WORLD BIOENERGY ASSOCIATION

May 2025

WBA White Paper

BRAZIL: POWERING THE TRANSITION THROUGH BIOENERGY LEADERSHIP

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The World Bioenergy Association is the global organization dedicated to **supporting the wide range of actors in the bioenergy sector**. Our mission is the **sustainable** development of **bioenergy** globally. Our members include national and regional associations as well as companies in the entire biomass to energy value chain including equipment manufacturers, fuel producers, traders, CHP facilities, utilities etc. from more than 40 countries.

Fields of Action:

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Our members:

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WBA White Paper

White papers from the World Bioenergy Association (WBA) offer a comprehensive overview of the bioenergy sector in a specific country or region. It encompasses the latest data on bioenergy development, policy frameworks, financing trends, and insightful case studies.

These papers go beyond conventional reports by adopting a commentary format, presenting a nuanced qualitative analysis coupled with the first-hand experiences of WBA within the respective countries of study. This approach aims to provide a deeper understanding of the unique challenges, successes, and opportunities in each context. It offers a rich perspective that goes beyond mere data points to capture the essence of bioenergy development in different global landscapes.

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Acknowledgements

The World Bioenergy Association would like to gratefully acknowledge the contributions of Atvos, as well as the following individuals, whose insights and support were invaluable in the development of this white paper:

- Prof. Luiz Augusto Horta Nogueira – Federal University of Itajubá (UNIFEI) and FAPESP Bioenergy Research Program (BIOEN)
- Prof. Glaucia Mendes Souza – University of São Paulo (USP) and FAPESP Bioenergy Research Program (BIOEN)
- Walter Maccheroni Junior – São Martinho

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Executive Summary

Brazil's approach to bioenergy has been shaped by a combination of natural resources, longstanding public policies, and sustained political support for energy security and economic development. Over the past decades, bioenergy has become a central part of Brazil's energy matrix, contributing not only to domestic supply but also to broader climate and sustainability goals.

Today, Brazil is one of the largest producers and consumers of biofuels globally, with a diversified portfolio that includes ethanol, biodiesel, bioelectricity, biogas, and emerging low-carbon fuels. Continued investment in bioenergy is viewed as critical to meeting national emissions targets, advancing the energy transition, and supporting rural economic development.

In 2024, several key trends and milestones were observed:

- **Ethanol:** Record production of 37.3 billion liters, with 29.7 billion liters from sugarcane and 7.7 billion liters from corn. Net exports totaled 1.7 billion liters.
- **Bioelectricity:** Bagasse accounted for 74.5% of biomass energy to the grid. Sugarcane plants supplied 2.4 GW on average, a 14% increase from 2022.
- **Fuel Markets:** Hydrous ethanol remained price competitive, with consumption rising 30% and gasoline demand falling 5%.
- **Biodiesel:** Blend mandate increased to 14% (B14). Production grew 21% to 9.1 billion liters, mainly from soybean oil.
- **Emissions Reduction:** Use of biofuels and bioelectricity avoided 85.6 $MtCO_2eq$ in 2023.
- **Biogas and Biomethane:** Installed capacity reached 131 MW. Biomethane production rose to 81.5 million m^3 in 2024.
- **Emerging Fuels:** Development of renewable diesel (HVO), sustainable aviation fuels (SAF), and hydrogen initiatives.
- **Fuel of the Future Law:** New blending targets set for ethanol and biodiesel, aiming for 705 $MtCO_2eq$ avoided by 2037 and R$ 260 billion (45.7 billion USD) in investments.

This white paper presents an overview of Brazil's bioenergy sector in recent years, highlighting key production figures, market trends, policy developments, and real case studies. It draws from sectoral data and insights from the World Bioenergy Association's experience in the country to provide an up-to-date assessment of Brazil's progress and prospects.


Source: Atvos

1. Introduction

Brazil has long been recognized as an emerging economic power, owing to its large population, abundant natural resources, and vast land area. In 2023, the GDP in Brazil totaled R$10.9 trillion (1.89 trillion USD) and increased by 2.9% compared to 2022[1]. Generations of political will have brought policy frameworks, reforms, and national development programs that support sectors like food and agriculture, and renewable energy, among others[2].

