Chapter 6

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The energy cane revolution in Brazil: delivering food, bioenergy, and biomaterials

1. Introduction

With a history dating back almost 500 years, the sugarcane industry plays a major role in the Brazilian economy. With around 380 mills, 70,000 cane growers, and 750,000 direct jobs (Mapa, 2019; MTPS, 2019), the sugarcane supply chain has annual net revenues close to USD 25 billion (Unica, 2019) and ranks as the fourth largest export sector in Brazil, having generated almost USD 7 billion in foreign exchange in 2018 (MDIC, 2019).

In the sugar market, Brazil is the world's largest producer and exporter of the commodity, with a share of around 25% of world production and about 40% of all the sugar traded worldwide (USDA, 2019).

In the energy sector, the sugarcane supply chain is the main renewable source in the Brazilian matrix, accounting for 17.4% of all domestic energy supply in 2018 (EPE, 2019), both for electricity and fuels.

In terms of the transportation matrix, Brazil has the largest program in the world to replace fossil fuels with biofuels. In 2018, for example, Brazil managed to replace 48% of all the gasoline in its transportation matrix with ethanol. Ethanol is used as fuel in two distinct ways. The first one is in a fleet of nearly 30 million light vehicles and more than 5 million motorcycles that can be fueled by any combination of gasoline and ethanol, referred to as flex-fuel cars and motorcycles. This decision depends solely on the relative pump price between the oil derivative and the renewable fuel and on consumer preferences. The second way fuel ethanol is used in Brazil is through mandatory biofuel blending in gasoline, currently set at the level of 27%.

Ethanol also provides undeniable environmental benefits: several studies show that, as compared to gasoline, Brazilian ethanol can reduce greenhouse gas (GHG) emissions by up to 90% (Seabra & Macedo, 2008). This attribute is even recognized by the US Environmental Protection Agency (EPA), which classifies Brazilian ethanol produced from sugarcane as an advanced fuel due to its better environmental performance compared to that produced from other feedstocks.

In fact, since the launch of flex-fuel vehicles in 2003, up until 2019, ethanol consumption in Brazil has reduced GHG emissions by about 600 million tons of CO2eq. For the same CO_2 savings to be achieved, it would be necessary to plant more than 4 billion native trees over the next 20 years (Unica, 2019).

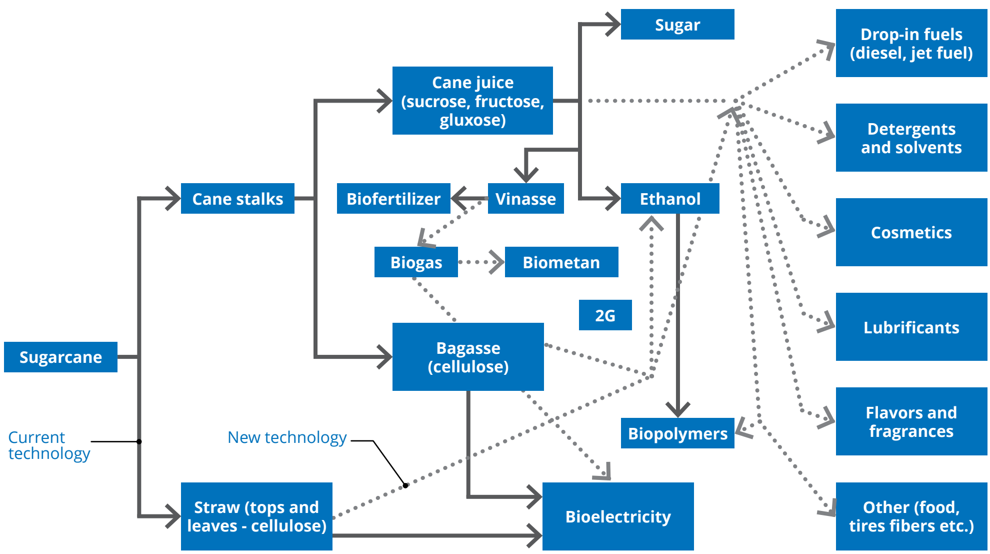
In addition to significantly reducing emissions compared to other fuels, sugarcane ethanol also provides an extremely favorable energy balance: it generates more than nine units of renewable energy for each unit of fossil energy consumed in the process (Seabra & Macedo, 2008b).

Additionally, the use of biofuel has yielded public health benefits by significantly reducing local pollutants and NOx and particulate matter emissions, alleviating one of the main problems in several global large cities around the world facing high pollution levels. According to the World Bank, 2016, car-generated pollution accounts for nearly 200,000 annual deaths and costs some USD 225 billion a year due to premature deaths from cardiovascular and lung diseases.

Still in the energy area, special mention should be made of the expansion of the supply of electricity generated from burning sugarcane bagasse and straw, the so-called bioelectricity. Currently, biomass accounts for 9% of the power generated in the Brazilian electricity matrix, and is the 3rd largest source of installed power, behind hydroelectric and wind power.

It is also worth stressing that, in addition to sugar, ethanol, and bioelectricity, there are a number of new products originating from sugarcane, such as biogas, jet fuel, bioplastics and others. Figure 1 schematically shows traditional sugarcane products and other products under development in Brazil and in the rest of the world.

Figure 1. Sugarcane products and uses



Source: Unica (2019).

The figures attest to the importance and potential of the Brazilian sugar-energy industry, while using just over 1% of the national territory for growing sugarcane (IBGE, 2019) managed to reach an impressive level in food and renewable energy supply on a sustainable and economically feasible basis.

Although the Brazilian example has characteristics of its own, the description presented here raises key elements for understanding the recent dynamics of the sugar-energy industry. This chapter details technological and productive transformations in this sector, as well as discussions about public policy instruments that have guided the development of this industry in Brazil over the last 5 decades.

In addition to this introduction, the chapter is made up of four other sections. The second one describes the evolution of the Brazilian sugar-energy industry, with emphasis on the role of public policies in fostering growth and sustainable development in sugar and ethanol production. The third section presents some of the other products produced – or under development – from sugarcane, such as bioelectricity, biogas, and renewable jet fuels. Section 4 presents the environmental legal framework for the sugarcane industry in Brazil. Section 5 reflects on the possibility of cooperation and interaction between China and Brazil in markets linked to the sugar and ethanol industry and, finally, the last section presents the chapter's conclusions.

2. History of the sugarcane industry

Introduced by the Portuguese in the 16th century, sugarcane in Brazil is a key element of the country's history and economy. That said, and considering that it is beyond the scope of this paper to provide details about the historical component associated with this industry, the description provided in this chapter portrays the evolution of the sugar-energy industry over the last five decades, starting from the first cycle of significant sugarcane increase fostered by the launch of the National Ethanol Program (Proalcool).

