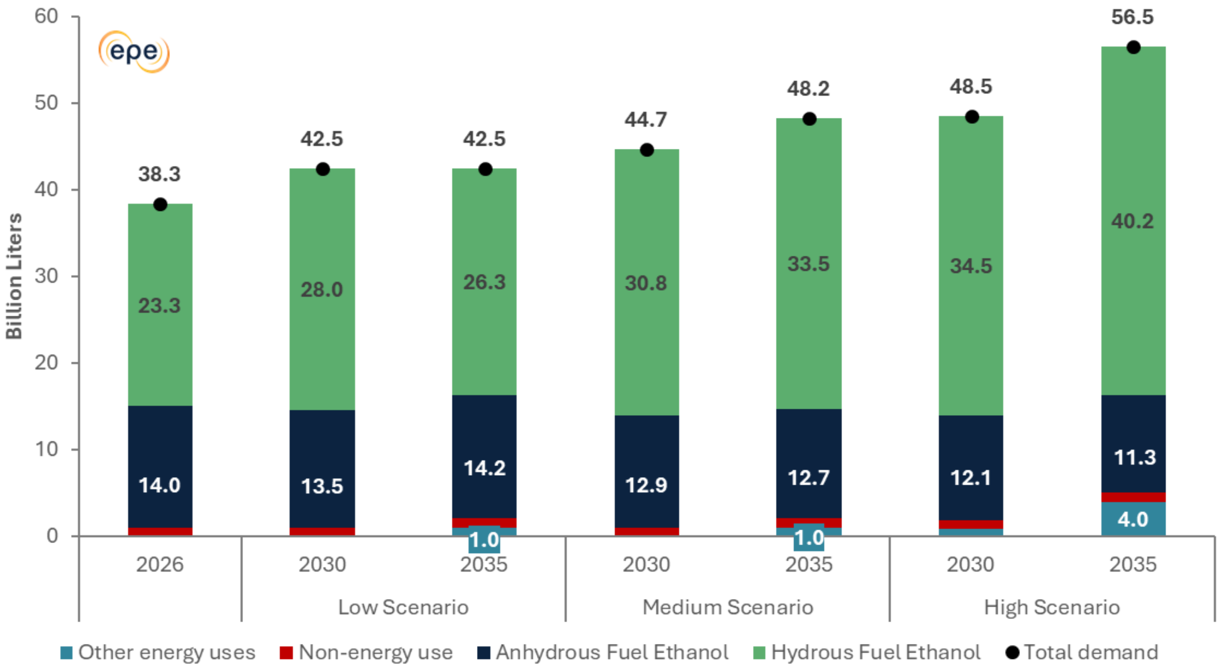


Source: EPE (Own elaboration)

Other energy uses

Besides the use of fuel ethanol (anhydrous and hydrous) for fueling the Otto cycle fleet, a demand is also estimated for SAF production through the ATJ route and use in the waterway sector. Considering these portions, the total biofuel demand, for the low, medium, and high growth scenarios, is presented in Chart 28.

Chart 28 – Ethanol demand (energy and non-energy)



