## CHAPTER 3

# THE PRESENT SITUATION OF BIOFUELS IN BRAZIL

### 3.1. INTRODUCTION

Typically, every time Brazil faces an energy crisis (oil increase or water/electricity shortages) ends up with a new emphasis to expand RE, in particular biofuels. This was the case during the energy crisis of 1920s, WWII, 1973, 1979, 2007, and now in 2022. Different reasons precipitated these crises, all of them affecting Brazil, both from the energy or the economic points of view. The difference now is that new increase of oil prices, due to the Russian war on Ukraine, coincides with an energy transition process that will take decades.

Energy wise, Brazil is currently a country with a relatively low per capita use. According to IEA (2021) the country is the world's 8th largest energy consumer but the 69th largest energy per capita.[1] In addition, traditionally, Brazil has made considerable progress in renewable energies, both for electricity production and transport. In the Brazilian energy matrix, the contribution of renewables was 48.1% in 2020. In electricity production, 83% is renewable[2] and in transportation, ethanol represents 43% of fuel in light vehicles, and biodiesel 10% of fuel in heavy vehicles. (MME, 2021). Brazil is, therefore, the greatest renewable energy economy in the world (see Table 3.1).

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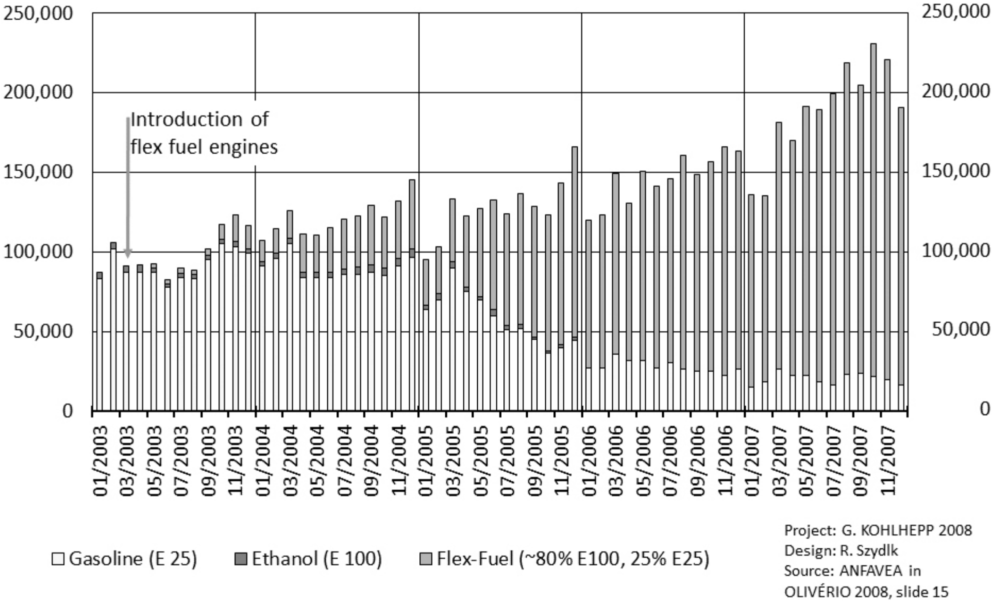
[1] https://worldpopulationreview.com/country-rankings/energy-consumption-by-country

[2] According to the Brazilian Government energy statistics (MME, 2021) 62.5% is hydro, 9.8% wind, 8.8% biomass, and 1.9% solar photovoltaics.

**Table 3.1** Production of modern bioenergy in Brazil in 2021. Sources: as indicated in the table.

| Type of biofuel | Feedstock | Production | Policy | Source |
|---|---|---|---|---|
| bioethanol | Sugarcane (90%)<br>Corn (10%) | 29.2 billion litres | E27.5 and E100 | [3] |
| biodiesel | Soybeans (90%) | 6.4 billion litres | B10 | [4] |
| Bioelectricity | Sugarcane bagasse | 9.1% of total electricity generated | ------- | MME (2021) |

The use of ethanol has intensified in the last two decades, particularly after the introduction of flex-fuel engines in 2003. Figure 3.1 shows ethanol (hydrous and anhydrous) for the 2003-2007 period. This gives an idea how fast this change has occurred. As the figure shows, the consumers initially accepted well the flex-fuel innovation, although currently expectations are much lower.



Project: G. KOHLHEPP 2008
Design: R. Szydlk
Source: ANFAVEA in OLIVÉRIO 2008, slide 15

**Figure 3.1** Evolution of gasoline (E25) and hydrous ethanol (E100) consumption in Brazil depending to the engine type. Source: ANFAVEA, cited by Olivério (2008).

Therefore, it can be stated that Brazil is the country among the 10 largest economies with the best profile in renewables, both for electricity production and liquid biofuels. No other economy, despite its technological development compared to advanced economies, has made so much progress in encouraging renewable energies, biofuels included, that Brazil.

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[3] https://www.gov.br/pt-br/noticias/agricultura-e-pecuaria/2021/10/producao-de-etanol-de-milho--avanca-no-pais-como-opcao-sustentavel-e-de-valor-agregado

[4] https://www.noticiasagricolas.com.br/noticias/politica-economia/272575-producao-de-biodiesel-do--brasil-cresce-85-em-2020-diz-abiove.html#.YfA1fOrMI2w

So, the issue in energy transition in Brazil can be better understood by growing overall energy production while maintaining the relative importance of renewables. As a trend in energy transition for electricity, Brazil has excellent possibilities with solar, wind, and biomass. Regarding liquid biofuels there is still a room for much greater contribution of bioethanol and biodiesel, both for domestic market and when exports are considered. Also, if future markets such as biofuels for aviation and maritime are included, the prospects are also very good.

The opportunities are also very good concerning the production of new biomaterials, the so called "green" materials and fine chemicals. An example is the bio-based polyethylene wax developed by Braskem.[5] This new renewable material open possibilities in multiple markets, such as adhesives, cosmetics, coatings and masterbatches.

Of course, the realization of these opportunities will greatly depend on how the country successfully deploys the existing relative advantages, such as available fertile land and other natural resources, together with human capacity and capital.

## 3.2. CURRENT SITUATION OF ETHANOL IN BRAZIL

The Brazilian Ministry of Agriculture (MAPA) registered in 2020, 361 sugar & ethanol producing plants, with a capacity to process 745 million tons of sugarcane (EPE, 2022). The same source estimates the total sugarcane harvested area will grow from 8.3 Mha in 2021 to 9.3 Mha in 2031. Productivity is expected to increase by 1.4%/year, reaching 83 tc/ha in 2031, while the yield should be around 141 kg of Total Recoverable Sugars (TRS)ATR/tc.

### 3.2.1. AN OVERALL VIEW OF PRESENT STATUS OF ETHANOL

Ethanol is currently known as bioethanol, meaning of biological origin, as well as biodiesel. This renaming simply emphasizes its biological nature rather than any chemical change. In recent years, ethanol supply has not been affected as much as it was often the case in the past. The price of fuel ethanol (E100), however, is closely linked to price variations of gasoline (E27.5) (see Figure 3.2)

This, of course, discourages the consumer, particularly those located far from the production regions. Flex fuel engines do not represent, in practice, an economic advantage to the consumers. And so, it seems, would be the case for 2G ethanol in the near future unless the economics can be improved significantly. Corn ethanol, on the contrary, is expanding fast, benefiting consumers from Mato Grosso and Goiás states. Nevertheless, productivity will have to improve significantly to be able to compete with sugarcane ethanol producing regions.

This chapter assesses the present status of biofuels in Brazil with the objective of analysing its possible role in the energy transition which the world is going through.

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[5] https://www.braskem.com.br/imgreen/bio-based-en

The main argument is that sugarcane ethanol, together with biodiesel, represent a great contribution for GHG emissions mitigation, and consequently there aren't any reasons to adopt other strategies. To explain this, following is an analysis of each parameter of the production phase and biofuels GHG emissions, in relation to the commitments signed by Brazil in the Paris Agreement of 2015.

Figure 3.2 shows estimated ethanol production (hydrous and anhydrous) from 2021 through 2031. As can be appreciated, the increase is primarily hydrous ethanol. Figure 3.3 illustrates ethanol trade (domestic and international) from 2008 to 2019, according to EPE estimates.

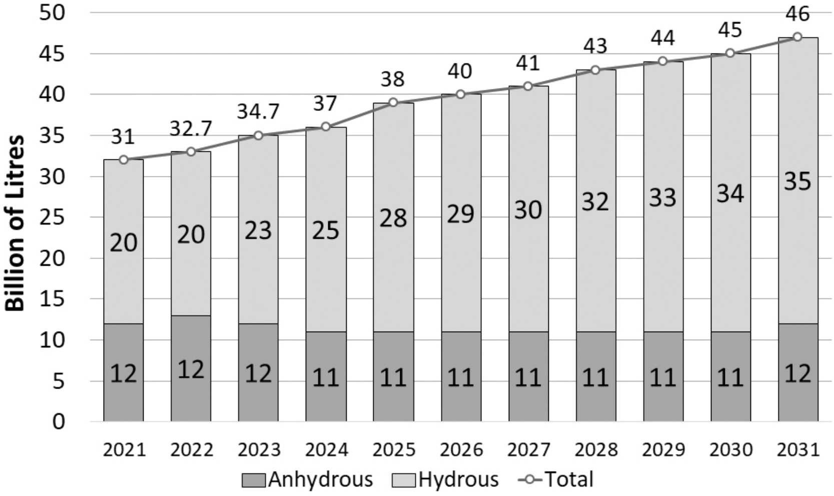

**Figure 3.2** Present and future estimations of ethanol production and imports from Brazil.
Source: EPE based on EPE (2017).

Although there is a concern of ethanol imports, historically it represents less than exports (figure below).

**Figure 3.3** Brazilian exports and imports of ethanol from 2008 to 2019. Source: EPE (2020) from MME (2020).

### 3.2.2. THE PRESENT STATUS AND OPPORTUNITIES FOR SUGARCANE

As stated before, for a biofuel to be competitive, the feedstock needs to be produced in a competitive environmentally sustainable manner since, typically, it is responsible for 70-80% of the overall cost.

As stated in the previous chapter, Brazil has made a considerable effort to diversify sugarcane varieties to increase productivity, drought resistance, and new and more adapted varieties to increase the harvesting period.[6] It is important to state that present productivity, around 75 tons/ha/yr, is relatively small because of reductions associated with adverse climatic conditions aggravated by the introduction of harvesting mechanization which requires heavy machinery causing soil compaction. Figure 3.4 below shows the share of cane going to ethanol and to sugar production together with estimated cane productivity from 2021 through 2031.