2.1. Proalcool and the first cycle of production growth

Ethanol began to be used as fuel in Brazil when it was first blended with gasoline at the rate of up to 5% in July 1931. However, fuel ethanol gained notoriety from 1975, when the National Ethanol Program (Proalcool) was established. In its first phase, the program encouraged the production of anhydrous ethanol to be blended with gasoline at a rate of 20% and, by the end of the 1970s, it also began to promote the use of pure use of hydrous ethanol as a fuel for vehicles.

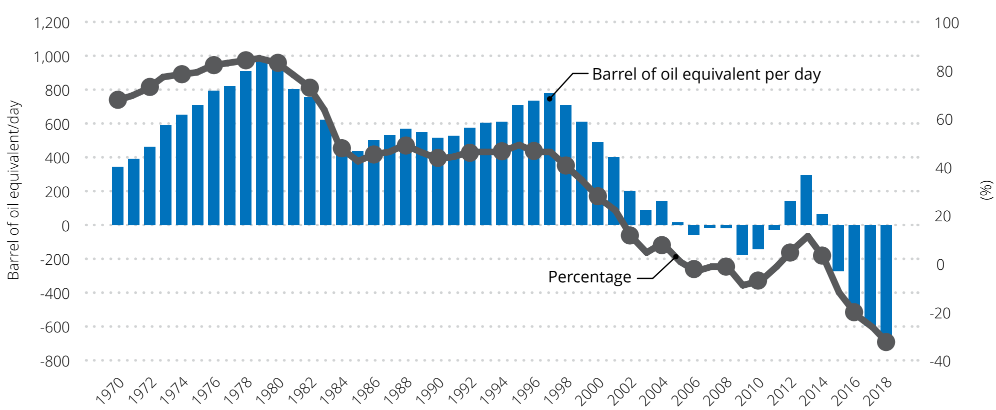
At that time, the environmental and social benefits afforded by the biofuel were secondary considerations. The incentive to using ethanol was therefore seen as an instrument to ensure energy security, whose main objectives were guaranteeing fuel supply and affordable prices.

In fact, the two oil shocks in the 70's brought greater energy supply insecurity and exposed how the Brazilian economy was vulnerable to changes in oil prices. In the first shock, world oil prices more than tripled from USD 2.9 to USD 11.65/barrel in just three months. At current values (2018 prices), this hike would represent an increase from UD 15/barrel to almost USD 60/ barrel (BP, 2019).

Brazilian expenditures on imports of oil and oil by-products increased by almost 450% between 1973 and 1974, from USD 750 million to USD 4.1 billion in the following year, even though the volume imported increased by only 15%.

The same upturn in oil prices in the world market was observed a few years later, in the late 1970s, when the market value of oil, at 2018 prices, soared from USD 54.00/barrel in 1978 to USD 112.24/barrel in 1980 – a shift known as the second oil shock (BP, 2019).

Figure 2. Brazil: evolution of its external dependence on oil



Source: EPE (2019).

It was in this scenario that the Proalcool program, combined with the other measures implemented by the Brazilian government to increase production and decrease the consumption of oil and its derivatives, made it possible for Brazil to gradually reduce its dependence on foreign fuel. Before the first shock, more than 80% of domestic consumption was supplied by imported oil; from 1979 onwards, the oil deficit in proportion to the country's domestic consumption took a downturn, reaching a level close to 45% in 1985 (Figure 2).

The launch of the Proalcool program and the measures taken to stimulate ethanol production incorporated biofuel into Brazil's transportation matrix for good not only as a supplement to gasoline (anhydrous ethanol as an additive), but mainly as a substitute for the fossil fuel (hydrous ethanol).

During the period of intense state intervention in the fuel industry, which began with the launch of the Proalcool program and lasted until the mid-1990s, the government had a considerable number of options and tools to address the complexity of the fuel sector and ensure the supply needed to meet domestic consumption demand.

In addition to controlling the domestic supply of oil by-products, especially gasoline, the Brazilian state also had instruments to address the evolution of ethanol supply. Besides subsidized credit provided by the government for the construction of ethanol distilleries, the control exercised by the government was applied, on the one hand, through an annual crop plan and, on the other, by setting prices to be received by producers for selling sugarcane (in the case of cane growers), ethanol (anhydrous and hydrous ethanol), and sugar.

An annual crop plan was published systematically and defined quotas for sugar and ethanol production for each production unit operating in Brazil. Sales prices received by producers were also set by the state and determined the profitability of the activity.

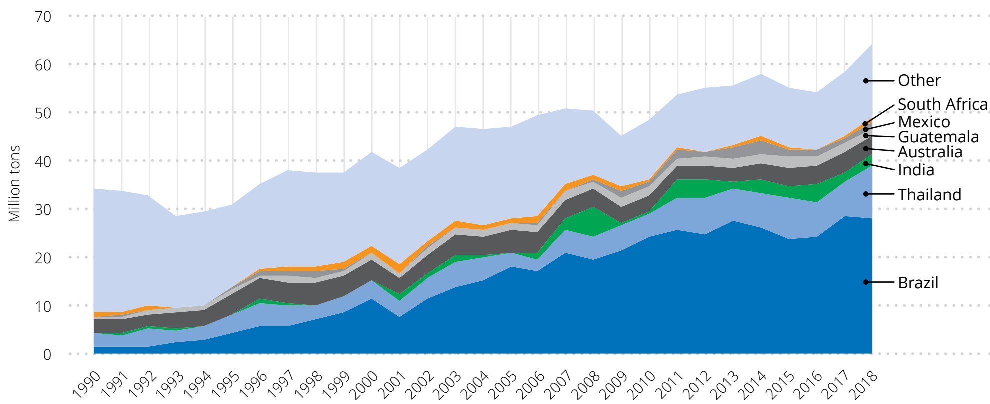
In this scenario, in which the government owned oil exploration and the production of oil by-products, controlled fuel pump prices, set the prices paid to ethanol producers, and set production quotas for biofuel industrial units, managing the supply of fuels and the interaction between the policy for the oil sector and the one applied to ethanol was less difficult, albeit often costly.

This dynamic, shaped by several political and economic policy aspects throughout the 1980s, began to change in the early 1990s, when oil prices took a downturn on the world market, the sugar and ethanol industry began to be deregulated, and fuel ethanol lost relevance in Brazil.

