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BIO FUELS

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Summary

Executive Summary

- *RenovaBio*, as an integral part of the National Energy Policy, aims to ensure predictability for the participation of renewable fuels in the fuel market, promote the generation of investment and jobs in the biofuels sector, as well as to promote Brazil's competitiveness in the international biofuels market, and boost technological development and innovation to increase their competitiveness.

- The growth prospects of the ethanol sector revolve around the resumption of investments and the increase in production, having as its motto: the scenarios of opportunity created by the commitments made at COP 21, a new regulatory proposal aimed at the promotion of biofuels (*RenovaBio*), the technological development with focus on increasing productivity, ensuring the supply of Otto cycle fuels and improving combustion engines to be more efficient with the use of ethanol, as well as the development of hybrid engines and electric engines by fuel cell.

- The scenario presented for the biodiesel sector foresees the increase in production from the following reasons: the scenario of opportunities created by the targets set at COP 21 (reduction of GHG emissions and percentages defined for bioenergy in the matrix); new regulatory proposal for the promotion of biofuels; increased blending mandates, already established by Law and authorized through the implementation of tests; development of programs aimed at the production of new oilseeds, such as palm; the use of the idle capacity of soybeans crushing, with the expansion of the bran market.

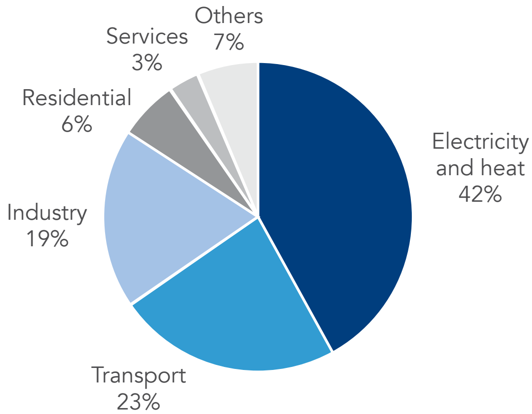
- Besides having extensive experience in the production of biofuels and having favorable climatic conditions for such production, Brazil has enough agricultural area to plant crops for energy purposes, something that should be taken advantage of, since it does not affect food production. The positive externalities of increased biofuel penetration are many, including the creation of jobs, the increase in income and the technological development, as well as the reduction of impacts on climate and human health.
- Brazil's prominent position in this matter is internationally recognized, given its leadership role in major world forums. The country has already made important commitments at COP 21, but these need to be broken down into clear targets with established deadlines, involving a regulatory framework that brings security and reliability and market mechanisms that promote the competitiveness of biofuels, in a way that is possible to resume investments and that the country corresponds to what is expected of it and, above all, to take advantage of its full potential.

Introduction

During the 21st Conference of the Parties, in 2015, the Paris Agreement was approved, in which one of the objectives is to keep global warming below 2°C with efforts to limit the temperature rise to 1.5°C in relation to pre-industrial levels. The agreement was considered a milestone in the climate discussions, since 195 countries signed it and 155 ratified, almost 80% (United Nations Framework Convention on Climate Change, 2017), indicating a strong global movement in the search for solutions regarding environmental impacts caused by anthropogenic action. In order to achieve the objectives of the Agreement, the participating countries have presented their commitments to reduce greenhouse gas (GHG) emissions, in their Nationally Determined Contribution (NDC).

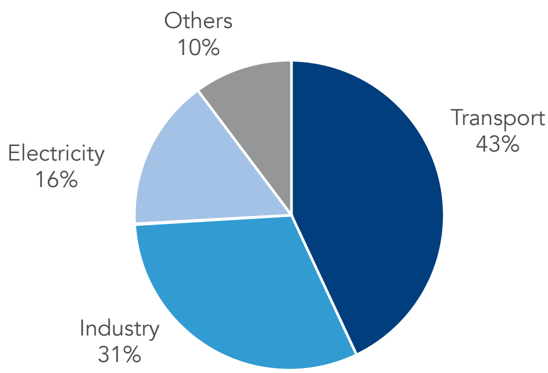
In this context of increasing concerns regarding global climate change, the reduction of greenhouse gas emissions by the transport sector is considered a priority. The sector is responsible for approximately 23% of the emissions from combustion, as shown in Figure 1, being second only to the generation of electricity and heat (42%). In Brazil, the share of CO_2 emissions by the transport sector is even higher (43%), as seen in Figure 2, while electricity accounts for 16% of emissions, due to the intense use of hydroelectricity and bioelectricity (from sugarcane biomass).

FIGURE 1: GLOBAL CO_2 EMISSIONS FROM FUEL COMBUSTION BY SECTOR IN 2014



Source: *International Energy Agency* (IEA, 2016)

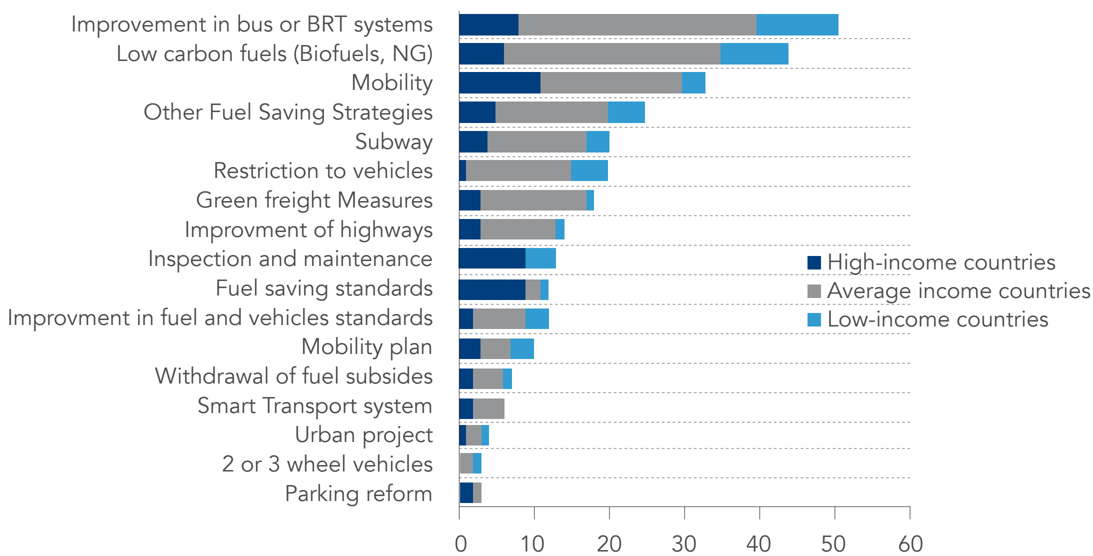
FIGURE 2: BRAZILIAN CO_2 EMISSIONS FROM ENERGY GENERATION AND CONSUMPTION BY SECTOR IN 2015



Source: *Ministério de Minas e Energia – Ministry of Mines and Energy* (MME, 2016)

Among 160 NDCs, representing 187 countries, which were submitted until August 2016, 75% explicitly identified the transport sector as a source of mitigation and more than 63% of the contributions propose specific measures for the sector (Gota, S. et. al., 2016). The proposed mitigation strategies include several actions, as shown in Figure 3, of which biofuels appear as the second most cited strategy, to be adopted, mainly by countries considered to be of average-income[1].

FIGURE 3: MITIGATION STRATEGIES FOR THE TRANSPORT SECTOR PROPOSED AT THE NDCS



Source: Gota, S. et al. (2016)

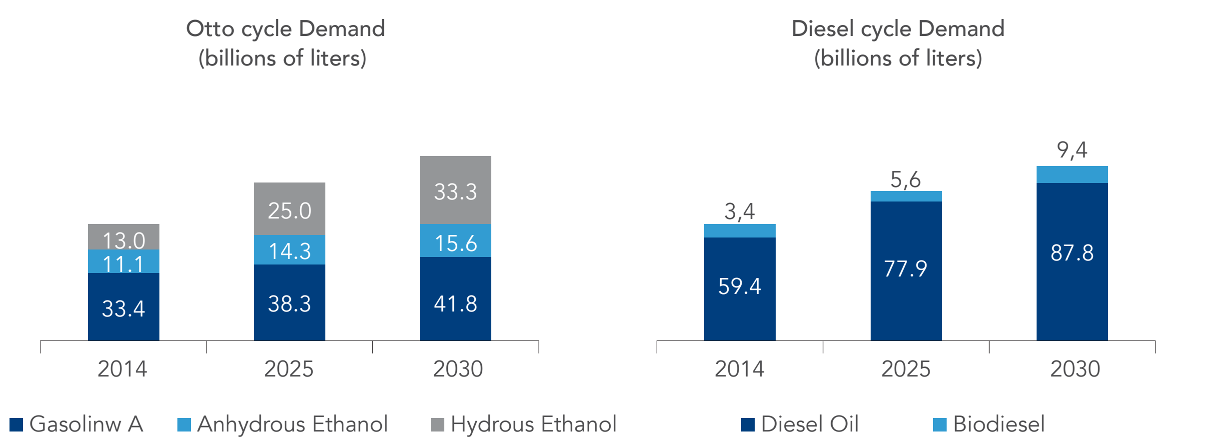
Brazil, in its NDC, made a commitment to reduce the country's total GHG emissions by 37% in 2025, and signaled to reduce emissions by 43% in 2030, using 2005 as a reference. The commitments made include achieving an estimated 45% of renewable energies in the composition of the energy matrix in 2030 and the increase of the share of sustainable bioenergy in the Brazilian energy matrix to approximately 18% by 2030; the expansion of biofuel con-

1. According to the World Bank's (2015) methodology, the economies are classified, according to the Gross National Income per capita, in: low income, when this value is equal to or less than US$ 1,025; average income, when the value is between US$ 1,026 and US$ 12,475; and high income when is above US$ 12,476.

sumption; the increase in the supply of ethanol, by increasing the share of advanced biofuels (second generation); and increasing the biodiesel content in the diesel blend.

In a document that shows the calculation memory for the commitments made at COP 21, EPE (2016a) estimates that it will be necessary to increase the supply of ethanol by 25 billion liters, between 2014 and 2030, to cover the increase of demand for fuels from the Otto cycle (the study considers the 27% anhydrous ethanol level in the gasoline during the whole period) and predicts that production will reach a volume of 54 billion liters by 2030, of which 2, 5 billion liters will come from second-generation ethanol. Regarding the demand for fuels of the Diesel cycle, the document predicts the need to produce 9.4 billion liters of biodiesel by 2030. The demand values for Otto cycle and Diesel cycle fuels mentioned in the document are shown in Figure 4.

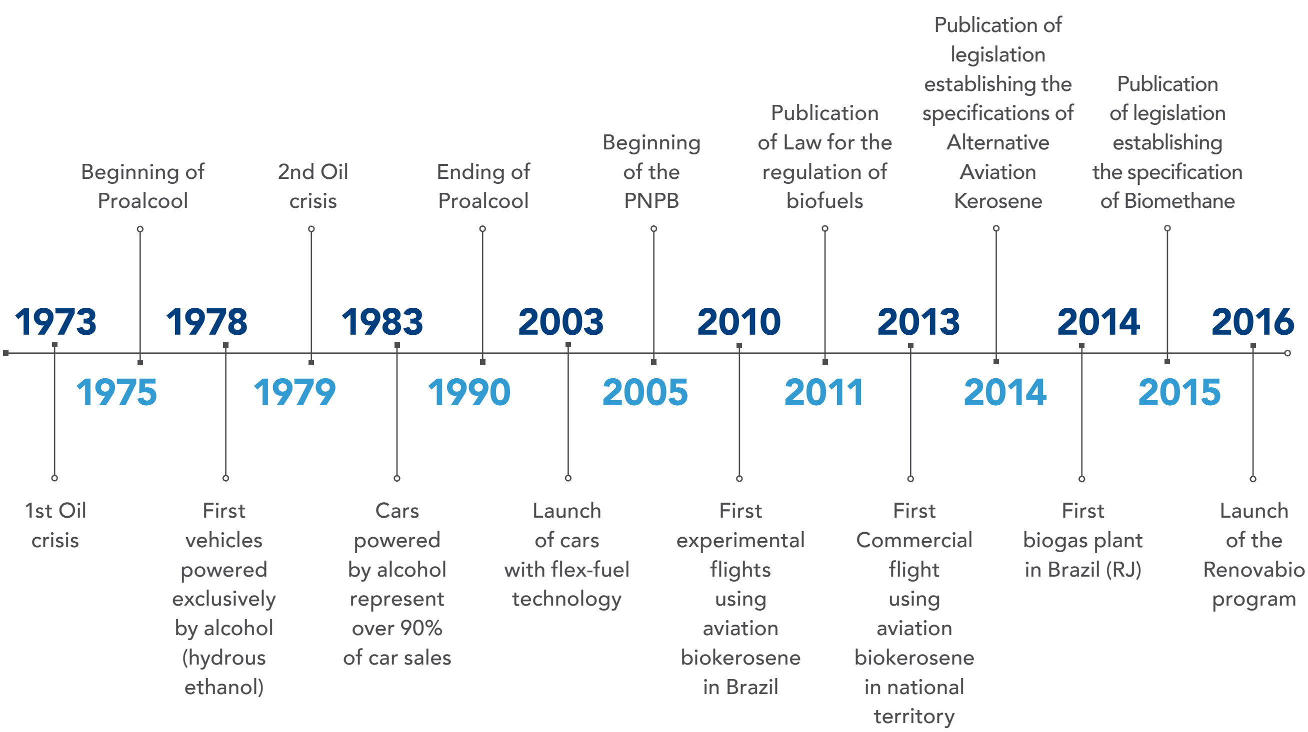
FIGURE 4: OTTO CYCLE AND DIESEL CYCLE FUEL DEMAND



Source: Adapted from EPE (2016a)

The introduction of biofuels into the Brazilian energy matrix occurred with ethanol, starting with the National Alcohol Program (Proálcool) in 1975, a second stage occurred in 1979. This program emerged as a response to the oil crisis, with the objective of reducing the country's dependence on imported oil. Therefore, even before there was an environmental concern, Brazil turned to biofuels for energy security reasons, in a technologically advanced position in relation to most countries in the world. The National Program for the Production and Use of Biodiesel (PNPB), which started in 2005, had as its principles the promotion of social inclusion and regional development, through the generation of employment and income. The program was also environmentally friendly, since it encouraged the production of a fuel that contributes to the environment, as its combustion emits less CO_2, particulate matter and other pollutants. Figure 5 shows the milestones related to the participation of biofuels in the Brazilian fuel market.

FIGURE 5: TIMELINE OF BIOFUELS IN BRAZIL



Source: Own elaboration

Brazil has comparative advantages in agricultural production and, therefore, in the production of energy from biomass, due to the country's favorable climatic conditions, as well as the large amount of arable land available. Unlike European countries, for example, Brazil does not have agricultural area restrictions, so planting energy crops does not compete with food production. EPE (2016a) evaluated the potential area for expansion of the agricultural frontier in Brazil and found the amount of 140 million hectares without legal impediments, most of which already have anthropic use classified as livestock or agriculture. As a comparison, the total area occupied by the cultivation of sugarcane in Brazil today is approximately 9 million hectares and the area occupied by soybean production, the main raw material for the production of biodiesel, is 33, 9 million hectares.

The Brazilian energy matrix is among the cleanest in the world, with 43.5% renewable energy (in 2016) and bioenergy (products derived from sugarcane and vegetable oil, in this case biodiesel), representing more than 18% (17.5% participation of sugarcane`s biomass and 1% of biodiesel) in 2016 (EPE, 2017a), however this does not mean that the commitments assumed are not audacious. Considering the projections of increased demand for energy over the next 13 years, a strong effort is required to achieve the commitments made under the Paris Agreement.

The main challenge posed by the targets is the need for high investments, according to the base document prepared by order of the Ministry of the Environment (MMA, 2017), which mentions the need of R$ 161 billion, between 2020 and 2030, for the modernization and expansion of the sugar-energy industry. This industry, however, is going through a delicate time, with the stagnant production and high indebtedness of its companies. The biodiesel segment, on the other hand, despite acting with high idle capacity, will require new investments in the medium term to follow the expected increase in production.

It is notorious that the biofuel sector, especially hydrous ethanol, requires government actions capable of ensuring greater predictability, one of the main bottlenecks pointed out by the sector in order to unlock the investments. Breaking the COP 21 commitments into clear targets with realistic deadlines would be a first step in this direction, allowing the sector to structure itself in order to pursue the objectives. To this end, a regulatory framework must be established, that brings security and reliability to the investor, also including mechanisms that allow the structuring of the biofuels market and the promotion of their competitiveness in relation to fossils, considering all the externalities involved, as well as the definition of economic and financial instruments that help to attract new investments.

At the end of 2016, MME launched the RenovaBio program, aiming to stimulate the production of biofuels in the country, and which presents proposals for structural changes widely discussed with industry agents. FGV Energia talked to over 50 industry agents (government representatives, business associations, companies, consultancy companies, law firms and others), of which the majority consider that the targets are feasible and that the RenovaBio program will contribute to the resumption of investments.

In the face of this scenario, it can be said that the commitments derived from COP 21 create unprecedented conditions for the recognition of the importance of biofuels in the energy matrix, especially as it deals with mastered technologies that are capable of delivering short-term results. In addition to the environmental benefits of the increase in biofuels usage, it is worth mentioning the importance that this sector may have for the resumption of economic growth, generating jobs in the inner regions of the country and contributing to reduce the trade balance deficit, by substituting the import of fuels. According to the National Petroleum Agency (ANP, 2016), demand for Otto cycle fuels in 2030 is expected to exceed 23.7 billion liters, while that difference should be 24.6 billion barrels of liters in the case of diesel cycle fuels. To reduce projected external dependence, part of this demand could be met by domestic biofuel production.

Considering the opportunities created by the commitments made in the Paris Agreement and by the new regulation proposed by RenovaBio and their implications in the production of biofuels in Brazil, the present FGV Energia Notebook was structured as follows: in Chapter 2, the proposal of the RenovaBio will be shown in more detail, addressing the concepts that support it, its mechanism of operation and the role of the agents involved. Chapters 3 and 4 will focus on ethanol and biodiesel, respectively, containing, in addition to an initial description of the characteristics and specifications of biofuel, analyzes related to the following items: regulation, market, productivity and sector perspectives. Chapter 5 will deal with new biofuels: aviation biokerosene, biogas / biomethane and hydrotreated vegetable oil (HVO). Finally, the final considerations of this work will be presented, which intend to demonstrate the current situation of the sector, pointing out the main obstacles to its growth and the prospects for resumption of investment.

RenovaBio

The RenovaBio Program was launched by the government in December 2016 aiming at stimulating the production of biofuels in the country, like ethanol, biodiesel, biogas and aviation bio-kerosene, contemplating the commitments made in the Paris Agreement. The main contribution intended by the Government will be the definition of a specific regulation for the sector, with clear rules and mechanisms that ensure the necessary predictability to attract investments.

The content of the program was made available for Public Consultation in February 2017, receiving contributions from various agents in the biofuel production and distribution sector. In June 2017, the o Conselho Nacional de Política Energética (CNPE) - the National Energy Policy Council approved RenovaBio's strategic guidelines, derived from four strategic axes (Figure 6), and these were published in the Official Gazette on the 30th of the same month (Resolution no. June 8, 2017).

FIGURE 6: RENOVABIO'S STRATEGIC AXES

Source: MME (2017a)

The way the project is handled, whether by means of a provisional measure or as a proposed bill, is being defined. However, Resolution 14 stipulates that MME must set up a Working Group (GT) with the participation of specialists from the various areas involved in the production, distribution and use of biofuels, in order to continue the work of RenovaBio. This GT will have 90 days, from the date of publication of the Resolution, to deliver to MME proposals to improve the legal framework of the biofuels sector.

MME (2017a) has already submitted a document containing the Proposal for Improvement of the Biofuels Legal Landmark and its latest version was made available in August 2017. The text says that the government intends to define the National Biofuels Policy - RenovaBio, as an integral part of the National Energy Policy, aiming at ensuring predictability for the biofuels participation in the fuel market, promoting the generation of investments and jobs in the biofuels sector, as well as promoting Brazil's competitiveness in the market of biofuels, among others. As a matter of principle, the Policy also has to boost technological development and innovation to increase the competitiveness of biofuels and the insertion of advanced fuels and new biofuels, and will include, among others, the following instruments: Decarbonisation credits; certification of biofuels; the compulsory additions of biofuels to fossil fuels; and fiscal, financial and credit incentives.

The role of each agent in the industry will be detailed below:

A. PRIMARY ISSUERS

They are the producers or importers of biofuels, authorized by ANP, the National Agency of Petroleum, Natural Gas and Biofuel, and qualified to request the emission of Decarbonisation Credit, undergoing a pre-certification process. The amount of decarbonisation credits issued will be proportional to the volume of biofuel produced or imported and commercialized and will also depend on the Energy-Environmental Efficiency Report, individually assigned to each primary issuer, representing the difference between the carbon intensity of its substitute fossil fuel and its established carbon intensity in the certification process. Such note shall be included in the Certificate of Production or Efficient Import of Biofuels, document issued by a certifying company.

B. FUEL DISTRIBUTORS

The fuel distributors will have individual targets, defined annually by ANP, proportional to their respective market share in the commercialization of fossil fuels in the previous year. In order to prove the fulfillment of the individual targets, the distributors must demonstrate the possession of Decarbonisation Credits. The fuel distributor will be free to prove the achievement of its individual target according to its strategy, without damaging the volumetric additions of anhydrous ethanol to gasoline and of biodiesel to diesel. The fuel distributor may prove up to fifteen percent (15%) of the individual one-year target in the subsequent year, provided that this distributor has demonstrated full compliance with the target in the previous year.

C. GOVERNMENTAL BODIES

The CNPE will be responsible for establishing annual compulsory GHC emission reduction targets for the commercialization of fuels, which will be defined with an emphasis on improving the carbon intensity of the Brazilian fuel matrix over time for a minimum period of ten years. These targets can be set to start as of July 1, 2018, and the National Council for Energy Policy, CNPE, may define a transition period with individual targets on a voluntary basis.

The annual mandatory target will be deployed by ANP, for each current year, in individual targets, applied to all fuel distributors, proportionally to their respective market share in the commercialization of fossil fuels in the previous year. In the scope of certification of the efficient production or importation of biofuels, ANP shall supervise the movement of marketed fuels in order to verify their adequacy with the Decarbonisation Credits issued and the fulfillment of the individual mandatory targets.

The operating mechanism of RenovaBio is inspired by international initiatives such as the Renewable Fuel Standard (RFS) of the United States, the Low Carbon Fuel Standard (LCFS) of California, and the Renewable Energy Directive (RED) of the European Union. The emissions performance assessment will use the Life Cycle Assessment methodology[2] to calculate the carbon intensity, which is the ratio of the emission of greenhouse gases, computed in the fuel production process, per energy unit. The lower the carbon footprint of the biofuel production process, the higher the plant is graded. Parameters will be evaluated, such as industrial production of biofuel, consumption of fuels, consumption of fertilizers, consumption of electric power energy and surplus electricity, among others. In the first phase of the program, the scope includes the production of the following biofuels: sugarcane ethanol (first and second generation), corn ethanol, biodiesel, aviation biokerosene and biogas / biomethane. Imported biofuels will also be certified in order to compete equally with the national ones. A relevant point is that the grades of the plants are not fixed, and may be valid for up to four years, which encourages more efficiency.

This is an unprecedented model in Brazil, based on the recognition of the ability of each fuel to contribute to the reduction of GHG emissions and to promote decarbonisation, unlike the traditional way that is being used, by tax differentiation or the use of environmental taxes (or on carbon), which are values based on analyzes that, in general, give a higher weight to macroeconomic situations than to the specificities of the fuels and biofuels sector. The initiative, which is centered on the assessment of the carbon intensity of each fuel, also has a high potential to promote energy efficiency gains in the production and use of biofuels, which is not the case with tax-based models, which do not stimulate efficiency gains, since they treat all producers equally.

2. Life Cycle Assessment (ACV) is a tool for assessing environmental impacts based on the quantification of material and energy consumed by the production process and emitted to the environment throughout the life cycle of a product.

International initiative to promote biofuels

United States and California

The initial motivation of the United States biofuel incentive legislation was to diversify the energy matrix of fuels to reduce their vulnerability to the geopolitical oscillations of oil and oil products. Subsequently, the environmental concern gained strength and today is relevant in the decision making process.