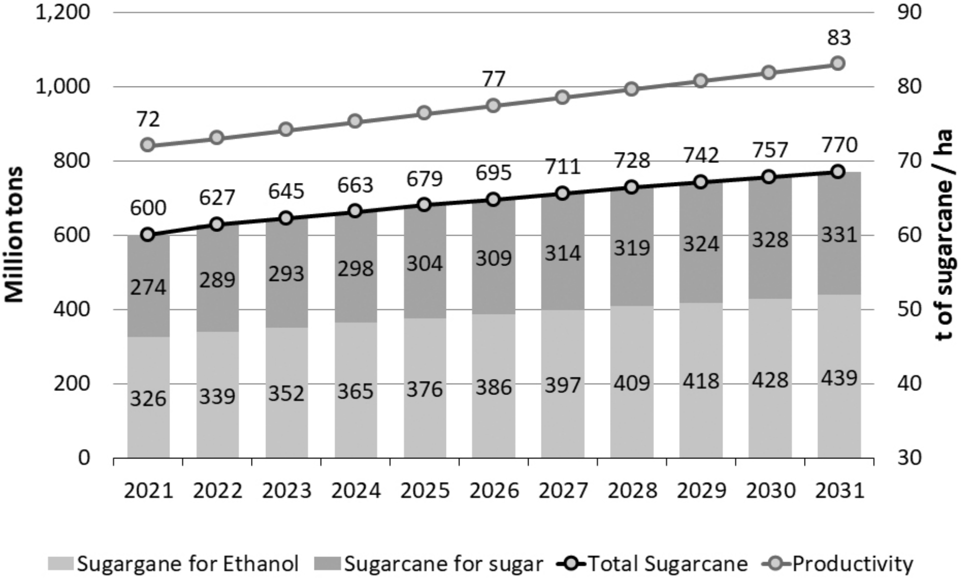

**Figure 3.4** Productivity, harvested cane, and destination to ethanol and sugar. Source: EPE (2022).

Therefore, of the 9-10 Mha dedicated to sugarcane production, nearly half goes to sugar and the other half to ethanol. With nearly to 4.5 Mha equivalent dedicated to sugar, Brazil has become the leading exporting country in the world (Figure 3.5 below).

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[6] The first harvest typically occurs 18 months after the cane stalks are planted. Then, the following harvests occurs after 12 months. Typically, the harvesting yields decline making necessary to replant the cane after 5-6 harvests.

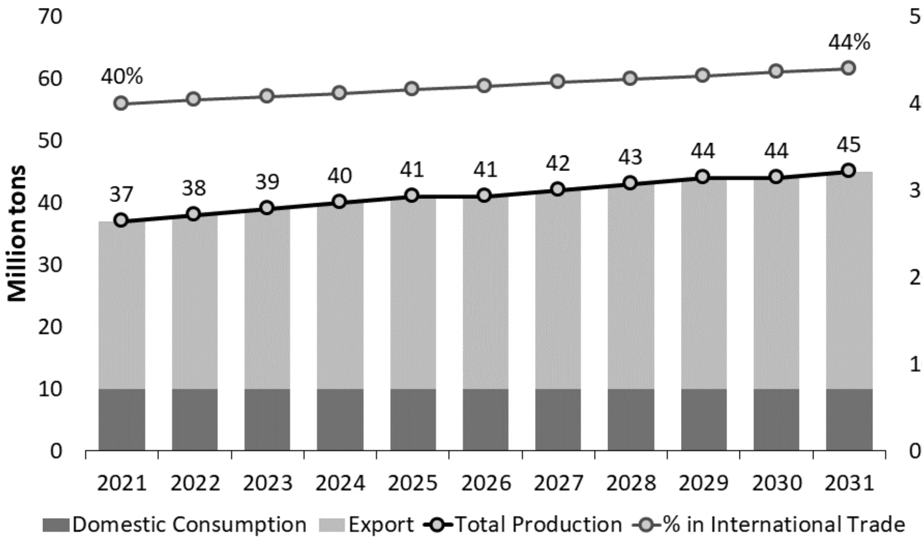

**Figure 3.5** Projection of Brazilian production of sugar until 2031. Source: EPE (2020).

A major recent improvement with sugarcane as feedstock (for ethanol, electricity and 2G ethanol) was the introduction and development of energycane,[7] a cane variety that proportionally produces more fibre than the conventional cane. It has been tested by GranBio in Alagoas in its 2G ethanol production plant. Energycane could also be, potentially, an excellent source for electricity production. One negative side of energycane is that its high fibre content renders the extraction more difficult, requiring more energy and equipment maintenance. Hence more technical improvements are required in preparing the cane prior to extraction. As for sugar, energycane produces less sugar per weight but more sugar by area.

With the introduction of flex mills, operating with sugarcane and corn, will also require more studies on energy integration. Equipment companies such as DEDINI are aware of the problem and the opportunity it represents and is looking for solutions. Corn ethanol is expanding in Brazil, as it will be seen later in this book.

Figure below (3.6) shows the map with the main localities of sugarcane plantations in Brazil.

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[7] According to EPE (2022) energycane will represent around 100 thousand ha, corresponding to 1.1% total sugarcane area in 2031.

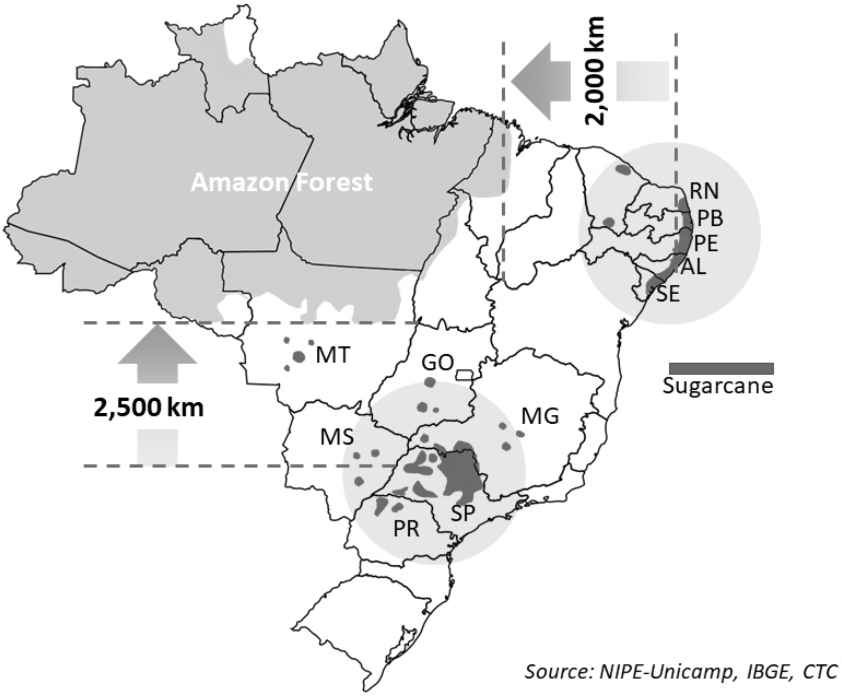

**Figure 3.6** Map of sugarcane distribution in Brazil. Source: NIPE-Unicamp; IBGE; CTC (2017).

Sugarcane has several positive features e.g., more resilient to climate change, good soil coverage preventing erosion, high fibre content besides sugar, adaptation to different soil conditions, and very good productivity when compared to other crops.[8] On the other hand, sugarcane needs to be processed quickly after its harvest to prevent sugar losses, while its harvesting season typically covers 7-8 months in Southeast and Centre-South. The introduction of green cane mechanical harvesting brought also problems associated with diseases and soil compaction. The later, together with droughts, are probably the most important factors responsible for the drop in cane yields experienced in the last decade.

Sugarcane is produced in about 100 countries, though a few countries dominate e.g., Brazil, and India, as main producers. It is a difficult crop to harvest since most of the biomass is basically water and fibre. Because of the difficulties associated to harvesting conditions and the relatively small market size, in most countries, when compared to the top world crops[9] (rice, corn, wheat, and soybeans) it is difficult to convince agricultural machine manufacturers to show interest to develop the required technology. For example, lighter machinery, with lower potential to cause soil compaction should be a priority.

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8 In 2020, sugarcane average yield for Brazil was 75.6 tons/ha/yr. This yield expresses the harvesting of cane stalks only. If cane straw is added, additional 25-30 tons needs to be added.

9 https://en.wikipedia.org/wiki/List_of_most_valuable_crops_and_livestock_products

There is a considerable potential to grow more sugarcane in Brazil. In a study conducted by Leite et al (2009), to substitute 5% of all gasoline consumed in the world by 2025 (estimated 1.7 trillion litres of gasoline), it would require 102 billion litres of ethanol, considering energy density differences and increased engine efficiencies. The paper identified 12 selected areas with sugarcane potential, located in several states in Central Brazil. These areas were previously occupied with pastureland and considering sugarcane-to-ethanol overall productivity of 6,000 litres/ha/yr[10] using first generation technology, not more than 21 Mha would be required to satisfy the 5% goal. Should this target be achieved, annual ethanol production could be raised from 30 to 102 billion litres, besides the electricity surplus derived from sugarcane bagasse cogeneration. Naturally, there would be positive economic impacts in other agribusiness sectors e.g., yeast production as animal feed.

As feedstock for biofuels, sugarcane presents a very good production model with sugar as coproduct. In the 2020/21 harvest, Brazil produced 41.2 million tons of sugar[11] and exported around 32 million tons[12]) and produced around 29.7 billion litres of ethanol from sugarcane[20]. The reader should be reminded that most ethanol distilleries in Brazil also produce sugar. Around 50% of sucrose entering the mill goes to sugar production (A and B sugars) and the remaining sucrose goes to fermentation for ethanol production. This production model guarantees good profitability since sugar has good international prices. This model was created during the evolution of the ethanol program and is responsible for the elimination of subsidies associated with the ethanol fuel production and use (see Chapter 2).

The so-called "alcohol account" was therefore terminated. Using this model Brazil became the largest producer, at least temporarily,[13] and exporter of ethanol in the world. Unfortunately, sugar market is not as elastic as fuel ethanol. Another consideration is the trend to decrease sugar consumption. So, if fuel ethanol production increases in Brazil, using the same sugar-ethanol model, proportionally more sugar should also be produced. However, world demand for sugar is declining in many countries, primarily in the more advanced economies. Therefore, if Brazil has the intention to expand its ethanol production, another model should be developed or at least complement the existing sugar-ethanol model.

On this regard, although most mills produce sugar and ethanol, they also have capacity to vary the proportion of such products, depending on the economic and technical circumstances. Most mills producing sugar and ethanol have a flexibility level of 60-40, meaning they can adjust the proportion to anything within this range.