2.2. The process of deregulating the economy: Brazil becomes a global sugar-producing power

The process of deregulating the sugar-energy sector and the withdrawal of the state from this market was gradually implemented throughout the 1990s. Ethanol became less competitive and controls imposed on sugar production

Figure 3. Evolution of world sugar exports

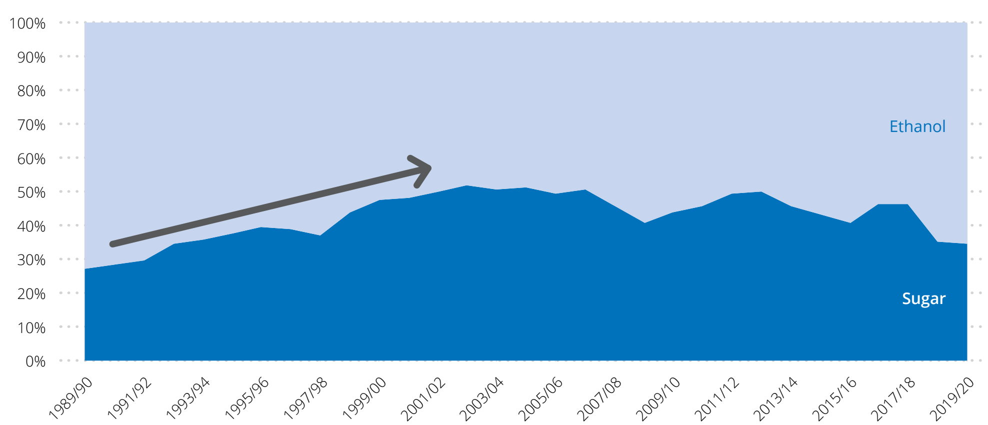


Source: USDA (2019).

and exports were eliminated, which made it possible for Brazilian producers to begin to competitively operate in the world sugar market.

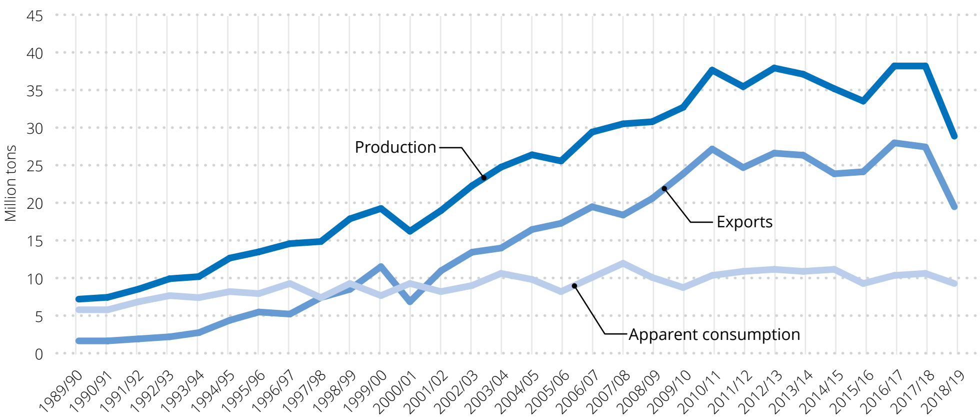
As can be seen in Figure 3, Brazil's share in the world sugar market, which was negligible in the early 1990s (around 4%), began to grow significantly, turning the country into the world's largest exporter of the commodity, with an average share exceeding 45% of the total traded in the last five years.

Figure 4. Proportion of sugarcane used to produce ethanol and sugar



Source: Mapa (2019) and Unica (2019).

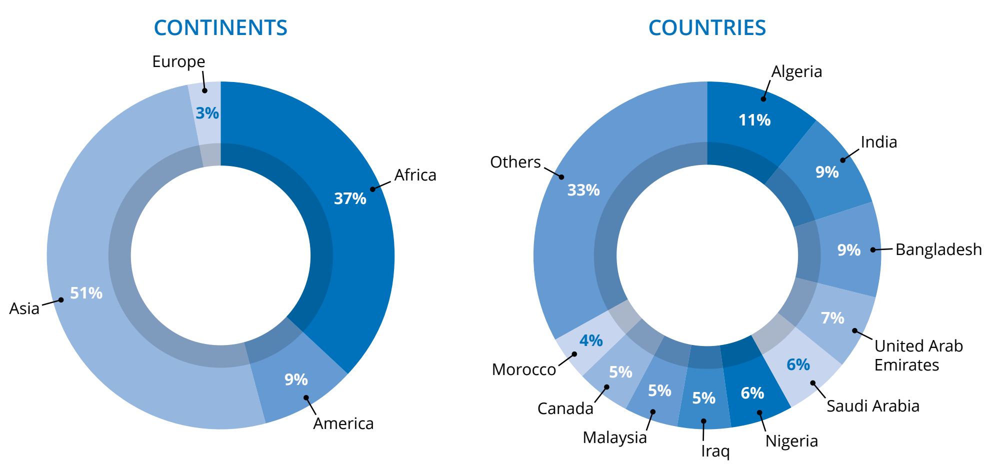
Figure 5. Brazil: sugar production, export and domestic consumption



Source: MDIC (2019) and Unica (2019).

As can be seen in Figure 4 and 5, Brazilian sugar production has been steadily increasing since the early 1990s, reaching an average annual growth rate of 6% per year. This dynamic is clearly supported by the higher volume of exported sugar, as the domestic sugar market grows only modestly, in line with the population increase recorded in the country.

Figure 6. Share of the main continents and countries to which Brazil exported sugar in 2018



Source: MDIC (2019).

In 2018, Brazil exported 21.2 million tons of sugar to 4 different continents and 120 different nations around the globe (Figure 6). The destinations of Brazilian sugar include particularly countries in Asia (51% of the total) and Africa (37%).

The deregulation of the sector, which began with authorization to access the world sugar market, was completed in the late 1990s through the liberalization of the prices of ethanol, sugar, and sugarcane.

During this period, Law 9,478 of August 6, 1997, known as the "Oil Law," was also passed, substantially changing how the state operated in the oil and oil by-products markets. With this law, private companies were granted permission to operate in all links of the oil supply chain under concession or upon authorization from the appropriate government authority. The role of the state, formerly of producer and provider, shifted to regulator and supervisor.

The same law established the National Energy Policy Council (CNPE) with the task of proposing policies for the energy industry and the National Petroleum, Natural Gas and Biofuel Agency (ANP) with the mission of regulating the fuel market in Brazil.