To meet its growing energy needs, bioenergy has become Brazil's most promising solution. By 2023, total energy consumption had surged by 169% compared to 2000, with industrial energy consumption increasing 1.5 times and transportation energy use doubling over the past two decades[3]. In response to this rapid growth, Brazil's biofuel production has doubled since 2000, now accounting for 33% of the country's total energy supply[4].

Since 1931, Brazil has mandated ethanol gasoline blending with good results. After the 1970s, it launched broader initiatives in bioenergy aimed at securing the domestic energy supply by leveraging its geographical advantages and thriving agricultural sector[5]. While reducing external energy dependence is still one of the country's primary goals, Brazil now faces the challenge of balancing industrial growth with its national climate objectives. With a well-established biofuel infrastructure, Brazil remains a global leader in bioenergy, positioning biofuel production as a key driver of future economic and environmental progress.

After officially joining the Paris Agreement in 2015, Brazil submitted its first Nationally Determined Contributions (NDCs), pledging to reduce domestic emissions by 37% by 2025 and 43% by 2030, both relative to 2005 levels[6]. In 2024, Brazil's second Nationally Determined Contribution (NDC) outlines the country's commitment to reducing net greenhouse gas emissions by 59% to 67% by 2035, relative to 2005 levels. In absolute terms, this target translates to a reduction of 850 million to 1.05 billion tons of carbon dioxide equivalent by 2035.

To align its national policies with its climate commitments, Brazil has made significant efforts in bioenergy development to achieve its energy transition goals. In 2024, Brazil promulgated the Fuel of the Future bill that aims to decarbonize the transport matrix by promoting the use of sustainable and low-carbon-intensity fuels, where liquid biofuels are a great part of the mix[7].

This white paper explores the opportunities and challenges of Brazil's bioenergy development from multiple perspectives. It examines the current bioenergy landscape, agricultural resources, policy frameworks, and financial mechanisms. In addition, it presents case studies and insights from WBA's own experience in the country to provide a comprehensive industry perspective on Brazil's bioenergy growth, offering an in-depth analysis of the country's overall bioenergy development.