According to ANP (2021), in July 2021 the mills authorized to produce ethanol have a production capacity of 130 million litres/d of anhydrous and 230 million litres/d of hydrated. The estimated annual production capacity was 23 billion litres and 41

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[10] Today the sugarcane ethanol productivity is estimated about 7,000 litres/ha/yr.

[11] http://www.iea.sp.gov.br/ftpiea/AIA/AIA-21-2021.pdf

[12] https://www.statista.com/statistics/249646/exported-amount-of-sugar-from-brazil/

[13] The USA became the largest producer of ethanol in world.

billion litres for anhydrous and hydrated ethanol, respectively. This is based on an average of 180 day harvesting period.

Figure 3.7 below shows historical evolution of bioethanol distilleries from 2006 to 2020 and estimated for 2021 to 2030.

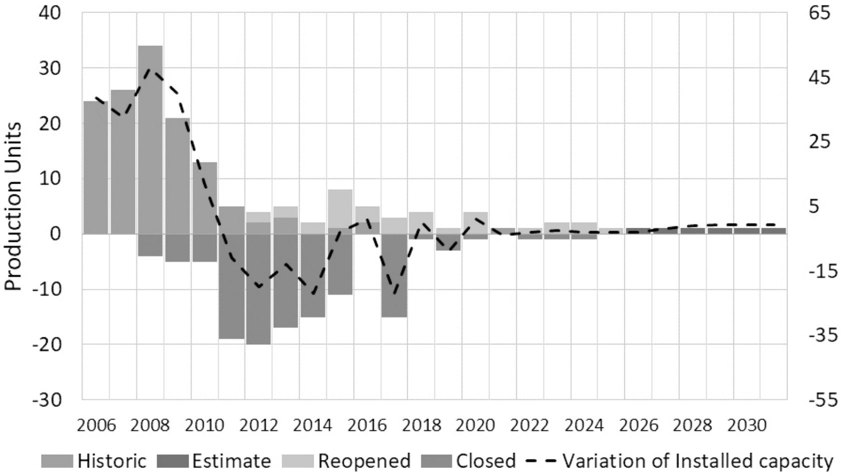
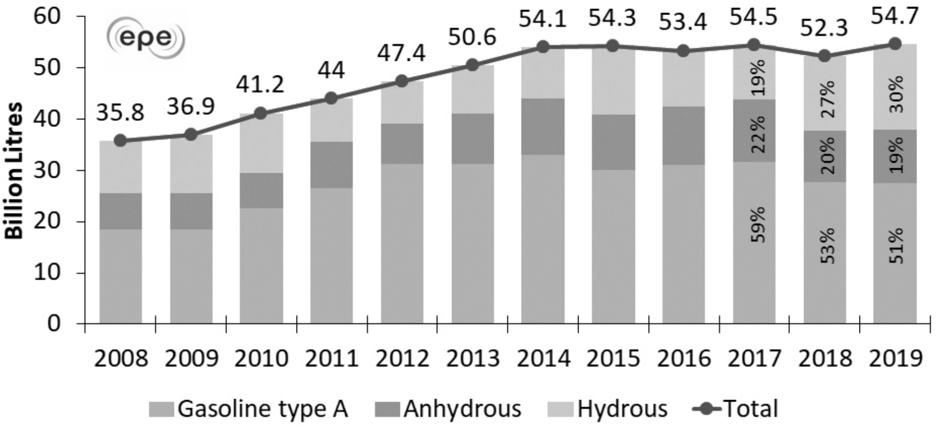


**Figure 3.7** Ethanol mills entering in operation 2006-2030 (projected). Source: EPE (2022) based on MAPA, UNICA, and EPE projection.

## 3.2.3. PRESENT DEMANDS FOR ANHYDROUS AND HYDROUS ETHANOL

The volumes of Otto cycle fuels demanded in the Brazilian market grew steadily from 2008-2013 following closely the economic growth. After this period demand practically stabilized (Figure 3.8).



Note: Demand data excludes the CNG share.

**Figure 3.8** Otto cycle demand and share of different fuels. Source: EPE (2020).

An important point is the ratio between ethanol price (E100) in relation to gasoline price. Typically, it stays between 65-72% reflecting ethanol lower heating value, as illustrated in Figure 3.9.

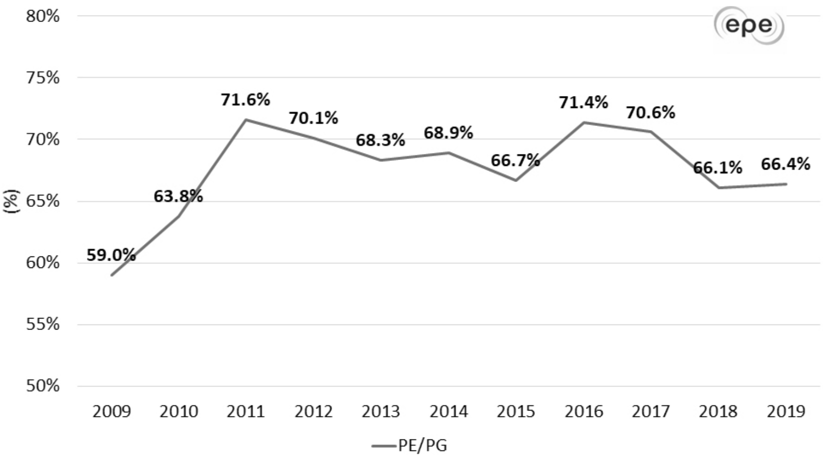
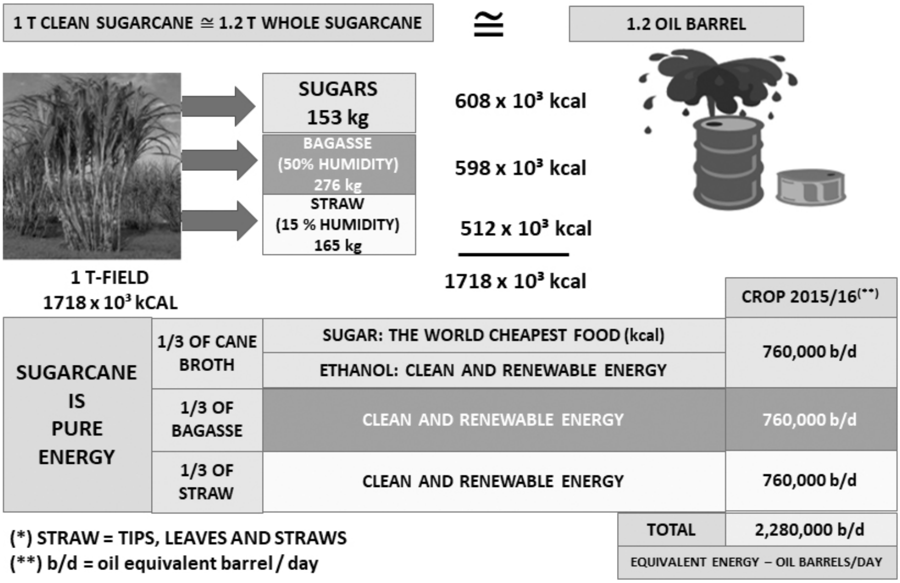


**Figure 3.9** Average price of fuel ethanol in relation with gasoline C (E27.5). Source: EPE (2020) from ANP.

## 3.2.4. PRESENT SITUATION AND MID-TERM POSSIBILITIES OF BIOELECTRICITY IN BRAZIL

Sugarcane bagasse is an excellent by-product. Roughly, about 1/3 of sugarcane are sugars and 2/3 is fibre (bagasse and straw). When we look at these figures it is obvious this crop represents a good agricultural yield, associated with very good potential energy use. A more complete energy breakdown of sugarcane is given below, Figure 3.10.



| | | | CROP 2015/16$^{(**)}$ |
|---|---|---|---|
| SUGARCANE IS PURE ENERGY | 1/3 OF CANE BROTH | SUGAR: THE WORLD CHEAPEST FOOD (kcal) | 760,000 b/d |
| | | ETHANOL: CLEAN AND RENEWABLE ENERGY | |
| | 1/3 OF BAGASSE | CLEAN AND RENEWABLE ENERGY | 760,000 b/d |
| | 1/3 OF STRAW | CLEAN AND RENEWABLE ENERGY | 760,000 b/d |
| | | TOTAL | 2,280,000 b/d |
| | | | EQUIVALENT ENERGY – OIL BARRELS/DAY |

(*) STRAW = TIPS, LEAVES AND STRAWS
(**) b/d = oil equivalent barrel / day

**Figure 3.10** Sugarcane composition and its energy value. Source: DEDINI (2016).

The fibres, 2/3 of the cane, are an indication that substantial amount of electricity can be generated from it. In some countries where bioelectricity is highly encouraged such as Mauritius, bioelectricity is sold at premium. Brazil is encouraging its use but still has a considerable potential for improvement.

According to ANEEL (2017) the installed bioelectricity from sugarcane reached 9.4 GW in 2017, an increase of 60% from the previous five years. Of the 378 mills in operation, about 200 sold electricity to the grid and just 50% took active participation in energy auctions. Up to May 2016, 53 auctions took place but just 21 sugar and ethanol mills taking part (EPE, 2022). According to the same source these contracts represented 1.8 $GW_{avg}$ at the end of 2021. Figure 3.11 illustrates well current energy contracted, and the potential expected to be commercialized in the free market, from 2021 to 2025.

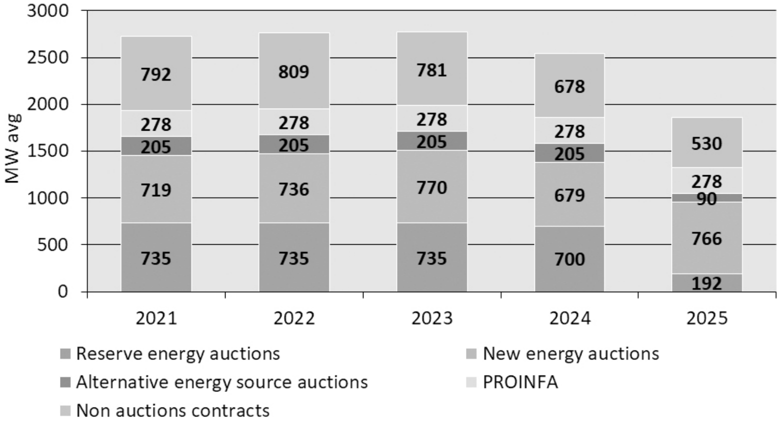


**Figure 3.11** Electricity contracted in energy auctions by free market -2021-2025. Source: EPE (2022).

According to EPE the technical potential for selling electricity by the sugar & ethanol mills/distilleries is 6.2 $GW_{avg}$ without considering whole green cane harvesting. If whole green cane was to be considered, using 500 and 787.5 kWh/ton of cane trash and tops respectively, the potential goes up from 6.8 to 10.7 $GW_{avg}$ by 2031 (COGEN, 2009, and EQUIPAV, 2009). Figure 3.12 show current and potential contribution of sugarcane bagasse to the national grid, from 2021 and up to 2031.