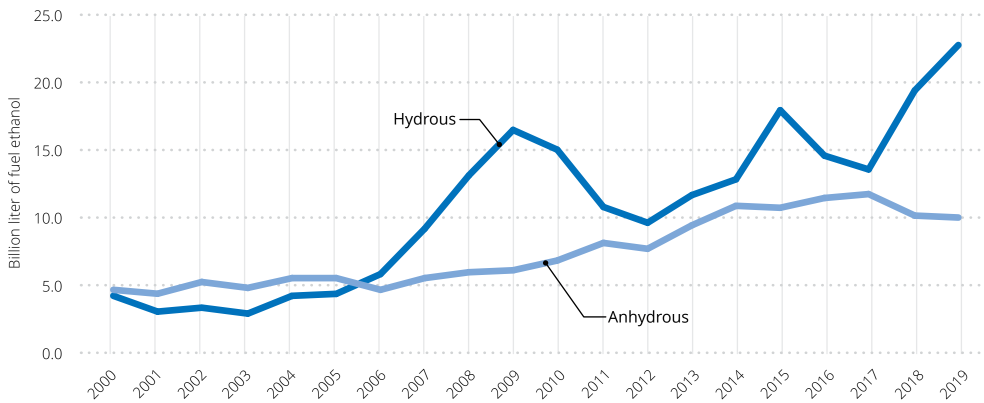
These changes led to profound transformation in the market structure and in the regulatory sphere associated with the Brazilian fuel industry.

2.3. The free market and the second cycle of ethanol expansion induced by flex-fuel vehicles

In the latter part of the 1990s, and early 2000s, hydrous ethanol consumption declined gradually due to the small number of ethanol-fueled cars sold and to the scrapping of the biofuel-powered vehicle fleet. As a result, the mills were prioritizing sugar rather than ethanol production.

However, from 2003 this downturn in ethanol consumption changed significantly due to the launch of flex vehicles (Figure 7). This initiative of the automobile industry, boosted by the competitiveness of ethanol against gasoline at that time, made it possible for flex-fuel vehicles to consolidate themselves in the domestic market. The wide acceptance of flex cars can be measured by the fact that, in four years, virtually 90% of all new cars sold in the country fell under that category.

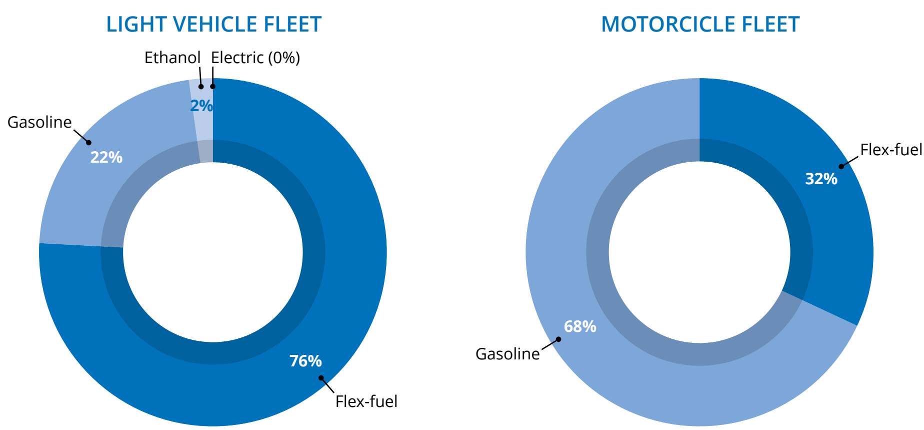
Figure 7. Consumption of anhydrous and hydrated fuel ethanol in Brazil



Source: Mapa (2019) and Unica (2019).

In 2018, out of the 38 million light vehicles circulating in Brazil, 76.4% were equipped with flex-fuel technology. In the case of motorcycles, the proportion of flex-fuel engines amounted to 32.5% of the circulating fleet (Figure 8).

Figure 8. Brazil: share of different technologies in the fleet of light vehicles and motorcycles



Source: Anfavea (2019), Abraciclo (2019), and Unica (2019).

Deregulation of the sugar-energy industry and the new configuration of the oil market coupled with the technological change of flex vehicles made it possible for consumers to decide on the type of fuel they wanted to use when filling their tanks. This required regulatory changes in the fuel industry and turned Brazil into a unique country in the world not only for its large-scale use of hydrous ethanol and availability of flex vehicles, but also for the possibility it afforded to consumers to use two substitute fuels – ethanol and gasoline – with a completely different production system and market structure coexisting in a free market environment.

Under this new configuration, the price relationship between hydrous ethanol and gasoline at the pump became a key factor in determining demand for these products, since the selection of fuel was no longer made when they bought a car, but rather when they filled their tanks.

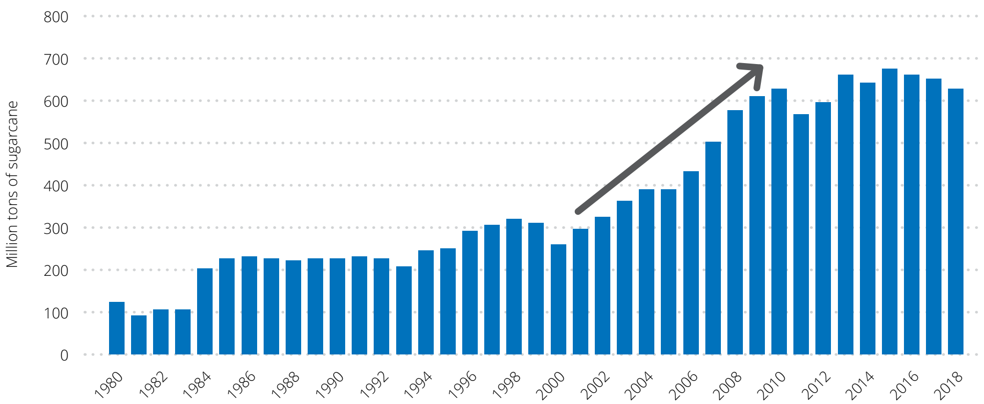
This led to a different dynamic in the fuels market than that observed in the past, when demand for ethanol and gasoline responded more slowly and less intensely to changes in relative fuel prices. In a deregulated environment with a significant presence of a flex fleet, demand for ethanol began to change rapidly in response to changes in relative fuel prices.

2.4. The new fuel market structure and the onset of the crisis in the sugar-energy industry

The business environment that emerged after the launch of flex-fuel vehicles offered great prospects for the sugar-energy industry. This was due to the introduction and consolidation of this technology in the domestic market, to the low cost involved in producing ethanol, to an upward trend in oil prices in the world market, to the tax differentiation applied to renewable fuels in relation to their fossil competitor domestically, and to a widespread global interest in renewable fuels, as particularly evinced by an ambitious program launched in the United States.

As a result, a new cycle of expansion of sugarcane and ethanol production was recorded in Brazil. Between 2002 and 2010, Brazilian sugarcane production virtually doubled, over 100 new production units were built, and significant investments were made to expand the existing industrial park (Figure 9).

Figure 9. Annual evolution of sugarcane processing for manufacturing sugar and ethanol in Brazil



Source: Mapa (2019) and Unica (2019).