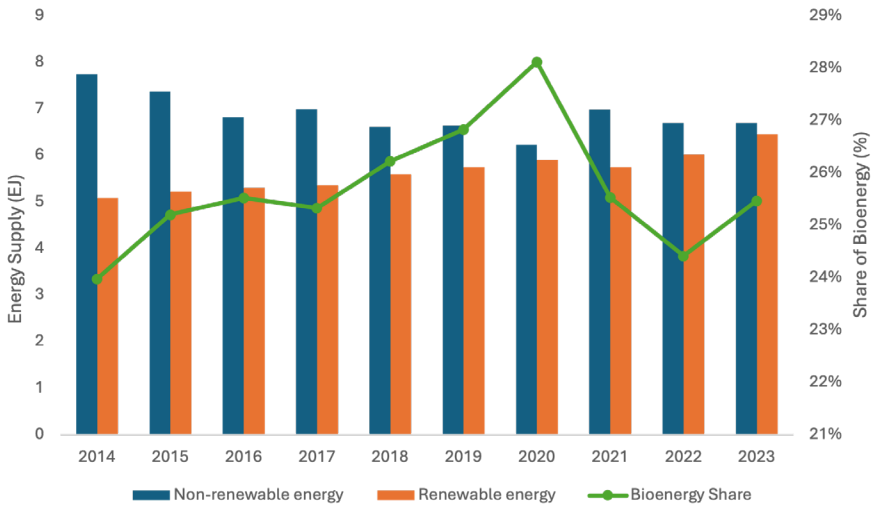

Source: Canva

2. Brazilian Energy Mix

2.1 Suply

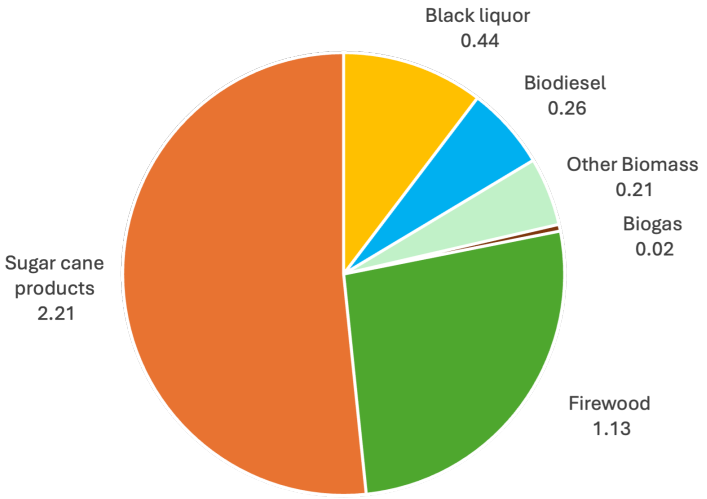
In 2023, Brazil reached 13 EJ of domestic energy supply, a slight increase from the previous year[8]. Non-renewable sources like oil products, coal, and gas have slowly decreased by 14% in the last decade. The same year, their share was 50.9%, with oil and oil products making up 35% of the total energy supply. Renewable energy sources accounted for 49% of total energy supply, a 2% rise compared to 2022. Sugarcane biomass remained the largest renewable source, making up 17% of the total supply. Other bioenergy sources, such as black liquor, biodiesel, and biogas, contributed an additional 7.2%, with black liquor being the most significant among them[9].

Figure 1 **Total Energy Supply in Brazil.**
Source: Ministry of Mines and Energy (Brazil), 2024



In Brazil, solid biomass is the primary source of bioenergy, supplying about 3.76 EJ, or 75% of the total bioenergy use. A significant portion of this energy comes from sugar cane by-products, primarily bagasse, which powers the electricity and ethanol sectors. Residential energy consumption of solid biomass, mainly firewood, accounts for roughly 0.31 EJ. Liquid biofuels, such as biodiesel, represent the other 25% of bioenergy utilization. Biogas contributes modestly, adding about 0.02 EJ to the overall bioenergy landscape[10].

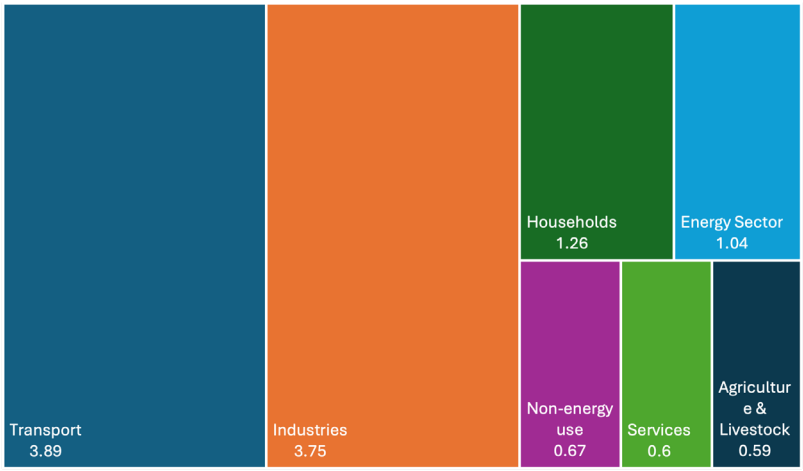
Figure 2 **Energy Supply with Biomass in Brazil (2023).**
Source: Ministry of Mines and Energy (Brazil), 2024



2.2 Consumption

Brazil's total energy consumption increased by 4% from 2022 levels, reaching 11.8 EJ in 2023. Transport (cargo and passenger transport) and industrial sectors were the largest consumers, contributing 33% and 31.8% respectively[11]. By source, oil products are still the biggest source (39%), followed by electricity (19%), diesel oil (17%), and sugarcane bagasse (12%)[12].

Figure 3 **Brazilian Energy Consumption by Sector in EJ (2023).**
Source: Ministry of Mines and Energy (Brazil), 2024



In the transport sector, renewables made up just 22.5% of energy use in 2023. Oil, diesel, and gasoline continued to dominate. Biodiesel, accounting for only 5.2% of transportation energy, saw a notable 19.2% rise compared to 2022[13]. Ethanol consumption also grew by 6.3%, reaching 17.3%. Notably, in 2023, the biodiesel blending mandate with fossil diesel was set at 12% (B12) starting in April 2023.

The industrial sector consumed 3 EJ, with almost two-thirds of its energy coming from renewable sources. Sugarcane bagasse holds the largest share in the energy sector, accounting for 22.4%. In comparison, black liquor dropped to 8.7%, reflecting a 2.8% decline caused by a reduction in cellulose production[14].