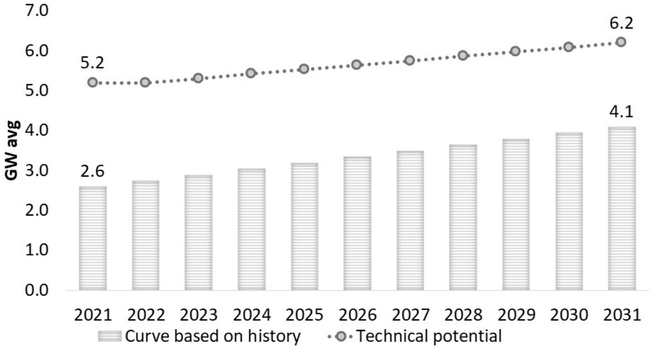


**Figure 3.12** Potential for electricity exports from sugarcane bagasse to the grid. Source: EPE (2022).

It is important to mention that the greater share of the total electricity & power generated with sugarcane is consumed inside the mill to provide all energy and heat needs (see Figure 3.13).

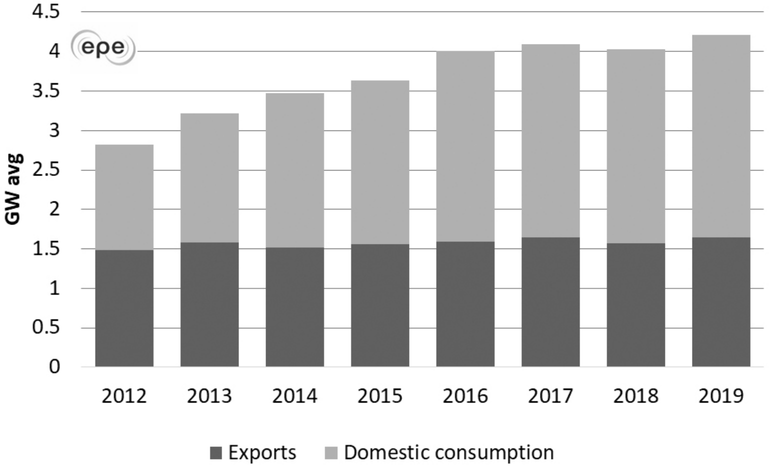


**Figure 3.13** Self-consumption and electricity sold by sugar & ethanol mills in Brazil. Source: EPE (2020).

Bagasse is also a good feedstock for G2 ethanol and pyrolysis bio-oil production, as will be discussed further in this chapter.

### 3.2.5. THE ECONOMICS OF SUGARCANE ETHANOL

Table 3.2 shows the main items integrating the cost of ethanol. It is important to observe the high share represented by feedstock cost, 2/3 of total costs are related to the raw material.

Of the cost of feedstock, harvesting (cutting and loading), and transporting represents almost 50% of overall feedstock costs.

**Table 3.2** Raw material, industrial, and administration costs (R$/tc) of sugarcane ethanol in Brazil: harvest 2015/16. Source: Leal (2022) based on PECEGE/I (2015).

| | **Traditional** | **Expansion** | **Northeast** |
|---|---|---|---|
| **Raw Material** | 87.42 | 86.67 | 105.58 |
| **Industrial** | 28.15 | 26.73 | 33.87 |
| **Administration** | 12.78 | 14.10 | 16.68 |
| **Total** | 128.34 | 127.50 | 156.13 |

Obs: the expansion areas are mainly concentrated in Central West states of Goiás, Mato Grosso, and Mato Grosso do Sul.

Another important consideration regarding final prices of fuel ethanol in the petrol stations, relates directly to taxes paid by the consumers. Table 3.3 illustrates the importance effects of taxes for both the government in general and PETROBRAS, in particular.

**Table 3.3** Composition of gasoline price in Brazil – Feb 2022. Source: LEAL (2022) PETROBRAS, based on ANP and CEPEA/USP data

| | |
|---|---|
| Price at the Gas Station | R$ 6.79[14] |
| ICMS (state tax) | R$ 1.75 |
| Distribution and resale | R$ 0.92 |
| Anhydrous ethanol | R$ 0.86 |
| Taxes (CIDE, PIS/PASEP, COFINS) | R$ 0.69 |
| PETROBRAS | R$ 2.37 |

Transporting ethanol is another important issue, particularly when production plants are located far from consumers. Naturally, less diesel[15] is used for transportation the better the economics and GHG emissions. There are basically two pipelines for ethanol transportation as can be seen in figure below. Figure 3.14 shows the geographical distribution of all ethanol mills in the country (both from sugarcane and corn), and Figure 3.15 the main pipelines. Notice the large concentration in the State of Sao Paulo.

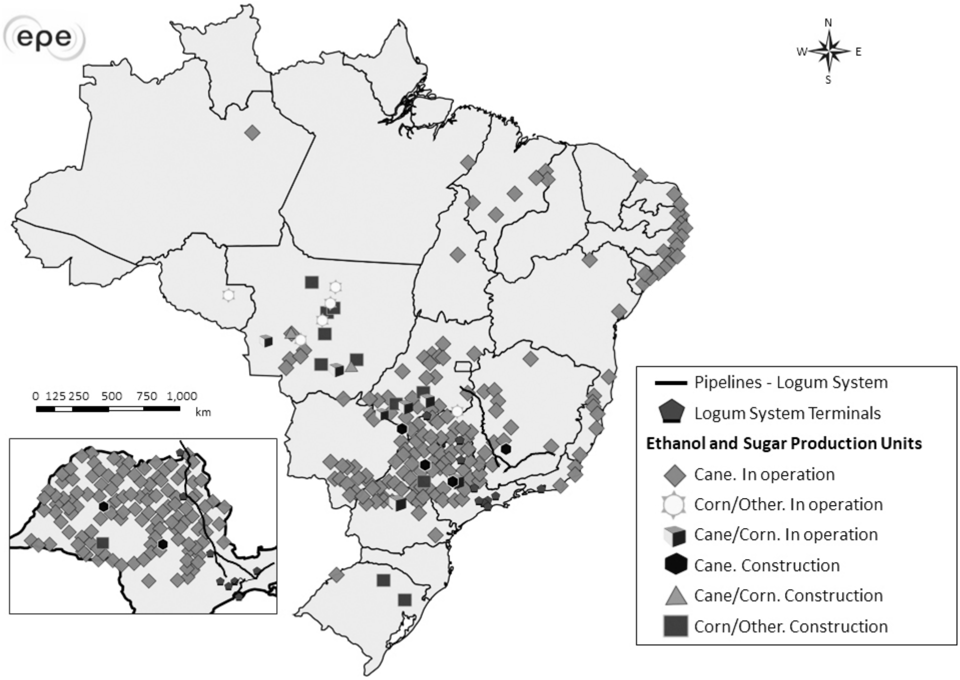


**Figure 3.14** Ethanol and sugar producing mills and logistics infrastructure (pipelines) in Brazil. Source: EPE (2022) based on MAPA and LOGUM

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[14] Exchange rate between R$ 5 to R$ 5.50 during the period.

[15] Ethanol is transported by diesel trucks, mainly.

As the market grows more pipelines are being installed. It is important here to remember that these pipes need to be operated throughout the year. Ideally, it would be adequate to have more homogeneous production year-round.

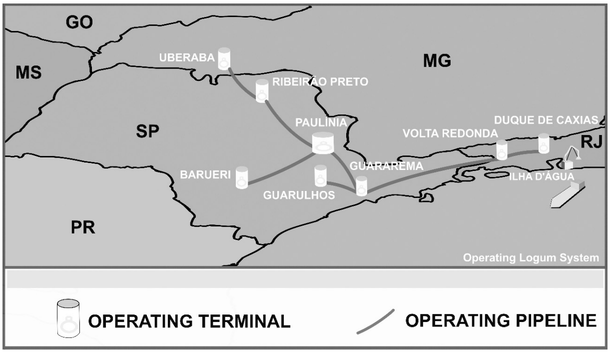

**Figure 3.15** Integrated logistics system for ethanol transportation using pipelines in São Paulo and Rio. Source: adapted from LOGUM/EPE (2020)

The pipeline sections that are already in operation are:

- Ribeirão Preto (SP) – Paulínia (operating capacity of 2.8 billion litres/year)
- Uberaba (MG) – Ribeirão Preto (SP) (operating capacity of 1.8 billion litres/year).

In addition, LOGUM also has pipelines such as Paulínia (SP) – Barueri (SP), Paulínia (SP) – Rio de Janeiro (RJ), and Guararema (SP) – Guarulhos (SP). When all these pipelines operate in its full capacity, they will handle 6 billion litres/year.[16]

Among the projects for expanding the pipeline network under consideration, is the planned connection of the Guararema Land Terminal to the distribution bases in São José dos Campos, in São Paulo State. The 42.5-km ethanol pipeline will pass through the municipalities of Guararema, Santa Branca, Jacareí and São José dos Campos with a yearly capacity of 40 million litres (NOVACANA, 2020).

## 3.3. CORN: THE NEW FEEDSTOCK FOR ETHANOL IN BRAZIL

Corn is also a traditional crop in Brazil and planted in two different seasons: summer (as a main crop harvest or *"safra"*) and winter (as second crop or "*safrinha*", after soybeans is harvested). There is also corn harvested as third crop in Northeast Brazil, although the production is relatively small (MACHADO, 2021). As can be seen, most of the corn produced today, around 70-80%, is as second crop sharing annually land with soybeans (Figure 3.16).