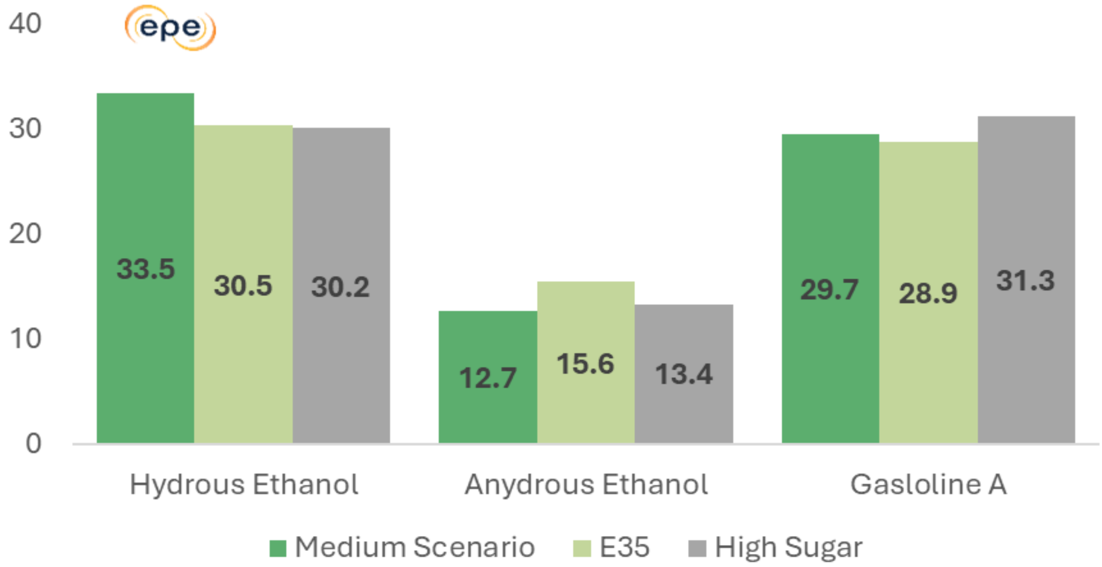
Note 1: The terms hydrous and anhydrous fuel refer to that used in road transport. For other energy uses and non-energy use, the indicated demand includes the portions of anhydrous and hydrous.
Note 2: The portion destined for export (of 2.3 billion liters in 2035) is not included in this chart.
Source: EPE (Own elaboration)

5. Sensitivity Analyses

In this item, sensitivity analyses of the impact on Otto cycle fuel demand will be presented considering: the allocation of ethanol for the increase of anhydrous content in gasoline C, from 30% to 35%, a possibility presented by the Fuel of the Future Law (BRASIL, 2024), and a greater allocation of TRS for sugar production, with the appreciation of this commodity and the expansion of Brazil's prominent position in the international market. The allocation of ethanol for SAF production (ATJ route) and waterway use are already contemplated, as indicated in the previous items.

For the medium growth scenario, these sensitivities will be, primarily, presented separately, analyzing the effect of each one, being denominated E35 (considering the increase of 1% per year, starting in 2030) and High Sugar, according to Chart 29. Additionally, the absolute and percentage variation in the demands of each of the sensitivities can be observed in Table 12.

Chart 29 – Isolated impact of sensitivities on hydrous, anhydrous, and gasoline A demands in 2035



Fonte: EPE (Own elaboration)

Table 12 - Variation of sensitivities on hydrous, anhydrous, and gasoline A demands in 2035

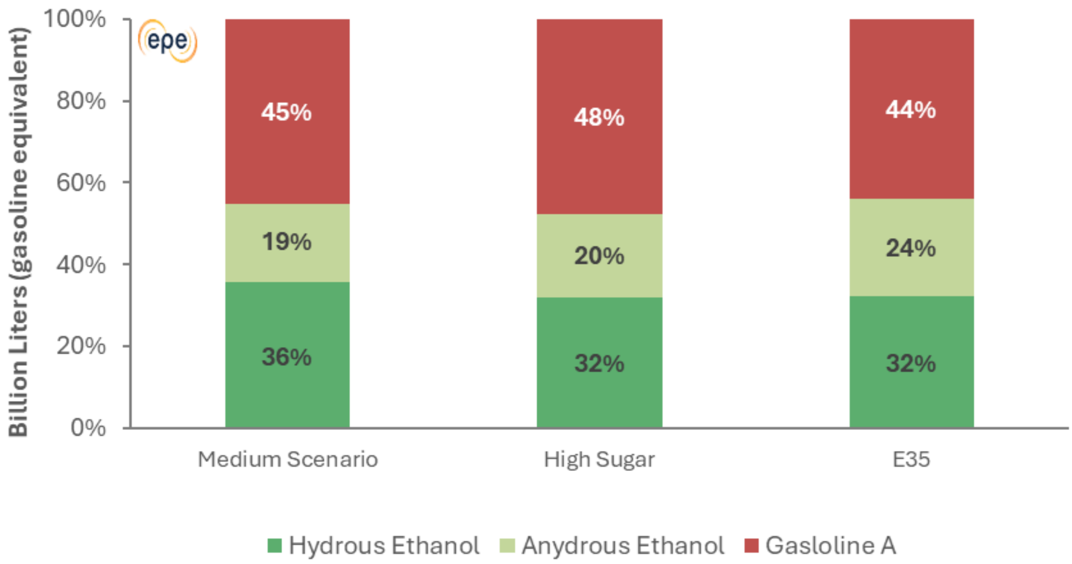
	Hydrous Ethanol	Anhydrous Ethanol	Gasoline A
Scenarios		**Variation (bn liters/%)**	
E35	-3.0 (-9.0%)	2.9 (22.5%)	-0.7 (-2.5%)
High Sugar	-3.3 (-9.9%)	0.7 (5.5%)	1.6 (5.5%)