RFS is a federal program, derived from the Energy Policy Act (EPA) of 2005, which was expanded and extended by the Energy Independence and Security Act (EISA) of 2007. This law defines increasing volumes of biofuels to be blended with conventional fuels until the year 2022. Each renewable fuel category in this program is classified according to the amount of GHG emitted in the life cycle of biofuels[3] in relation to the fuel derived from the oil that is replaced. Ethanol consumption is related to that of gasoline, by the mandatory E10 blend (10% ethanol). However, mixtures E15 (15% ethanol) and E85 (85% ethanol) are also allowed (EPA, 2017). As for biodiesel, there is no minimum mandatory blend defined nationally, however, there is an optional use in several percentages, in each state in the federation, with B20 (20% biodiesel and 80% fossil diesel) being the most used (United States Department of Energy - US DOE, 2017).

To ensure compliance with government-mandated goals within RFS, the Renewable Identification Number (RIN), a certificate used to track the use of biofuels within targets, was created. Fuel refineries, distributors, and importers are required to submit to the US Environmental Protection Agency (EPA) the number of RIN credits corresponding to the fossil fuels they trade, meeting what is defined by RFS. Issued at the time of biofuel manufacturing, RINs can be commercialized to market agents to meet physical targets (EPA, 2017).

3. Classification of the RFS: renewable (ethanol and biobutanol from corn), advanced (ethanol from sugarcane), biomass diesel (biodiesel or HVO - Vegetable Oil Hydrotreated) and cellulosic (ethanol and cellulosic biodiesel).

Among the state initiatives, the LCFS in the state of California stands out. Created by the California Air Resource Board - CARB (CARB, 2017), the LCFS aims to reduce GHG emissions by at least 10% of carbon intensity of the State's transport fuels by 2020 (CARB, 2017), based on the year 2010. The program provides credits based on the carbon intensity generated by each fuel, having fossil emissions as reference. Fuels with a carbon intensity below the established standard receive credits, and the value will be higher, the lower their carbon intensity is.

Other jurisdictions are following in California's steps, represented by the Pacific Coast Collaborative, a regional agreement between California, Oregon and British Columbia, to align policies aiming to reduce GHGs and promote clean energy. In the long run, LCFS programs will create an integrated West Coast market for low carbon fuels, which will increase their attractiveness, bringing more confidence to low carbon alternative fuels investors (CARB, 2017).

European Union and Sweden

In December 2008, the European Union announced a set of targets for 2020, called "Triple 20", which consists in reducing CO2 emissions by 20% (in relation to 1990 levels), increasing the role of renewable energy sources in the total of energy consumption by 20% and increasing energy efficiency by 20%. In addition, it was established that for automotive fuels, 5% would come from renewable sources by 2015, increasing to 10% by 2020 (EU-EU, 2008).

The Renewable Energy Directive, Directive 2009/28 / EC, was released on 23 April 2009 (EU, 2009), replacing Directive 2003/30 / EC, the Biofuels Directive. In addition to the target of 20% of renewables in final energy consumption, it established minimum participation quotas for renewables to be met by each member country for the period from 2011 to 2020.

A change to the energy security and GHG mitigation policy was announced in 2016, with definitive milestones for 2020, 2030 and 2050. By 2020, the *Triplo 20* targets (20% reduction in emissions, increase of renewables in energy consumption and increase in energy efficiency) (EURACTIV, 2017). By 2030, the targets were increased, respectively, to 40%, 27% and 27%. By the year 2050, Europe has plans to reach an 85% to 90% reduction in GHG emissions (European Commission - EC, 2016).

The new proposal aims to focus on advanced energy sources, including second-generation biofuels. The European Union has strengthened its position of disadvantaging traditional biofuels (sugarcane and corn ethanol and oilseed biodiesel), limiting a maximum of 7% share of energy demand in 2020 and reducing it to 3.8% by 2030.

Each EU country has specific legislation and consumption targets for biofuel blends with fossil fuels. In particular, Sweden has adopted the E85 blend (85% ethanol and 15% gasoline). The policies for the use of biofuels in that country were stimulated by the oil crises in the 1970s, starting with the substitution of fossil fuels for domestic heating and subsequently migrating to transport, since the fossils were, from then on, progressively taxed (European Biomass Association - AEBIOM, 2012).

Sweden initiated the decarbonisation policies of its transport matrix in the 1990s with the introduction of E85 vehicles in 1994, prompting the country to draft laws requiring fuel resellers to implement ethanol pumps. In parallel, the Swedish government subsidized the purchase of "green" vehicles with values of US$ 1,500.00. Since then, the number of vehicles powered by ethanol and biodiesel has grown (the estimated fleet of flex-fuel vehicles for E85 in 2014 was 400 thousand automobiles). The government's target is, that by 2030, there will be a reduction in emissions in the transport sector of around 70% when compared to 2010, which implies the total abandonment of fossil fuels (Government Offices of Sweden - GOS, 2017).

Since 1980, Sweden produces ED95 buses. Those are 95% ethanol and 5% of a compound that allows the blend to operate under diesel cycle conditions. The capital Stockholm has a total fleet of 2,300 public transport buses, of which around 400 are ED95 models (Svensk Kollektivtrafik - SK, 2015).

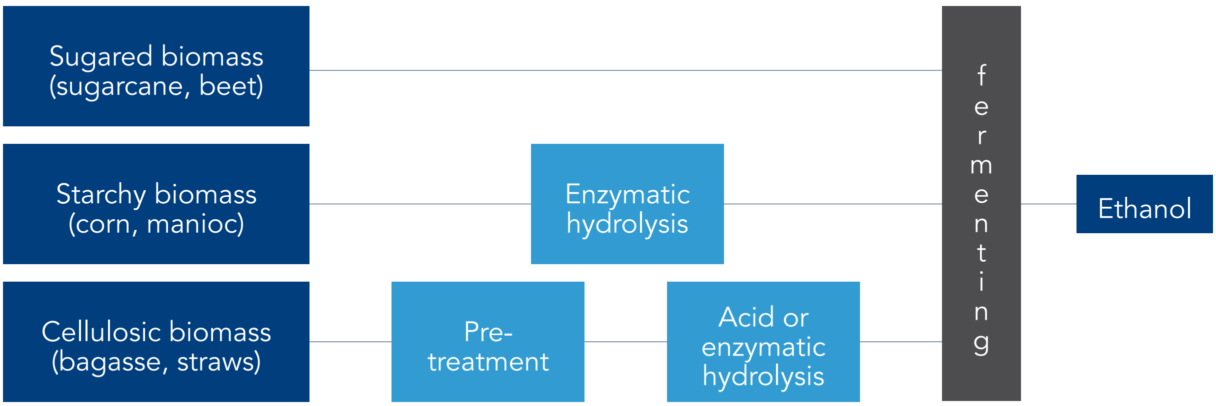
Ethanol

A. CHARACTERISTICS AND SPECIFICATIONS

Ethanol is an alcohol usually produced by the fermentation process of sugars. The simplest production process, involving fewer stages, is the one that uses sugar-based raw materials, such as sugarcane and beet, since the sugar to be fermented is already available. The biomass must undergo a stage of extraction of the sugars, which can be done by means of milling or diffusion processes, and then fermenting. The production of ethanol from starch-containing raw materials such as corn and manioc, for example, requires an additional step, called hydrolysis, in which the starch is broken down into sugar by means of enzymes (enzymatic hydrolysis). These Two production routes are considered conventional and the alcohol obtained is called first-generation ethanol. The most complex process is the production of cellulosic or second-generation ethanol obtained from cellulosic biomass, such as bagasse and sugarcane straw. The cellulosic materials have a rigid and ordered structure, making it difficult for the enzymes to reach the substrate; therefore a pretreatment step is required prior to hydrolysis.

Figure 7 presents a simplified scheme of ethanol production routes, highlighting the different steps according to the types of biomass used.

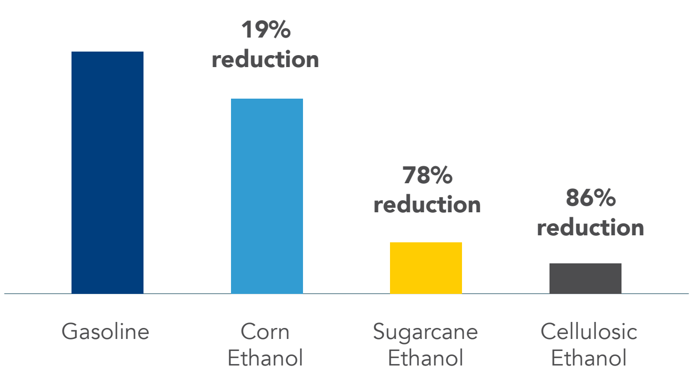
FIGURE 7: TECHNOLOGICAL ROUTES FOR THE PRODUCTION OF ETHANOL



Source: Adapted from *Banco Nacional de Desenvolvimento Econômico e Social* (BNDES, 2008)

Almost all of Brazil's ethanol production uses sugarcane as its raw material, while the United States, the world's largest producer of ethanol, uses corn. As shown in figure 8, ethanol from sugarcane is able to reduce GHG emissions by 78% when compared to gasoline, while corn ethanol reduces on average 19%. Second-generation ethanol, however, allows for even higher reductions, of 86% in relation to fossil fuel.

FIGURE 8: POTENTIAL FOR REDUCING GHG EMISSIONS IN DIFFERENT ETHANOL PRODUCTION ROUTES



Source: Adapted from Wang et al. (2007)

Due to its physicochemical properties, ethanol can be used as fuel in internal combustion engines, of the Otto cycle type, with spark ignition. In a first moment of the *Proálcool* program, the expansion of alcohol use as fuel occurred by mixing anhydrous ethanol[4] with gasoline, which increased from 4.5% in 1977 to 15% in 1979, reaching 22% % in 1985. After the second oil crisis in 1979, the second phase of *Proálcool* began, and in addition to anhydrous ethanol added to gasoline, hydrous ethanol[5] also started to be stimulated by the program for use in vehicles with engines dedicated to this fuel, which started to be commercialized in the country and represented more than 90% of sales in 1983. At the end of the 1980s, *Proálcool* was not as relevant as it once was, due to factors such as the fall in international oil prices, the increase in domestic oil production and the increase in the price of sugar on the international market, which led to a reduction in ethanol production and a serious supply crisis in 1989.

Currently, the percentage of anhydrous ethanol blended in gasoline can vary from 18% to 27.5% in volume, according to Law 13,033 / 2014, and the maximum content of 27.5% was defined after testing, which proved that this volume would not compromise engine performance. Since March 2015, the blending percentage, valid for the whole national territory, is 27% (not 27.5%, because the blending measuring equipment installed in the pumps do not have the accuracy for the half percentage point) in regular gasoline and 25% in premium gasoline. Table 1 shows the evolution of the percentages of addition, since 1998.

TABLE 1: HISTORY OF THE BLENDING CONTENT OF ANHYDROUS ETHANOL IN THE GASOLINE

% Anhydrous Ethanol in the Gasoline	
May/98	24%
Aug/00	20%
May/01	22%
Feb/06	20%
Jun/07	25%
Jan/10	20%
May/10	25%
Oct/11	20%
May/13	25%
Mar/15	27%

Source: Own elaboration based on data from ANP

4. Alcohol containing less water (at most 0.4% by volume), used as a blending component in A (pure) gasoline for the composition of gasoline C (gasoline containing ethanol in an amount determined by ANP).
5. Alcohol containing higher water content (between 4.0 and 4.9% by volume) marketed as a finished fuel.

The addition of anhydrous ethanol to gasoline does not require major changes to the engine prepared for gasoline, and it also has advantages related to vehicle performance and reduction of GHG emissions. The octane rating (or Octane Number) of ethanol is higher than one of gasoline, as can be seen in Table 2. This parameter measures the capacity of the fuel to withstand spontaneous detonation, being one of the main indicators of the quality of automotive gasoline, since a higher octane rating results in a higher energy efficiency. One way to increase this parameter is by the use of anti-detonating[6] additives, such as tetraethyl lead and MTBE (methyl tert-butyl ether). In Brazil, ethanol has been used, substituting these additives, which are in disuse because they are toxic and cause environmental problems. In addition to improving the performance of the gasoline engine, ethanol is environmentally cleaner as it is produced from renewable raw materials and their combustion emits a smaller amount of GHG.

TABLE 2: PROPERTIES OF GASOLINE AND ANHYDROUS ETHANOL

Properties	Gasoline	Anhydrous Ethanol
Lower calorific value (MJ/liter)	32.18	22.35
Specific Mass (kg/m^3)	720-780	792
Motor Octane N° (MON)	80-92	89-96
Stoichiometric air/fuel ratio	14.5	9

Source: Adapted from BNDES (2008)

The emergence of the flex-fuel automotive technology in 2003 provided a new increase in the biofuel's share in the Brazilian matrix. Vehicles with this technology allow the use of pure gasoline or hydrous ethanol or blends of the two in any proportion and such models accounted for 88% of the licenses in addition, 71% of the fleet of light vehicles in 2015 (EPE, 2017b). The use of both fuels requires some adjustments in compression rates, in the fuel supply system and the ignition, to compensate for differences in the air / fuel ratio, as seen in Table 2, which

6. These additives prevent the detonation or combustion of the gasoline before the right time.

The calorific power of ethanol is approximately 30% lower than that of gasoline, which resulted in a price parity relation applied by consumers, which only considers the use of ethanol to be advantageous when its price corresponds to up to 70% of the price of gasoline.

is made possible by the existence of a sensor of oxygen content, which detects the proportion of the alcohol-gasoline blend being used.

The calorific power of ethanol is approximately 30% lower than that of gasoline, which resulted in a price parity relation applied by consumers, which only considers the use of ethanol to be advantageous when its price corresponds to up to 70% of the price of gasoline. Automotive performance, however, does not only depend on the calorific value, but is also a function of other parameters, such as octane rating, and of the engine's own efficiency, which may vary between the models and the year of manufacture of the cars. The 70% ratio also does not take into account the increase of the anhydrous ethanol content in gasoline, which ends up reducing the calorific value of the final fuel. It is also possible to optimize the flex engine for use with ethanol, which would also change the parity, already widely known and used by consumers and would contribute to more consumers opting for hydrous ethanol instead of gasoline. We will address these issues in more detail in the item on engine technology.

B. REGULATION

Until the mid-1990s, the Brazilian state's interference in the distribution and resale of automotive fuels included the control of prices, margins of sale and freight. Then, a process of price liberalization was initiated throughout the oil, natural gas and biofuel production chain, as well as a gradual reduction of government subsidies. It was only from the Petroleum Law that the liberalization in the automotive fuels market took place in a more effectively way and was concluded on December 31, 2001. As of that date, fuel price readjustments have been exclusively allocated to each economic agent - from the well to the gas station - who set their selling prices and commercialization margins in a free competition scenario, according to ANP (ANP, 2016a).

STOCKS

As a way of ensuring the national fuels supply, ANP requires regulated companies to maintain minimum stocks and to prove their capacity to supply the market. In the Resolution 67/2011, the agency established criteria for the acquisition and creation of anhydrous ethanol stocks, for both producers and distributors, as detailed below:

i. Distributors

The acquisition of anhydrous ethanol from distributors can be done in two ways:

- **Supply contract regime:** contracting anhydrous ethanol fuel between anhydrous ethanol supplier and distributor of automotive liquid fuels, in the period from May 1 of each year to April 30 of the subsequent year. When opting for this modality, the distributor must contract 90% of the volume commercialized in the previous year, which can be done as follows: having the 70% volume or more contracted up to April 1st and 90% volume until June 1.

- **Direct purchase regime:** acquisition of anhydrous ethanol fuel to create their own closing stock in each month, in sufficient volume for the commercialization of gasoline C (gasoline with added anhydrous ethanol) in the following month. In this modality, the distributor must demonstrate on a monthly basis, owning, in his own physical stock, enough volume of anhydrous ethanol for the commercialization of gasoline C in the following month.

Distributors must own, on March 31, their own stock of anhydrous ethanol fuel, in a volume corresponding to, at least, 15 days of their average commercialization of gasoline C, having as reference the total volume of gasoline sold in March of the previous year.

ii. Producers

The producer, the producer's cooperative or the company that commercializes ethanol shall have, on 31 January and on 31 March, their own stocks with minimum volumes of 25% and 8%, respectively, of their commercialization of anhydrous ethanol with the distributor in the previous calendar year.

In case the producer, the cooperative or the company that commercializes ethanol has signed a contract with the distributor of, at least, 90% of the volume of anhydrous ethanol sold in the previous year, he shall only prove the minimum stock required on March 31 (corresponding to the minimum volume of 8% of what was commercialized in the previous year), not being necessary to demonstrate the minimum volume of 25% stock on January 31.

In April 2017, through Resolution No. 11, dated 04/11/2017, CNPE determined that agents who carry out the import of biofuels must comply with the same obligations to maintain minimum stocks and to prove capacity to supply the market demanded from biofuel producers in the country.

TAX REGIME

The tax burden on fuels has a significant weight in the final price to the consumer, representing roughly 45% for gasoline and 28% for ethanol, according to the National Federation of Fuel and Lubricants Commerce (Fecombustíveis, 2017).

The taxes currently imposed on automotive fuel operations are: Contribution to the Program for the Social Integration of Workers and the Formation of Patrimony of Public Servants (PIS / PASEP); the Social Contribution for Social Security Financing (COFINS); the Tax on Operations related to the Circulation of Goods and on Services of Interstate and Intermunicipal Transportation and Communication (ICMS) and the Contribution of Intervention of the Economic Domain (CIDE). There are also, in some cases, the Import Tax (II). Each item will be detailed below.

PIS and COFINS are federal social contributions. The purpose of which is the financing of social security and are applied concerning the total income calculated by legal entities. The rates of these taxes on gasoline C amounted to R$ 0.3816 / liter since May 2015 and increased to R$ 0.7925 / liter in July 2017, an increase of R$ 0.4109 / liter, or 108%. In the case of fuel ethanol (hydrous), the rates were zero since 2013, increasing to R$ 0.12 / liter in January 2017, affecting only the producers (and not the distributors). In July 2017, the aliquots were changed to R$ 0.1309 / liter for the producers, and from zero to R$ 0.1109 / liter (initially, the tax rate was established at R $ 0.1964 / liter, but the value was revised), for distributors, totaling R$ 0.2418 / liter, which represents an increase of R$ 0.1218 / liter, or 102%. The PIS / COFINS aliquots are therefore different for gasoline and ethanol.

CIDE-Combustibles is another federal tax, for fuel operations, and is destined to investments in transportation infrastructure, to subsidize the prices of fuel alcohol, natural gas, oil and its derivatives, and to finance environmental projects. It concerns gasoline C in the amount of R $ 0.1000 / liter, although it is zeroed for ethanol.

ICMS is a state tax, which has as a generator the circulation of merchandise, even the one that starts abroad, but is destined for the domestic market. Aliquots differ between states and vary from 23% to 33% for gasoline and from 11% to 30% for ethanol. Of the 27 states, 12 apply differentiated rates of gasoline and ethanol, the states with the most significant difference are: Minas Gerais, with a 15% difference (aliquots of 31% for gasoline and 16% for ethanol), and São Paulo, with 12% (aliquots of 23% for gasoline and 11% for ethanol).

Ethanol import and export activities in Brazil are exempt from duties. The import tariff was zeroed in 2010 after ethanol was included in the list of exceptions to the Mercosur Common External Tariff (TEC), with the goal of opening markets for Brazilian ethanol. The United States, the main destination for Brazilian ethanol, also eliminated its tariffs at the same time, facilitating the exchange between the countries. Brazil, since the second half of 2016, in addition to exporting, started to import significant volumes of US ethanol, due to the low prices resulting from record harvests of corn in the United States. This fact led to the discussion among domestic producers about the return of import tariffs, which is being evaluated by the Foreign Trade Chamber.

C. MARKET

SUGARCANE

The Brazilian production of sugarcane and, consequently, of ethanol, can be analyzed by dividing the producing areas into two regions: North-Northeast and Center-South. The Center-South region concentrates more than 90% of the production and its crop is well delimited, happening from April 1 to March 31, with a harvest period between April and November, while the North-Northeast region varies between states.

Brazilian sugarcane production in the last harvest (2016/17) was over 657 million tons, in a planted area of approximately 9 million hectares, which represents around 12% of the area agricultural in use in Brazil, approximately 75 million hectares, according to the Brazilian Institute of Geography and Statistics (IBGE, 2017). Regarding ethanol, the production of the last crop was 27.8 billion liters, of which the Central-South region accounted for 94% (24.6 billion liters). The state of São Paulo is the most prominent, accounting for 56% of the total sugarcane production and 49% of the country's total ethanol production in the 2016/17 crop year (Companhia Nacional de Abastecimento - Conab, 2017(National Supply Company).

PRODUCTION UNITS

In February 2017 (ANP, 2017a), there were 384 authorized ethanol producing plants, of which 211 (55%) are located in the Southeastern region (Figure 9). The total capacity of the 384 authorized ethanol-producing plants is 216,883 m^3 / day of hydrous ethanol production and 117,036 m^3 / day of anhydrous ethanol.

FIGURE 9: ETHANOL PLANTS LOCATION

Source: União dos Produtores de Bioenergia (UDOP, 2015)

The producing units can be classified in: plants, which produce exclusively sugar; independent distilleries, which produce exclusively ethanol; and mixed plants (or with annexed distilleries), which produce both products. Proálcool financed the expansion of ethanol production, both in independent distilleries and in annexed ones. During the period of the program, the number of independent distilleries surpassed that of mixed plants, but these came to predominate since the 1990s. In May 2017, mixed plants represented 64% of the total, while only 5% of the units corresponded to plants producing sugar exclusively. In mixed plants, it is possible to adjust production to produce more sugar or more ethanol, in proportions up to 60-40% for one of the two products, which gives a higher flexibility to the producer, which can define the destination of sugarcane according to market conditions.

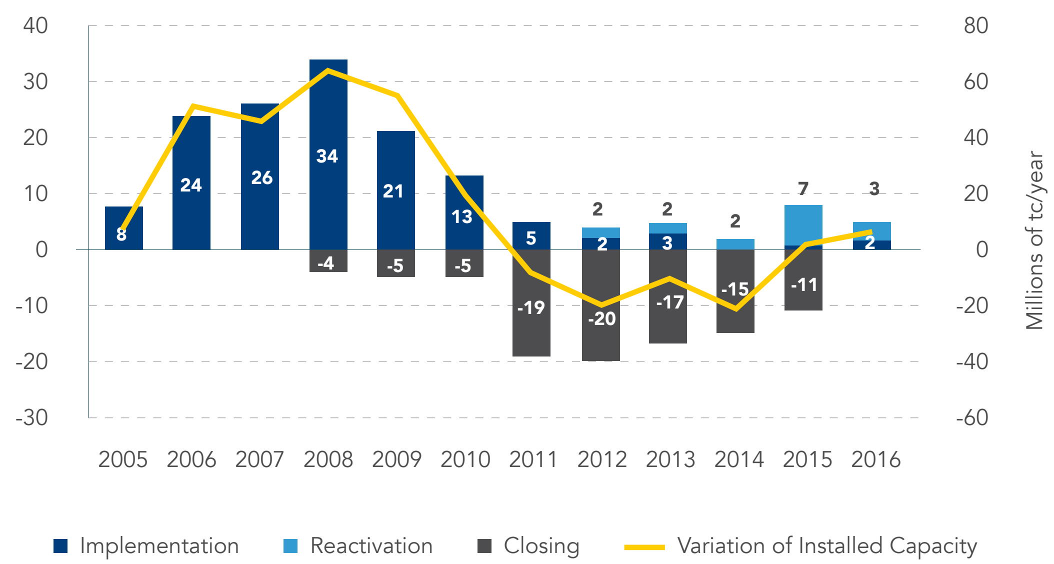
In addition to sugar and ethanol, the plants also generate electricity from bagasse and sugarcane straw, mainly through the cogeneration process[7]. Some of the sugar and alcohol plants use low efficiency cogeneration processes and plants, consuming, basically, biomass to meet their own energy demand (heat and electricity), generating little or no surplus. However, many units have been modernizing and investing in efficient cogeneration processes in order to generate higher surpluses of electricity ("bioelectricity") and thus increase their revenue. Consequently, in only a few years, the term "sugar-ethanol plant" has been replaced by "sugar-energy plant". Another energy source that has also been generated by this industry, but still in insignificant quantities, is biogas, which can be produced from vinasse, and will be shown in more detail (as well as bioelectricity) later.