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[16] https://www.udop.com.br/noticia/2021/08/05/dutos-da-logum-chegam-a-grande-sao-paulo.html

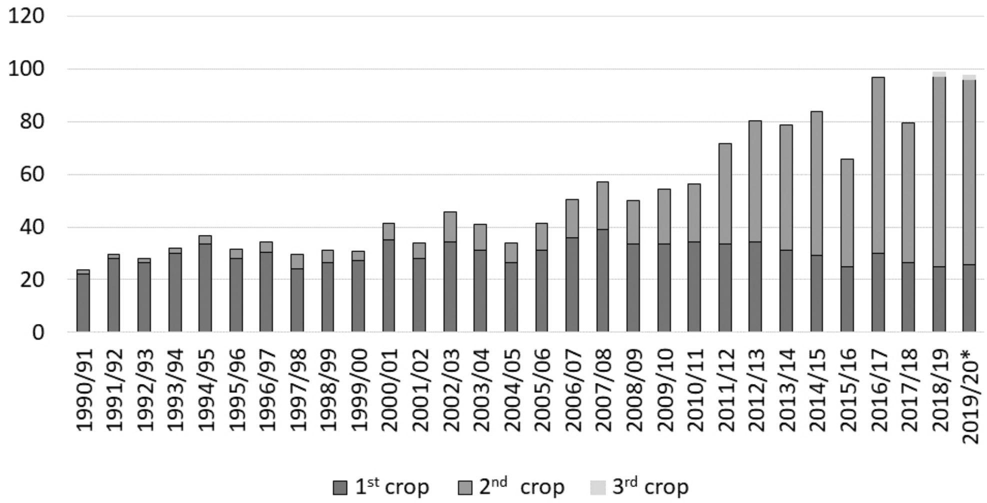

**Figure 3.16** Overall corn production in Brazil. Source: CONAB / elaborated by Scot Consultoria.

Ethanol using corn as feedstock is growing rapidly in Brazil, as shown in the figure below.

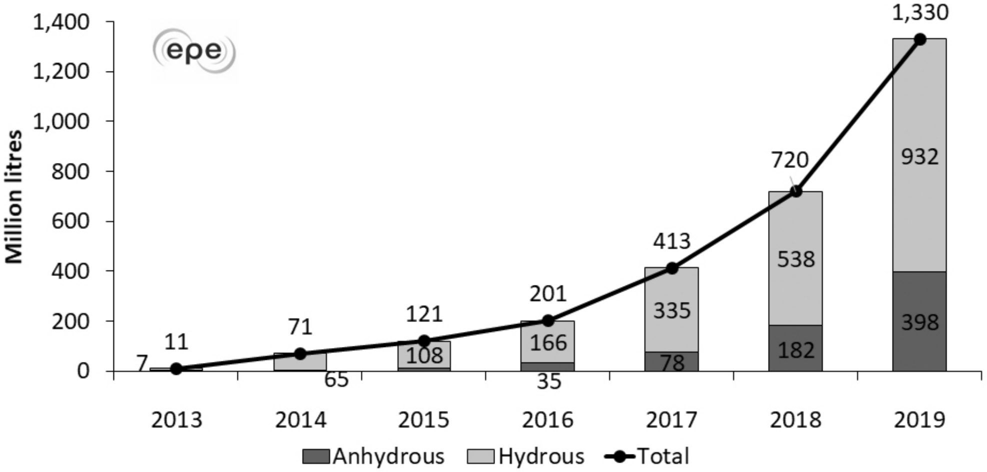

**Figure 3.17** Corn ethanol production in Brazil. Source: EPE (2020) from UNICA.

Currently about 19.9 Mha are devoted to corn in Brazil, with a production of 87 Mt in 2020/21; it is expected to reach 20.9 Mha and 112.9 Mt in 2021 to 2023 (CONAB, 2022). It is important to emphasize that "safrinha" uses the same agricultural land of corn and soybeans. The main idea is to use the remaining fertilizer left after soybeans are harvested, as it is well known their nitrogen fixation effect.

Geographically, corn is planted in several states, but mostly in Mato Grosso and Paraná. Because of the nature of corn, it facilitates its cultivation in different climate such as Central-West and South of Brazil.

Presently, corn production supplies three market objectives: the domestic market, exports, and ethanol production. Brazil is the world's second corn exporter with nearly 10-15%.[17] Around 3.7 billion litres of ethanol were produced in 21 plants (both corn dedicated and flex), predominantly in Mato Grosso and Goiás states; all ethanol production uses corn as feedstock. It is predicted that corn ethanol could reach 9.0 billion litres/year in 2031 in 54 ethanol plants, as shown in Table 3.4.

**Table 3.4** Installed capacity of corn ethanol plants in Brazil. Source EPE (2022) based on MAPA (2021)

| | **2021** | | **2031** | |
|---|---|---|---|---|
| | **Number of units** | **Installed capacity of ethanol (billion litres)** | **Number of units** | **Installed capacity of ethanol (billion litres)** |
| Total | 21 | 3.7 | 54 | 9.0 |
| Flex | 11 | 1.2 | 20 | 2.9 |
| Full | 100 | 2.5 | 34 | 6.1 |

The prospects of corn ethanol production in Brazil are very good. The life cycle of corn ethanol is also good because other sources can be used as an energy source e.g., eucalyptus and sugarcane bagasse, in corn ethanol plants, particularly when there is a possibility to integrate corn and sugarcane production in the same plant. There are some other benefits associated e.g., continuous operation (all year around) of the plant without the need for storage tanks since the off-season[18] period can be eliminated.

## 3.4. THE PRESENT STATUS OF BIODIESEL IN BRAZIL

The world production of biodiesel in 2020 was approx. 47 billion litres (FAME and HVO), and Brazil contributed with about 6.4 billion (~14%), being the 3rd largest producer behind Indonesia (~17%) and the USA (~15%) (REN21, 2021). (See also Chapter 1).

Originally, when PROBIODIESEL was setup and during the early years of its implementation, the idea was to use small family farms and alternative feedstocks such as sunflower and castor oil. This was not a realistic approach. As explained in Chapter 2, the reasons why sugarcane succeeded as feedstock for ethanol production was the existence of expertise and knowledge in sugarcane cultivating in large scale, in addition to a well-developed infrastructure and the influence of the sugarcane lobby. This lesson was ignored when PROBIODIESEL was first set up. Naturally, the most important crop in Brazil, soybean, became the best candidate to produce large scale vegetable oil for biodiesel production. Soybeans is a seasonal crop, typically planted with the

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[17] https://www.gov.br/pt-br/noticias/agricultura-e-pecuaria/2021/10/producao-de-etanol-de-milho--avanca-no-pais-como-opcao-sustentavel-e-de-valor-agregado

[18] Sugarcane ethanol plants in Brazil are highly concentrated the Central South region (about 80% of the country´s production. Ethanol production in the Central South region is normally done in between April and October.

first rains in October and harvested near April. Soybeans, shares the same land with "safrinha" corn, so if there is rainfall delay this may affect the "safrinha" corn planting and productivity. Also, soybeans are crushed to produce soybeans oil, by far the least expensive cooking oil in Brazil. In the crushing process, soybeans cake is produced, which is mostly used as animal feed primarily in poultry and pigs' farms.

Brazil is the world's largest producer and player in soybean grains exports (IBGE, 2021). Although soybean was not an energy crop, Brazil had sufficient knowledge on how to cultivate it in large commercial scale; there is a good infrastructure and well-organized and powerful producers' associations. The Brazilian Association of Vegetable Oil Industries (ABIOVE) is the largest private group representing the soybeans sector.

Another sector that benefited from large scale biodiesel production is the beef cattle industry. Tallow is produced in large quantities and so far, there was not a good market for it.

Other raw materials such as cotton, corn and residual oils also benefited from PROBIODIESEL because of its regional advantages, seasonal availability, and share logistics. Currently, a large spectrum of raw materials is used to produce biodiesel, although nearly 68% is from soybeans (Figure 3.19 below).

Soybean requires substantial amount of land, and hence is not as good energy crop as sugarcane. This results in low oil productivity (about 600 litres of soybean oil/ha/yr), compared with palm oil in Malaysia with about 5,000 litres of oil/ha/yr. However, it is not foreseen soybeans will lose its leadership as raw material for biodiesel in Brazil, at least not until 2030. It would be important to encourage other alternative energy crops such as palm oil to grow for this important and growing market.

Few palm oil projects were established in Brazil, with AGROPALMA being one of the most important. Also, the iron ore company, VALE, is involved in setting up palm oil plantations. For example, it has set up BIOPALMA in Pará state, where it has a 57,000 ha of palm plantations.[19] The main difficulties so far have been associated with agronomy aspects.

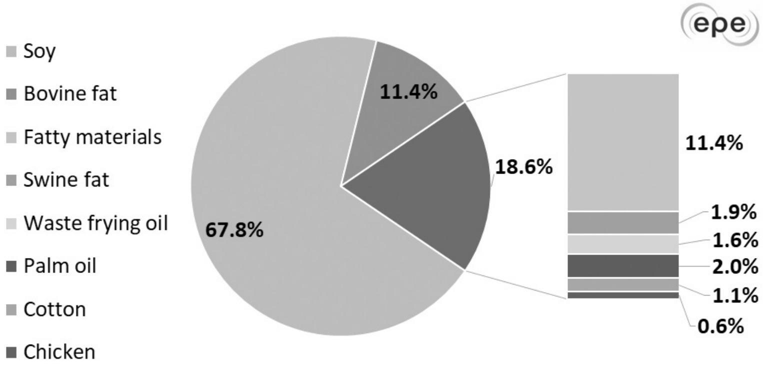

**Figure 3.18** Share of raw materials for biodiesel production in 2019 in Brazil.
Source: EPE (2020) from ANP (2020).

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[19] https://ubrabio.com.br/2013/05/22/vale-investimente-na-producao-de-oleo-de-palma/

If Brazil wants to export less soybean grains and process them domestically benefiting the production of vegetable oil and soybean cake, it should change the existing exemption of export taxes given to raw materials.[20]

Production of soybean and exports continue to increase. According to IBGE (2021) soybean production went from 128 million tons in 2020 to 133 million tons in 2021. Soybeans grains exports increase to 83 million tons in 2020 (12% higher than 2019) (ABIOVE, 2021a).

As for the production costs associated with biodiesel, the raw material typically represents about 80% (IEA, 2004). EPE studies indicate there is a correlation between prices of biodiesel and prices of soybean grains and soybean oil in the domestic market.

It is expected that during the next 10 years biodiesel demand will practically double (Figure 3.19).

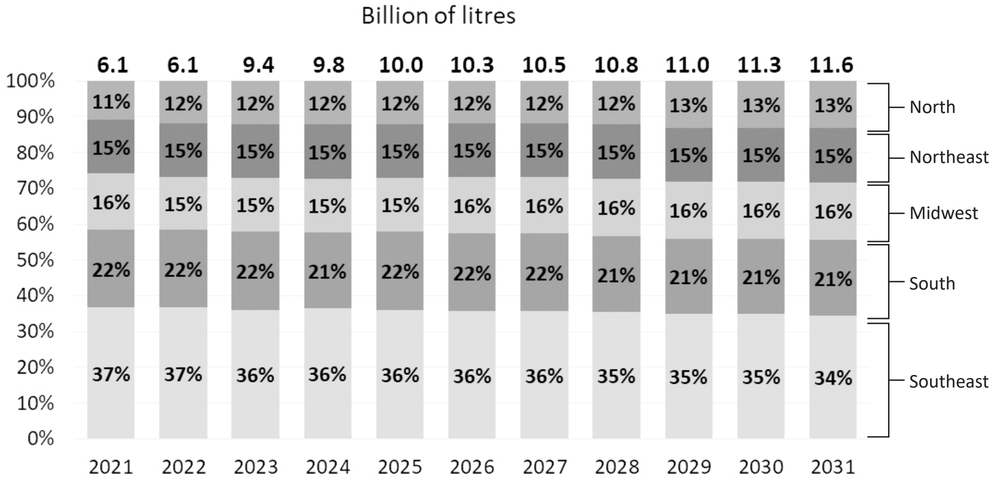

**Figure 3.19** Biodiesel expected demand by Brazil. Source: EPE (2022).

It is also Important to note from the Figure 3.19 above, that there is a certain equilibrium in the production of biodiesel from different regions, although demand is different.