Note: The variation and rates are in relation to the medium growth scenario.

Source: EPE (Own elaboration)

The composition of the Otto cycle demand, based on the sensitivities analyzed for the medium growth scenario, in isolation, are presented in Chart 30.

Chart 30 – Otto cycle composition for medium scenario sensitivities in 2035

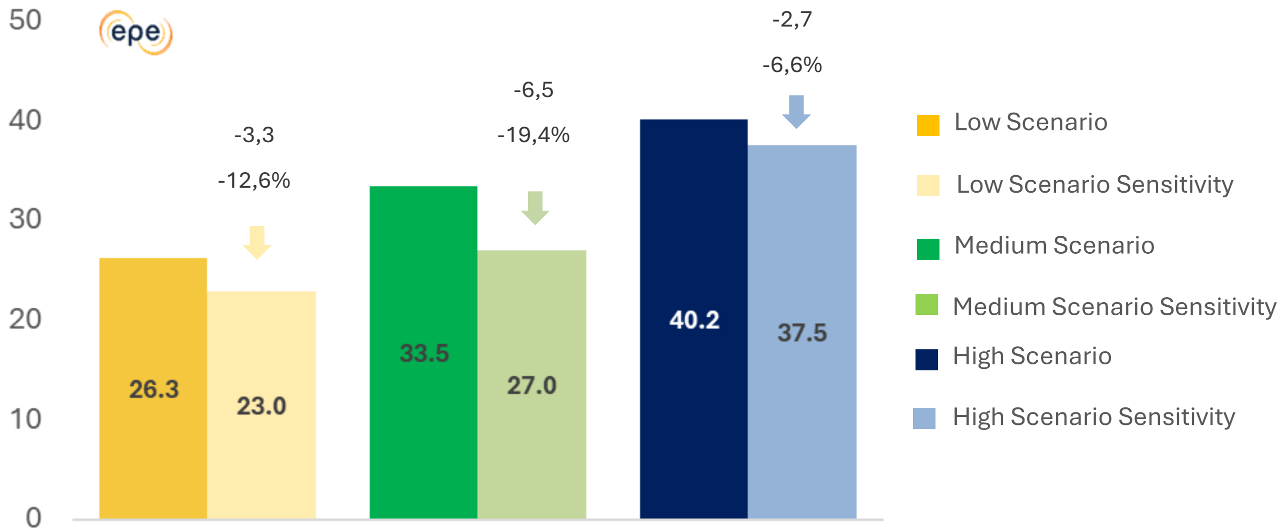


Source: EPE (Own elaboration)

Next, for all scenarios, the analyses will be performed in a grouped manner, that is, a scenario maintaining the sugarcane production factors, adjusting the allocation of TRS with a view to higher sugar production (according to Item 0), in addition to the evolution of a 35% anhydrous ethanol mixture in gasoline C in 2035. Such scenarios will be denominated: Low Sensitivity Scenario, Medium Sensitivity Scenario, and High Sensitivity Scenario.

It is worth mentioning that the high growth scenario already considers higher sugar production, as indicated previously. Charts 31, 32 e 33 indicate the results for hydrous ethanol, anhydrous ethanol, and gasoline A, respectively.