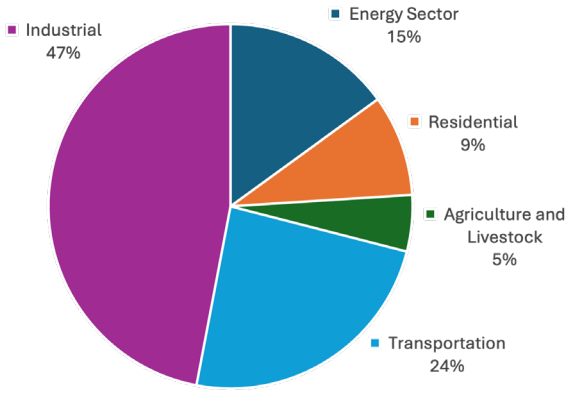
Biomass consumption by sector

In 2023, Brazil achieved a remarkable milestone, with renewables constituting nearly 51% of its final energy consumption across all sectors. Bioenergy plays a critical role in this landscape, contributing 31% of the total energy consumption, equivalent to 3.66 EJ[15]. The industrial sector dominates bioenergy use, accounting for nearly half of the total bioenergy consumption. Within this sector, the food and beverage industry stands out as the largest consumer (0.95 EJ), followed by the paper and pulp (0.44 EJ) and iron and steel (0.15 EJ) industries. Transportation and the energy sector also make significant contributions, with bioenergy consumption at 0.88 EJ and 0.55 EJ, respectively.

Table 1 **Bioenergy Consumption by Sector in Brazil (2023).**
Source: Ministry of Mines and Energy (Brazil), 2024

Source	Energy (EJ)
Total	**3.66**
Energy Sector	0.55
Transportation	0.88
Residential	0.33
Agriculture and Livestock	0.18
Industrial	1.72
▪ Iron and steel	0.15
▪ Foods and beverages	0.95
▪ Paper and Pulp	0.44
▪ Ceramics	0.07
▪ Others	0.07

Figure 4 **Bioenergy Consumption by Sector in Brazil (2023).**
Source: Ministry of Mines and Energy (Brazil), 2024



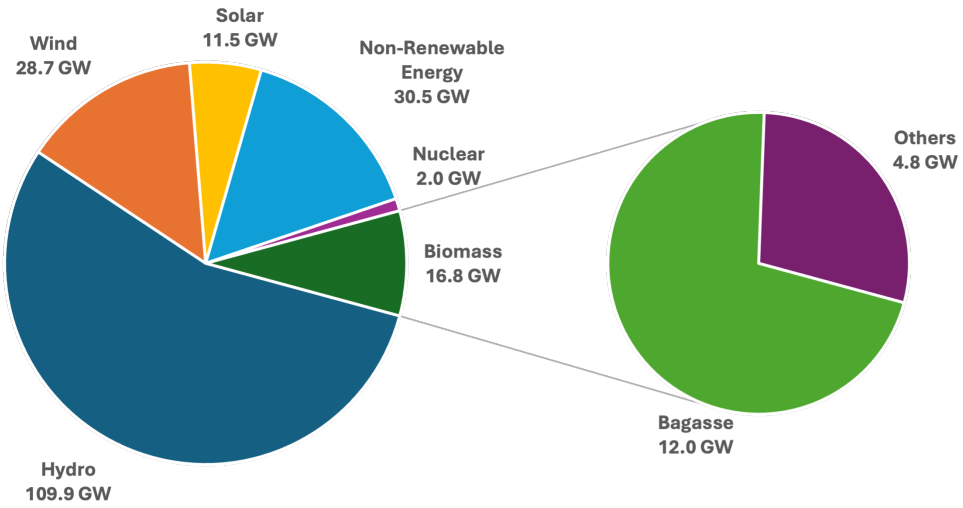
2.3. Installed Electricity Capacity and Generation

Brazil's installed electricity capacity was nearly 209 GW in 2024 with renewable energy holding a share of 85% of the total[16]. Among all the energy sources, biomass ranks fourth, making up 8.4% of installed capacity. Hydropower was the largest renewable source, representing 55% of the total share, followed by wind (15%) and solar (6%)[17]. By 2024, the installed capacity of bioenergy reached its peak, with a net increase of 322 MW compared to 2023 levels, reaching a total of 17.81 GW[18].