Table 3.5 summarizes the expected biodiesel processing capacity and compulsory consumption for different regions, from 2020 to 2031. Figure 3.20 shows the map where biodiesel plants are located which, as can be appreciated, Mato Grosso has the largest concentration. And Figure 3.21 summarizes blending and the regulatory framework. As can be seen blending increased from 2% in 2005 to an expected 15% in 2023.

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[20] The Kandir Law in Brazil, exempts raw materials such as soybean grains on paying ICMS taxes for exports.

**Table 3.5** Expected biodiesel processing capacity and compulsory consumption for different regions in Brazil from 2020 to 2031. Source: EPE (2022).

| | 2021 | | | 2031 | | |
|---|---|---|---|---|---|---|
| **Region** | **Nominal installed capacity** | **Compulsory consumption** | **Balance** | **Nominal installed capacity** | **Compulsory consumption** | **Balance** |
| North | 320 | 756 | -436 | 932 | 1,525 | –593 |
| Northeast | 880 | 971 | -91 | 1,240 | 1,791 | –551 |
| South | 4,569 | 2,437 | –1,613 | 5,057 | 2,443 | –1,313 |
| Southeast | 824 | 1,413 | 3,156 | 1,130 | 3,978 | 1,079 |
| Central-West | 4,728 | 1,031 | 3,697 | 5,932 | 1,818 | 4,114 |
| Brazil | 11,321 | 6,609 | 4,712 | 14,291 | 11,557 | 2,734 |

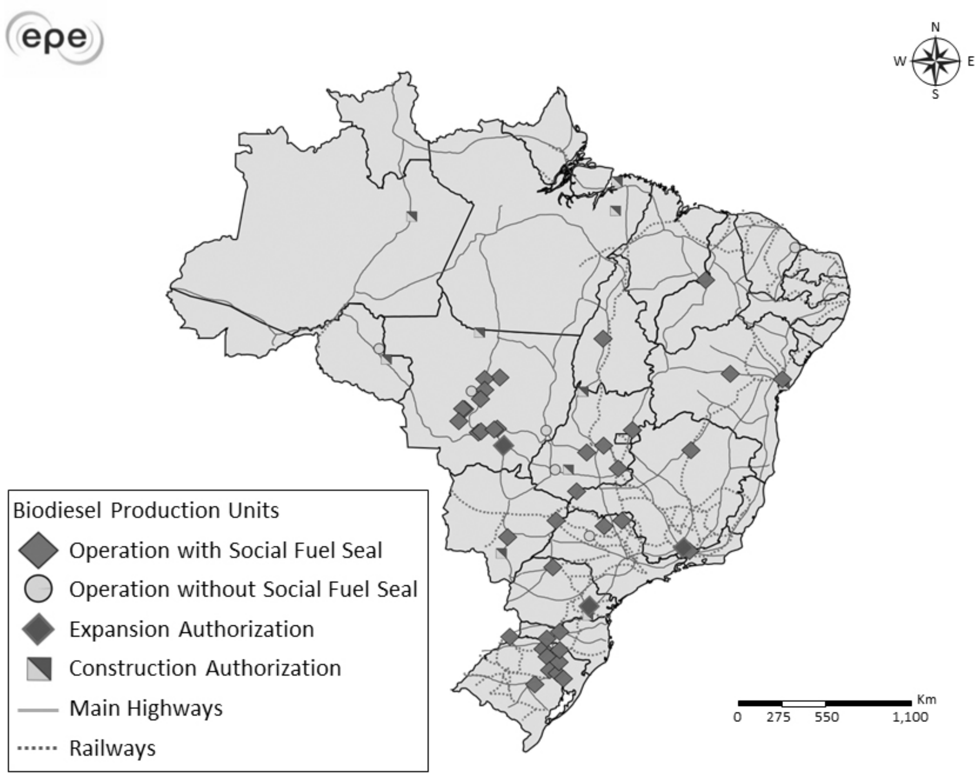
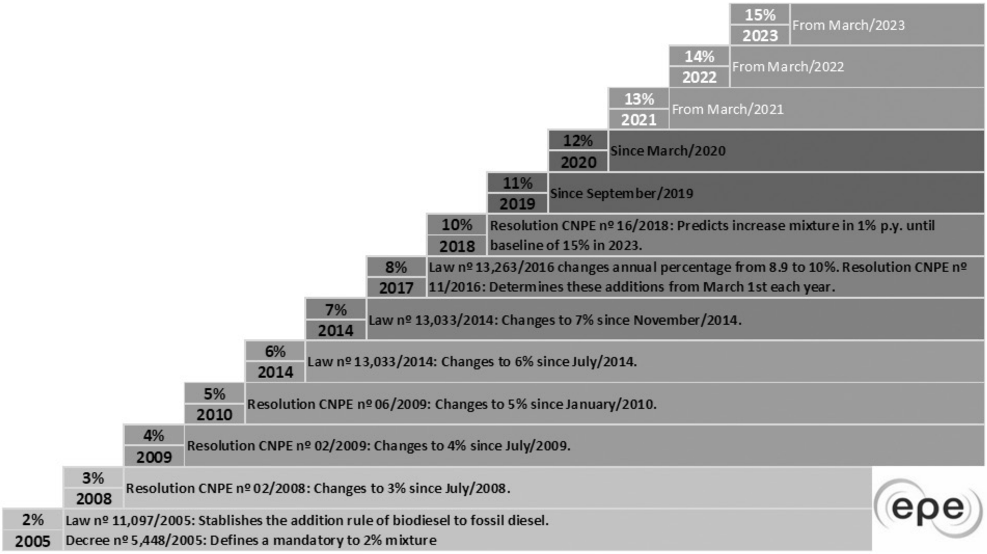


**Figure 3.20** Localization of biodiesel plants and its logistics routes. Source: EPE (2022).

The evolution of biodiesel mandates is given in the figure below.



15% 2023 From March/2023

14% 2022 From March/2022

13% 2021 From March/2021

12% 2020 Since March/2020

11% 2019 Since September/2019

10% 2018 Resolution CNPE nº 16/2018: Predicts increase mixture in 1% p.y. until baseline of 15% in 2023.

8% 2017 Law nº 13,263/2016 changes annual percentage from 8.9 to 10%. Resolution CNPE nº 11/2016: Determines these additions from March 1st each year.

7% 2014 Law nº 13,033/2014: Changes to 7% since November/2014.

6% 2014 Law nº 13,033/2014: Changes to 6% since July/2014.

5% 2010 Resolution CNPE nº 06/2009: Changes to 5% since January/2010.

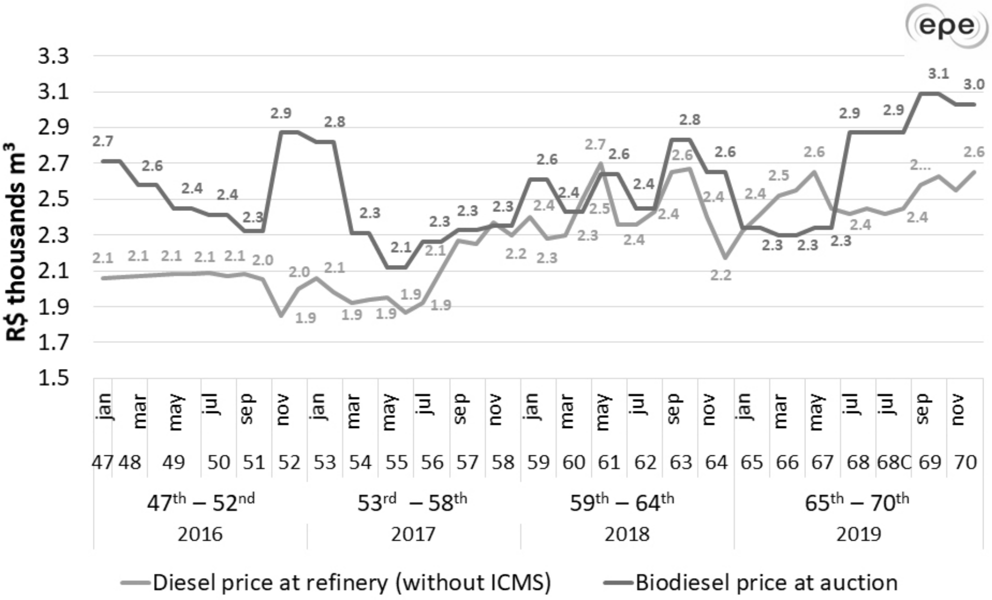
4% 2009 Resolution CNPE nº 02/2009: Changes to 4% since July/2009.

3% 2008 Resolution CNPE nº 02/2008: Changes to 3% since July/2008.

2% 2005 Law nº 11,097/2005: Stablishes the addition rule of biodiesel to fossil diesel. Decree nº 5,448/2005: Defines a mandatory to 2% mixture

Figure 3.21 Evolution of biodiesel regulatory framework in Brazil. Source: EPE (2020).

It is also important to observe biodiesel prices volatility which oscillate significantly, probably in response to soybean prices and its costs, as shown in Fig. 3.22.



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

Figure 3.22 Average prices for biodiesel and diesel in Brazil, without taxes ICMS), from 2016 to 2019. Source: EPE (2020).

## 3.5. CAN EUCALYPTUS BE A FEEDSTOCK FOR BIOFUELS?

Eucalyptus was introduced in Brazil in the mid-20th century. Under Brazilian edaphoclimatic conditions this fast-growing tree adapted very well in the country and contributed to the production of cellulose and multi-use construction wood. Additionally, eucalyptus helped the reduction of unnecessary deforestation caused by charcoal production used in the pig-iron steel industries (ROSILLO-CALLE et al, 1996).