More recently, starting in 2011, plants in Brazil started to emerge, using corn as raw material for the production of ethanol, usually in an integrated way with sugarcane, called flex power plants. In these, corn ethanol production occurs during the period between sugarcane harvests, from December to March and can last from 90 to 120 days per year. Since sugarcane is perishable and cannot be stored, plants that only use this raw material operate only in the harvest months, being idle in other months. Integration with corn, therefore, takes advantage of the downtime to increase ethanol production, in addition to other by-products of corn, such as oil and protein for animal food. The alternative has become particularly interesting in the Midwestern region by the significant increase in corn production, which has generated large surpluses at a low price.

Since the entry of flex fuel vehicles into the Brazilian market in 2003, the sugar and ethanol sector started to invest heavily in the expansion of production capacity. The number of new plants increased from 8 in 2005 to 34 in 2008, the peak of new ventures (Figure 10). Two other factors contributed to the growing demand for ethanol: a ban on the use of additives for gasoline, such as methyl tert-butyl ether (MTBE), mainly in the United States and the European Union; and the expectation of an international race for clean fuels to meet the Kyoto Protocol. The 2008 international crisis, however, frustrated expectations and made the growth scenario change. The sector, which was heavily indebted due to high investments, was drastically affected by the credit constraint. The prospects for the increase in exports also did not consolidate, as the main importers of Brazilian ethanol, the United States and the European Union, began to encourage the domestic production of biofuels through specific legislation, as well as to establish tariff and non-tariffs barriers on the entry of ethanol into their markets.

7 Cogeneration is the process that allows the combined generation of electric energy and thermal energy (heat and / or cold), both of which are later used.

FIGURE 10: IMPLEMENTATION, REACTIVATION AND CLOSING OF ETHANOL PLANTS



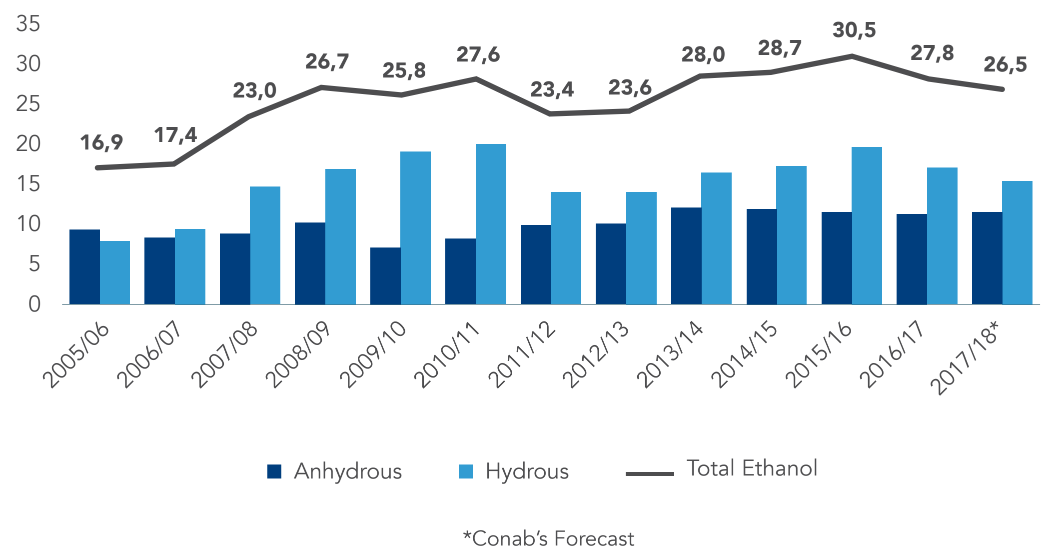
Source: Adapted from EPE (2017b)

Since 2009, not only has the investment in new plants decreased, but also the sector has come to face the closing of many units. From that point on, mergers and acquisitions processes also increased, reflecting the fall in asset prices. As a result, the sector has become more concentrated and more internationalized, due to the higher injection foreign capital. 2012 shown the largest number of closed plants, however, this amount decreased progressively and the reactivation of some units started to happen. Currently, due to the bad financial situation of several companies, a new consolidation process is expected before investments in new projects are made.

PRODUCTION

As shown in Figure 11, the production of ethanol, which had been increasing until 2011, reaching the volume of 27.6 billion liters produced, and it began to decrease due to sugarcane productivity losses, resulted from several factors, among them: the reduction of investments in sugarcane reforestation and crop care, climatic issues and an increase in the sucrose loss index with the mechanization of the harvest, leading to an increase in production costs.

FIGURE 11: EVOLUTION OF ETHANOL PRODUCTION (BILLIONS OF LITERS)



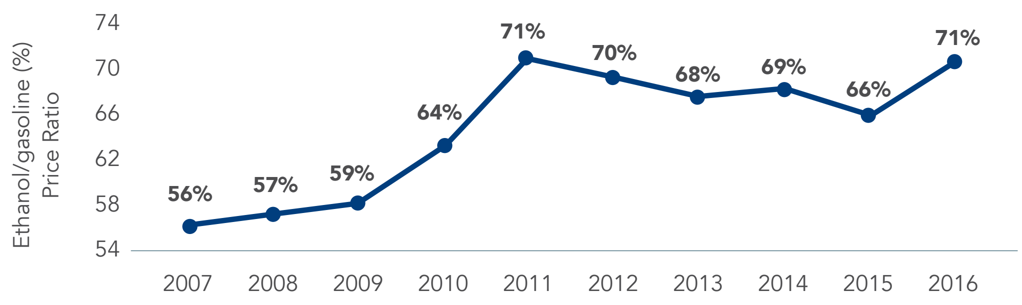
Source: Own elaboration based on data from Conab

In 2013, production increased again, as a result of some government decisions, which were important to send a positive signal to the industry, such as the PIS / COFINS exemption on the sale of ethanol. In the 2015/16 crop, biofuel production reached a new peak of 30.5 billion liters, the highest volume ever produced in the country. Several actions contributed to this resumption of growth, among them the increase in the percentage of anhydrous ethanol in gasoline (from 25% to 27%), the return of CIDE's charge on gasoline and the maintenance of the zero rate of PIS / COFINS for ethanol, while raising the aliquot for gasoline. In addition, by 2015, gasoline prices have stopped undergoing government intervention, which has kept such prices artificially low since 2011 in order to contain inflation. Thus, there was an improvement in the margins and the sector was able to partially recompose its finances.

PRICE RATIO: ETHANOL E GASOLINE

Politic decisions aimed at stabilizing inflation have strongly contributed to the loss of competitiveness of hydrous ethanol from 2011, when the ratio of ethanol and gasoline prices surpassed the 70% (average value for the country) mark, as shown in Figure 12. From 2012, the ratio became more favorable to the use of ethanol, reaching the average value of 66% in 2015. In 2016, however, the ratio reached values above 70% once more.

FIGURE 12: HISTORY OF THE PRICE RATIO BETWEEN ETHANOL AND GASOLINE (%)

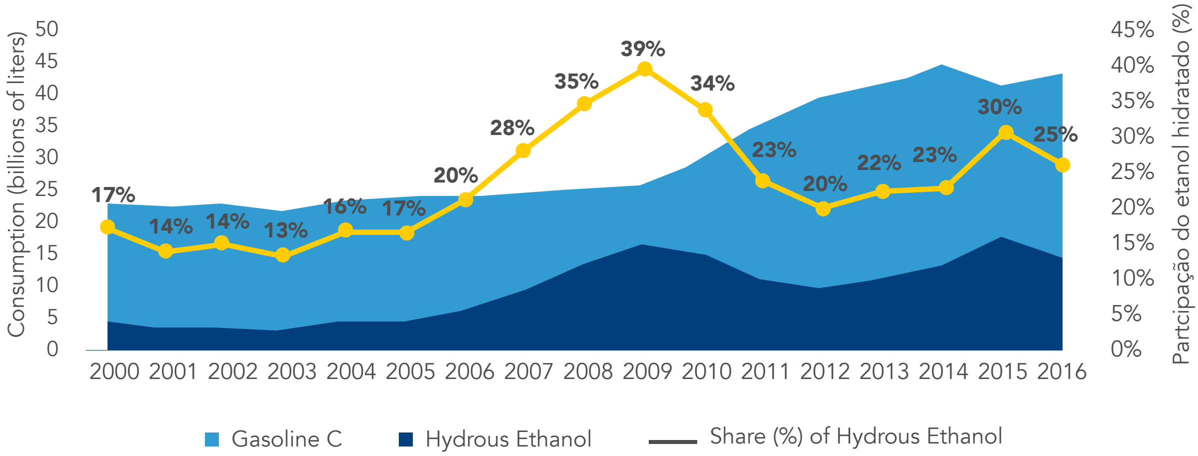


Source: Adapted from EPE (2017b)

DEMAND

The consumption of hydrous ethanol reached a peak of 16 billion liters in 2009, which represented a 39% share of the total demand for fuels from the Otto cycle (Figure 13). From that year, gasoline consumption started to increase, while hydrous ethanol consumption was reduced, until it resumed its growth path in 2013. Demand for fuels from the Otto cycle in 2016 was lower when compared to 2015, and hydrous ethanol was the most affected, due to prices that were not competitive with those of gasoline, undergoing an 18% reduction in consumption, while gasoline consumption increased by 5%.

FIGURE 13: CONSUMPTION OF DE HYDROUS ETHANOL AND GASOLINE C AND SHARE (%) OF HYDROUS ETHANOL



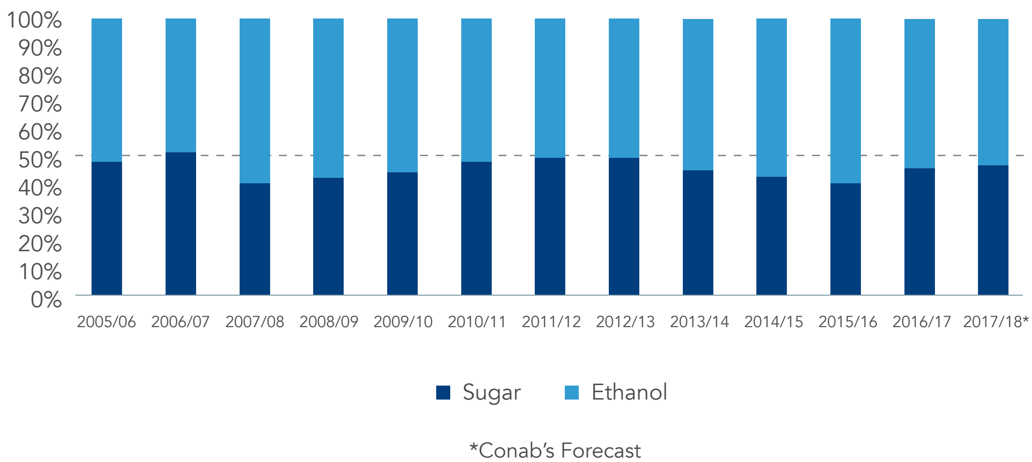
Source: Own elaboration from data by ANP

Anhydrous ethanol has its demand guaranteed, since it is added to gasoline in mandatory percentages. The same does not occur with hydrous ethanol, which is subject to price changes in both sugar and gasoline, two significantly different markets. As mentioned before, sugar prices in the international market influence if the allocation of sugarcane for this commodity will be higher or lower, also affecting the share of hydrous ethanol production. In flex-fuel vehicles, this biofuel competes directly with gasoline, which has its price, ultimately, related to oil (assuming there is no government interference to artificially maintain fuel prices).

SUGARCANE X ETHANOL

The allocation of sugarcane, which, since the 2007/08 crop, followed a "sugar" trend," was once again following a trend related to alcohol, from the 2013/14 crop (Figure 14). The increase of the percentage of anhydrous ethanol in gasoline, from 20% to 25% in 2013, and a new increase, from 25% to 27%, in March 2015, in addition to a scenario of sugar prices dropping in the international market since 2011, were the main reasons that led producers to allocate higher percentages of the raw material for ethanol. In 2016, however, the production profile changed again, due to the international prices of sugar, which were increasing significantly and causing the plants to target sugarcane for this commodity. Conab's expectation is that the allocation of sugarcane increases from 45.9% in the 2016/17 cycle to 47.1% in the 2017/18 cycle, considering that the international price of sugar will remain in remunerative levels.

FIGURE 14: SUGARCANE ALLOCATION



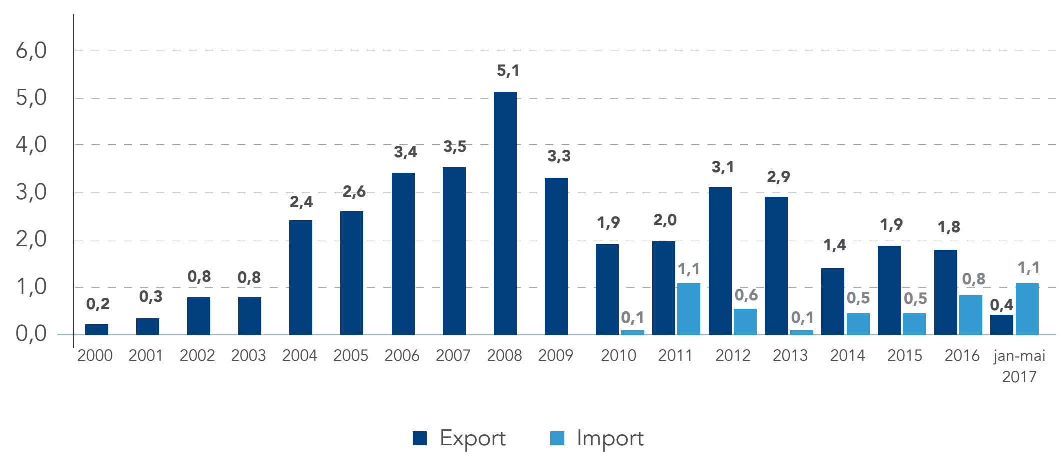
Source: Own elaboration based on data from Conab

IMPORT AND EXPORT

Brazil is the second biggest exporter of ethanol, behind only the United States. In international transactions, anhydrous ethanol is the most commercialized, due to the possibility of being added to gasoline. In general, exports are higher in the harvest periods, when there is an excess of product in the domestic market, while imports are intensified in the off-season to compensate for the fall in production. Although the United States is the number one producer of biofuels in the world, the country is the main destination for Brazilian exports, because Brazilian sugarcane ethanol is considered an advanced fuel by the US biofuels incentive programs and, therefore, receives a reward in its price in 2016, 44% of Brazilian ethanol exports were destined for the United States and 35% went to South Korea. Regarding Brazilian imports, 99% originates from North America.

The Brazilian import of ethanol is a recent phenomenon when compared to exports, as can be seen in Figure 15. The increase of Brazilian imports in 2016 was not motivated by internal supply difficulties, it was intended to take advantage of the opportunity of price differential, since US, biofuels were cheap after a record corn harvest. In the first five months of 2017, import has already surpassed 2016 volumes and this not only has the Brazilian authorities concerned, but it has also resulted in dissatisfaction among the national producers, who demand the return of import tariffs, which are currently zeroed.

FIGURE 15: EXPORTS AND IMPORTS OF ANHYDROUS ETHANOL (BILLIONS OF LITERS)

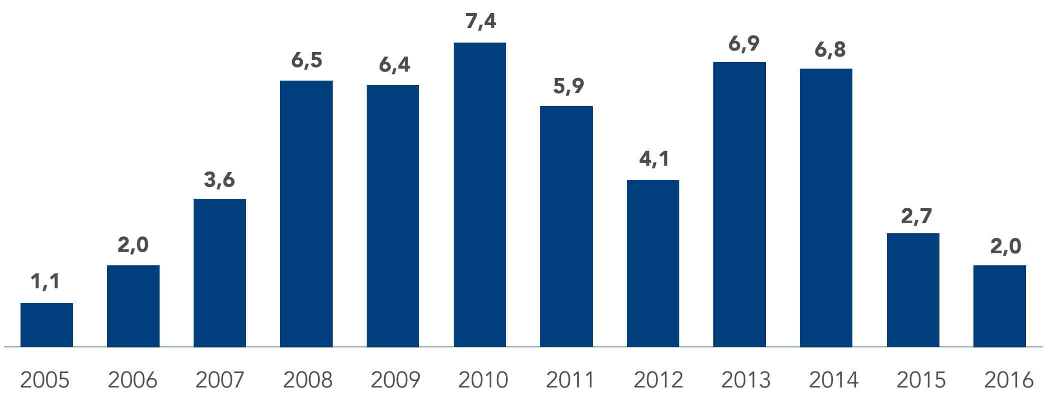


Source: Own elaboration based on data from ANP and the Brazilian Sugarcane Industry Association (UNICA)

FINANCING

As mentioned before, since the entry of flex-fuel vehicles in the Brazilian market, the sugar-energy industry started to invest heavily in increasing production capacity and BNDES was the main source of financing to support this growth. As of 2005, the Bank's disbursements intensified, reaching R$ 7.4 billion in 2010, as shown in Figure 16. The record volume disbursed in 2010 reflected the creation of emergency measures to mitigate the negative effects of the international financial crisis on the Brazilian economy. Among the measures were: the implementation of the Investment Support Program (PSI) and the Support Program for the Sugar and Alcohol Sector (BNDES PASS). The first provided resources at fixed interest rates subsidized by the Treasury, which reached the lowest level in 2012 (2.5%), for the acquisition of machinery and equipment aimed at expanding production or renewing the agricultural fleet. The latter aimed to finance the storage of fuel ethanol.

FIGURE 16: BNDES DISBURSEMENTS FOR THE SUGAR-ENERGY SECTOR (IN BILLIONS OF REAIS)



Source: Own elaboration based on data from BNDES (2011, 2013a, 2015), G1 (2016) and Rede Agroservices (2016)

As of 2010, many of the planned investments were postponed due to the high indebtedness of the companies, which reflected in the reduction of what was disbursed by BNDES. The resumption of investments in 2013 had the incentive of new programs, focusing mainly on innovation projects, as a way to promote the technological development of the sector.

The Joint Plan for Supporting Industrial Technological Innovation in the Sugar-based Energy and Chemical Sectors (PAISS), a program developed as a partnership between BNDES and the Research and Projects Financier (Finep), introduced in 2011, had three thematic lines: 2nd Generation bioethanol; new sugarcane products, including the development from biomass of sugarcane through biotechnological processes; and gasification, with an emphasis on technologies, equipment, processes and catalysts. The success of PAISS motivated the introduction, in 2014, of PAISS Agrícola, the new version of the plan, also a result of the partnership between BNDES and Finep. The focus of the new plan was to accelerate the development of new agricultural technologies - such as transgenic sugarcane and sugar-energy varieties and new planting and harvesting machines - that would increase the agricultural efficiency of the sugarcane sector and consequently, productivity in the mid and long terms.

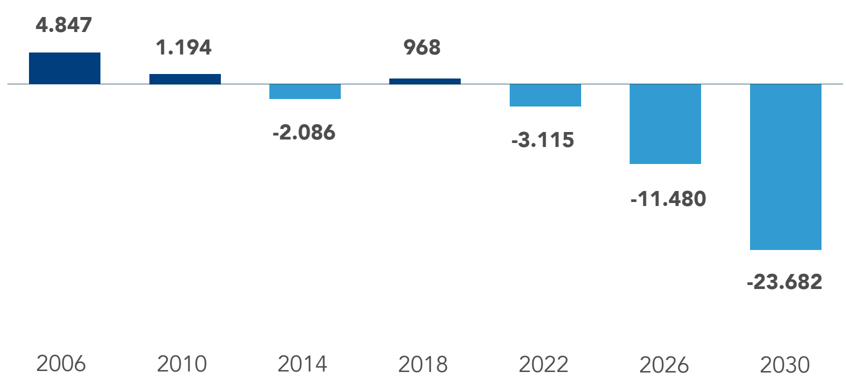
In addition to these, another extremely important financing line was the Program to support the renovation and implementation of new sugarcane plantations (BNDES Prorenova), created in 2012, aimed at the renovation of sugarcane plantations. The program collaborated in a decisive way for the resumption of sugarcane productivity levels and contributed to the reduction of the average age of sugarcane plantations from 3.9 to 3.2 years, according to BNDES's estimates. In 2017, the government made the Prorenova line permanent, following an old claim of the sector (before that decision, it was necessary to negotiate, every crop year, the amount and form of financing for Prorenova).

By 2015, the bank's disbursements were 60% lower than in 2014, as a result of higher interest rates and delays in the release of resources from the ethanol storage line. In 2016, the volume of loans was even lower. The government's budget constraint, the scenario of uncertainties, the high indebtedness of the plants and the losses suffered by BNDES caused by the companies in the sugar-energy sector are among the reasons for the reduction of the resources provided by the bank.

SUPPLY SCENARIO – OTTO CYCLE

From 2010, Brazil stopped being an exporter of gasoline to become an importer, due to the increase in demand for fuel and the lack of investments in increasing refining capacity. ANP estimates that by 2030 there will be an internal production deficit for the Otto cycle of approximately 24 billion liters (Figure 17). In addition, it represents an annual expenditure of around R$ 32 billion in current values, importing this volume requires investments in port infrastructure, pipelines and storage capacity.

FIGURE 17: OTTO CYCLE FUELS PRODUCTION DEFICT



Source: Adapted from Chambriard (2016)

In its Ten-Year Energy Expansion Plan (PDE) 2026, EPE (2017c) estimates that there will be an expansion of the ethanol supply and that the domestic ethanol fuel market will continue its expansion path in the next ten years, in order to meet the Otto cycle demand. EPE also forecasts that investments in the ethanol sector, along with signs of public policy such as RenovaBio, will increase the competitiveness of ethanol face to gasoline. Therefore, biofuel will play a key role in reducing the petroleum-derived fuel deficit expected by ANP.

Fuel Brazil Program

In February 2017, MME introduced the *Combustível Brasil* (Fuel Brazil) initiative, focused on attracting investments in the derivatives sector, including the expansion of the national refining park and the logistics infrastructure of this market, in order to ensure the supply of fuels.

The initiative is motivated by consumption growth projections (preliminary EPE studies indicate that by 2030 the country should consume 3.1 million barrels per day of petroleum derivatives, compared to consumption of 2.3 million barrels per day in 2016), the increase in the import of derivatives (487 thousand barrels per day in 2016), as well as the need to adjust this market to the repositioning of Petrobras, which should reduce its participation in refining and logistics, while also failing to ensure the national supply.

As was the case of RenovaBio, Fuel Brazil was developed in a participatory manner, with technical workshops involving the private sector and technicians of the MME, EPE and ANP coordinating the initiative together.

CNPE's Resolution 15, approved on June 8, 2017, defined the strategic guidelines for the development of the fuels market, additional petroleum derivatives and biofuels, with the purpose of supporting the proposal of measures that contribute to ensure the national supply. The Resolution states that the ongoing actions under the Fuel Brazilian Initiative are aimed at proposing measures that encourage the entry of new economic agents in the fuels, biofuels and other petroleum derivatives sector, as well as promoting free competition.

CNPE also defined the creation of the Integrated Technical Committee for the Development of the Fuel Market, other Petroleum Derivatives and Biofuels, the CT-CB, which will aim to propose actions and measures to MME to improve the legal framework of the sector and to the development of the fuel market, other petroleum derivatives and biofuels, as well as evaluating the implementation of the proposals presented in the Fuel Brazil initiative. The committee will be composed of representatives of all governing bodies involved in implementing the strategic guidelines and may invite experts and representatives from other bodies and entities, as well as the society and associations, to attend meetings and provide advice on specific topics.

The Resolution also determines that the CT-CB will observe the alignment of its proposals with other initiatives and programs in the energy sector, especially RenovaBio. Such alignment is extremely important, since the two programs are convergent. Both programs start from the premise that demand for fuel will increase and that Brazil needs to prepare to supply it. The discussions on Fuel Brazil revolve around two scenarios: the first considers that Brazil should seek self-sufficiency in the production of derivatives, which suggests the need for investments in refining capacity, the construction of new refineries and / or the expansion of existing units; the second one assesses that Brazil will become dependent on imports and, therefore, it must invest in infrastructure and logistics for the importation of derivatives, such as ports, pipelines and inventories. RenovaBio intends to stimulate the production of biofuels, knowing that the country has the capacity to increase the production of ethanol and biodiesel, in order to guarantee a good part of the supply of fuels in the mid-term. The supply issue is strategic for Brazil and should be thought of in an integrated way, aiming at optimizing the investments and taking advantage of the internal production potential.