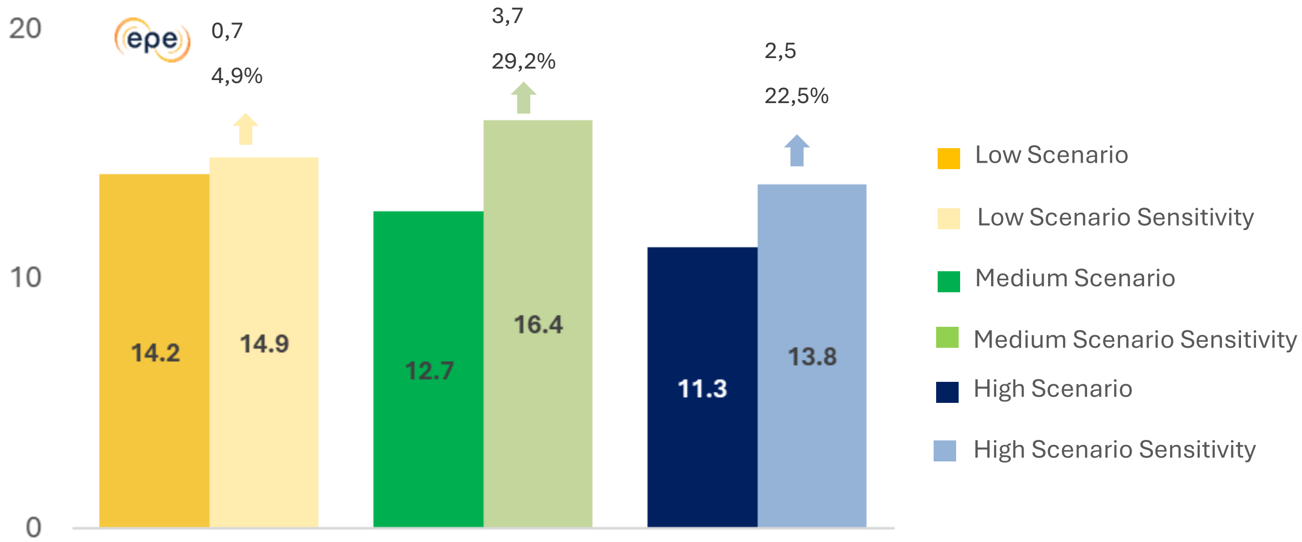
Chart 31 – Reflections on hydrous ethanol demand for each scenario in 2035



Note: The low, medium, and high scenarios correspond to those described previously.

Source: EPE (Own elaboration)

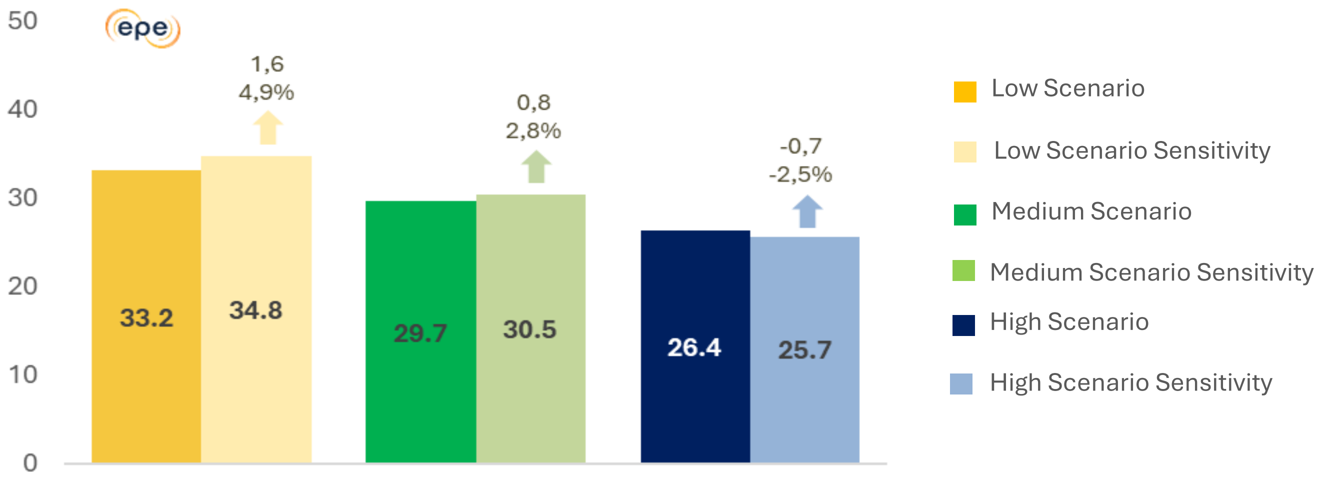
Chart 32 – Reflections on anhydrous ethanol demand for each scenario in 2035.