However, the global financial crisis, and especially the elimination of the tax differential between ethanol and gasoline and use of fossil fuel prices for inflation control purposes completely changed this scenario.

The combination of global economic turmoil, credit crunch, and rising financial costs in an environment of low ethanol prices led some ethanol-producing companies to incur an unsustainable debt burden. Since 2009, this triggered a broad debt consolidation process involving about one third of all companies operating in this industry. Capitalized groups already in business and new players, including multinationals operating in different sectors such as the trading and oil industries, acquired existing assets to the detriment of building new production units.

In addition, since 2006 a structural change in how the energy policy was conducted has been observed, especially in the fossil fuel pricing dynamics in the domestic market. Since that year, gasoline sales prices in Brazilian refineries were artificially frozen, and federal oil taxes were sharply reduced.

This system of keeping gasoline prices artificially low, coupled with rising costs for producing ethanol, led to an unprecedented crisis in the sugarcane industry, reinforcing the importance of consistent and long-term public policies to ensure sustainable growth in the sector.

The mechanisms adopted for keeping gasoline prices under control in the domestic market caused losses to ethanol producers and Petrobras, the Brazilian public oil company. Thus, as of late 2017, the company began to adopt a new domestic pricing policy under which domestic prices reflected international oil prices converted into the Brazilian currency, reducing the uncertainties associated with how gasoline was being priced in the domestic market and leading government to adopt a new, long-term policy with clear rules that will likely usher a new phase of investment in the sector.

These measures have provided additional incentives for the ethanol industry to invest in an additional source of raw material, i.e., corn as a feedstock. In fact, since 2017, corn ethanol has gained relevance, and in the 2019/2020 harvest season, it should reach about 1.5 billion liters, representing almost 5% of total Brazilian ethanol production (Unica, 2019). Corn-based ethanol is mainly produced in Brazil's mid-west region in two different ways: in so-called "flex plants", which can process both sugarcane and corn – according to their different harvest periods – and in plants exclusively dedicated to processing corn. Corn ethanol production will likely increase in the coming years and complement the supply of ethanol to meet the decarbonization targets of the country, established by the new program, RenovaBio, described in the next session.

2.5. Looking ahead: The RenovaBio program

The need to address these challenges culminated in the approval of Law 13,576 of December 26, 2017, which established the National Biofuel Policy, also referred to as RenovaBio.

The program represents a major milestone in the Brazilian public policy, as it intended, in an unprecedented way, to establish a joint strategy between public and private agents. It aims at ensuring predictability and recognizes the role of all biofuels as instruments for decarbonization of the Brazilian transportation matrix, in line with the goals to reduce GHG emissions undertaken by Brazil under the Paris agreement.

In addition to the important environmental benefits it can afford, this program will also attract significant investments, with direct impacts on employment and income in more than 30% of all Brazilian municipalities.

Finally, it will also result in a reduction in dependence on imported oil and increase energy security in the country.

This national biofuel policy was completed in the end of 2019, and all the mechanisms to make it operational are effectively in place for the program to start in this harvest season of 2020.

The main objectives of the Program are: i) reducing greenhouse gas emissions, in line with the environmental commitments undertaken at COP21; and, ii) contributing to the security of fuel supply in Brazil, encouraging the expansion of biofuel production.

RenovaBio is based on market mechanisms and is in line with successful experiences in other countries, and it does not involve governmental subsidies, tax incentives, or new taxes.

The mechanisms of the Program incorporate the following measures:

- Government-defined greenhouse gas emission reduction targets – the national target will have a 10-year deadline and predictably induce a competitive and efficient reduction in carbon intensity in the fuel chain. There will also be an annual breakdown of the ten-year individual targets for fuel distributors.
- Issuance of Emission Reduction Certificates (CBios) – as an incentive tool for productive efficiency and a bond whose value corresponds to the carbon intensity of the biofuel produced in its life cycle. CBios will be issued by biofuel producers and purchased by fuel distributors on the stock exchange.
- Analysis of the life cycle of biofuels – each CBios issuing plant will have an efficient biofuel production certificate according to its productive efficiency. The greater the efficiency of an industrial plant, the greater its capacity will be to issue CBios.

The ten-year targets set by the federal government suggest that ethanol production is likely to grow significantly in the coming years to achieve the carbon intensity reduction proposed for the domestic energy matrix. The Program is expected to usher in a new cycle of investment domestically by ensuring greater predictability to the share of biofuels in the domestic matrix, incorporating a mechanism for recognizing the positive externalities of biofuels through carbon pricing via the market, and stimulating the pursuit of economic and environmental efficiency gains in ethanol production by differentiating production units according to the characteristics of their production process.

2.6. Important lessons learned from ethanol programs: the importance of clear and long-term rules

This brief description of the history of the sugarcane industry in Brazil points out the broad spectrum of public policies and regulation applied to sugar markets and especially to the domestic ethanol market over the last 5 decades.

The result of these policies evinces the need for predictability and clear and lasting rules to stimulate investment in a capital-intensive industry that takes a long time to mature. This is undoubtedly the key requirement for any program designed to boost biofuel production.

Another key element for consolidating renewable energy and particularly biofuels is recognizing the environmental benefits afforded by these products. Positive externalities require active state participation to incorporate this component into the pricing system.

This is a classic case where the proper functioning of markets alone is not sufficient to stimulate the investments needed to generate optimal consumption of the environmentally friendly product. The presence of positive externalities and the non-exclusion phenomenon prevent the market, by itself, from ensuring optimal conditions from the social point of view.

In the case of ethanol, consumers as a rule resist the idea of paying for air quality by not using the fuel that may be occasionally cheaper but is more polluting. Vehicle owners believe their contribution is limited and insufficient to change environmental conditions. In addition, if others pay for this clean fuel, they will not be excluded from the environmental benefits it provides. By not including environmental benefits in their decision, consumers' willingness to pay pushes the market price down, resulting in underinvestment in fuels that reduce CO_2 emissions.

Without any regulation, this rationale would be different only when the costs for producing clean and renewable fuels are higher than those for producing fossil fuels. From an environmental point of view, it may be too late.

This condition requires effective actions on the part of the state as regulator, establishing instruments that recognize the environmental advantages afforded by clean energy and allowing competition between fossil and renewable sources to incorporate all the social costs and benefits of this choice. The most widespread instruments for this purpose include carbon taxation and trade programs based on emission reduction targets.

In the Brazilian case, in recent years a tax on fossil fuels has been misused for inflation control, generating uncertainty and significant losses for the sugarcane industry and society. Despite imposing some transaction costs on the system, the mechanism proposed under the National Biofuel Policy – RenovaBio – will in turn ensure greater predictability for agents in the supply chain, based on decarbonization targets and recognition of the power of biofuels to reduce emissions through the CBios market. In addition, the mechanism proposed by RenovaBio will stimulate efficiency gains in biofuel production, as the number of CBios emitted by each producer will depend on the environmental efficiency of their production system.