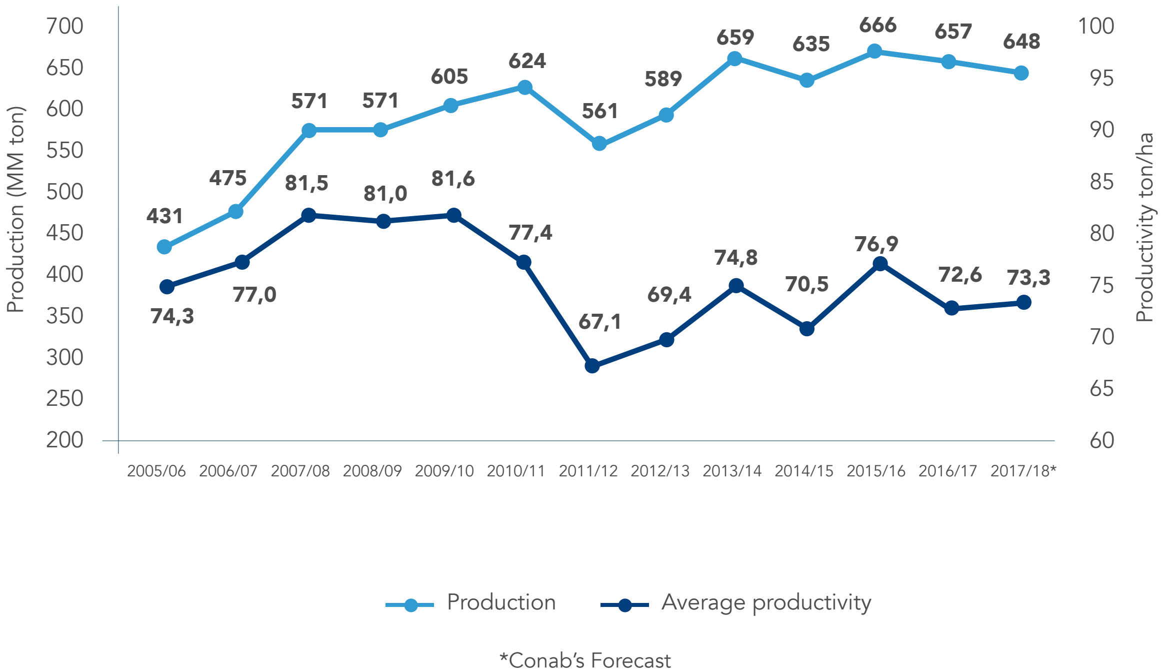
D. PRODUCTIVITY

The competitiveness of the sugar-energy sector is closely related to sugarcane productivity, measured in tons per hectare (ton / ha), since increasing production in a given agricultural area leads to higher yields in terms of harvesting and lower agricultural costs. Productivity depends on several factors. The main ones are: soil and climatic conditions, quality of the sugarcane varieties used, renewal of sugarcane plantations, adequate cultural practices, and use of the best mechanization techniques for planting and harvesting. On the other hand, sugarcane yields, measured by the Total Recoverable Sugars (ATR) index per ton of sugarcane, is influenced by factors such as: maturation of sugarcane (cane harvested at the beginning of the crop has a lower ATR), variations (temperature, relative humidity, rainfall), soil conditions and farming practices.

To meet production expansion targets associated with COP 21 commitments, which nearly double the volume of ethanol currently produced, the industry expects that it will not be necessary to double the area planted, as there should be a significant increase in productivity. The bets range from 30% to 70% in relation to current levels. Part of this will come from the dissemination of the best practices that have already been adopted by the best companies sector (the productivity differential between the industry average and the best companies is estimated at 15%). It is already known that in the Midwest productivity gains are being obtained due to a phenomenon still not widely known, which is the role of sugarcane in the recovery of the soil quality of pasture areas used for the expansion of the sugar-energy industry. Productivity, which in the first cycle was 75 tons / ha, has reached 100 tons / ha in the second cycle. Another part of the contributions will come from innovations such as the development of new sugarcane varieties, new agricultural techniques and ethanol production.

Productivity, which at the beginning of Proálcool was 45 tons / ha, reached values close to 82 tons / ha in the 2009/10 crop (Figure 18). From 2009 to 2011, there was a sharp fall in agricultural productivity, which has been slowly recovering since then. The expansion of sugarcane plantations, with the implementation of new plants in the first years of this century, was done in a disorderly manner, without adequate criteria for the allocation of varieties to the edaphoclimatic characteristics of the expansion areas, being one of the main factors that led to the decreases in productivity and increased production costs. Other factors that contributed to this scenario were the occurrence of adverse climatic conditions (droughts), the lack of financial resources for the renewal of reeds and for the application of farming practices to existing sugarcane plantations, as well as the rapid implementation of mechanization.

FIGURE 18: AVERAGE PRODUCTION AND PRODUCTIVITY OF SUGARCANE



Source: Own elaboration based on data from Conab

Introduced, initially, by State Law (SP) n ° 11.241 / 2002, the mechanization of the harvest also began to be required in the other producing states. In addition to improvements in working conditions, it enabled the sugarcane plantations to be harvested without burning, with significant environmental benefits by reducing emissions. Harvesting without burning also has benefits in soil conservation, since the straw left in the crop allows the erosion and humidity control in hot and dry areas, contributes to the increase of soil organic matter and nutrients, and helps in the control of weeds.

The implementation of mechanized harvesting and planting technologies, however, caused important impacts in the sector, leading to productivity losses due to lack of appropriate soil preparation during planting, to inadequate alignment of the cane field, insufficient qualification of the operators and by the sugarcane varieties not adapted to the mechanical cutting. Milanez et al. (2012) argue that, according to sector specialists, productivity losses as a result of mechanization can be explained by at least three reasons: (i) soil compaction; (ii) the lower density of plants per planted area, since the planting should adjust to the mechanized cut; and (iii) the highest the thatch is cut by the harvesters in relation to the manual cutting height, so as to prevent the machine from pulling out the sugarcane shoots at the time of the harvest.

However, the losses that occurred at first, with the introduction of the harvest mechanization have been recovered with the improvement of agricultural techniques, among them precision farming[8], and with the learning curve resulting from the knowledge accumulated with subsequent crops. Therefore, the first efforts to obtain productivity gains should be directed at expanding the use of best practices, since it represents the cheapest investment. Productivity gains in the agricultural area lead to a growth in production, maintaining the same base of planted area, being necessary to invest only in the expansion of the industry, which occurs faster and with less risk. The following will present some technological solutions in development and / or improvement phase and that bring good prospects for the resumption of the sector's productivity growth.

GENETIC IMPROVMENT

The search for the increase in productivity involves the development of new varieties of sugarcane, since the maintenance of a healthy sugarcane field requires that periodic renewal be made and that different varieties of sugarcane be planted. Genetic improvement techniques seek to develop varieties that are more productive, more resistant to pests and diseases, as well as to specific climatic conditions, and more adapted to mechanized harvesting.

In Brazil, there are three programs for genetic improvement of sugarcane: the Inter-University Network for the Development of the Sugarcane Industry (Ridesa), composed of a technical cooperation agreement among ten federal universities; the Sugarcane Technology Center (CTC), a private company that has as its shareholders the largest companies in the sector; and the Agronomic Institute of Campinas (IAC), a research institute of the Paulista Agency for Agribusiness Technology, of the Agriculture and Supply Secretariat of the State of São Paulo.

The techniques used in plant breeding range from traditional, like crossing and selection, to the use of genetic engineering. Traditional genetic improvement uses the crossing between varieties of the same plant, involving thousands of genes, in order to achieve certain characteristics. These technologies, however, have considerable limitations. The complete development (until the commercialization) of a new variety of sugarcane takes, in average, ten years. Although commercially successful (after the decade of development), the new variety takes at least another five years to be among the most commonly used by the plants (Nyko et al., 2013). In addition, some commercially desirable traits cannot be

8 Agricultural management system based on the spatial and temporal variability of the production unit.

introduced into the sugarcane through classic improvement techniques. In these cases, new improvement techniques, such as the transgenesis one, are needed.

Many plants' crops, such as corn and soybeans, for example, have been using these techniques for a long time, but the world's first transgenic sugarcane has only recently been approved for use in Brazil. In June 2017, the commercial use of the first genetically modified sugarcane, developed by CTC, was approved. The new variety, CTC 20 Bt, is characterized by the resistance to the sugarcane borer (Diatraea saccharalis), the main pest threatening crop. Transgenic techniques require high investments in Research and Development (R&D), which are often considered incompatible with the expected returns, but the president of the CTC Council, Luís Roberto Pogetti, estimates that with the introduction of the seven varieties that are under development, productivity gains of up to 30% may be achieved.

PRE-SPROUTED SEEDLINGS

A technological leap relevant to the productivity of sugarcane is also expected from the development of new planting techniques, which traditionally is made using pieces of sugarcane (thatch), which are arranged on the ground to sprout. On average, 18 to 20 tons of sugarcane are needed for each hectare.

With the technique of the pre-sprouted seedlings (MPB), instead of using the thatches, a plant is used, the pre-sprouted seedling. The seedlings are produced in nurseries, from thatches submitted to appropriate care and management. The MPB are high quality seedlings, free of diseases and pests and with a multiplication capacity higher than traditional planting. The system involves the creation of nurseries for rapid multiplication of new sugarcane materials and is a simple method that can be adopted by small producers and associations, not being restricted to the plants.

According to IAC, among the benefits of the technique is the reduction of the amount of seedlings that goes to the field. For the planting of one hectare of sugarcane, the consumption of seedlings falls from 18 to 20 tons in the conventional plantation, to 2 tons in MPB. This means that the 16 to 18 tons that would be buried as seedlings will go to the industry to produce alcohol and sugar, resulting in profits for the producer.

SUGARCANE SEEDS

Being considered a technology with potential for high productivity gains, the development of sugarcane seeds (cloned cane cells) has been conducted in Brazil by CTC and is the development of seeds obtained by large-scale cloning techniques, in a bioreactor, so that millions of seeds can be produced from a single plant.

According to the president of the CTC Council, Luís Roberto Pogetti, of the 18 tons of cane currently used to plant a hectare, only 300kg will be needed. According to Pogetti, the current challenge is to gain scale and give rusticity to the seeds, so that they can be resistent to obstacles after planting. With this technology, a reduction in the cost of planting is expected to be so significant that it will be possible to renew the cane field in a shorter time, increasing the average productivity. Seeds are expected to be available in the market in approximately five years.

SUGARCANE-ENERGY

Another important technology to help increase productivity in the sugar-energy sector is sugarcane-energy. It is a variety produced by means of genetic improvement, in order to contain a higher percentage of fibers than conventional cane, initially focusing on the production of electricity and second-generation ethanol.

The most prominent feature of sugarcane-energy is its productivity. While common cane has average values of 70 to 100 tons / ha, companies such as GranBio and Vignis announce that they produce sugarcane varieties with yields of 180-200 tons / ha. This means doubling the production, without increasing the agricultural area used. Table 3 shows a comparison between some characteristics of the conventional sugarcane and the sugarcane-energy produced by GranBio.

TABLE 3: COMPARISON BETWEEN SUGARCANE - ENERGY AND CONVENTIONAL SUGARCANE

Characteristics	Sugarcane (high productivity)	Cane-energy
Fiber content (%)	17,4	27
Sugar content (%)	12,6	8,5
ATR (kg of ATR / ton of cane)	135	93
Productivity (ton/ha)	100	180
Number of crops per cycle	5	10
Bagasse (ton/ha)	25	92,6
Sugar (ton/ha)	13,5	17,2

Source: Own elaboration based on data from GranBio (2017) and *Portal Canaonline* (2016)

Sugarcane-energy bagasse production can reach almost four times more than that of conventional cane, leading to a second-generation electric power and / or ethanol yield significantly higher than the traditional variety. Another advantage of the sugarcane-energy is that it requires smaller amounts of water and inputs, which allows it to be planted in degraded areas that are not favorable to food production, and therefore do not compete with the production of these. In addition to being more resistant to adverse weather and soil conditions, it also more resistant to pests and diseases.

A The quality of the sugar present in the currently available sugarcane-energy is not suitable for the production of sugar. However, several varieties are under development, which may contain a near or higher content of sucrose than traditional sugarcane, and may also enable the production of first-generation sugar and ethanol. One of the varieties under development by Ridesa maintains the sugar content of the current varieties, around 15% sucrose, with an increase in the amount of fiber to 18% (conventional cane has a 14% average). This will be directed at meeting the current companies of the Brazilian sugar and ethanol sector's needs, aimed at the production of sugar, ethanol and electricity. Another type, with a low content of sucrose (close to 6%) and high fiber content (close to 25%) is intended for the production of electricity.

Another relevant issue for the dissemination of sugarcane-energy is the fact that the current harvesting machines do not have the capacity to cut it. Since it has a different shape and more fibers than conventional cane, the use of the variety requires adaptations of the plant's industrial and agricultural machinery. According to Pereira (2017), the research around these new varieties develops on several fronts: in mechanization, with equipment that are forage hybrids and cane harvesters; in the crystallization of the sugar, since the purity is inferior to the one of the sugarcane; and direct burning, which would take the sugarcane-energy from the field straight to the boiler. GranBio states that it has already developed, in partnership with a traditional agricultural machinery company, a forage to perform the harvest, which is already in the fifth prototype and available for market-scale production, at competitive costs in relation to the costs of harvesting conventional cane.

Given the quality and availability of sugar and the problems related to its harvesting and processing, most producers are resistant to its adoption, since it would be restricted to electricity and ethanol markets. Therefore, it is expected that the introduction of sugarcane-energy will initially be carried out at the beginning and at the end of the crop, adding increased production of first-generation ethanol and electricity, allowing conventional sugarcane to be harvested later, when it will have higher sugar concentration and better use of its potential. On the other hand, as second-generation ethanol becomes a reality, the use of sugarcane-energy tends to be expanded.

SECOND-GENERATION ETHANOL (E2G)

The production of ethanol from cellulosic raw materials is also considered a technology capable of revolutionizing the productivity of the sugar-energy sector. The use of bagasse and straw represent a potential that can reach values close to 50% increase in biofuel production from the same amount of raw material already used in conventional production today.

In Brazil, the first E2G plants started to emerge in 2014, as a result of an initiative of BNDES and Finep (the PAISS program), introduced in 2011. The plan made the implementation of three plants possible, two on a commercial scale, of GranBio, located in Alagoas, and Raízen, in São Paulo, and a demonstrative one, of CTC, in São Paulo. The GranBio and Raízen plants are among the five companies operating in the world, along with those of Poet-DSM (Iowa, United States), Beta Renewables (Crescentino, Italy) and DuPont (Iowa, United States). Brazilian companies have a great advantage in terms of costs, since they use the cheapest inputs for the production of cellulosic ethanol, bagasse and sugarcane straw. According to the consulting firm Lux Research (2017), these biomasses can cost less than half of the corn straw, the raw material used in the United States.

Although cellulosic ethanol plants are more sophisticated and have higher investment costs, with a cost of capital estimated at 30% higher than that of a conventional plant, the integration between the first and second-generation processes allows a synergy, which can increase ethanol productivity by 30-40% without the need to expand the agricultural area. Brazil's long-standing experience with the first-generation is another advantage, therefore, for the production of E2G, which, if well used, can make Brazil a leader in the segment of second-generation biofuels.

As mentioned before, the E2G production process involves two steps prior to the fermentation of sugars: pre-treatment and enzymatic hydrolysis. The choice of an efficient pre-treatment technology is essential for the economic viability of cellulosic ethanol, since this step affects the yield of all subsequent stages.

The technologies most used as pre-treatment are chemical processes, such as acidic and / or basic hydrolysis, and physico-chemical, such as the steam explosion. Companies with E2G projects have encountered more difficulties than expected on this stage, when going from the pilot scale to the industrial scale. One of the main sources of problems is the content, higher than the expected, of mineral impurities (earth, sand and stones), which comes with the raw material at the plant, causing damage to structures such as valves, pumps and pipes, as well as corrosion due to the high pressure and temperature of the process. Among the solutions found are the coating of the structures with ceramic material and the pre-washing of the biomes. Another source of complications is in the equipment used to treat biomass. The companies believed that it would be possible to use the machinery initially created for the pulp and paper industry, but the raw material is different and required efforts to make the necessary adaptations. With so many obstacles, the hydrolysis and fermentation stages also had their continuity compromised. The reaction times are above desired, while the yields are below.

It is worth mentioning that, since the input used is the same (bagasse and sugarcane straw), it is possible to have competition between the production of E2G and bioelectricity. The same biomass that results in the surplus of electric energy to be commercialized can be directed to the production of cellulosic ethanol and this will be another decision of the producer. As it manages the proportion of cane that will be destined for sugar and ethanol, it will also be able to choose between the allocation of the biomass for E2G or electricity, according to market conditions. It will be up to the producer to assess the risk and return of each option.

Although bottlenecks still exist, many of the critical points of second-generation technology have already been solved, such as the development of enzymes to break down complex structures of the cellulosic raw material and yeasts for the fermentation of sugars.

Nevertheless, of the two existing plants in Brazil, Raízen expects to run this crop (2017/18) with 50% capacity and reach, in the next crop, 100% of the capacity. Similarly, GranBio aims to reach 55% occupancy in this crop and 100% capacity next year.

CORN

Corn could play a significant role in the expansion of ethanol production, especially in the flex plants, which use the grain during the sugarcane off-season. This is only feasible in the corn-producing states of the Midwest, where production has generated surpluses at a low cost. Corn has the potential to contribute to the rapid increase of production in the short term, since the implementation of the investment occurs in 18 months, while a sugarcane field takes about 5 years to reach its full implementation.

In August 2017, the first ethanol plant made exclusively of corn was inaugurated in Mato Grosso, and the success of this plant could be a fomenter to new and similar investments. It is worth mentioning that the carbon footprint of Brazil's corn ethanol should be the same as or close to that of sugarcane ethanol, since its production will use renewable energy from the burning of biomass, while the North American plants use energy from fossil sources.

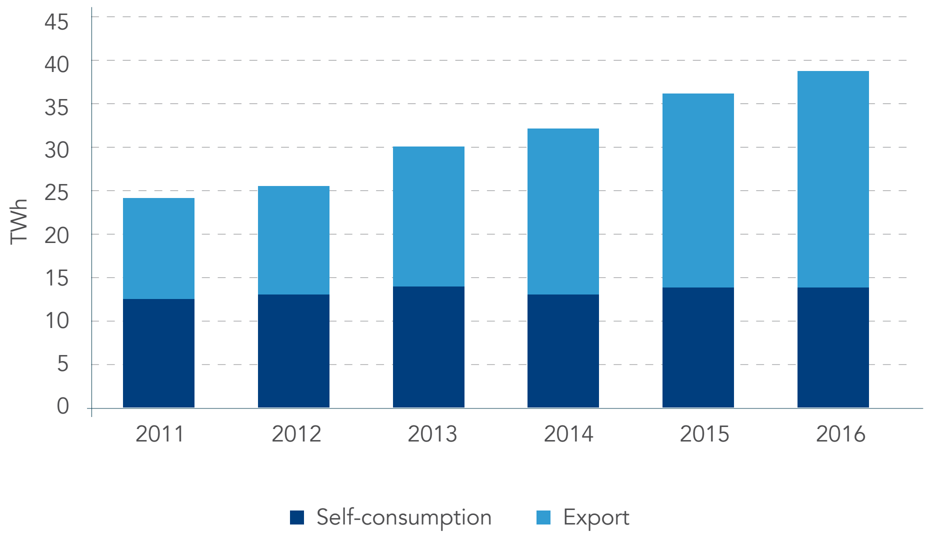
Bioelectricity

378 The participation of bioelectricity from sugarcane bagasse in the country's electricity generation has been increasingly relevant. In addition to producing enough energy for their own consumption, plants commercialize the excess volume, which has increased significantly each year. Electric generation by the sugar-energy sector has the advantage of being complementary to the hydroelectric generation, since its production occurs during the crop months, which are the driest of the year, when the hydroelectric reservoirs are lower. According to EPE (2017b), among the 378 sugarcane biomass plants in operation in 2016, 44% commercialized electricity. This number shows a slight increase in relation to the previous year, of 40%, but it shows that there is still a relevant potential to be explored. The plants export energy to the Brazilian Interconnected Power System (SIN), part of which operates exclusively in the Free Contracting Environment - ACL[9] (57%) or in the Regulated Contracting Environment - ACR[10] (8%) and the rest (35%) operates in both contracting environments.

According to UNICA (2017), since 2013, the sugar-energy sector has been generating more electricity for the Interconnected Power System than for the own consumption of the plants, with 60% of energy for the grid and 40% for consumption. In addition, from 2004 to 2016, bioelectricity from sugarcane already commercialized a total of 125 projects in regulated auctions totaling 1,662 average MW (or 14,559 GWh - annual). The supply of energy by the sucro-energy sector in 2015 was 20 TWh, corresponding to 4.4% of the national consumption of electricity.

9 In ACL, the contracting takes place through free negotiation between buyers and sellers, who carry out bilateral contracts of purchase and sale of energy. Distributors are not allowed to purchase energy in this market.
10 In ACR, the purchase and sale of energy takes place through energy auctions, such as new energy (A-3 and A-5), reserve (RSI) and alternative energy sources (LFA).

SELF-CONSUMPTION AND EXPORT OF BIOELECTRICITY



Source: EPE (2017b)

Among the government initiatives that have boosted the increase in bioelectricity participation are the promotion of energy auctions aimed at alternative sources and the creation of the Program of Incentives for Alternative Electricity Sources (PROINFA), whose purpose was to encourage diversification of the electric energy matrix, introducing renewable sources and increasing the participation of wind power, biomass and small hydroelectric plants. BNDES also contributed to this segment by providing financing lines aimed at the renovation and modernization of cogeneration facilities at the plants.

Another relevant factor for the increase in the commercialization of this type of energy is the price offered in the auctions. When these were competitive for the economics of the projects, the sector responded with the implementation of the 125 projects mentioned before. On the other hand, the commercialization of surpluses sold in the free market on the Settlement Price (PLD[11]) basis, provided good revenues for the sector, since, in recent years, PLD values have been high due to low generation of hydroelectric power plants and an increase in the participation of thermal plants in the load supply, reaching a price of 822.83 R$ / MWh in February 2014 (an amount about 7 times higher than the average since 2003).

Currently, most of the bioelectricity is generated by the burning of sugarcane bagasse, but there is also room to increase the generation by burning the straw. The manual harvesting of sugarcane involves the practice of burning the straw, which does not occur in the mechanized harvest, and in this case, a considerable amount of straw remains in the field. There are agronomic benefits in leaving the straw in the field, but it is possible to take advantage of much of this material, which will depend on the economic viability of the cost of collecting and transporting the straw to the plant. According to the Ministry of Science, Technology, Innovations and Communications (MCTIC, 2017), CTBE researchers are developing a project to increase the production of electricity from sugarcane straw harvested during the sugarcane harvest without burn. The Sugarcane Renewable Electricity (Sucre) project, funded by the Global Environment Facility and managed by the United Nations Development Program (UNDP), began in 2015 with an investment of US$ 67.5 million during five years, in order to identify the barriers that are making the use of straw in the plants difficult. Experts estimate that it is possible to increase energy output by seven times and for this, researchers work on identifying and solving problems that create obstacles for the generation of electricity by power plants in a full and systematic way.

11 PLD is a value determined weekly for each load level based on the Marginal Cost of Operation, limited by a maximum and minimum price in effect for each calculation period and for each Sub-Market (Chamber of Electric Energy Commercialization - CCEE, 2017).

E. ENGINE TECHNOLOGY

Unlike the case of vehicles with engines running on one type of fuel, where all parameters are set to operate at the optimum point of the fuel used, whether it is alcohol or gasoline, this is not the case for flex-type vehicles, which operate with average values, therefore, out of the optimum point of each fuel. Some experts, such as Nigro and Szwarc (2009) and Smith (2010), point out that flex-type engines do not take full advantage of the advantages associated with higher octane rating and higher ethanol combustion efficiency.

For the Energy Efficiency National Institute (INEE, 2015), flex-fuel engines are gasoline engines that also operate with ethanol, basically thanks to software adjustments that control the engine. As a result, they often cannot take advantage of the properties of ethanol (such as their total calorific value), which are advantageous for engines used in light vehicles (Otto cycle). However, some flex engines already show higher yields with ethanol than with gasoline, a tendency that can evolve with the more generalized use of direct injection and turbos. The INEE's Efficient Ethanol Program (PrEE), which calculates and discloses the relative efficiencies of the various models based on information from the National Institute of Metrology, Quality and Technology (INMETRO), has verified that of the total number of flex models sold in 2015, the majority (85%) were more efficient using ethanol than gasoline, representing a significant advance when compared to 2014, when only 25% of cars were more efficient with ethanol. This means that for 85% of the models, consumers would accept to fill the tanks with ethanol when it was in a price ratio above 70%. According to INEE, this improvement reflects the technological advances stimulated by the Program of Incentive for Technological Innovation and the Intensification of the Productive Chain of Automotive Vehicles (Inovar-Auto) Program, which provides tax benefits to the automotive industry, but requires, as a counterparty, an increase in the efficiency of the models.