Currently eucalyptus plantations occupy approximately 10 Mha, notably in the states of Minas Gerais, Espírito Santo, Pará, and Bahia. Eucalyptus is a permanent crop with a short production cycle compared to other tree species. After the plant is stablished, the first cut should be anything between 5 to 7 years, depending on its final use. Also, the culture is very adapted to hilly conditions as it happens in Central states and therefore eucalyptus do not compete directly with food crops such as soybeans, corn, or even sugarcane, since they require different type of mechanization. It helps that about 30% of Brazilian territory is hilly and therefore unsuitable for mechanization.

Finally, eucalyptus is more flexible with regards to water requirement. It is much more resilient than other plants when periods of drought occur, as it is happening periodicity in Central Brazil, notably in the last two decades.

As stated before, eucalyptus is also a good candidate for bioelectricity, charcoal, and/or bio-oil production, which are been considered for maritime transport. Brazil should seriously consider the use of eucalyptus to increase the resilience in projects concerning corn ethanol (energy supply), sugarcane ethanol (electricity exports), and production of biofuels for other new markets such as maritime transport.

## 3.6. SOLID URBAN WASTES (SUW) AND ITS POTENTIAL IN BRAZIL

Solid wastes are not the most suitable source for biofuels production, but its use is important for GHG emissions and sustainability criteria. This worldwide abundant feedstock is in fact the result of several wasteful inefficiencies, particularly in large cities of middle income and poor countries. Brazil is not an exception, since nearly 80% of the country population live in urban areas today and urban wastes represents a serious environmental problem.

SUW is beginning to be used in Brazil, particularly for recovering methane produced in landfills e.g., in the Bandeirantes landfill nearby São Paulo where a 20 MW thermoelectric plant was installed for that purpose.[21]

With the objective to regulate this sector, the Brazilian federal government, through IBAMA, approved in 2010, *Law n. 12.305* creating a national policy of solid wastes.[22]

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[21] https://www.infraestruturameioambiente.sp.gov.br/noticias/2004/03/termeletrica-do-aterro-bandeirantes-reduz-emissao-de-co2-para-atmosfera/

[22] https://antigo.mma.gov.br/cidades-sustentaveis/residuos-solidos/politica-nacional-de-residuos-solidos.html

## 3.7. LAND USE OPPORTUNITIES AND BIOFUELS PRODUCTION

At this point we may ask, what land use has to do with biofuels in Brazil given its enormous land mass? What is the possible relationship and implications?

When the Environmental Protection Agency (EPA)[23] of the USA classified biofuels according to their GHG emissions mitigation potential, they stated that Brazilian sugarcane ethanol has the potential to reduce up to 61% GHG emissions when compared to gasoline. This was somewhat 20% lower than expected as calculated by the Brazilian experts. Why this discrepancy? Because EPA introduced a new iLUC concept (or indirect land use change) reducing the mitigation potential.

Direct land use change (LUC) is the direct change impact in the use of land. So, when 1 ha of pasture is replaced by sugarcane, the LUC effect is the GHG emissions accounting of that 1 ha going from pasture to sugarcane. The iLUC is a more sophisticated concept in which it takes also into consideration the possibility of that 1 ha of pasture, reappears when deforestation occurs in the Amazon Forest, for example. So, 1 new ha of sugarcane not only occupies the 1 ha of pastureland, but it also destroys 1 ha of forest, through deforestation. So, both effects LUC and iLUC should be considered when calculating the life cycle of ethanol though sugarcane expansion.

This is, of course, a controversial subject. It is very difficult to establish this direct relationship. Most likely the deforestation process in Brazil has much more to do with other actions and reasons, such as former governmental policies, such as INCRA, to promote land occupation in the agricultural frontiers, promoting the movement of people to occupy new lands, fiscal incentives, illegal exploitations, etc. In other words, sugarcane and biofuels are not responsible for additional deforestation.

Whatever reason, the fact is that many researchers[24] believe in iLUC, and further research needs to be done to clarify this issue, back up by scientific data. With 1.1% of Brazilian territory occupied by sugarcane, the country is number one as sugar producer and exporter, and second as fuel ethanol producer. Ethanol is almost a coproduct of sugar, and it can be said that one benefits the other from the economic and environmental points of view.

The problem is that this nice synergy between sugar-ethanol can no longer adequately reflects increase of ethanol production. There is not a worldwide market for sugar, should ethanol production increase significantly, and hence the parity sugar-ethanol model needs to be changed.

So, the question is, how can fuel ethanol production increase significantly and sustainably from an economic point of view? It seems clear that a new model is therefore needed.

There are two possibilities: 2nd G ethanol or corn ethanol. 2nd G ethanol from sugarcane is expected to mitigate 81% of GHG emissions. Corn ethanol produced in Brazil

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[23] http://www.ethanolproducer.com/articles/15755/increasing-the-role-of-advanced-biofuels-in-the-us

[24] https://en.wikipedia.org/wiki/Indirect_land_use_change_impacts_of_biofuels

can offer different opportunities. Both possibilities are feasible, and one complements the other. Both represent a change of existing model and should be encouraged.

This is, of course, good news. However, we need to move faster and look for different production models, such as the American model, to produce ethanol and beef. The US corn ethanol has a relatively bad reputation as it has lower productivity when compared with sugarcane ethanol[25] and also, much lower GHG emissions mitigation potential than sugarcane.[26]

The USA has developed a very solid system for producing ethanol from corn while using its main by-products DDG or WDG.[27] Both, the high protein DDG and WDG, can be used as animal feed, typically cattle. This system is efficient because it allows a significant lower use of land than natural extensive pasture.

About 25 years ago, Brazil was a good example for producing beef in grazing and natural pastureland because the world was seriously affected by the mad cow decease. However, this situation has changed, particularly in the last 15 years, when Brazilian sugarcane ethanol was also criticized because of the iLUC effect.

Brazil dedicates around 20% of its 850-855 Mha to pastureland, with an average animal density of about 1 animal/ha. However, it can vary from anything below 0.5 to 3 or 4 animals/ha. Pastureland supporting capacity depends very much on several factors such as how cattle and land is managed,[28] quality of land and rainfall, etc., but it can certainly be improved.

Therefore, if the animal density is raised from 1 to 2 animals/ha, then a significant amount of land (nearly 100 Mha) could become idle/spared. This increase in animal density could be accomplished by implementing actions, such as:

- Creating a national and effective policy on *Land Use Reform*, to encourage better land occupation while protecting ecological sanctuaries such as the Amazon Forest and Pantanal.
- Introducing corn ethanol in combination with cattle integration, particularly in areas and states where pastureland is presently occupied with low animal density.

A high priority should be given to the southern border of the Amazon region, the Pantanal, and few other regions with more intensive cattle production. Those are endangered regions and should be prioritized and protected.

Cattle-ranching is still a highly extensive activity in Brazil with relatively small percentage of intensive farms e.g., approximately 5%. What is proposed here is not

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[25] Sugarcane ethanol produces around 7,000 litres/ha/yr and corn ethanol around 4,000 litres/ha/yr

[26] Corn ethanol typically uses natural gas as a source of energy and sugarcane ethanol uses sugarcane bagasse. This difference explains the between life cycle of sugarcane ethanol.

[27] In the USA there are two methods to produce corn ethanol, the dry method that generates the Dry Distillers Grains – DDG and the wet method that generates the Wet Distillers Grains – WDG.

[28] Pastureland support capacity certainly depends on climatic conditions which may vary seasonally.

necessary to go from extensive to highly intensive cattle production. What is proposed is to go from highly extensive to semi-intensive cattle production as a mechanism to free land for other uses, including the regeneration of the native forests.

This *Land Use Reform* could result in the following benefits:

- Help to protect endangered ecological sanctuaries
- Allowing more sustainable agriculture to expand to pastureland
- Increase cattle production sustainably
- Increase biofuels production in combination with food and avoiding any iLUC effect.

There are still few important questions, requiring answers e.g.,

- How to adapt existing cattle breeds to a more intensive production?
- What is the DDG/WDG "shrinking" land capacity?
- What would be the new corn ethanol life cycle under these new conditions?

## 3.8. IMPACTS: AGRICULTURE, SOCIAL, AND ENVIRONMENT

The initial objective to produce biofuels locally to enhance energy security in Brazil has been fully accomplished. Now, the intention is to expand biofuels production to contribute to enhance sustainable development.

As far as GHG emissions, Brazil has a peculiar situation. Most of its emissions are non-energy related, as it happens in most of large economies, and relate either to land-use and forestry or agriculture. Energy is responsible for about 1/5 of the country total GHG emissions. So, the first conclusion derived from these data is that, if something is to be done to reduce GHG emissions, the focus should be first on land-use and forestry, and secondly in agriculture and then energy (see Table below).

**Table 3.6** Brazil´s emissions in 2019 and 2020 (tCO2e – GWP-AR5). Source: SEEG (2021).

| Sector | 2019 | % | 2020 | % |
|---|---|---|---|---|
| Agriculture | 562,987,702 | 29% | 577,022,998 | 27% |
| Energy | 412,466,747 | 21% | 393,705,260 | 18% |
| Industrial processes | 99,472,616 | 5% | 99,964,389 | 5% |
| Waste | 90,399,714 | 5% | 92,047,812 | 4% |
| Land-use change and forestry | 806,996,124 | 41% | 997,923,296 | 46% |
| Total gross emissions | 1,972,322,903 | | 2,160,663,755 | |
| Total net emissions | 1,336,613,309 | | 1,524,954,161 | |

When examining Fig. 3. 23 below, it is important to recognize that significant reductions can be observed on land-use and forestry between 2003 and 2009, probably because of economic development downturn during that period.

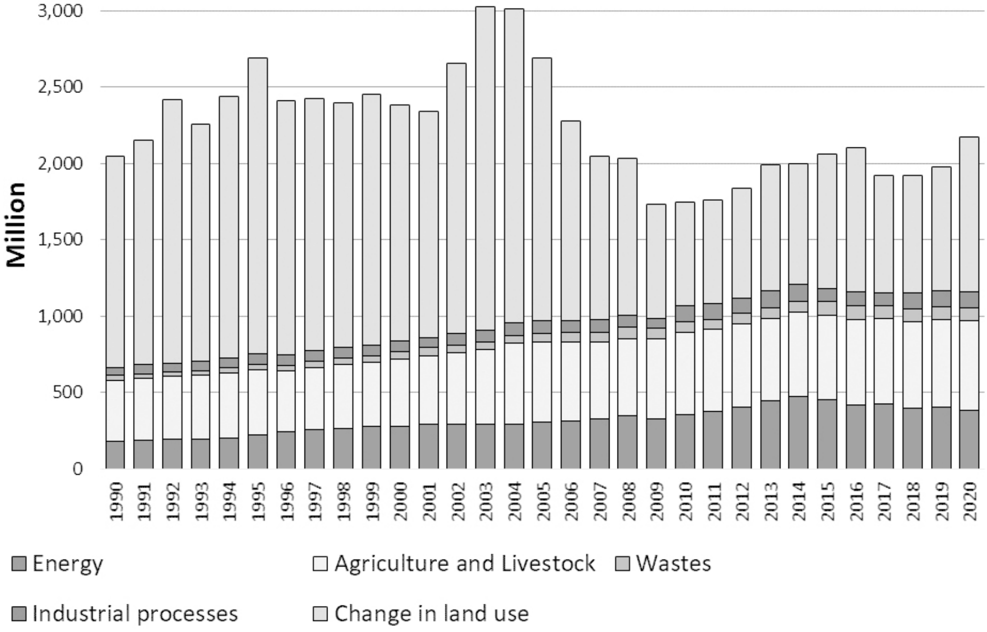

**Figure 3.23** GHG emissions in Brazil from 1990 to 2020 ($GtCO_2e$). Source: SEEG (2021).

However, in recent years, due to the economic and political crises, there was a deterioration in controlling deforestation. Also, because the Federal Government has relaxed deforestation control.