Note: The low, medium, and high scenarios correspond to those described previously.

Source: EPE (Own elaboration)

Chart 33 – Reflections on gasoline A demand for each scenario in 2035.

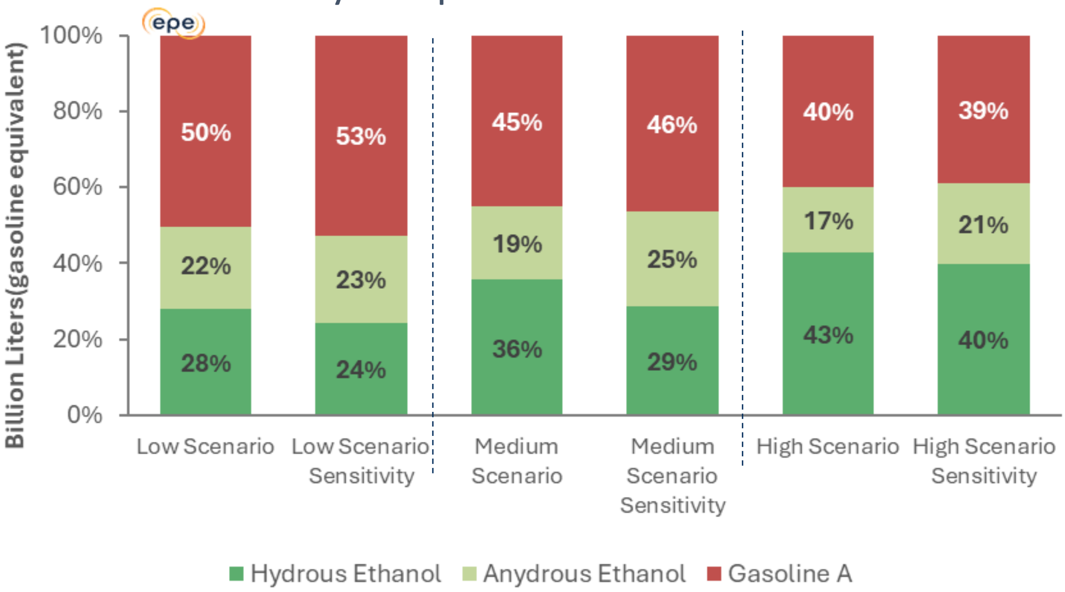


Note: The low, medium, and high scenarios correspond to those described previously.

Source: EPE (Own elaboration)

The composition of the Otto cycle demand, for the analyzed scenarios and their sensitivities, are presented in Chart 34.

Chart 34 – Otto cycle composition for scenario sensitivities in 2035.



Source: EPE (Own elaboration)

BOX 1 – Stabilization in Ethanol Supply

It aims to present an analysis of ethanol supply and Otto cycle demand, considering a stable scenario for the biofuels sector regarding public policies and company actions. Additionally, international oil prices will be situated at moderate levels. Thus, despite RenovaBio and the Fuel of the Future, the economic attractiveness of the ethanol sector would not be sufficient to induce relevant investments.

Regarding new units, only those with estimated entry by 2028 were considered, based on construction authorization requests at the ANP (position in March 2025) (ANP, 2025b). In terms of cane, with this criterion, there will be the entry of one new mill (280 million liters) and expansions totaling 2.4 billion liters. The closing balance of those in unfavorable financial situations is also considered, resulting in a loss of processing capacity of 6 million tons of cane (460 million liters for ethanol). Regarding corn, new units and expansions sum 2.6 billion liters in nominal ethanol production capacity.