The Inovar-Auto government program, which was introduced in 2013 and ends in December 2017, promotes tax incentives aimed at new investments, raising the technological standard of vehicles, parts and components, and vehicle energy security and efficiency. Although the program seeks to improve energy efficiency as a whole, without specifically focusing on ethanol optimization, in 2014, the law that instituted the program (Law 12.715 / 2012), began to allow the possibility of setting IPI (Tax on Industrialized Products) lower rates for vehicles with flex-fuel engines that had a consumption ratio between hydrous ethanol and gasoline higher than 75%.

Rota 2030 is still being elaborated, but discussions have already begun and there is an expectation regarding the alignment of definitions between it and RenovaBio, seen by the signing of an agreement between representatives from the National Association of Automotive Manufacturers (ANFAVEA) and UNICA.

The government is already structuring the program that will succeed Inovar-Auto in 2018, named Rota 2030, an initiative of MDIC. Rota 2030 is still being elaborated, but discussions have already begun and there is an expectation regarding the alignment of definitions between it and RenovaBio, seen by the signing of an agreement between representatives of the National Association of Automobile Manufacturers (ANFAVEA) and UNICA. The agreement aims to combine the strategies of the two programs with the goals set at COP 21 and is centered on three pillars: predictability and ensuring the biofuels supply (proposed by RenovaBio); higher energy efficiency (proposed in Route 2030); and reduction of GHG emissions, which permeates the scope of both programs (AutomotiveBusiness, 2017).

The role of biofuels in electric mobility

Electric vehicles have been gaining more and more space on the roads around the world. In 2016, the stock of electric cars surpassed the mark of 2 million units (IEA, 2017). These figures concern, for the most part, 100% electric and hybrid vehicles. Fuel Cell Electric Vehicles (FCEV) are still few - by 2016, there were only three FCEV models in select markets in the United States: Toyota Mirai, Hyundai ix35 / Tucson and Honda Clarity (IHS Markit, 2016). In comparison, the number of pure and hybrid electric models reaches thirty-five. However, electric fuel cell technology has been developing, and new possibilities are already emerging, such as the Solid Oxide Fuel Cell (SOFC), which produces hydrogen from ethanol.

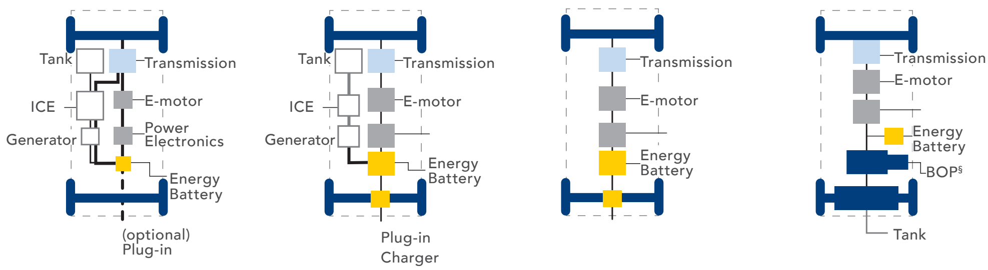
Before discussing how biofuels can contribute to the development of electric mobility in Brazil, it is better to understand the different technologies of electric vehicles. The different types of electric vehicles are:

1. Pure Electric (BEV) (Battery Electric Vehicle): They have only one electric engine, which is responsible for putting the car in motion. They are also known as "100% electric" or "purely electric";

2. Hybrid Electric Vehicles (HEVs) have two engines, an electric engine and an internal combustion one. Hybrids that have a plug for recharge in the electrical network are called plug-in Hybrid Electric Vehicles (PHEV). In addition, the hybrids can be in series or in parallel. In hybrids in parallel, what puts the car in motion is an internal combustion engine, the electric engine has an auxiliary function. In hybrids in series, the electric engine puts the car in motion, while the internal combustion engine supplies power to the main electric engine. Hybrids in series are known to have extended range, as long as there is fuel for the internal combustion engine to generate electricity, the vehicle will run.

3. Fuel cell electric vehicles (VCFs) have only one engine, which is electric. The electricity that puts the car in motion is the result of a chemical reaction between hydrogen and oxygen in the fuel cell. The source of oxygen is air, while hydrogen is stocked and stored in a tank in the vehicle.

DIFFERENT TECHNOLOGIES OF ELECTRIC VEHICLES



Hybrids in parallel (HEV and PHEVs = Plug-in) | Hybrids in series (E-REV or REX) | Pure Electric (BEV) | Fuel Cell (FCEV)

Source: FGV Energia Booklet – Electric Vehicles (2017)

Biofuels, especially ethanol, can be a great differential for Brazilian electric mobility. In addition to traditional FCEV, the Solid Oxide Fuel Cell (SOFC), which uses ethanol, is being developed by Nissan and is expected to be available in the next decade.

In addition, flex hybrid electric cars are also a technological possibility that present themselves as an opportunity for Brazil. In the same way that flex-fuel technology has been developed in the last decades, flex-fuel hybrids and ethanol are expected to become a reality in the future. So much so, that EPE, in the Ten-Year Energy Plan 2026, already considers flex-fuel hybrids to be a reality from 2021[12]. Given that Brazil has comparative advantages in both biofuel production and flex-fuel technology, and that hybrid electric cars are a transition technology that will continue to be used for many years to come, the country has much to gain from the development of electric to ethanol.

Biofuel hybrid electric vehicles can also be used to transport passengers. The advantage of the use of alternative fuels, such as biofuels and electricity, in the public transport fleet is its ability to have a considerable effect on the decarbonisation of road transport, since public transport is highly demanded, consuming a lot of fuel and, consequently, also emitting many greenhouse gases. Electric hybrid buses that use biodiesel have been circulating in Curitiba for some years (G1, 2012). In São Paulo, a municipal law required that, by 2018, all buses in the city use renewable fuels, not fossil fuels. The use of flex hybrid buses would be a good option. This goal, however, was postponed until 2037 (ESTADÃO, 2017).

In sum, biofuels can contribute considerably to the development of electric vehicles in Brazil. Hybrid electric technology, however, is seen as transitional, so that in the future, 100% electric cars will become predominant. Initially, the production of flex-fuel hybrids by Brazilian traditional automakers should start - these vehicles are already considered by the planner as of 2021. In the meantime, SOFC technology will improve, so that, even in the 2020, it becomes a reality in the production of domestic electric cars. It is certain that the future of the world of mobility is electric. In Brazil, this will not be different. But, before being 100% electric, this future in our country will be ethanol hybrid, and can then be ethanol cell.

12 In EPE's 2026 PDE (2017c), the hybrids will be the majority of Brazilian electric cars, whose expected participation in the fleet is forecasted to be less than 1% in 2026. It should be noted that, in such horizon, only hybrid vehicles are considered, and those will be assumed as flex-fuel hybrids from 2021.

E. PROSPECTS

The growth prospects of the sector, taking into account the scenario presented, focusing on the resumption of investments and the increase of ethanol production, will have as drivers the following reasons:

1. Scenario of opportunities created by the commitments assumed at COP 21: GHG emission reduction targets and defined percentages for bioenergy in the matrix
2. New regulatory proposal to promote biofuels – **RenovaBio**
3. Development of technologies focused on increasing productivity, bringing more competitiveness to the sector
4. Need to ensure Otto cycle fuels supply in the mid-term
5. Improvement of combustion engines to be more efficient with the use of ethanol in addition to the technological possibility of development of l flex-fuel hybrid engines and fuel cell electric engines with hydrogen from ethanol

Biodiesel

A. CHARACTERISTICS AND SPECIFICATIONS

Unlike ethanol, biodiesel is not a single composition product, but a blend of fatty acid esters that vary depending on the raw material and the route of production employed. ANP, in Resolution no. 30/2006, defines biodiesel as a fuel with composed of alkyl esters of long chain carboxylic acids, produced from transesterification and / or esterification of fatty materials of vegetable or animal origin, and that meets a certain specification.

Biodiesel is predominantly produced from vegetable oils, animal fats or residual oils[13]. Such oils and fats undergo a reaction with an alcohol (usually methanol or ethanol), called the transesterification reaction, resulting in compounds known as esters of fatty acids (biodiesel) and glycerin. The transesterification reaction is necessary to obtain a fuel with properties similar to diesel, to be used in a compression ignition engine (diesel cycle). The reaction promotes the reduction of viscosity and density of vegetable oil, as well as other properties that affect combustion and, consequently, engine efficiency.

13. In theory, biodiesel can be produced from any source of fatty acids. So, besides animal or vegetable oils and fats, fatty residues also appear as raw materials for the production of this biofuel. Examples of these are frying oils, refining lees, grease from sewage, unspecified vegetable or animal oils or fats, fatty acids, among others.

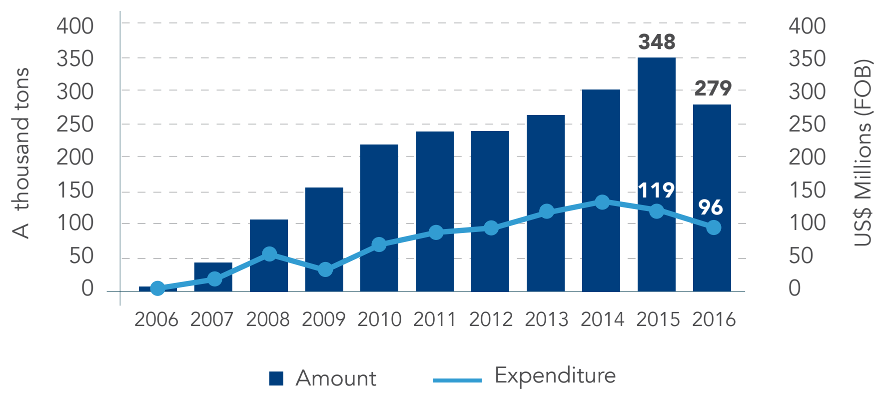
Despite the availability of ethanol in Brazil and the lower toxicity of this alcohol, when compared to methanol, methylic route (which uses methanol) is the most used in country and the world. From a technical perspective, the methylic route is simpler than the ethylic route (which uses ethanol). In the methylic one, reaction time is lower, glycerin separation is easier and the reaction presents higher yield. The reaction with ethanol has a lower yield which results in the need for more reagents, higher temperatures (therefore, more energy), and larger reactors, making the process more expensive. Even though Brazil is dependent on the import of methanol (there is no production of this alcohol here), methanol still has the advantage of being cheaper than ethanol.

Methanol

Methanol, or methyl alcohol, has several industrial applications as a solvent in the plastics industry, for example, and is a key input for the production of biodiesel. The most common methanol production route is the one that uses the synthesis gas, which can be obtained from natural gas. The United States concentrates world production because of its high production of natural gas at low prices.

Brazil does not produce this alcohol, therefore, all the volume used is imported, mainly from Chile. The main suppliers to Brazil are Methanex, which has two production plants in Chile (only one is currently in operation), and Southern Chemical Corporation (SCC), with operations in Trinidad and Tobago. In 2016, Brazil imported 279 thousand tons of alcohol, which involved the spending 96 million dollars, both values 20% below those of 2015. The economic recession caused diesel consumption in 2016 to decline, causing a reduction in the demand for biodiesel. As a consequence, demand for methanol also declined.

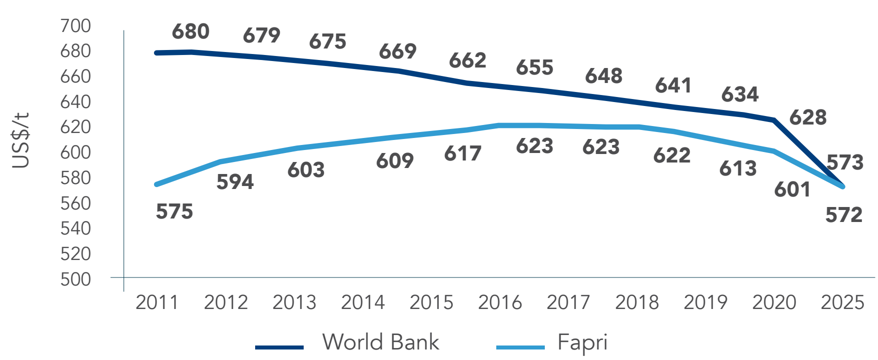
IMPORT OF METHANOL EXCLUSIVE FOR BIODIESEL



Source: EPE, 2016

According to the World Bank (2016) and FAPRI (Food and Agriculture Police Research Institute, 2017), methanol prices are expected to fall, since natural gas, the main input of methanol production, has shown a strong downward trend in Brazil and the world.

METHANOL PRICE PROJECTION

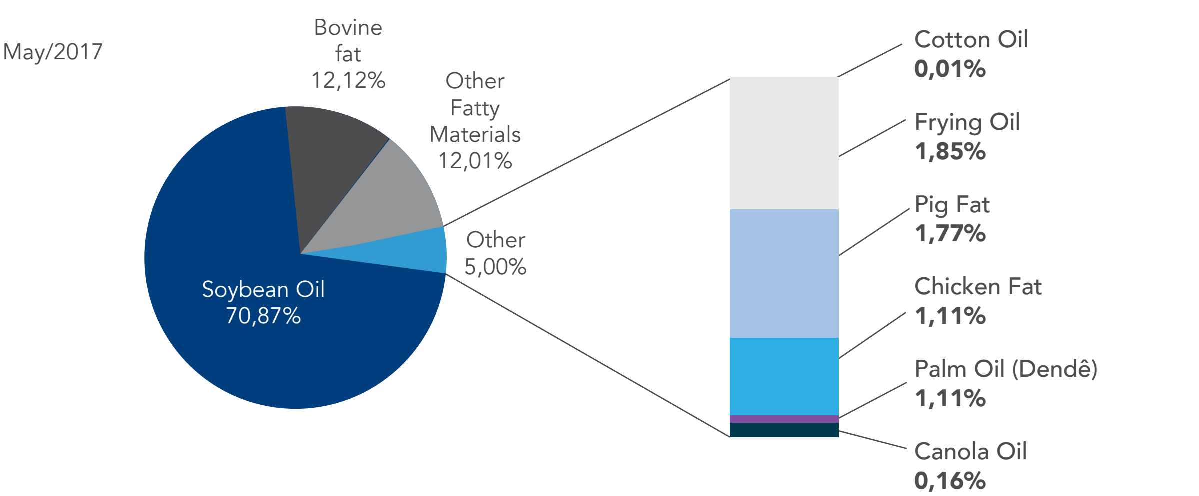


Source: World Bank (2016) and Food and Agriculture Police Reserach Institute (FAPRI, 2017)

The characteristics of the oil / fat used as raw material influence the properties of the biodiesel produced. Biodiesel made from bovine fat, for example, due to the higher presence of saturated fats, tends to solidify more easily at low temperatures than biodiesel produced from vegetable oils and this can cause the clogging of injector nozzles, compromising the efficient combustion of the fuel. In addition to the physico-chemical properties that can affect storage, distribution and combustion within the engine, the raw material choice must take into account factors such as agricultural productivity, which also depends on soil and climatic conditions, and production costs, among others.

Figure 19 shows the percentage participation of each raw material used in Brazil in May / 2017, and it can be seen that approximately 83% of the production is based on soybeans (71%) and bovine fat (12%). Although the soybean crop is not the most productive when compared to other oilseeds, its high relevance in the production of biodiesel is due to some reasons, such as the high level of structuring of the productive chain and its insertion in a typical global market of an international commodity, the accumulation of years of research and technological development (both in Brazil and abroad), besides being an inexpensive, available product that can easily meet demand, since Brazil is the second largest producer in the world, behind, only, the United States. Bovine fat is also a low-cost material and is available in large quantities, yet it is environmentally interesting, since it does something with the residue. In addition, the use of tallow to produce biodiesel adds value to the bovine meet chain and does not compete with food production.

FIGURE 19: RAW MATERIALS USED IN THE PRODUCTION OF BIODIESEL IN BRAZIL



Source: ANP (2017c)

Table 4 shows some properties and specifications determined by ANP for S10 diesel and for pure biodiesel (B100). Although it has a calorific value lower than the diesel, biodiesel has higher values of the Cetane Number, a standard that measures the ignition quality of the fuel and is, therefore, related to the engine efficiency. The viscosity of the biofuel is higher than that of the fossil fuel, but it does not compromise the engine, since biodiesel is added to diesel at low percentages.

TABLE 4: PROPERTIES OF DIESEL AND BIODIESEL

Characteristics	Diesel S10	Biodiesel (B100)
Lower Calorific Power (MJ/kg)	42,3	37,7
Specific mass at 20°C (kg/m³)	815-850	850-900
Cinematic Viscosity at 40°C (mm²/s)	2,0 a 4,5	3,0 a 6,0
Cetane Number	48-52	50-65
Oxidation Stability at 110°C, min (Hours)	-	8
Water Content, max. (mg/kg)	-	200
Cold Filter Clogging Point (°C)	-	5 a 19

Source: Own elaboration based on data from ANP

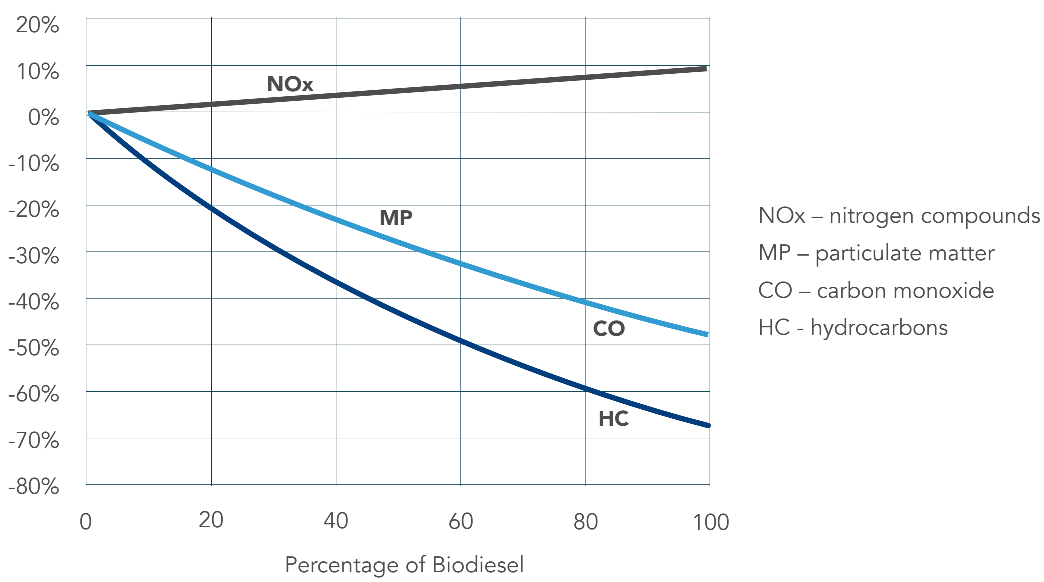
Oxidation stability is a property that directly affects the stability of biodiesel during the storage period. Due to the presence of unsaturations (double bonds) in the biodiesel molecule, it can undergo reactions that cause its degradation, causing changes in its physical and chemical characteristics and, consequently, affecting its quality. Fossil fuels, on the other hand, are stable compounds, which maintain their characteristics unchanged for long periods. Another important characteristic of biodiesel is the Cold Filter Clogging Point, which is related to the biofuel flow characteristics, as it tends to solidify or lose fluidity at low temperatures. The values specified by ANP for this parameter vary between the states and between the months of the year.

The Brazilian specification is the most demanding with regard to water content. The 200 mg / kg adopted in Brazil is about half of what is tolerated in the rest of the world, a requirement that is necessary, for example, due to the logistic peculiarities of the extensive national territory. It is worth mentioning that the high hygroscopicity (capacity to absorb water) of biodiesel required investments in Brazilian plants, not only to obtain biodiesel below this level, but also to maintain it during transportation and storage (Ministry Agriculture, Livestock and Supply - MAPA, 2015).

According to the North American Department of Energy (DOE, 2014), biodiesel can be blended with diesel in different proportions, with B20 being the most common in the United States. Engines using B20 show consumption, power and torque values similar to those operating with fossil diesel. In addition to having a higher Cetane number, biodiesel has higher lubricity (ability to lubricate pumps and fuel injectors) than mineral diesel, so it burns more easily and lubricates the fuel system. The addition of biodiesel in diesel became even more important with the reduction of the sulfur content in fossil diesel, since it was this component that allowed the lubrication of the engines.

The addition of biodiesel to diesel fuel contributes to the reduction of pollutant emissions as shown in Figure 20. The addition of 20% biodiesel reduces hydrocarbon emissions by 20% and carbon monoxide and particulate matter by 12%. On the other hand, there is an increase of emissions of nitrogenous compounds, although not very significant (2%) in blends containing up to 20% biodiesel.

FIGURE 20: IMPACT OF BIODIESEL ADDITION ON THE REDUCTION OF EMISSIONS



Source: EPA (2002)

B. REGULATION

PNPB is an inter-ministerial program of the Federal Government, created in 2004, which aims at the sustainable implementation, both technically and economically, of the production and use of biodiesel, with a focus on social inclusion and regional development, through job creation and income. The main guidelines of the program are: to implement a sustainable program, promoting social inclusion; ensure competitive prices, quality and supply; and to produce biodiesel from different oil sources, strengthening regional potentialities for the production of raw materials (Ministry of Agrarian Development - MDA, 2017).

Law 11,097 / 2005, which materialized the introduction of biodiesel into the Brazilian energy matrix, defines biodiesel as a biofuel derived from renewable biomass for use in internal combustion engines with compression ignition or for the generation of other types of energy, which can partially or totally replace fossil fuels. This law defined the mandatory minimum percentage of 5% biodiesel addition to biodiesel (B5), with a deadline of up to 8 years for its implantation, and defined the use of an intermediate blend of 2% (B2) for three years. This initial obligation started in January 2008 and the blending percentage was gradually increased, as shown in Table 5.

Law 13.263 / 2016 established a schedule for increasing biodiesel content in diesel for the years 2017 (B8, which was introduced in March), 2018 (B9) and 2019 (B10). However, the sector has been demanding the anticipation of the B9 and B10 mandates, or even the direct passage from B8 to B10 in March 2018, which is under discussion with the government.

TABLE 5: HISTORY OF BIODIESEL BLEND CONTENT IN DIESEL

% Biodiesel in Diesel	
Before 2008	optional
Jan/2008	2%
Jul/2008	3%
Jul/2009	4%
Jan/2010	5%
Aug/2014	6%
Nov/2014	7%
Mar/2017	8%
Mar/2018	9%
Mar/2019	10%

Source: Own elaboration based on data from ANP

It is worth mentioning that other countries already use biodiesel blends above B8, in effect in Brazil, among them Argentina (B10) and the United States (up to B20).

The same law also provides for the possibility of adding up to 15% biodiesel in diesel, which is necessary to carry out tests and rehearsals that validate the use of the blend by the automotive industry. The tests are being carried out, with completion scheduled for up to 18 months from July 2017, the date on which the Cooperation Agreement between the parties was signed, and the B10's tests must be completed by February 2018 (EXTRA, 2017). There will be 49 tests for the use of B10, B15 and B20, involving 23 companies among automakers and suppliers of auto parts. Entities of the sector, such as the Brazilian Association of Vegetable Oil Industries (ABIOVE), the Association of Brazilian Biodiesel Producers (APROBIO) and the Brazilian Union of Biodiesel and Biokerosene (UBRABIO) propose that mandates reach B15 by 2025 and B20 in 2030.

It is worth mentioning that other countries already use biodiesel blends above B8, in effect in Brazil, among them Argentina (B10) and the United States (up to B20). Most car manufacturers in the United States give assurances for the use of up to 20% biodiesel, and since the automotive industry is a global industry, it can be argued that used vehicles and engines abroad are the same used in Brazil, and therefore, it would not be necessary to realign the tests provided for in Law. However, the Brazilian Association of Automotive Engineering (AEA) justifies the performance of the tests due to several factors related to fuel and also to vehicles. Brazilian biodiesel has mainly soybean and bovine tallow as raw materials, while in the United States and Argentina biodiesel has soybean oil predominantly in its composition, generating a product with some characteristics different from those produced in Brazil. On the other hand, as the emissions and fuel specifications are different in each country, there are differences between some engine components used in each market. In this way, the tests will evaluate aspects such as engine performance variations (torque curve, power and consumption), filter efficiency, gas conversion and accumulation of impurities in the catalysts, as well as compatibility with the materials used in the components of the injection systems (polymers, elastomers and metals).