3. Beyond sugar and ethanol

As mentioned in the introduction of this chapter, the sugar industry has the potential to go far beyond sugar and ethanol production. It can also generate, among others, bioelectricity (or energy generated from sugarcane biomass), biogas, and renewable bio-jet fuel. These three by-products and their benefits are described below.

3.1. Bioelectricity

Currently, biomass from the burning of the sugarcane accounts for almost 9% of all the electricity generated in Brazil and is the 3rd largest source in terms of installed capacity, behind only hydroelectric and fossil energy.

Bioelectricity (which is the power generated from the burning of the sugarcane bagasse in Brazil) is seen as a distributed, renewable, and clean form of power generation. Some of the benefits provided to civil society by the production and use of bioelectricity in Brazil will be highlighted below:

- Benefits from complementarity with hydroelectricity: sugarcane biomass (bagasse) is usually generated during the dry season, between April and November, when hydroelectric dams empty their reservoirs. Developing the potential of bioelectricity means adding new renewable and sustainable "virtual reservoirs" to the Brazilian electricity industry.
- Lower energy transportation losses and savings in transmission

investments: bioelectricity is predominantly generated close to large consumer centers and distributed in a way that reduces technical losses in the system and provides investment savings in transmission. In 2017, 84% of all the bioelectricity generated for the grid was concentrated in Brazil's mid-west region, which accounts for almost 60% of its domestic consumption.

- Bioelectricity avoids GHG emissions: in 2017, it was estimated that the bioelectricity made available to the Brazilian grid avoided the emission of about 10 million tons of CO_2 into the atmosphere, a volume equivalent to growing 67 million native trees over 20 years.
- It brings reliability to the system: bioelectricity generation for the grid is seen as quite stable and predictable throughout the year, mainly due to the predominance of sugarcane biomass as feedstock. Thus, bioelectricity is not seen as an intermittent source, such as solar and/or wind energy. Due to its greater predictability and reliability, it is regarded as a seasonal source, as is hydroelectricity, but not as intermittent as wind and photovoltaic sources. Adding bioelectricity to the system contributes to its reliability and mitigates the effects of the expansion of intermittent sources in the Brazilian electricity matrix.

3.2. Biogas

Biogas may be consolidated as a new product manufactured at scale in the coming years. Some plants have already made investments in producing biogas and others are considering this option.

It is a product made from the bio digestion of vinasse. Vinasse is an effluent produced from the distillation of an alcoholic solution called fermented wine at an approximate rate of 12 liters of vinasse for each liter of ethanol.

Although its composition varies according to the characteristics of its raw materials, inputs, and production process, it can be assumed that the average composition of vinasse is 93-97% water and 7-3% solids. Approximately 75% of the solids in its composition is biodegradable organic matter and 25% consists of minerals.

The presence of considerable levels of calcium, magnesium, phosphorus, nitrogen, and sulfur in vinasse makes it possible for it to be used in natura as a biofertilizer in soil where sugarcane is grown in a process referred to as fertirrigation, providing major agronomic and economic benefits. Vinasse is currently being used to meet a percentage of sugarcane fertirrigation varying from 30% to 40% of the total sugarcane harvesting area and it is applied by spraying the product on the crop soil.

Anaerobic biodigestion of vinasse with biogas production opens the possibility of using this effluent to produce energy, in addition to its agronomic use as described above.

Biogas obtained from this process can be used for generating thermal, electrical, and mechanical energy. It can also be purified into biomethane, ensuring its use as a fuel with the same characteristics as those of natural gas. This product can be traded in the natural gas market or even to fuel machinery and equipment run on sugarcane farms.

In the state of Sao Paulo alone, the main producer in Brazil, the theoretical potential for producing energy from vinasse and other by-products from ethanol production would make it possible to: i) replace 80% of the natural gas consumed in the state; or ii) replace 70% of all diesel oil consumed in Sao Paulo; or iii) meet 93% of the state's demand for residential electricity (Coelho et al., 2019).

3.3. Renewable bio-jet fuel

Accounting for about 2% of GHG emissions worldwide and with its demand likely to double over the next two decades, the aeronautics industry is already taking steps to develop sustainable fuels, targeting a 50% reduction in CO_2 emissions into the atmosphere by 2050 in relation to 2005 levels (International Air Transport Association, IATA, 2018). Several alternatives are already emerging, but so far biokerosene is the most concrete option.

Brazil is one of the pioneering countries in using sugarcane to produce aviation fuel. It is a cleaner compound than the aviation kerosene being used today, renewable, and requires virtually no adaptation in aircraft, engines, or even in the supply chain. This is because in order to be certified and approved for use in aircraft, renewable fuel must have the same characteristics as fossil fuel, without any need for major adaptations in aircraft or ground systems, regardless of the feedstock used for producing it. Studies show that sustainable aviation biofuels emit at least 70% less carbon over their life cycle than fossil aviation fuel (Klein et al., 2019). More than 1,600 commercial flights using aviation biofuel have been operated worldwide between 2011, when the use of this type of fuel was approved, and 2018, and biofuels may become a major source of renewable energy for aviation in the future, overcoming current technology and cost barriers (Aeromagazine, 2019).

4. The environmental regulatory framework in the sugarcane industry

Brazil has one of the most rigorous and advanced environmental legislations in the world. Created by Federal Law No. 12,651, of May 2012, the Brazilian Forest Code established an important regulatory framework in the country. The Code defines permanent protection areas (riverbanks, hill tops, etc.) and requires producers to maintain a portion of rural property with native vegetation (this proportion of native vegetation, called the legal reserve, varies from 20% to 80% between regions of the country).

Moraes, Zilberman and Rodrigues (2014) also highlight the Resolution No. 001/7,986-1986 of the Brazilian National Environmental Council (Conama, National Environmental Council) as a fundamental element of the Brazilian environmental framework. This Resolution establishes guidelines for the evaluation of environmental impacts for the industrial and for agro-industrial facilities.

In addition to these rules that are applied to the agricultural sector in Brazil, the sugarcane industry will also have to comply with specific rules from the National Biofuel Policy (RenovaBio), which impedes the suppression of native vegetation for the planting of sugarcane since 2018. According to this policy, rural properties with suppression of native vegetation are not permitted to participate in the Program.

This regulatory framework ensures that the production and expansion of sugarcane production in the country occurs in an orderly manner, without any type of degradation of forests or sensitive biomes.