There were 637 active biomass-powered projects across Brazil in 2023[19]. Out of these, 422 plants used sugarcane bagasse as their primary fuel source, collectively producing 12 GW of power. Another 76 facilities utilized forestry residues, contributing 0.8 GW. Biogas systems generated 0.2 GW, while 22 plants harnessed black liquor, a waste product from the pulp and paper sector, to generate 3 GW, making it the second-largest contributor among biomass sources[20].

The Brazilian electricity mix has been predominantly run by renewables (89% in 2023). Electricity generation reached 708.1 TWh, with hydropower accounting for 60% (426 TWh), wind power for 14% (96 TWh), and biomass for 8% (58 TWh). Bioelectricity, mainly composed of sugarcane bagasse (63.3%) and black liquor (26.1%) in 2023, maintained an 8.2% share in electricity generation. 57.8 TWh of bioelectricity was generated in 2023[21].

Figure 5 **Installed Capacity by Source (2023).**
Source: Ministry of Mines and Energy (Brazil), 2024




Source: Canva

3. Bioenergy Supply

Brazil, the world's largest sugarcane producer, has long prioritized agricultural development as a cornerstone of its economy. Brazil's agriculture sector demonstrates significant potential as a bioenergy feedstock provider, with 1.07 billion tons of biomass produced across 91.5 million hectares, covering nearly 10% of the country's land area[22]

Soybeans represented the largest share of the harvested area (44.69%), followed by maize (22.99%) and sugarcane (10.78%). However, in terms of production volume, sugarcane dominated, contributing 67.36% of the total production, while soybeans and maize accounted for 11.26% and 10.14%, respectively[23].

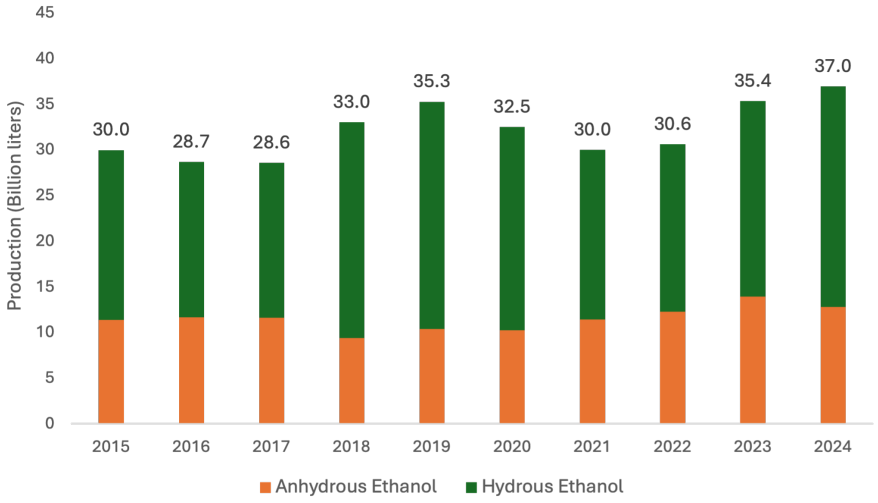
Geographically, the Southeast and Central-West regions emerged as key areas for bioenergy feedstock production. São Paulo alone contributed 56.10% of Brazil's sugarcane output, with the Southeast region producing 67.35%, followed by the Central-West at 19%[24]. The Central-West also led in corn and soybean production, providing 59% of Brazil's corn and 50% of its soybeans[25]. Mato Grosso was particularly dominant, accounting for 38% of Brazil's corn and 29% of its soybeans. The South region ranked second in both crops, producing 19% of the corn and 24% of the soybeans, with Paraná leading in production[26].

3.1 Ethanol

Brazil is the world's second-largest producer of ethanol, after the United States, with sugarcane and corn as the main feedstocks[27]. In Brazil, ethanol is sold as either pure ethanol fuel (**hydrous ethanol**), which can be used directly in E100 vehicles and flex-fuel vehicles, or blended with gasoline (**anhydrous ethanol**), which is typically blended with gasoline to create E20 to E27 fuel. Compared to hydrous ethanol, the production of anhydrous ethanol requires more energy due to the dehydration process[28].

In 2024, Brazil's ethanol production totaled approximately 37 billion liters, with hydrous ethanol accounting for about 65% and anhydrous ethanol making up the rest[29]. This marked a new peak after COVID-19 production levels.