On the other hand, distributors ask for predictability in the process of increasing blending percentages, since such changes require planning by the distributors, budget for infrastructure adjustments (loading and unloading platforms and tanking) and product quality control.

AUCTIONS

As defined by CNPE Resolution No. 5, dated 10/3/2007, biodiesel is sold through public auctions organized by ANP, on a bimonthly basis, for the delivery of biodiesel in the two months following the month of the auction. Biodiesel auctions are aimed at the acquisition of biodiesel from suppliers (biodiesel producers) by purchasers (producers and importers of diesel oil) to meet the mandatory blending percentage, and also for voluntary use purposes. ANP determines the volume to be commercialized, the technical characteristics, the conditions of delivery and the maximum reference price of biodiesel in the bidding documents. The format of the auctions has already undergone some changes over the years, reaching the current model, which occurs online, using Petrobras' trading platform, Petronect.

Petrobras, which holds more than 99% of the country's diesel production, is considered, by ANP, to be the sole buyer and it is up to Petrobras to operationalize the auctions' commercialization stages, making the selection of the producers' offers in accordance with the needs of its customers (distributors). To this end, the company receives a value of 25.00 R $ / m³, defined as Petrobras' Margin.

According to Ordinance MME nº 476/2012, to promote of each Public Auction, ANP establishes the Maximum Reference Price (PMR) for each region to be observed by suppliers when presenting the offers for biodiesel commercialization, and it must be considered, among other criteria, the regional cost of one or more raw materials that are predominant in the production of biodiesel and, where applicable, the costs to meet the Social Fuel Seal (SCS). The offered unit price for each individual offer, in R$ / m³, for delivery to the supplier's production unit, including federal taxes imposed on biodiesel, cannot be higher than the PMR, and the total volume offered, in cubic meters, cannot exceed the effective availability of biodiesel supply from the production unit.

The first phase of the auction involves the negotiation of 80% of the total volume to be commercialized and is restricted to the producers who have the SCS. The seal is a certificate granted to biodiesel producers who purchase minimum percentages of raw material from family farming (15% to 40%), by signing contracts with family farmers, setting deadlines and conditions for delivery of the raw material, as well as the provision of technical assistance to these farmers. In addition, the seal holders are also benefited by having access to better financing conditions with financial institutions and to PIS / PASEP and COFINS aliquots with differentiated reduction coefficients, which vary according to the raw material acquired and the region in which it was acquired. The process of SCS concession is done through audits carried out by MDA, which certifies the fulfillment of raw material acquisition and technical assistance obligations, reviewing the SCS concession annually for each biodiesel producer.

Within the scope of PNPB, the SCS had as its original goal, the social inclusion of family farmers, especially the castor bean farmers from the Northeastern region, who would benefit from technical assistance and the acquisition of their production. However, due to these producers' lack of structuring, which increased the cost of providing technical assistance, the producers concentrated the acquisition of raw materials from family farming, together with soybean producers in the Southern region of the country, where there was already a culture of cooperativism, for several decades, providing lower costs to obtain the SCS. Thus, of the 72,485 families that supplied raw materials in the SCS arrangements in 2015, only 3,926 were from the Northeastern region. Given this concentration of beneficiaries in the Southern region, sector agents are expected to change the SCS rules in order to create new incentives that promote the inclusion of family farmers from other regions of the country, as well as simplifying the rules for obtaining and revalidating annual of the seal, which leads to additional costs to producers.

Biodiesel Auctions are considered a transparent commercialization mechanism, since it is a public event, where all the volumes traded and their respective suppliers are known, as well as the price conditions. Moreover, the auctions offer equal access among suppliers and do not discriminate the size of the biodiesel producer (APPROBIO, 2017). In general, the agents involved in the production and commercialization of biodiesel seem to be satisfied with the current model of the auctions, which ensures transparency and isonomy to the market, minimizing the possibility of tax fraud. However, there are those who advocate for the end of the auctions, arguing that the best solution would be to have a free market, in which the producers and buyers of biodiesel would make private bilateral contracts, in which they would determine prices, volume, delivery and other conditions, without external interference.

In addition to regular auctions, ANP may conduct complementary or specific auctions in situations where it is necessary to: i) supply the volumes of biodiesel not delivered by the producers to the purchasers; and ii) acquisition of biodiesel in amounts higher than the demand required to meet the minimum mandatory percentage (ANP, 2016b).

20% in captive fleets or road consumers supplied by fueling station; 30% in rail transport; 30% in agricultural and industrial use; and 100% in experimental, specific or other uses.

In 2013, the MME published Ordinance No. 116, which establishes specific guidelines for creating of biodiesel stocks. The document defines that ANP will establish the minimum volumes of biodiesel for inventory purposes to be maintained by each purchaser (producers and importers of petroleum-derived diesel), in proportion to their respective participation in the domestic market of pretroleum-derived diesel. The Ordinance also made it possible to transfer responsibility for the regulatory and strategic stocks to biodiesel plants. The contracting modality is a modern negotiation mechanism, used in other sectors, but now introduced to biofuels. The purchasers (Petrobras, basically) contract the right to take out biodiesel when necessary, at any time. The sellers (plants) are obliged to complete the transaction at the agreed price. The biodiesel will continue in the regular stock of the producers, whose movement is daily or weekly. This avoids the degradation of the product when stored for long periods. It also eliminates the need for physical transport from the plant to Petrobras. In the eventual need to consume the safety stocks, the biodiesel will go directly from the producer to the distributor (MME, 2013).

CNPE Resolution No. 3 of 09/21/2015 authorized and defined the guidelines for the commercialization and voluntary use of blends using biodiesel, the authorizing market, in quantities higher than the percentage of their mandatory addition to diesel oil, observing the following maximum limits for the addition of biodiesel to diesel oil, by volume: 20% in captive fleets or road consumers supplied by fueling station; 30% in rail transport; 30% in agricultural and industrial use; and 100% in experimental, specific or other uses.

The ANP has established the rules for authorizing biodiesel, with the objective of stimulating and take advantage of the conditions that may make it competitive with diesel oil, especially in regions far from petroleum refineries and with an abundance of productive capacity. In order to make the acquisition of this shareof biodiesel possible, some existing rules were changed as from the 48th auction (April / 2016), with the approval of state environmental agencies, engine manufacturers' declarations of agreement (or final user declaration assuming any risk), the identification of the person responsible for the analysis of the fuel used and the list of vehicles that would use the authorizing blend.

Despite the measures to facilitate the development of the authorizing market, there has been practically no demand in this regard. The main potential users would be the fleets of trucks and agricultural machinery, which operate near biodiesel production plants and away from petroleum refineries, a situation in which there may be a higher biodiesel competitiveness in relation to fossil diesel. In order to have an better understanding on the size of this market, only the diesel consumption of the agricultural machinery of soy production reaches 1.6 billion of liters per year. EPE (2017c) in its 2026 PDE indicates that this still incipient market may grow, since part of the sale of auction 53 was to supply the Isolated System's electric power generation units in the northern region of the country, where the locally produced fuel, using raw materials from the region may have prices that are more attractive when compared to fossil diesel, which requires special delivery logistics at remote locations.

BIODIESEL TAX REGIME

The biodiesel tax rules regarding PIS / PASEP and COFINS determine that these taxes are charged only once and that the taxpayer is the industrial producer of biodiesel. It may choose between a percentage rate that affects the price of the product, or the payment of a specific rate, which is a fixed amount per cubic meter of commercialized biodiesel, according to Law No. 11,116, dated May 18, 2005. This Law also provides that the Executive Power may establish reduction coefficients for the specific rate, which may be differentiated according to the raw material used in production, the production region of said raw material and the type of supplier (family farming or agribusiness).

Tables 6 and 7 show, respectively, the values of the reduction and differentiated reduction coefficients of PIS / COFINS for biodiesel. Regarding diesel oil, the rates of PIS and COFINS totaled R$ 248.00 / m^3 until July 2017, increasing to R$ 461.50 / m^3 in the same month.

TABLE 6: PIS / COFINS REDUCTION COEFFICIENTS FOR BIODIESEL

Law n° 11,116/05		**Decree 5,297/04**	**Decree 5,457/05**	**Decree 6,606/08**	**Decree 7,768/12**
Reduction Coefficients (%)		67	67,63	73,57	78,02
PIS (R$/m^3)	120,14	39,65	38,89	31,75	26,41
COFINS (R$/m^3)	553,19	182,55	179,07	146,20	121,59

Source: EPE (2016b)

TABLE 7: PIS / COFINS DIFFERENCIATED REDUCTION COEFFICIENTS FOR BIODIESEL

Law n° 1,116/05		**Decree 5,297/04**		**Decree 6,458/08**	**Decree 7,768/12**	
Reduction Coefficients (%)		Castor bean or Palm (N, NE and seminar)	Family farming (PRONAF)	Family farming (PRONAF) Of the regions: N, NE and seminar	Castor bean or Palma (N, NE and seminar)	Family farming (PRONAF)
Reduction Coefficients (%)		77,5	89,6	100	81,29	91,35
PIS (R$/m^3)	120,14	27,03	12,49	0,00	22,48	10,39
COFINS (R$/m^3)	553,19	124,47	57,53	0,00	103,51	47,85

Source: EPE (2016b)

The Lei Kandir (Kandir Law) of 1996 was a milestone in the taxation of the soybean chain, as it removed the ICMS tax on the export of primary and semi-processed products, including soy in natura.

Another federal tax, CIDE has a single-phase incidence on the commercialized volume by the Producer / Importer / Formulator. Thus, the tax is levied separately on the volumes of diesel A (without addition of biodiesel) and of biodiesel. In biodiesel, the incidence rate is zero, while in diesel A the rate is currently R$ 50.00 / m^3. Therefore, in practice, the price paid by the final consumer (resale price) only includes amounts related to the CIDE calculated on the volume of diesel A that enters the blend (currently 92%). As the percentage of biodiesel increases in the blend, the incidence of the CIDE will be lower (EPE, 2017). The ICMS, a state tax, is imposed with a taxation equivalent to 12% of the operations' value when biodiesel leaves the refinery (B100), resulting from the industrialization of: grains, animal tallow, seeds, palm, oils of animal and vegetable origin and seaweeds.

TAX REGIME OF SOYBEAN PRODUCTION CHAIN

The Lei Kandir (Kandir Law) of 1996 was a milestone in the taxation of the soybean chain, since it removed the ICMS tax on the export of primary and semi-processed products, including soy in natura. The use of soybean as a raw material, to be processed (or crushed) and produce the bran and oil, is subject to interstate ICMS (rate of 12%), causing distortions within the country (Table 8). When the processing industry is located in the same state where the grain is produced, there is no incidence of ICMS. However, if the industry is located in a different state from where the soy was produced, the tax on the raw material that will be processed must be paid. The solution found was the construction of plants in soy producing states, or the verticalization of production. Exemption from the export of soy in natura was fundamental to increase Brazilian production and exports of the commodity, but made the export of grains more advantageous than the export of bran and oil, products with higher added value.

TABLE 8: INCIDENCE OF ICMS IN THE SOYBEAN CHAIN

Activity	Location	Incidence of ICMS
Soy in natura export	any State	No
Soy processing	production and processing industry located in the same State	No
Soy processing	production and processing industry located in different States	Interstate ICMS on The raw material (12%)
Bran and Oil Export	any State	No
Sale of oil in the domestic market	Consumer and processing industry located in the same State	Reduction of the assessment base in 7%
Sale of bran in the domestic market	Consumer and processing industry located in the same State	No

Source: Own elaboration

C. MARKET

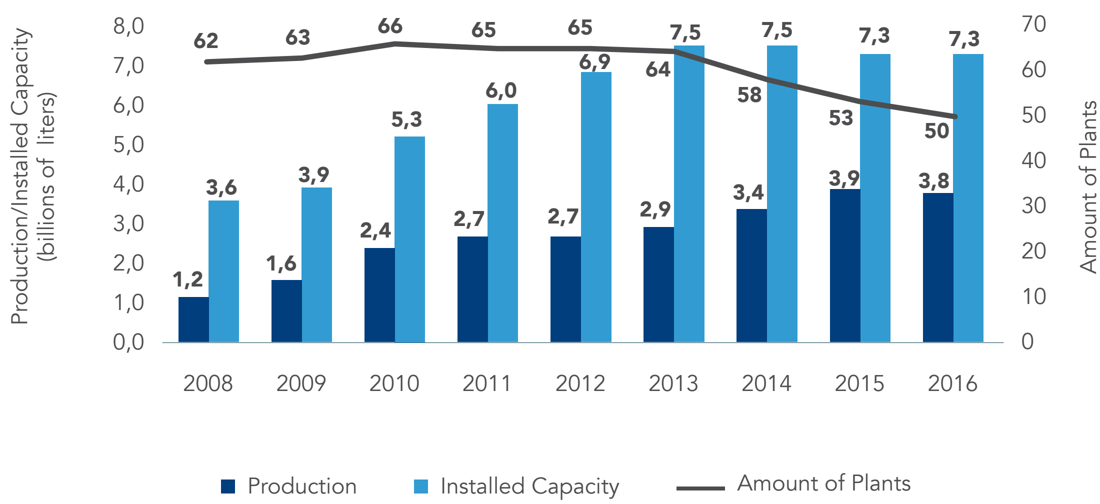
PRODUCTION AND INSTALLED CAPACITY

According to data from ANP (2017), in 2016 3.8 billion liters of biodiesel were produced in Brazil. Brazil is the second largest producer and consumer of biodiesel, behind, only, the United States. Subsequently, in the ranking, are: Germany, Indonesia and Argentina.

Figure 21 shows the evolution of production and installed capacity of biodiesel in Brazil, as well as the number of plants authorized by ANP. Production has followed a growth trend from the beginning, following the increase in blending mandates. In 2016, however, the volume suffered a reduction of 3.5% in relation to 2015, due to the reduction in consumption of diesel fuels caused by the country's economic recession.

The biodiesel industry has been operating with an installed capacity well above the production level, and in 2016, the idle capacity was 48%. Since the beginning of PNPB, the biodiesel sector has been preparing for a gradual increase in the biodiesel blending mandate for mineral diesel, but this increase has been slower than the growth of the plants' capacity. As shown in Table 5 (History the blend content of biodiesel in diesel), the time elapsed between the 5% (in January 2010) and 6% (in August / 2014) mandates was more than four years and the increase from 7% (in November 2014) to 8% (in March / 2017) took almost three years to happen. The lack of predictability in relation to the increase in compulsory percentages led to a feeling of in insecurity in the sector and the result was the closure of power plants. The number of plants decreased from 66 in 2010 to 50 in 2016.

FIGURE 21: EVOLUTION OF THE PRODUCTION, INSTALLED CAPACITY AND AMOUNT OF BIODIESEL PANTS



Source: Own elaboration based on data from ANP

According to ABIOVE, APPROBIO, and UBRABIO (2016), in 2030 the production of 18 billion liters of biodiesel will be required, considering the term of addition of 20% of biodiesel in diesel, which means more than quadruple the production and more than doubling the current installed capacity (Table 9).

TABLE 9: FORECAST FOR THE NATIONAL MARKET OF BIODIESEL UNTIL 2030

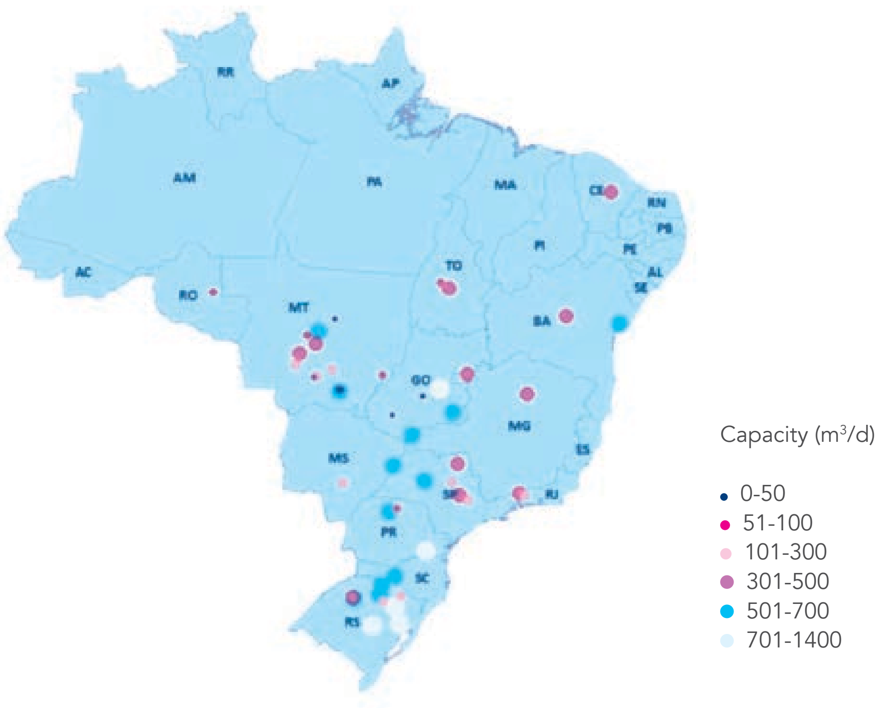
Premises/Forecasts	2016	2020	2025	2030	Unit (millions)
Mandatory Blend	B7	B10	B15	B20	%
Composition of raw materials					
Soybean oil	77	77	77	77	%
Bovine tallow	18	15	11	8	%
Palm oil	0	2	5	8	%
Others	5	6	7	7	%
Diesel B volume	55	64	76	90	m^3
Biodiesel volume	3,9	6,4	11,4	18,0	m^3
Soybean biodiesel volume	3,0	4,9	8,8	13,9	m^3
Soybean oil for biodiesel	2,6	4,3	7,7	12,2	t
Processes soybean for biodiesel	14,1	23,4	41,8	65,9	t
Bovine tallow diesel volume	0,7	1,0	1,3	1,4	m^3
Tallow for biodiesel	0,6	0,8	1,1	1,3	m^3
Equivalent slaughters	27	37	48	55	heads
Palm oil biodiesel volume	0,0	0,1	0,6	1,4	m^3
Palm oil for biodiesel	0,0	0,1	0,5	1,3	t
Required planted area	0,0	0,03	0,11	0,25	ha

Source: ABIOVE, APROBIO AND UBRABIO (2016)

PLANTS

In December 2016, there were 50 biodiesel production plants authorized by ANP. According to ANP, in February 2017, the number of plants increased to 51, in addition to three new plants being authorized for construction and another three for increasing production capacity. Since biofuel production uses soybean as the main raw material, most biodiesel plants are located in regions with the highest concentration of this grain's production (Figure 22). The number of units is distributed as follows: Midwest, 45%; South, 27%; Southeast, 16%; North, 6% and Northeast, 6% (data from ANP - February / 2017).

FIGURE 22: LOCATION OF BIODIESEL PLANTS



Source: (ANP, 2017b)

According to Mendes and Costa (2010), in the biodiesel sector, companies can be classified as integrated, partially integrated and non-integrated. The integrated companies are those that plant or commercialize vegetable crops (soybeans, sunflower, cotton, etc.), crush the grain of that crop to produce vegetable oil and produce biodiesel based on oil. Integrated companies have the option of selling grain, vegetable oil or biodiesel. Typically, these companies choose to sell the products that have the best margins in a given period. In addition, these companies are the most competitive and efficient in the commercialization of biodiesel, The partially integrated companies are the ones that can produce vegetable oil, since they have a crushing plant, and biodiesel. Therefore, they can market both vegetable oil and biodiesel. These companies do not plant or commercialize vegetable crops. Non-integrated companies do not have the option to manufacture diversified products (biodiesel, vegetable oil, or grain), since they produce only biodiesel. They acquire vegetable oil at market price and not at the cost of production, such as integrated companies. They are focused on the market and need to work continuously, avoiding the usual stops of flexible production, to compensate for higher raw material costs. Table 10 shows the biggest companies, in terms of production capacity and the degree of verticalization of each. It is worth mentioning that there are more integrated companies.

TABLE 10: CAPACITY AND DEGREE OF VERTICALIZATION OF THE BIGGEST BIODIESEL PRODUCERS

Company	Capacity (m³/year)	Degree of verticalization
Granol	887,879	integrated
ADM	670,320	integrated
Oleoplan	507,600	partially integrated
PBio	478,030	non-integrated
Caramuru	450,000	integrated
BSBios	424,800	integrated
Potencial	382,680	non-integrated
Olfar	378,000	integrada
Bianchini	324,000	partially integrated

Source: Own elaboration based on data from ANP and from available information on the companies' websites

SOYBEAN COMPLEX

Since soybean accounts for more than 70% of the raw materials used in Brazilian biodiesel production, it is relevant to address some of the characteristics of this commodity's market. Brazil is the second largest producer of the grain andfights for the leadership spot in exports with the largest producer, the United States. Table 11 shows some data from the soybean complex. In 2016, Brazil produced 96.2 million tons of soybean and, of this total, exported 51.6%. In the same year, 39.5 million tons of this grain were processed, a reduction of 3% in relation to the previous year. By 2017, ABIOVE expects to produce 113.2 million tons of soybeans, 18% more than in 2016, of which 63 million tons will be exported and 41 million tons will be processed.

TABLE 11: ANNUAL DATA FROM THE SOYBEAN COMPLEX (MILLIONS OF TONS)

	Amount (MMton)			Variation (%)	
	2015	2016	2017 (P)	2016/2015	2017/2016
Soybean					
Production	97,0	96,2	113,2	-1%	18%
Export	54,3	51,6	63,0	-5%	22%
Processing	40,6	39,5	41,0	-3%	4%
Processing (%)	42%	41%	36%	-1%	-5%
Processing capacity	61,8	65,0	65,0a	5%	0%
Processing capacity used (%)	66%	61%	63%	-5%	2%
Bran					
Production	30,8	30,2	31,1	-2%	3%
Domestic Consumption	16,0	15,8	15,8	-1%	0%
Export	14,8	14,2	15,5	-4%	9%
Oil					
Production	8,1	7,9	8,1	-2%	3%
Domestic Consumption	6,5	6,6	6,9	1%	5%
Export	1,7	1,3	1,3	-24%	3%

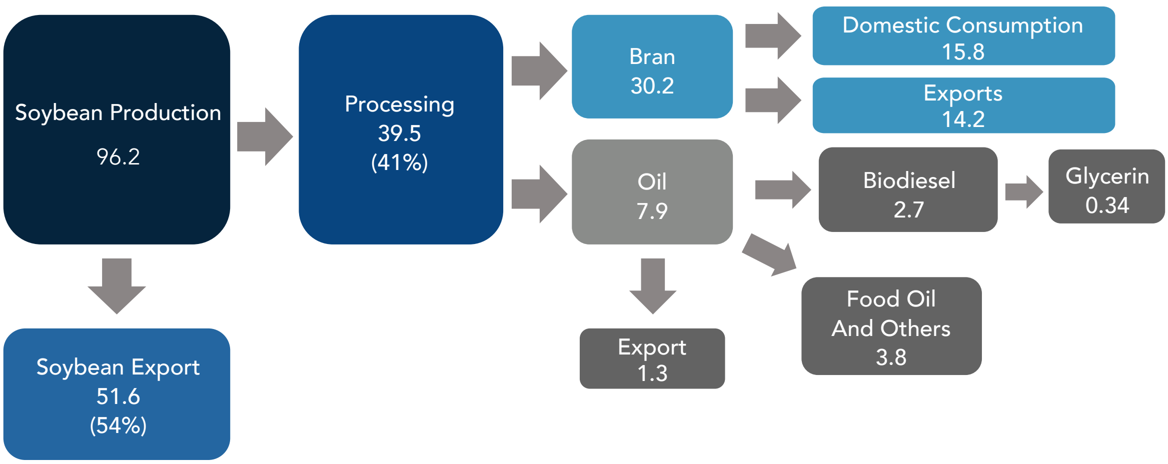
(F) - Forecast
a - The numbers of 2016 were repeated in 2017

Source: Own elaboration based on data from ABIOVE and EPE (2017)

Because it is exempt from taxation, the export of grain in natura ends up being privileged, to the detriment of its processing, which results in oil and bran, products with higher added value. By 2016, Brazil had the capacity to process 65 million tons of soybeans, but processed only 39.5 million tons of the grain, which represents 61% of its capacity. Figure 23 shows the logistic of the soybean complex, with numbers regarding 2016.