In this analysis, the same estimates were adopted for yield, national sugar production (reference), exports, ethanol for other energy uses (similar to the low and medium scenarios), and ethanol for non-energy use. The estimated nominal installed capacity will be 832 Mtc for cane and 28 Mton for corn in 2035. The processed cane area is 8.5 Mha and agricultural productivity is 75.9 tc/ha in the same year. As a result, a quantity of about 645 million tons of ground cane is estimated at the end of the period. The ethanol supply by raw material is indicated in Table 13.

Table 13 - Ethanol supply by raw material in 2035 (billion liters)

Cane1G	Cane 2G	Corn	Import	Total Supply
24.4	0.5	12.7	0.5	37.5

Source: EPE (Own elaboration).

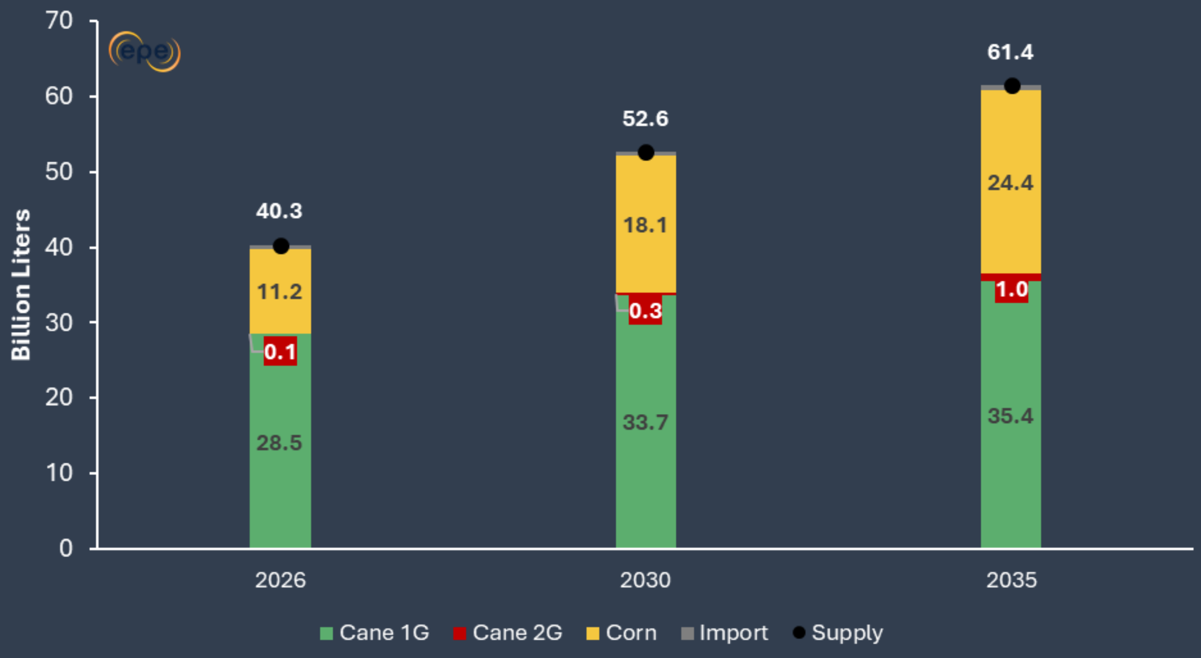
Considering the purpose of ensuring national energy supply, this analysis was based on the reference Otto cycle demand. In this case, it was found that the volumes of gasoline A and anhydrous ethanol would reach, respectively, 37.4 billion liters (increase of 7.7 billion liters) and 16.0 billion liters (increase of 3.3 billion liters). This growth is a consequence of the lower volume of hydrous ethanol made available by producers for the fuel market, approximately 17.7 billion liters (a value 15.8 billion liters lower than the reference scenario).

Finally, when analyzing the national balance of gasoline A, adopting its production based on the PDE 2035 (EPE, 2025e), it becomes necessary to import 7.7 billion liters in 2035, which corresponds to 21% of the fossil fuel demand. In the case of the analysis based on the production average between 2018 and 2022, it would be necessary to import 11.1 billion liters (30%). Note that the historical maximum import of this fossil fuel was 4.9 billion liters in 2020 (EPE, 2025c), and it is stated that a subsequent evaluation of the national fuel movement infrastructure capacity would be necessary.