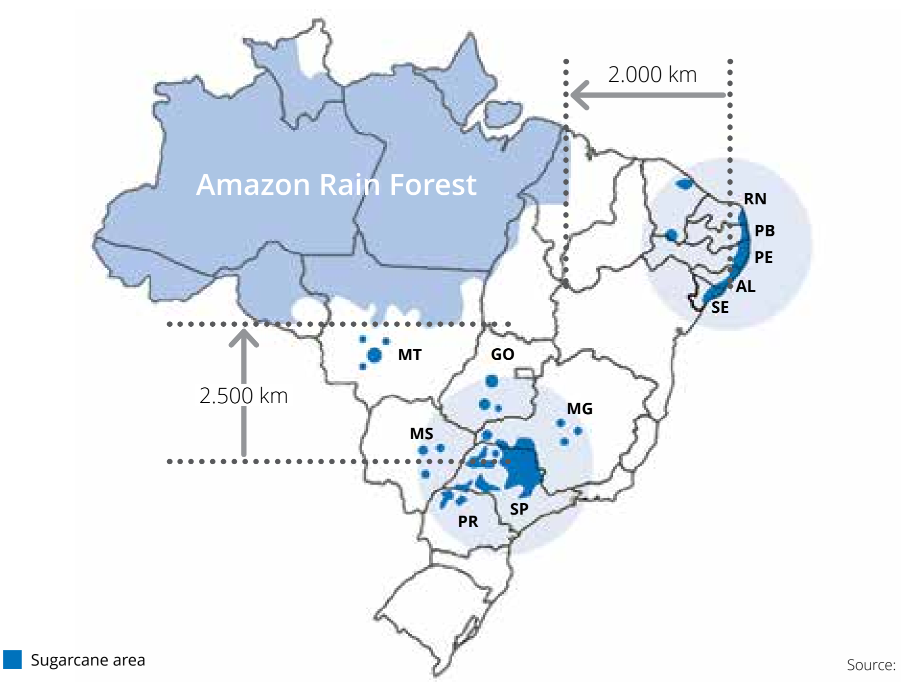
In fact, the most recent expansion of production has taken place primarily on degraded pasture land. Since the year 2000, for example, the increase in the amount of sugarcane planted and processed in Brazil has allowed ethanol production to triple, from 10.6 billion liters to more than 33 billion liters in the 2018 harvest/2019. In the same period, both sugar production and grain production (soy, corn, rice, wheat, cotton, among others), more than doubled (Mapa, 2019).

These numbers show that it is possible to increase the production of food, fiber, meat and bioenergy without deforestation, just by intensifying production on pastures and expanding the productivity gains observed historically in the agricultural sector of the country.

Today, only 1.2% of the Brazilian territory is used for the cultivation of sugarcane, of which 0.8% is used for the production of ethanol (IBGE, 2019; Mapa, 2019).

At this point, it is also worth mentioning that sugarcane production is located especially in the Midwest (more than 90%) and Northeast (about 10%) regions of the country, more than 2 thousand kilometers away from Amazon Rain Forest (Figure 10). In addition to the legal restrictions imposed

Figure 10. Location of sugarcane production in Brazil



Source: Unica (2019).

by the regulations presented, the planting of sugarcane in the Amazon is not economically effective because the region does not have adequate edaphoclimatic conditions for cultivation. Sugarcane needs a warm, rainy season to grow, alternating with a cold, dry season so that the plant can concentrate sugar in its stalks. The Amazon region does not have this cold and dry period, significantly reducing the activity yield.

In the last two decades, the environmental agenda has guided the sugar-energy sector. In Sao Paulo, a state responsible for more than 50% of national production, the elimination of fire for burning cane straw during harvesting operations was voluntarily anticipated by the productive sector. The Agro-Environmental Protocol, celebrated in 2007 by producers and the State government, guaranteed the elimination of sugarcane burning as early as 2014.

This agreement also involved other environmental actions, resulting in the preservation of more than 6,850 water springs existing in the sugarcane fields, in the recovery and preservation of 210,719 hectares of riparian forests, in the planting of about 38 million seedlings of native species and the reduction in water consumption in sugarcane plants by 37% (São Paulo, 2019).

In addition to complying with environmental legislation and establishing voluntary agreements with the government, the sugar-energy industry has long adopted environmental standards in order to meet the prerequisites established in the main certification schemes.

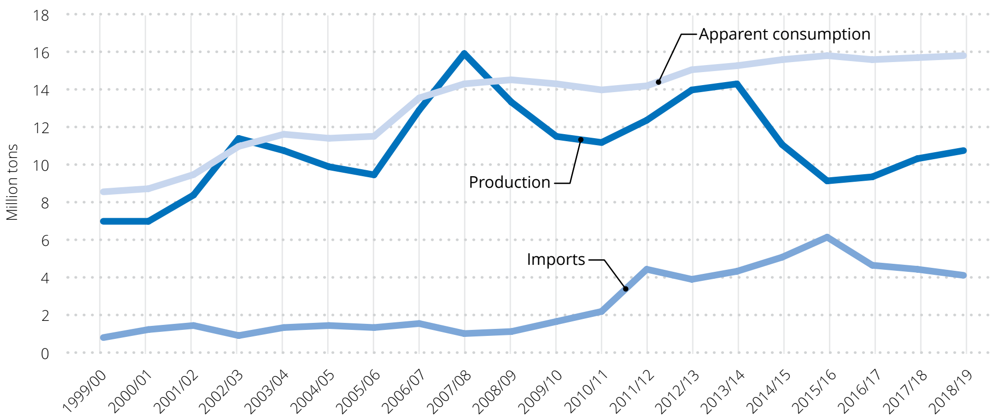
Sustainability standards and private certification initiatives, such as those developed by Bonsucro, have gained prominence in this industry in recent years. Namely, Brazil currently has 62 companies certified by Bonsucro, standing out as the country with the largest number of certified plants.

5. Cooperation opportunities with China

Brazil and China both claim potentially large consumer markets, and China, because of its large population and lower availability of arable land, will likely become more dependent on several imported commodities over the next few decades.

Sugar will surely be one of these products. Consuming around 15 million tons of sugar yearly, China produces only around 2/3 of this total, meaning that its annual dependence on imports is close to 5 million tons (Figure 11). As a result, China is the second largest sugar importer in the world, after Indonesia (USDA, 2019).

Figure 11. Evolution of sugar production, consumption and imports in China



Source: USDA (2019).

It is also noteworthy that for several recent years, China has been the major destination of Brazilian sugar, and Brazil, in turn, has been the largest supplier of this commodity to China. In fact, between 2011 and 2016 Brazil exported average volumes in the order of 2.5 million tons per year to China, which represented 10% of all Brazilian sugar exports and more than 60% of the total volume imported by the Asian country (MDIC, 2019; USDA, 2019).