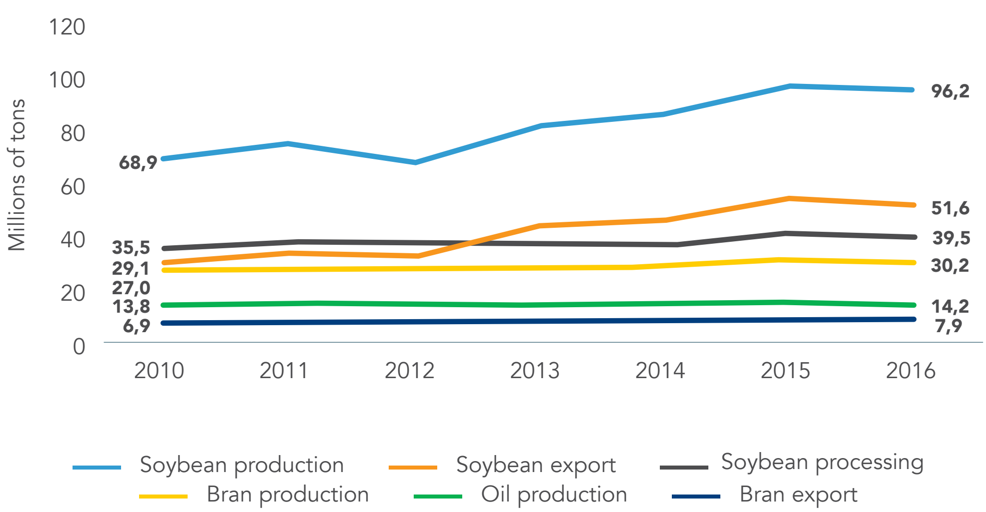
Figure 24 shows that between 2010 and 2016, soybeans exports increased by 77% (from 29.1 to 51.6 million tons), while processing increased by 11% (from 35.5 to 39.5 millions of tons). Exports of bran increased by only 3% in relation to 2010, but ABIOVE forecasts that the volume exported in 2017 will be 9% higher than it was in 2016. The increase in the export of bran demands some governmental actions, such as the diversification of the destination, resolution of tax issues, and also investments in logistics.

FIGURE 23: SOYBEAN COMPLEX – 2016'S NUMBERS (MILLIONS OF TONS)



Source: Own elaboration based on data from ABIOVE and EPE (2017)

FIGURE 24: SOYBEAN COMPLEX EVOLUTION



Source: Own elaboration based on data from ABIOVE

Brazilian soybean bran market

Soybean bran is a result of the soybean crushing process, which produces degummed soybean oil as its main byproduct. This is used as the main raw material for the production of refined soybean oil and biodiesel. Bran is used as an ingredient in the manufacture of many kinds of animal food.

The associations of soybean and biodiesel producers ABIOVE, APROBIO and UBRABIO (2016) forecast that 77% of biodiesel in 2030 will come from soybeans and, for this, it will be necessary to increase the grain processing from 40% to 65%. With this crushing percentage, Brazilian soybean bran production will reach 84.7 million tons (more than double the current production of 31 million tons). This amount will represent almost 20% of the world's production. Currently, Brazilian participation is 11%, according to estimates by the United Nations Food and Agriculture Organization (FAO).

According to data from ABIOVE (2017), of the total amount of bran to be produced, 41.5 million tons should be directed to the domestic market and supply the animal food for food chains, especially poultry, swine, and beef and dairy cattle, while 43.2 million tons should be exported. Industries and trading in the sector, that operate in Brazil, are preoccupied with growing domestic soybean bran and have as a priority access to the Chinese market, which is currently the largest global consumer of soybean bran (66.6 million tons per year), but all demand is supplied by local industries.

The Brazilian government is negotiating with the Chinese authorities to release a quota of 5 million tons of soybean bran a year in sales to the country. In addition to China, Brazil sees the need for negotiation and market opening in other Asian countries such as South Korea, Vietnam, Thailand and Myanmar, which already purchase 3 to 5 million tons of soybeans in Brazil, but are supplied by Argentinian bran (ABIOVE, 2016).

The distribution of domestic soybean bran production has been considered a challenge for the industries in the sector, since the country is increasing its production, but the volumes consumed have shown marginal growth. The increase in the production of bran is related to the recent changes in the blend of biodiesel and diesel, which increased from 7% to 8% this year and is expected to reach 10% in 2018. Therefore, Brazil will face an increasing surplus in the amount of bran generated as a result of the increased production of biofuel. According to Carlo Lovatelli, chairman of ABIOVE, each percentage point of vegetable fuel added to the fossil will result in an increase of 400 thousand tons in the annual production of soybean oil, which has as a byproduct about 2 million tons of bran. The chairman of the association recognizes that the greatest challenge for companies is to find buyers for this huge additional volume, which will hardly be absorbed by the domestic market.

However, the country still needs to overcome some of the barriers that affect the soybean production chain and its added value. Among them are the tax problems, which reduce the sector's international competitiveness face to its main competitors, such as China, the United States, Argentina and the European Union. Distortions linked to federal taxes and ICMS make it more expensive to export bran and oil in comparison to soybeans. ABIOVE claims that it is urgent to implement a new tax policy for the vegetable oils industry that ensures the equality of the exported product in natura via Funrural's[14] exoneration, accelerated reimbursement of PIS and COFINS credits and elimination of the incidence of ICMS in interstate operations of soybeans produced for exportation. These solutions will determine the ability of Brazilian industry to recover its profitability, be able to invest again, export products with higher added value and contribute to the country's mission of providing high quality food to the world at competitive prices.

14. The Rural Workers' Assistance Fund (Funrural) is a social contribution that must be paid by the rural producer.

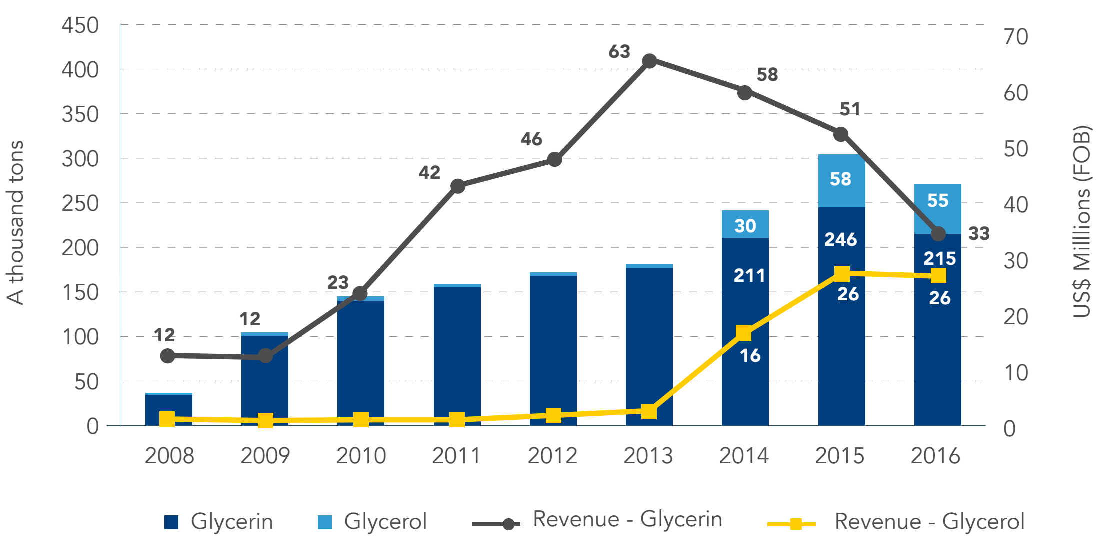
GLYCERIN

Crude glycerin is a by-product of the biodiesel chain, which corresponds to 10% in mass of the biofuel produced. The glycerin global market is booming. According to forecasts released by the global consultancy Persistence Market Research, demand is expected to grow about 4% per year between 2016 and 2024 (BiodieselBR, 2017). Glycerol is a classification for refined glycerin, which has better prices on the international market than crude glycerin, and several plants are installing equipment to purify it, aiming at higher revenues (EPE, 2017b).

In 2016, Brazil exported 215 thousand tons of crude glycerin and 55 thousand tons of glycerol (Figure 25). Revenue from the export of crude glycerin was 35% lower than that of 2015, while exports fell by 13%. In the case of glycerol, despite the reduction of the exported volume, there was no impact on the revenue obtained. China is the main destination for exports, with about 80% of the total.

Some alternatives for new uses of glycerin are also being developed to absorb the surplus of this compound in the market. An alternative that is worth mentioning is the addition of glycerin to the chicken, swine or beef feed. This addition has already been authorized by MAPA. For this purpose, the glycerin may constitute up to 10% of the feed and the minimum glycerol concentration should be 80%. Discovering and enabling new markets for glycerin is a challenge, but it will strengthen the proactive biodiesel chain (Biomercado, 2015).

FIGURE 25: EXPORTS OF CRUDE GLYCERINE AND GLYCEROL



Source: EPE (2017b)

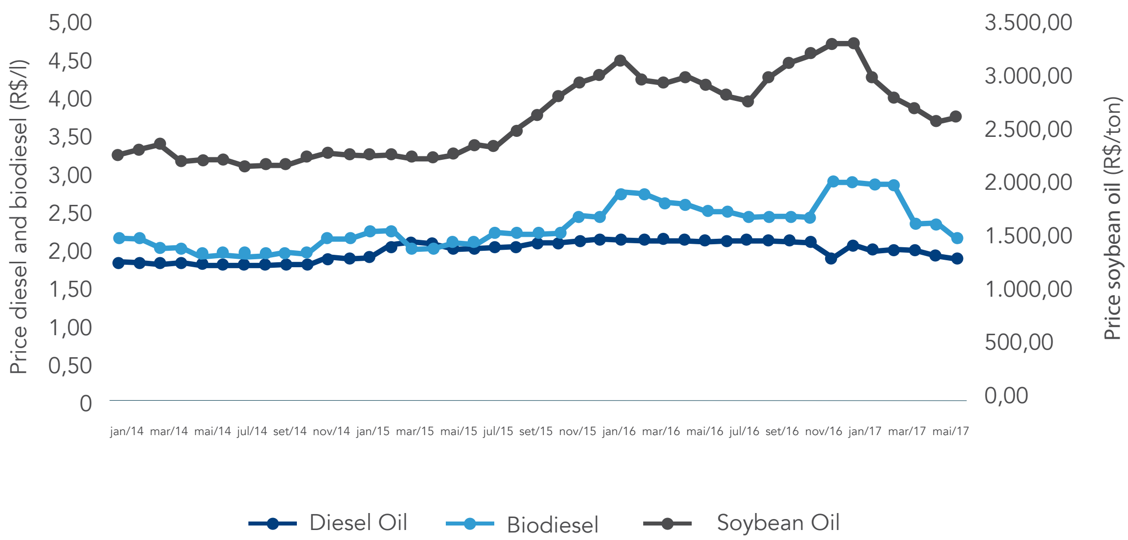
PRICES

Biodiesel prices depend heavily on the price of vegetable oil, since raw materials account for 80% to 85% of the cost of production. Another factor that determines price is the degree of competitiveness, which is directly related to the number of producers and the capacity of utilization or idleness of the plants. In ANP's auctions, the agency only determines the maximum price, and the average prices that are auctioned are determined according to the degree of competition between producers (Mendes and Costa, 2010).

According to the gathering of information on the evolution of soybean production costs in Brazil, in the period between the 2007/08 and 2015/16 crop years, carried out by Conab (2016), the items that had the biggest share of production costs were fertilizers, agrotoxins, machinery operations, seeds and the depreciation of machinery and implements, which together represent an average of 68.8% of the operating cost. The one with the highest share rate in operating costs is the fertilizers, with an average of 27.8%.

Figure 26 shows the evolution of biodiesel prices negotiated in the auctions, in addition to the prices of diesel oil and soybean oil. Although biodiesel has a higher price than diesel, its addition in small percentages in the fossil fuel hardly affects the final price to the consumer. However, the price differential makes it disadvantageous to use biofuels in higher percentages, which explains why the authorizing market has not yet taken off.

FIGURE 26: AVERAGE PRICES - BIODIESEL, DIESEL AND SOYBEAN OIL



Biodiesel and diesel: average price without ICMS
Soybean Oil: prices for the domestic market (São Paulo) with a 12% ICMS

Source: Own ANP e ABIOVE

FINANCIAMENTOS

Financial support for the implementation of biodiesel in the national energy matrix came mainly from two sources: the National Program for the Strengthening of Family Farming (PRONAF) and the Financial Support Program for Biodiesel Investments, implemented by BNDES. According to Decree No. 3.991, of October 30, 2001, PRONAF aims to promote the sustainable development of the rural environment, through actions aimed at implementing productive capacity increase, job creation and raising of income, with the goal of improving the quality of life and the exercise of citizenship of family farmers. Still according to the Decree, PRONAF, aims to support the agricultural and non-agricultural activities developed by family farmers, providing credit lines to meet their needs.

Through Resolution 1,135, dated December 3, 2004, BNDES prepared a financing program for the biodiesel production chain. The BNDES Biodiesel Investment Support Program promotes investments in the agricultural phase, in the production of crude oil, in the production of biodiesel, storage, logistics and equipment for the production of biodiesel.

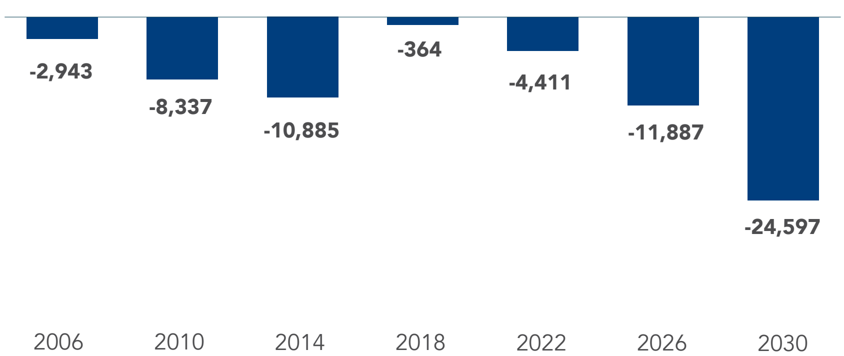
Brazil is an importer of diesel oil, since Brazilian refineries do not produce enough to meet the demand. Without the expansion of the refinery, the need for imports is increasing, resulting in an increase in external dependence on this derivative.

It is not only in the productive chain that BNDES provides lines of credit. The Bank supports and encourages the consumption of biodiesel in captive fleets, in agricultural implements and in electric generators, and grants loans to investments in the processing of co-products and by-products of biodiesel, such as glycerin and crushed residues, in addition to ensure differentiated conditions for projects that promote social inclusion, according to the SCS criteria.

SUPPLY SCENARIO - DIESEL CYCLE

Brazil is an importer of diesel oil, since Brazilian refineries do not produce enough to meet the demand. Without the expansion of the refinery, the need for imports is increasing, resulting in an increase in external dependence on this derivative. EPE (2017c), in its 2026 PDE, predicts that Brazil will remain as a net importer of diesel oil throughout the 10-year period. The document indicates that diesel production will increase mainly with the increase of the load processed on the 1st train of the Abreu e Lima Refinery (RNEST) in 2018 and with the entry of the 2nd train into operation in the same refinery in 2023, although it will still be necessary to import, nearly, 10 billion of liters in 2026. According to ANP's estimates (2016), in 2030 there will be an internal fossil fuel production deficit of approximately 24.6 billion liters (Figure 27). In this scenario, there is space for biodiesel to meet part of this demand, which should be strategically evaluated within the framework of the Fuel Brazil initiative, as discussed above.

FIGURA 27: FUEL PRODUCTION DEFICIT OF THE DIESEL CYCLE



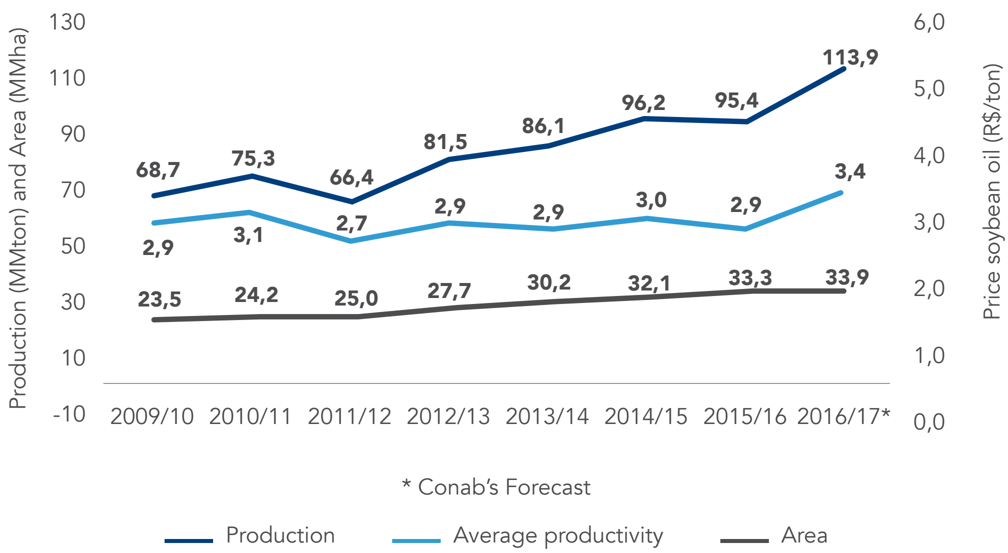
Source: Adapted from Chambriard (2016).

D. PRODUCTIVITY

Since soybean is the main raw material used in Brazilian biodiesel production, biofuel productivity analysis is based on the productivity analysis of this oilseed. As shown in Figure 28, Conab estimates that the 2016/17 crop will be a record, reaching almost 114 million tons of soybeans, and considers that the excellent development of the oilseed was backed by the climate conditions in practically all the regions of the country. Between the 2009/10 and 2015/16 crops, there was a 39% increase in grain production, while the occupied area increased by 42%. Considering the forecast for 2016/17, production will be 19% higher than the previous cycle, while the occupied area will increase by 2%.

The average productivity in the 2015/16 cycle was the same as in the 2009/10 crop and remained between 2.7 and 3.1 ton / ha during that period, but the forecast for the 2016/17 cycle is to reach 3.4 tons / ha, which would represent an increase of 17% in relation to the previous cycle. The production growth is justified by several factors, including technological advances, agricultural research and experiments, availability of rural credit and increased exports. These items allowed for improved crop management, increased crop efficiency and, consequently, increased productivity.

FIGURE 28: EVOLUTION OF SOYBEAN PRODUCTION AND PRODUCTIVITY



Source: Own elaboration based on data from Conab

Despite small productivity gains, soybeans are the crop with the highest production volume in Brazil, accounting for approximately 48% of the grain harvest. In this scenario of record crops and prospects for increases in the production of the commodity, the soybean complex is considered as the only capable enough to ensure the growth of the biodiesel sector with the expected evolution of the increased blending mandates of biodiesel in diesel. The forecasts for the soybean production growth carried out by the producers' associations (ABIOVE, APROBIO and UBRABIO, 2016) indicate the production of almost 165 million tons in 2030, occupying 44.6 million hectares, with an average productivity of 3.7 ton / ha. However, it will be necessary to increase the percentage of internal soybeans processing from the current 41% to 65%, in order to provide the oil necessary for biodiesel production. Considering that there are no obstacles to the growth of soybean production, it will require a great effort of the government and the productive sector to enable this increase in the industrialization of soybeans. Among the measures proposed by the sector it is worth mentioning: the alteration of the tax policy (Lei Kandir), in order to improve the competitiveness of products with higher added value (oil and bran), incentives to the growth of livestock and production of animal protein, which will help the growth of bran production, the expansion of the foreign bran market, and also investments in the expansion of the infrastructure for bran export.

The diversification of the raw materials mix for the biodiesel production will depend on the success of government programs, such as the Sustainable Palm Oil Production Program in Brazil (Propalma).

Bovine tallow, which is in second place among the raw materials for biodiesel production in Brazil, with around 12% of the market, is at its maximum level of availability for biodiesel. The sector produces 2 million tons of fats per year, with 38% destined to the production of biodiesel. The potential for supply growth is limited and will depend on the increase in the herds (10% growth is expected over 10 years) and the implementation of the animal carcass collection project (animals that die before being used by the food industry), with a 15% increase potential (300 thousand tons).

Even though palm (or palm oil) has an oil yield about 10 times higher than that of soybeans, the production of biodiesel from this oilseed is still not very significant in Brazil. In its 2026 PDE, EPE (2017c), assesses the fact that the diversification of the raw materials mix for the biodiesel production will depend on the success of government programs, such as the Sustainable Palm Oil Production Program in Brazil (Propalma). This program aims to order the expansion of palm production, ensure the competitiveness of the sector with investments in research and increase the income of family farmers.

The producer's associations (UBRABIO, ABIOVE and APROBIO, 2016) suggested in their contribution to RenovaBio, the creation of agroecological zoning for Brazilian palm trees, such as macaúba and babaçu, and the creation of credit lines for the sustainable extractivism and the promotion of commercial plantations and the processing industry of these palm trees, as a way of diversifying the raw materials for biodiesel, taking advantage of of these palm trees' full potential.

Another source of fatty material that should be promoted for the production of biodiesel is the waste oils and greases (OGR). This is an environmentally interesting source, since it gives use to the high volumes of waste, which, currently, are discarded incorrectly, resulting in water pollution and sewage systems clogging. This material has a low cost, but relies on the collection, which involves logistics costs. The use of OGRs today occurs through some initiatives throughout Brazil, such as the Sustainable Oil Program, in which ABIOVE's associate companies maintain 1,291 delivery points in 117 municipalities, where 1,162 million liters of residual cooking oil are collected (ABIOVE, 2017). The increase in demand for biodiesel and the creation of collection programs, whether by public or private initiatives, are expected to stimulate the use of this material in the production of biofuels in the coming years. The production of residual cooking oil in Brazil is estimated at 8 million tons.

E. PROSPECTS

Considering the scenario described, it is expected that, the increase of biodiesel production will have the following reasons as drivers:

1. Scenario of opportunities created by the goals assumed at COP 21 (reduction of GHG emissions and percentages defined for bioenergy in the matrix)
2. New regulatory proposal aimed at promoting biofuels, RenovaBio
3. Increase of blending mandates, already established by Law and authorized by means of conducting tests
4. Development of programs aimed at the production of new oilseeds, such as palm
5. Use of the idle capacity of soybeans crushing, with the expansion of the bran and oil market
6. Need to ensure the supply of Diesel cycle fuels in the mid-term
7. Expansion of biodiesel usage in captive fleets and on a voluntary basis

New biofuels

The regulatory proposal for the RenovaBio program includes, among its goals, to boost technological development and innovation and to accelerate the development and commercial insertion of advanced and new biofuels. In this chapter, new biofuels will be presented, with the potential to increase participation of bioenergy in the Brazilian energy matrix, making it cleaner and more sustainable.

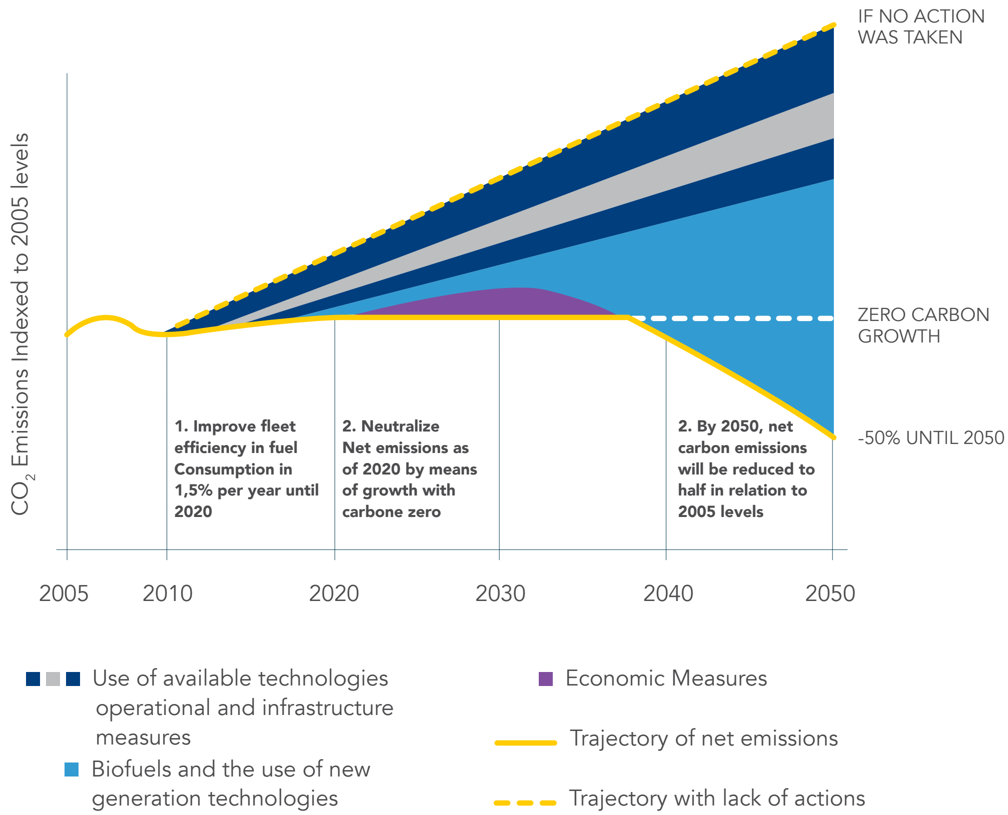
A. BIOKEROSENE FOR AVIATION

The aviation industry is extremely dynamic in the use of technologies and its progress in terms of energy efficiency is enormous. The aircrafts produced nowadays are 80 percent more fuel-efficient than those of the 1960s, according to the United Nations' specialized agency, the International Civil Aviation Organization (ICAO).