BOX 2 - High ethanol scenario x reference sugar production

It aims to present an analysis for ethanol supply and Otto cycle demand, considering the production factors of cane (1G and 2G) and corn indicated by the high growth scenario, however with the reference sugar production (used in the low and medium scenarios), so that it is even more favorable to the biofuels sector. Sugar production reaches 48.2 million tons in 2035, as described previously, maintaining Brazil's leadership in the international trade of this commodity. The Chart 35 presents the ethanol supply by raw material.

Chart 35 – Ethanol supply by raw material.



Source: EPE (Own elaboration).

Ethanol supply reaches 61.4 billion liters, 2.6 billion liters higher than indicated in the high growth scenario (58.8 billion). Based on the reference Otto cycle demand of this PDE, the volumes of gasoline A and anhydrous ethanol would reach, respectively, 24.7 billion liters and 10.6 billion liters. The volume of hydrous ethanol would be 43.5 billion liters. Thus, the Otto cycle composition would be 55.2% hydrous, 13.4% anhydrous, and 31.4% gasoline A.

The analysis of the national balance of gasoline A with its production based on the PDE 2035 (EPE, 2025e) indicates that there is no need for importation, with the exception of the years 2026 and 2027. In the case of the analysis based on the production average between 2018 and 2022 (26.3 billion liters), it would be necessary to import volumes by 2030.

6. Conclusion

Brazil stands out in the insertion of biofuels into its energy matrix and maintains potential to expand this participation, supported by structuring public policies, such as RenovaBio and the Fuel of the Future Law. Recently, commitments assumed at COP 30 (Belém) reinforce this trajectory, such as the global commitment Belém 4x Pledge, and the proposition of a global roadmap[42], containing structured actions to reduce and overcome dependence on fossil fuels, aligning efforts for a just and accelerated energy transition.

This study presented the ethanol supply scenarios considered for the 2026-2035 period and their respective reflections on the Otto cycle demand and the national balance of gasoline A. The relevance of ethanol as a vector for the energy transition is highlighted.

The elaborated scenarios indicate variations in the supply of fuel ethanol, considering sector actions aimed at investments and cost reduction (cane field renewal, adequate cultural treatments, etc.) and biofuel incentive policies (tax and contribution differentiations, availability of financing lines for the sector, among others). That is, different assumptions regarding the degree of economic attractiveness for investments in the sugar-energy and corn ethanol sectors.

Cane mills are adjusting their financial conditions and benefit from the attractiveness of sugar in the international market and internal opportunities, related to improvements in cane fields, reduction of cultivation costs, irrigation, biogas production, E2G, among others indicated in this study, and external ones that benefit their development. In parallel, units producing ethanol from corn have been showing consistent growth, starting their operations in a short time interval, with the possibility of more than one harvest throughout the year, in rotation, mostly, with soy. Several other opportunities arise for this sector, such as carbon capture and the production of SAF via the ATJ route and sustainable fuels for waterway use. As a result of these projections, it is verified that the ethanol supply could reach values ranging between 44.8 billion and 58.8 billion liters. It is highlighted that the share of corn ethanol should represent between 33% and 42% of the total supply at the end of the period, evidencing its relevance in the national energy matrix.

Based on the estimated Otto cycle demand and the corresponding fuel production, a sensitivity analysis was performed considering the gasoline A production of the PDE 2035 and the average value between 2018 and 2022, of 26.3 billion liters (average of the lowest values since 2011). For the first case, there will be a need for importation throughout the study horizon for the low scenario, reaching 3.5 billion liters in 2035. For the medium and high scenarios, imports occur until 2028 and 2027, respectively. For the production of 26.3 billion liters, there will be no need for importation throughout the period, for the three scenarios considered.

The study evidence that the contribution of cane biomass to the national energy scenario could become even more relevant. The participation of bioelectricity, in the most conservative assessment, could inject up to 4.2 GWm in 2035 in the high growth scenario, and 3.8 GWm in the low growth scenario. It is estimated that the biomass necessary for corn ethanol production varies between 12.2 and 19.4 million tons, this being a point of attention linked to the expansion of this sector.