## 3.9. BIOFUELS TECHNOLOGICAL INNOVATION FROM AGRICULTURE, PROCESSING TO FINAL USE

Innovation on biofuels needs to be understood as a series of R&D&I actions from agriculture to processing and final use (engines). As mentioned in the "lessons from biofuels" section, to accomplish an overall high efficiency, biofuels need to constantly pursue improvements in agriculture, processing, and final use, at the same time.

Throughout the implementation of Brazilian biofuel programs, both PROALCOOL and PROBIODIESEL, there was a constant preoccupation with technological innovation. Both programs also benefited from R&DD policies created during the 1990s when the energy agencies, ANP for petroleum and gas, and ANEEL for electricity, were created. With the setup of ANP,[29] which today also involves biofuels, and

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[29] Agência Nacional do Petróleo, Gás Natural e Biocombustíveis -ANP (National Petroleum Agency).

ANEEL[30] specific taxes were directed to promote technological innovation ranging from new processes to greater operational and energy efficiency.

### 3.9.1. INNOVATION IN AGRICULTURE

A considerable effort has been devoted to improving existing cane variety programs e.g., PLANALSUCAR, IAC, and COPERSUCAR. PLANALSUCAR, today RIDESA, was a program aimed to produce better varieties considering different edaphoclimatic conditions present in different areas of Brazil. It can be said that it is the most efficient national programs. The IAC is a State of São Paulo program to develop new and improve varieties, focusing on Southeast conditions. COPERSUCAR, today Centre of Sugarcane Technology (CTC), is a private program producing varieties for its cooperative members. It can be stated that there is a good complementarity between these three programs which have been quite successful in improving productivity for sugarcane (GAZZAFFI et al, 2010).

When PROALCOOL started in 1975, there was a huge concern with the problem posed by large volumes of vinasse. This limitation was first considered as a considerable obstacle to large-scale ethanol production from sugarcane. However, here was an important innovation on potassium-rich vinasse disposal as fertilizer thanks to scientific research and collaboration between the private sector and universities (MUTTON et al., 2010). Although it should be added that vinasse disposal still requires more attention. It is a high-volume residue from fermented sugarcane juice disposed in different ways among sugarcane ethanol producing countries, e.g., India and Colombia. Currently considerable progress has been achieved with vinasse biodigestion, as it will be discussed further bellow. A law was promulgated by the Secretary of Environment of the State of São Paulo, José Goldemberg, early this century, to promote green sugarcane harvesting in São Paulo State. This law allowed sugarcane growers a transition period of various years to replace burning to non-burning harvesting (green harvesting), so that the necessary investments, adjustments, and implementation, etc., could be made.

After the introduction of sugarcane mechanical harvesting there was some stagnation in productivity probably due to two phenomena: harvesting equipment, machinery, and trucks, were much too heavy and less precise cutting than manual labour, as already discussed. The long-term effect, associated with adverse climatic conditions, and lack of adequate investment particularly on fertilizers, has resulted in sugarcane productivity stagnating in the last 20 years in the country.

A positive impact of the non-burning law was an environmental improvement in the rural e areas e.g., improved air quality during the winter months. Heavy machinery also caused soil compaction and sugarcane root system bruising and more dirt to the mills. Naturally, another benefit was the resulting straw which increased the quantity of recoverable fibres but also worsen the cane cleaning process at the mill. From the

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[30] Agência Nacional de Energia Elétrica – ANEEL (National Agency of Electric Energy)

agronomic and industrial points of view, the introduction of machinery resulted in the deterioration of cane quality and increased costs.

The introduction of cane harvesting machinery, with corresponding need to improve harvesting synchronism and organization, favoured the introduction of information technologies. Nowadays the sugarcane sector uses IT allowing feedstock cost reduction and more effective and sustainable production monitoring.

There were also other improvements i.e., cane planting. Traditionally cane stalks were planted manually, which was substituted by "Plene", a technology developed by Syngenta to modernize cane planting. Another company, EACEA, also revolutionized sugarcane planting by producing-Sprouted Seedlings (MPB) in high-tech agricultural greenhouses installed next to ethanol distilleries. With operational costs mitigated through the recovery of tailings and $CO_2$ from the distillery, the high-quality seedlings cut prices compared to traditional planting, in a market estimated to be worth 7 billion reais (nearly US$ 1.3 billion). The sugarcane planting model through MPB changed 300 years of planting practices, by freeing up millions of tons of cane to produce sugar or ethanol, and even allowing for the immediate introduction of new, more productive, and more resistant varieties to climatic rigors and losses from diseases and pests. Figure 3.24 shows sugarcane seedlings grow in greenhouses.

**Figure 3.24** Sugarcane seedlings been grown in greenhouses as part of new planting systems. Source: image provided by Andrés da Silva (EACEA).

## 3.9.2. INNOVATION IN PROCESSING

An area which received special attention, notably after the 2002 energy crisis, was bioelectricity from sugarcane. The sugarcane sector was requested to contribute to the national effort to diversify energy sources, too dependent on hydro power. An important study was carried out by Sousa and Macedo (2010) to assess the potential contribution of sugarcane bioelectricity. A more recent study was carried out by Leal (2020) on sugarcane renewable electricity, including sugarcane straw and other possibilities. The project estimated that sugarcane primary energy is approximately 600 GJ/ha (nearly 2/3 is fibre) or nearly 100 barrels of oil.[31] So, in theory, annual fibre production from sugarcane represents nearly 1.8 million barrels/day.[32] Therefore, substantial surplus bioelectricity could be produced by the mills, particularly with higher prices if so required. Improvements in energy efficiency could result in even greater optimization of resources e.g., in boiler efficiency.

In the processing area, there is also a constant improvement such as equipment, processes, and practices. Besides improvements to allow greater electricity surplus, there was an also increasing concern to improve sustainability indicators. Significant achievements were obtained particularly on by-products production and applications, such as the DEDINI "zero effluents" concept (OLIVÉRIO, 2014). This concept allowed the development of several new products using just by-products.

Important breakthroughs have also been made on 2G ethanol production in the last 15 years. Progresses have been both in the scientific and entrepreneurial areas. For example, various research centres have been created e.g., Embrapa Agroenergia in 2006, and CTBE, today LNBR in 2010, and dedicated specific research programs such as FAPESP/Bioen in 2008.

In addition, BNDES created in 2011, PAISS[33] innovation program to encourage 2G ethanol plants. As a result, several projects and partnerships have been set up. For example, GRANBIO started operation of its Bioflex plant in 2014 in Alagoas, with a capacity of 84 million litres/year of 2nd G sugarcane ethanol. Today it produces around 30 million litres/year. RAÍZEN from Shell/COSAN, in Piracicaba, produces 41 million litres/year.[34] The new RAÍZEN G2 ethanol plant, due to start operation in 2023, will produce 82 million litres/year. According to these sources, together GRANBIO and RAÍZEN will produce around 150 million litres in 2023.

More recently, biogas production from vinasse biodigestion has received additional incentives. Vinasse application as fertilizer liberates methane. To avoid this unnecessary methane emissions, vinasse can be biodigested and its resulting methane use to produce electricity reducing its atmospheric impact and still making possible effluent use as fertilizer and reduce costs.

All these accumulated improvements on sugarcane agriculture and processing, led to a "learning curve" already mentioned in Chapter 2. This learning process brought cost reduction and improvement in sustainability indexes, making sugarcane ethanol more competitive with gasoline (GOLDEMBERG, 2004).

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[31] Primary energy of 1 barrel of crude oil is approximately 6.1 GJ.

[32] Estimated using MME (2021) data.

[33] https://www.bndes.gov.br/wps/portal/site/home/imprensa/noticias/conteudo/20130912_raizen

[34] https://www.energiaquefalacomvoce.com.br/2021/06/30/fns-brasil-se-prepara-para-ofertar-150-milhoes-de-litros-anuais-de-etanol-2g-e-a-maioria-ja-esta-vendida/

## FINAL REMARKS

Several energy crises have affected Brazil in the last 100 years with important economic and political impact. Typically, all energy crises reflected higher oil or electricity prices. These increases in energy prices somehow created the political will and the economic conditions to encourage RE, in particular biofuels. Since biofuels, typically need either subsidies or a well-structured economics, the raise of oil prices accomplished this task.

The present situation of renewable energies, in particular biofuels (ethanol and biodiesel) in Brazil, is benefiting from present high cost in oil prices, in a moment when the world the economic situation is worrying. Other factors such as climate change, the raise of China, and now the pandemics and the Russian war on Ukraine, are major new challenges for biofuels.

Brazil has been the subject of world attention particularly when it comes to the Amazon Forest. The deforestation of tropical forests affects both climate and global warming, and Brazil is considered the most important emitter of GHG emissions from deforestation. In the last two decades sugarcane ethanol and its iLUC was blamed for deforestation when in fact the culprit has been extensive cattle-ranching and soybean expansion. On the other hand, sugarcane ethanol currently faces a considerable challenge because of a combination of difficulties, including:

- Expanding production. In the present model sugarcane ethanol is only viable if its economics is compensated and supplemented with sugar sales
- Electric mobility. This option has been presented as a "clean" solution, although the main issue is how much sustainable electricity is going to be generated.
- Domestic difficulties associated with relatively low engine efficiencies. Flex-fuel engines are no longer adequately satisfying consumer needs.

As biofuels in Brazil do contribute significantly to mitigate GHG emissions, it is imperative to discuss new production models to satisfy the present needs, and to connect these modern biofuels with modified improved engines. These solutions require mid and long-term policies involving not only Brazil but also private enterprises and international cooperation.

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