According to the Intergovernmental Panel on Climate Change (IPCC), aviation (domestic and international) accounts for approximately 2% of of global CO_2 emissions and it is projected that that the demand for air transport tends to grow. Therefore, the aviation industry has started to create mechanisms capable of reducing its contribution to the effects of climate change.

Members of the International Air Traffic Association (IATA), which comprises 275 airlines and accounts for 83% of global air traffic, have committed to the following emission reduction targets: Improve fuel efficiency at 1.5% per year, from 2009 to 2020; to have neutral carbon growth from 2020; and reduce, in 50 percent, CO_2 net emissions by 2050, in relation to 2005 levels. To achieve these targets, the association has established strategies that include investment in new technologies, increased operations efficiency, infrastructure improvements and the use of biofuels, among others. Each strategy will contribute with a share of the reduction of emissions, however, biofuels play a key role in this, since, without its use, it will not be possible to reach the proposed targets, as shown in Figure 29.

FIGURE 29: SCHEMATIC MODEL OF THE MEASURES FOR EMISSION REDUCTION



Source: *Associação Brasileira das Empresas Aéreas* (ABEAR, 2017)

In 2010, ICAO and its members adopted the same target as that proposed by IATA: to achieve neutral carbon growth as of 2020. To this end, the organization approved, in 2016, the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), which determines that the international civil aviation industry, through its signatory countries (on a voluntary basis), should neutralize or compensate its GHG emissions above the neutral carbon growth line. As of June 2017, 71 countries, representing more than 87% of international aviation emissions, have already stated their intention to participate in this emissions compensation mechanism, which will be based on 2019-2020 emissions.

The most important requirement for aviation biofuels is that those are "drop-in", which means they must be fully compatible and miscible with conventional fuel, they cannot require aircraft, engine or fuel supply infrastructure adaptations and their use should not result in restrictions on the use of the aircraft. Depending on the production process, the biofuel can be considered drop-in only up to a certain blending percentage, since at higher levels, it would no longer meet the requirements mentioned above.

Currently, there are five aviation biokerosene production routes approved by the American Society for Testing and Materials (ASTM) and another sixteen new routes are under analysis. The raw materials for this biofuel can be classified into three major groups: oils and greases, sugars and starches, and cellulosic materials. The possibility of producing biokerosene from different raw materials is an advantage as it allows each region to develop the process from the material it has available.

ANP Resolution No. 63/2014, which sets the specifications for Alternative Aerosol Kerosene and B-X Aviation Kerosene (QAV B-X), covers three types of biofuels:

1. **Paraffinic kerosene synthesized by Fischer-Tropsch (SPK-FT):** it may use as raw material, both renewable and non-renewable biomass (cellulosic material and waste, for example) as well as coal or natural gas.

2. **Paraffinic kerosene synthesized by fatty acids and hydroprocessed esters (SPK-HEFA):** the use of vegetable oil and animal fats.

3. **Synthesized isoparaffins (SIP):** advanced process of sugar fermentation using genetically modified microorganisms.

The first two can be added in up to 50% to the conventional fuel, while the latter has an addition limit of 10%. Their use is voluntary, but must comply with ANP regulations.

There is already the commercial production of biokerosene in the country. Amyris, an American biotechnology company, in partnership with Total, a French oil company, has been producing aviation biofuels since 2012, in São Paulo, from sugarcane, using the advanced sugar fermentation route. The plant has a production capacity of 50 million liters per year and its process is based on the transformation of sugar into farnesene, a molecule that acts as a starting point for the production of several compounds, biokerosene being one of them. According to MME's Secretary of Petroleum, Natural Gas and Biofuels, Márcio Felix (2017), domestic demand for biofuels can reach between 1 and 1.6 billion of liters by 2030, considering the 10 % blend of biokerosene in fossil fuel.

OBSTACLES

Currently, the main challenge to be overcome is the economic one, since technological barriers have already been overcome. Fuel costs account for one-third of the airlines' operating costs (ATAG, 2016) and aviation biofuels can cost two to three times more than fossil fuels (IATA, 2017). In order to reduce capital costs, some biokerosene producing companies used pre-existing facilities, such as biofuel plants, or even abandoned or unused oil refineries. Another strategy to reduce costs, proposed by Embrapa (2015), - is the development of biokerosene production processes that can simultaneously generate other products, based on the concept of biorefinery, which would enable the production of aviation biokerosene at more competitive prices.

Another challenge in the production of aviation biofuels is the direct competition for raw materials already used for the production of road transport biofuels, such as ethanol and biodiesel, which have a much more significant demand, in addition to well-established markets and supply chains. It is also possible to have competition within the production process itself. According to the International Renewable Energy Agency (IRENA, 2017), practically the entire volume of commercially available biokerosene is now produced by the HEFA route, using vegetable oils, animal fats and residual cooking oils as raw materials. However, although there are some companies that are able to produce it, the same process results in the renewable diesel, a fuel with a larger market and higher sales prices, which is the reason why this is the main product of these plants.

Regarding the logistical challenges, it should be noted that the production of biokerosene must be located next to its consumer market, at the airports, in order to reduce transportation costs. Therefore, it is necessary to carry out a preliminary assessment of the possible existing raw materials or those likely to be produced in regions close to major airports.

DEVELOPMENT PLATFORM

In 2012, during the UN Conference on Sustainable Development, Rio + 20, UBRABIO, in partnership with private sector entities, launched the Brazilian Platform of Biokerosene, with the goal of developing an integrated value chain based on the program developed for biodiesel, PNPB, for the introduction of biofuel into the Brazilian energy matrix. In 2014, the Biokerosene Platform of Minas Gerais was launched, focusing on the development of an integrated value chain for the production of aviation biokerosene, using macaúba, a palm tree largely present in Minas Gerais, as the main input. Another similar initiative was the creation of the Biokerosene Platform of Pernambuco in 2015. In addition to these, the Brazilian Biokerosene and Renewable Hydrocarbons for Aviation Network (RBQAV) was launched in 2017 with a focus on research, development and innovation, through partnerships celebrated between academia, industry and government, as well as on the support for the creation of public policies and enabling actions for the production of biokerosene and renewable hydrocarbons.

B. BIOGAS AND BIOMETHANE

Biogas is a mixture of gases, mainly methane (CH_4) and carbon dioxide (CO_2), obtained by the decomposition of organic matter (organic waste) by means of bacteria, in a process called anaerobic biodigestion. In addition to biogas, the biodigestive process also results in the biofertilizer, an input of high relevance in agricultural production. Biogas can be used for the production of heat, electricity or biomethane.

Biomethane is a gaseous biofuel with high methane content in its composition, which is obtained from the biogas purification. Biomethane therefore has the same characteristics as natural gas and can be blended to it and be commercialized through the connection to the piped gas distribution network or in the form of compressed gas. Biofuel was regulated by ANP Resolution 8/2015, which applies to organic waste biomethane from agricultural and forestry activities and from commercial establishments and service providers, for vehicular use (Natural Gas Vehicle - CNG) and residential and commercial facilities. In June 2017, the agency also approved the use of biomethane from landfills and sewage treatment plants.

Brazil has a potential to produce about 78 million cubic meters a day of biogas and biomethane. This data takes into consideration figures from 2017 and consists of a survey presented by the Brazilian Association of Biogas and Biomethane (ABiogás). Of this volume, the most part, 56 million m^3, would come from the sugar-energy sector, 15 million m^3 from food production and another 7 million m^3 from basic sanitation (Canal Energia, 2017).

> In addition to the possibility of generating thermal and electrical energy and being used in vehicles in the form of NGV, biomethane can be used in another very important way, as a partial substitute for diesel in trucks, tractors and agricultural machinery.

The sugar-energy industry generates various residues, which could be used for the production of biogas, including straw, bagasse, filter cake and vinasse. Straw and bagasse are already intended for the production of bioelectricity or second-generation ethanol, as the cake and vinasse being high potential sources for the production of biogas and biomethane. Currently, almost all of the vinasse is used as fertilizer in the sugarcane plant, but the excessive use cannot only be detrimental to the crop, it also can cause environmental damage, through the contamination of the water table. In addition, the high cost of applying vinasse as a fertilizer, either through its transportation via trucks or through the application of pipes and channels, limits its use to areas closer to the plant.

According to UNICA, each liter of ethanol produced can lead to up to 12 liters of vinasse, which is a significant volume, considering that in the 2015/16 crop almost 30 billion liters of ethanol were produced. Raízen, a company in the sugar-energy sector, won an electric energy generation auction (A-5 New Energy Auction) in 2016 with a biogas project, which will be produced from filter cake and vinasse. This was the first biogas project to win an electric power generation auction and was contracted to enter into operation in 2021. The unit's production capacity will be 65 million m³ of biogas and the plant will have an installed capacity of 21 MW. Although the energy from the biogas can also be inserted in the electricity grid, as in this case of Raízen, its main form of use is in the distributed generation, which is even more advantageous for the country, since it reduces the need for investments in energy transmission, since it is generated in the same place where it is consumed.

In addition to the possibility of generating thermal and electrical energy and being used in vehicles, in the form of NGV, biomethane can be used in another very important way, as a partial substitute for diesel in trucks, tractors and agricultural machinery.

A biomethane-powered tractor produced by New Holland was tested and approved by producers on a farm in the state of Paraná. The vehicle has an autonomy of six hours and the supply of biomethane, besides promoting 40% savings when compared to diesel, it reduces the emissions of polluting gases by approximately 80%. According to ABiogás adviser, Marcelo Cupolo, biomethane is an excellent substitute for diesel, and can supply 44% of the product consumed in the country (PetroNotícias, 2017).

EXPERIENCES IN BRAZIL

The biogas treatment plant of the Dois Arcos Landfill, which was introduced in 2014 in São Pedro da Aldeia (RJ), is a pioneer in the production of biomethane on a commercial scale in Brazil. Initially, the biomethane will be supplied in cylinders, such as compressed natural gas (CNG), to industrial customers. However, the project includes, in the future, the connection of the plant to the distribution network of CEG and CEG Rio, piped gas utilities from Rio de Janeiro. Thus, purified biogas can reach residential and commercial consumers, as well as the use in vehicles, benefiting a population of 400,000 people.

The largest thermoelectric plant in Latin America powered by biomethane, Termoverde Caieiras, with an installed capacity of 29.5 MW, was introduced in 2016, in São Paulo. In 2017, the Energy and Mining Secretariat of São Paulo introduced the Management Committee of the Biogas Program of São Paulo, whose objective is to discuss public policies aimed at expanding biogas and biomethane in the energy matrix of the State of São Paulo, proposing, among other measures, the percentage of biomethane that must be injected into the piped natural gas network. As the largest sugarcane producer in the country, the São Paulo shows an enormous potential for using vinasse to generate biogas and biomethane.

The International Center for Renewable Energies - Biogas (CIBiogás) has 11 biogas production units, in small and medium-sized rural properties and in cooperatives in the West of Paraná and a unit under construction in Uruguay. The biomethane, produced from animal waste and agricultural residues at Granja Haacke, is compressed in cylinders and transported to the Itaipu Binacional supplying station, where part of the fleet of vehicles from the hydroelectric plant is supplied. By the end of 2016, this fleet had 59 vehicles powered by biomethane (Parque Tecnológico Itaipu, 2017). In June 2017, Itaipu Binacional and CIBiogás introduced a Biogas and Biomethane Demonstration Unit, located within the Hydroelectric Plant, with a 4 thousand m^3 production of biomethane per month, being able to supply 80 vehicles of the plant's fleet, considering an average use of 800 km per vehicle per month. Only this part of the fleet will save 5,650 liters of ethanol per month. At a cost of R$ 0.26 m^3 of biomethane, against R$ 0.36 of ethanol, the financial savings reach R$ 15 thousand every month. 300,000 liters of biofertilizer are produced, as a by-product, and will be used as fertilizer for the company's flowerbeds and lawns. In addition, the emission of

4 tons of greenhouse gases (CIBiogás, 2017) is avoided each month.

Given the great potential of production and the economic viability of the first projects implemented or under implementation, a high growth of this form of bioenergy's use is expected.

C. HYDROTREATED VEGETABLE OIL

The Hydrotreated Vegetable Oil (HVO), also called renewable diesel, green diesel or even HEFA (Hydroprocessed Esters and Fatty Acids), is a renewable fuel for use in diesel engines of the Diesel cycle. The raw materials used in their production are basically the same as the ones used in traditional biodiesel (produced by the esterification or transesterification processes) - vegetable oils and animal fats, as well as residual oils and fats.

Hydrotreatment (or hydrogenation) is a process already mastered and used in petroleum refineries worldwide, which can use vegetable oils as raw materials to generate a fuel with a composition very similar to diesel. Petrobras has patented the technology, which is called H-Bio, in which it up to 10% of vegetable oils (soybeans, corn or castor bean oil) were directly added into the diesel refining process.

HVO is considered a drop--in biofuel (fully compatible and miscible with conventional fuel) and can be used in high blending ratios in fossil, or even in pure diesel, of the Diesel cycle engines, without requiring adjustments to the engine. In addition to the fact that there is no limit to its blend in diesel, HVO has other advantages in relation to biodiesel, such as lower emissions of nitrogen compounds, higher oxidation stability and better low capacity in low temperatures. Another advantage is that the process used for its production leads to the co-production of aviation biokerosene, bio-naphtha and biopropane.

In 2016, 5.9 billion liters of this biofuel were produced, 22% more than in the previous year. The main producers were the United States, United Kingdom, Singapore, the Netherlands and Finland (Renewable Energy Policy Network for the 21st Century - REN21, 2017).

According to EPE (2017d), regarding HVO, there are no technical barriers to its production, however, there is also no specific regulation for its use. The conversion of vegetable oil to hydrogenated product requires a hydrotreatment step that burdens the process, generating a lack of competitiveness with similar fossil (mineral diesel) or vegetable (biodiesel) fuels. In addition, the oil used as raw material has a high value in the market, which, added to the operational cost of the hydrotreatment stage, makes HVO even more difficult to penetrate the Brazilian market. However, given its nature and HVO's international classification as an advanced biofuel, it is important that there is an incentive to its development.

Renewable Energy and Employment

The global renewable energy sector employed 9.8 million people in 2016, with a 1.1% increase in relation 2015. Jobs in renewable energy, excluding hydroelectric power, increased 2.8%, reaching 8,3 million in 2016. China, Brazil, the United States, India, Japan and Germany accounted for most of the works in renewable energy in the world.

With the notable exception of the European Union, bioethanol production has increased among all leading producer countries. Biodiesel production has also increased, although it has remained below previously established records in some countries, including Argentina, Brazil and Indonesia. World employment in biofuels is estimated at more than 1.7 million. Most of these jobs are in agriculture along the chain - in planting and harvesting various types of raw material. Fewer jobs, though often better paid, are found in the construction of fuel processing facilities and in O&M (operation and maintenance) of the existing plants.

Continuous mechanization has reduced labor requirements in countries such as the United States and Brazil. With approximately 783,000 jobs, Brazil continues to have the largest workforce in liquid biofuels. Job creation also declined in the United States, despite increased production of ethanol and biodiesel. Biofuel production remained at the same level in the European Union, while jobs decreased by 8.6% in 2015[15].

After a dramatic fall in 2015 due to the collapse of exports, Indonesia's biodiesel production began to grow, once again, in 2016, driven by growing domestic demand and government subsidies. IRENA (International Renewable Energy Agency, 2017)

15. The revised employment estimates for 2014 (Eurobserver, 2017) indicate that EU jobs in biofuels shown a 2% decrease, from 97,400 in 2014 to 95,900 in 2015

estimates that employment in the biofuel sector in Indonesia for the year 2016 was about 154,300 jobs, almost doubling the previous year's level.

Biofuel production is also increasing in Southeast Asian countries, such as Thailand and Malaysia, with an estimated 97,000 and 52,500 jobs, respectively. Jobs in the biofuels sector in the Philippines are estimated at about 42,400, almost evenly divided between ethanol and biodiesel[16].

Colombia is another important producer of biofuels and labor-intensive Latin American country. According to IRENA's estimates (2017), experts from the country indicate 85,000 jobs. However, a higher estimate of the National Federation of Biofuels of Colombia (FNBC, 2017) estimated more than 191,200 jobs regarding biofuels.

In 2015, in Brazil, most jobs in renewable energy were in the liquid biofuels sector. The total jobs shown a 5% decrease, such decline was related to ethanol, and to a smaller gain in biodiesel jobs. Although ethanol production increased by 8% in the same year, employment shown a 10% decreased, to 613,000[17]. About 30,000 workstations were lost in the sugarcane harvest and 15,000 jobs in ethanol processing due to mechanization. The mechanization of the sugarcane harvest continues especially in São Paulo, the largest producer of ethanol in Brazil. On the other hand, Brazilian biodiesel production decreased to 3.8 billion liters in 2016 (ABIOVE, 2017). However, there was a slight increase in overall estimated employment, to 169,700 jobs in 2015[18]. This was due to the changes in the blending of raw materials for raw materials that require additional labor inputs.

16. The National Bioethanol Council of the Philippines has sugarcane jobs related to the production of ethanol at about 20,000 (Biofuels International, 2015).
17. In 2015, Brazil had about 238 thousand workers in sugarcane plantation and 175 thousand workers in ethanol processing (MTE / RAIS, 2017). A rough estimate suggests there may be an additional 200,000 indirect jobs in the manufacturing of equipment.
18. Calculation based on employment factors (Da Cunha et al., 2014) and actuation of different raw materials (USDA-FAS, 2016b). The proportion of bovine tallow, for which production requires relatively limited labor input, has declined from 19% of the raw material in 2015 to 17% in 2016. The fever for soybean and other vegetable oils represent the most of the raw material.

According to the World Bank (2016) and FAPRI (Food and Agriculture Police Research Institute, 2017), methanol prices are expected to decrease, since natural gas, the main input of methanol production, has been showing a strong downward trend in Brazil and the world.

FIGURE 30: ESTIMATE OF DIRECT AND INDIRECT EMPLOYMENT IN RENEWABLE ENERGY IN THE WORLD BY TECHNOLOGY AND COUNTRY

	World	China	Brazil	USA	India	Japan	Ban-gla-desh	European Union		
								Ger-many	France	Other Coun-tries
Solar photovoltaic	3.095	1.962	4	241.9	120.9	302	140	31.6	16	67
Liquid Biofuels	1.724	51	783	283.7	35	3	–	22.8	22	48
Wind	1.155	509	32.4	102.5	60.5	5	0.33	142.9	22	165
Solar heating / cooling	828	690	43.4	13	13.8	0.7	–	9.9	5.5	20
Biomass	723	180	–	79.7	58	–	–	45.4	50	238
Biogas	333	145	–	7	85	–	15	45	4.4	15
Hydropower	211	95	11.5	9.3	12	–	5	6.7	4	35
Geothermal Energy	182	–	–	35	–	2	–	17.3	37.5	62
CSP	23	11	–	5.2	–	–	–	0.7	–	3
TOTAL (excluding hydropower)	8.305	3.643	876	777	385	313	162	334	162	667
Hydropower (broad)	1.519	312	183	28	236	18	–	6	9	46
TOTAL (including broad Hydropower)	9.823	3.955	1.058	806	621	330	162	340	171	714

Source: IRENA, 2017

Final considerations

The commitments made by Brazil under the Paris Agreement create unprecedented conditions for expanding the share of biofuels in the Brazilian energy matrix. To do so, a great effort of the productive sector will be required, with new investments, which will depend directly on the existence of public policies, capable of ensuring more predictability and competitiveness to the sector.

RenovaBio has been developed in this context, and in it reside the main expectations of the sector. The regulatory model proposed by the program represents a major development since it is based on the recognition of each fuel's capacity to contribute to the decarbonisation of the transport sector. Setting multiannual emission reduction targets results in predictability, the main demand of the industry, and has the potential to be an important market inducer, leading the sector to re-invest in the expansion of production. Equally important is the stimulus that the program intends to give to energy efficiency gains by rewarding the most efficient production processes. Given its innovative content, a transition and adaptation period will be necessary so that the new mechanisms can be understood and assimilated by the market. It is important to highlight the need for effective coordination between the RenovaBio and Combustível Brasil (Fuel Brazil) programs, since they converge towards the same objective, to ensure the supply of fuels, considering the increase of demand in the mid-term. Similarly, it is necessary to seek the alignment between the RenovaBio and Rota 2030 programs, making low-carbon fuels in the efficiency targets of the automotive industry a priority.

The sugar-energy industry has been experiencing a strong crisis, due to its high indebtedness, the decrease in productivity, the increase in costs and the loss of competitiveness of ethanol in relation to gasoline, which is further aggravated by the global context of restricting credit and of low oil prices. The resumption of investments must, initially,go through the consolidation of finances, and it is expected that the sector will undergo a new process of mergers and acquisitions, with the capital injection from the higher ranked companies or new players, which could

It is important to highlight the need for effective coordination between the RenovaBio and Combustível Brasil (Fuel Brazil) programs, since they converge towards the same objective, to ensure the supply of fuels, considering the increase of demand in the mid-term.

anticipate new investments, productivity gains and production increases. The growth potential of this industry is high, whether through the dissemination and incorporation of best practices or through the introduction of innovations, which will lead to significant increases in productivity, such as E2G, sugarcane-energy and sugarcane seeds, among others previously discussed in this booklet.

The biodiesel sector, which has also been facing the closure of plants, has good prospects with the blending increases already defined by law and the possibility of anticipating the B10 mandate, in addition to the expectation of reaching B15 in 2025 and B20 in 2030. The production of biodiesel should remain extremely dependent on soybeans, since these are the only oilseed capable of ensuring the expansion of the mandates. Considering that there are no obstacles to the growth of grain production, a great effort will be required to enable the increase of its industrialization in the country. Among the measures recommended by the productive sector it is worth mentioning: the alteration of the tax policy, which now favors the export of soy *in natura*, the definition of incentives for the growth of herds and the production of animal protein, enabling an increase in soybean bran production, and also the expansion of the foreign market and the infrastructure for the bran export. The sector still needs to find solutions to reduce biodiesel prices, reducing the impact of the increase in the final price of commercialized diesel. It is expected that the development of new raw materials, which are more productive than soybean, such as palm, babaçu and macaúba, will stimulate new regional production arrangements, favoring the establishment of the authorizing market in captive fleets, especially in regions where diesel is less competitive due to higher freight costs.

In the New Biofuels sector, which will also be encouraged by RenovaBio, biogas and biomethane show the highest capacity for growth in the short term, considering the relevance of the new projects that are being implemented and which should serve as examples, especially in the sugarcane sector, where its greatest potential lies. Biokerosene, on the other hand, whose production routes are already technically feasible, will have a more difficult path towards reducing production costs, so that it becomes competitive with its fossil equivalent. Despite this, the aviation industry is intensively mobilizing to reduce its emissions and proposes, among other measures, a higher participation of biofuels.

Finally, it is worth mentioning that, in addition to having extensive experience in the production of biofuels and favorable climatic conditions, Brazil has enough agricultural area so that planting crops for energy purposes does not affect food production, which is an advantage that must be explored. There are many positive externalities of the increased biofuel penetration, including job creation, income growth and technological development, as well as the reduction of impacts on climate and human health. Brazil's position is internationally recognized, due to its leadership role in major world forums. The country has already made important commitments at COP 21, but these need to be broken down into clear and targets with defined deadlines, involving a regulatory framework that provides security and reliability and market mechanisms that promote the competitiveness of biofuels, so that the investments can be resumed and the country can correspond to what is expected of it and, above all, reach its full potential.

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