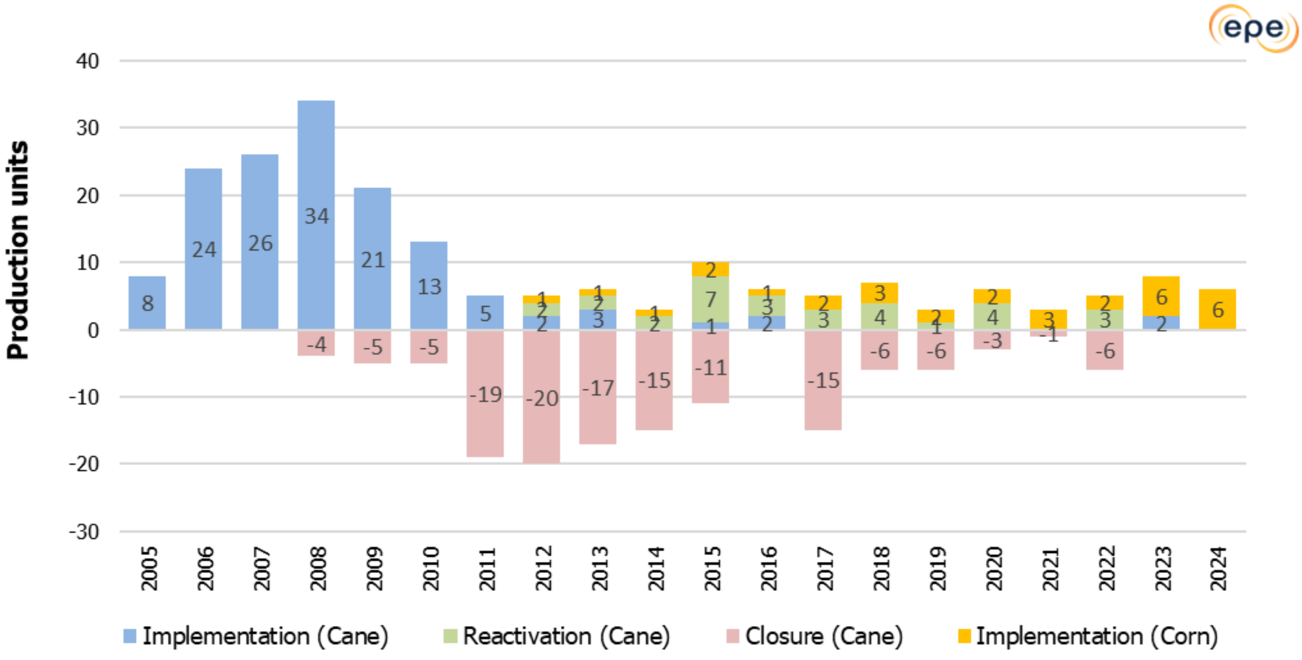
It is added that the utilization of residual cane biomass (vinasse and filter cake) for biomethane production, for this same horizon, enables the generation of 3.4 billion Nm^3 and 3.0 billion Nm^3 for the cited scenarios, respectively. Considering a more conservative analysis, more efficient groups with better financial health, the potential values would be 1.4 billion Nm^3 and 1.6 billion Nm^3, respectively. Furthermore, scenarios were presented for the entry of biomethane units, which may vary from 30 to 78, depending on the entry of investments in this sector.

[42] *Not incorporated into the final text of COP 30, but which will continue to be developed by working groups.*

Avoided GHG emissions by the use of cane products is 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 2035, between 80.5 MtCO2 and 71.8 MtCO2, for the high and low growth scenarios, respectively.

The study proves to be relevant to contribute to achieving public policies directed at supplying the Otto cycle vehicle market and meeting Brazil's international commitments under the Paris Agreement, and in national policies such as RenovaBio and Fuel of the Future, being important for the country's energy planning in the medium and long terms. Furthermore, energy needs must be met justly, considering social inclusion and the fight against poverty, a purpose for which biofuels have the potential to contribute.

Chart A1 – Flow of cane and corn mills in Brazil.



Source: EPE based on EPE (2025a); MAPA (2025), UNICA (2014a, 2014b)

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