It should also be noted that China is one of the countries with the highest potential for sugar demand growth in the world, as its annual per capita consumption of about 11 kg is still 50% lower than the annual average world consumption, which is in the order of 23 kg/inhabitant/year. In addition, the average sugar consumption growth rate in China has been increasing at three times the world average.

With the safeguard measure established by China in 2017 in the form of a higher import tariff on sugar, Brazil's share in Chinese imports decreased sharply. However, since the mechanism is scheduled to be lifted in 2020, trade between the two countries is expected to intensify once again. Actually, a more open trade flow will benefit both nations by ensuring the Chinese population access to a cheaper product of recognized global quality.

Another significant opportunity for cooperation is related to ethanol. With heavy reliance on imported gasoline and faced with the need to reduce greenhouse gas emissions and local pollutants, China has been signaling that it will strengthen its gasoline-ethanol blending program by 10% over the next few years across its territory.

A large-scale ethanol program would likely result in at least three major benefits: to the environmental, to public health, and to the Chinese economy.

From an environmental point of view, it should be emphasized that, according to an EU Report (2019), China is currently the largest emitter of greenhouse gas (GHG) in the world, accounting for 29.3% of global emissions. Its oil industry accounts for over 15% of those emissions and as a result China made a commitment at the United-Nations Climate Change Conference of Parties (COP) 21 in Paris to increase the share of non-fossil fuels in its matrix to 20% by 2030. It should be noted that China currently has a fleet of 240 million cars, a figure that is likely to double over the next 25 years, enhancing the problem.

The so-called "electrification" of vehicles (battery-powered cars) may be part of the solution, but it is being developed at a slow pace (battery-powered cars account for just over 1% of the fleet today) and is an expensive initiative due to the high costs of this technology and the need for investments in distribution infrastructure. Furthermore, this is not a complete solution at this moment, as much of the electricity to power these cars is generated by burning fossil fuels, particularly coal.

In this scenario, ethanol could be a complementary solution. Already tested in several countries and seen as economically feasible, it is a fuel that can reduce emissions by up to 90% compared to using gasoline. In addition to its use in combination with gasoline, biofuel can also be used in hybrid electric vehicles and especially to power fuel cell vehicles – a strategy with enormous potential for cooperation thanks to the Chinese technological expertise in the automotive industry.

In relation to public health, ethanol can also contribute to reducing local pollutants, which is still needed in most large Chinese cities. The

Organization for Economic Co-operation and Development (OECD) estimates that China spends USD 1.4 trillion a year due to health problems such as hospital admissions for cardiovascular and pulmonary diseases caused by air pollution (OECD, 2014). In fact, according to local pollution monitoring data produced by the World Health Organization (WHO, 2019), of the 100 most polluted cities in the world, 54 were Chinese cities in 2018.

According to Saldiva et al., (2014), the use of ethanol as fuel in eight major metropolitan regions in Brazil has been responsible for the reduction of around 1,400 deaths and almost 10,000 annual hospitalizations caused by health problems associated with the use of fossil fuels. This represents a savings of, at least, USD 430 million per year for the public and private health systems in Brazil, according to the authors.

Finally, on the economic side, large-scale biofuel use may contribute to reducing China's dependence on imported oil, which today supplies 65% of local demand, a figure that may rise to 80% by 2030 (Wang et al., 2018). In addition, increased ethanol consumption could provide an important income alternative for local rural producers and boost China's development in this area.

With an annual consumption in 2018 of about 4 billion liters, China is already blending biofuel with gasoline in 12 provinces (out of a total of 34), mainly biofuel produced from corn (at a rate of 70-80% of the production) and from cassava (at a rate of 10-20%), and it has been estimated that an increase in demand of about 15 billion liters of ethanol per year will be necessary for the 10% target to be achieved (USDA/FAS. Gain Report China Biofuels Annual, 2018).

Estimates suggest that part of this consumption will be met by domestic production, including as an interesting market diversification option for the sugarcane industry, and another part by imported ethanol, mainly from the United States and Brazil, the two largest ethanol producing and exporting countries. Until 2016, the ethanol import tariff stood at 5% and since 2017 it has risen to 30% and a reduction in this tariff is expected to contribute to reducing the cost of the imported product and to boost investments in producing it in both Brazil and the USA.

It should therefore be noted that there are clear opportunities for collaboration between Brazil and China either in the form of technical cooperation or of investment and trade. Specifically in the technical-scientific realm, relevant opportunities have been envisaged for exchanging experiences in the agricultural (sugarcane production and management), industrial (sugar and ethanol production, including second-generation ethanol), and automotive (improvements in vehicle technologies for electrification with biofuel in the future) areas, as well as in the area of regulation, given the experience of more than five decades of large-scale ethanol use in Brazil.

In addition to ethanol, cooperation arrangements may be developed around other products such as bioelectricity, biogas, jet-fuel, and even second-generation ethanol, as demand for energy in both countries is likely to continue to grow in the coming years.

Finally, it is worth mentioning that Chinese investments are already observed in the sugar-energy sector in Brazil. The COFCO International group, to cite one example, has been operating in the production of sugar and ethanol in the country since 2016 and today it ranks among the ten largest sugarcane producers in Brazil.

6. Final considerations

The Brazilian case of large-scale production and consumption of ethanol, sugar, and other energy sources, albeit designed for different purposes throughout its history, has become an illustrative and effective example worldwide of how fossil fuels can be replaced with renewables in conjunction with food production.

As in other countries, this shift in Brazil relied on the active participation of the state. Especially in the energy field, and more specifically in the case of ethanol, the presence of positive externalities associated with the production and use of biofuels requires public policies designed to induce their development, considering that the market cannot autonomously incorporate the value of these environmental benefits into the price system.

Although the Brazilian case provides an example with unique characteristics, this equation of the trade-off between energy security and climate change, including the instruments adopted to stimulate the use of biofuels, is not unique to Brazil. It actually began to permeate discussions on energy policy worldwide.

The way each nation will recognize this new component and address the energy security dilemma on a sustainable basis will likely shape the strategies adopted by states in the energy, political, and economic fields in the coming years.

In this scenario, stimulating the production and local consumption of ethanol by blending it with gasoline may be an efficient alternative for reducing pollution and greenhouse gas emissions in many countries around the globe. It is an economically feasible and readily available option that can be used in addition to other alternatives in the future that must be characterized by a multiplicity of clean and renewable energy sources.

China has already signaled its interest in expanding the share of biofuels in its energy matrix. It no doubt will need to rely on several sources of energy in the composition of its energy matrix. This is an unequivocal opportunity for technical and economic cooperation that can yield trade and investment gains for the two countries.

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