Figure 6 **Ethanol Production in Brazil.**
Source: ANP, 2024



In terms of geographical distribution, the Southeast region of Brazil has the highest potential for ethanol production, accounting for more than 45% of the national total, with 17 billion liters produced in 2024[30]. Following this trend, the Central-West region produced 16 billion liters (41.5% of total production). The Central-West was the largest producer of hydrous ethanol, accounting for almost 48% of production across all federal states[31].

Feedstock Contribution

The Brazilian ethanol industry has a varied feedstock pool. Sugarcane and corn are the major players in ethanol production. In 2024, sugarcane (by molasses from sugar production and direct sugarcane juice) accounted for more than 90% of the total, followed by corn, with around 15% of Brazil's total ethanol production. Bagasse, a by-product of sugarcane processing, is also used to produce cellulosic ethanol - also known as second-generation sugarcane ethanol – which continues to be mostly export-oriented to countries where strong policy support exists for fuels of its nature[32].

Table 2 **Feedstock for Ethanol production in Brazil.**

Feedstock	Production (Billion Liters)	Ethanol production share	Variation compared to 2022	Key Facts
Sugarcane	31.2[33]	51% [34]	Up 11%	Primary feedstock, co-generated electricity from bagasse and straw
Corn	6[35]	10%[36]	Up 40%[37]	Corn ethanol second cropping in Brazil uses just 0.5% of farmland and under 0.15% of total land[38].
Cellulosic biomass[39]	0.032	-	Down 40%	Despite the drop, it continues to attract interest due to its significantly lower carbon footprint, emitting 30% less carbon than traditional sugarcane ethanol[40].

Source: Canva

Key Industry Updates

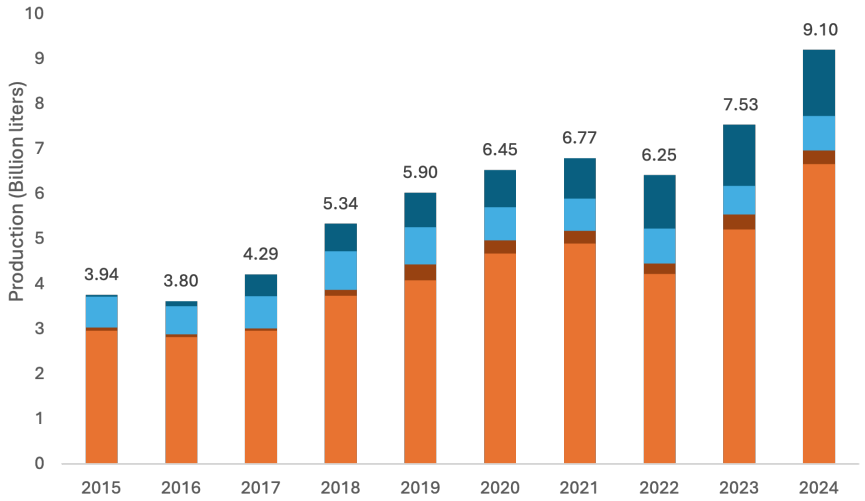
- As of July 2024, 356 sugarcane plants are operational in Brazil, of which 224 produce both sugar and ethanol, 13 focus on sugar production, and 112 are ethanol-only plants[41].
- In addition to ethanol production, bagasse, a by-product of sugarcane processing, is primarily used for electricity co-generation to power mills. In 2023, bagasse consumption accounted for approximately 22% of the industry's energy generation, making it the second-largest energy source after electricity[42].
- As of July 2024, there were 22 corn ethanol plants in Brazil, with a combined installed capacity of 7.22 billion liters/year[43]. Currently, nine additional corn ethanol plants are under construction, and 11 plants have already been commissioned.
- Brazil aims to boost its corn ethanol production to nearly 14 billion liters over the next eight years, more than doubling present levels, contingent on the completion of all planned projects[44].
- Raízen remains Brazil's only large-scale cellulosic ethanol producer, with a current production capacity of 164 million liters annually. The company is actively expanding its operations, planning to launch four new plants soon and aiming to operate 20 cellulosic ethanol facilities by 2031, with a combined annual capacity of 1.6 billion liters[45].

3.2 Biodiesel

In 2024, Brazil produced 9.1 billion liters of biodiesel, a 21% increase from the previous year and more than doubling since 2017[46]. Soybean oil remains the main feedstock for biodiesel production, contributing to more than 70% of the total production, and the remaining comes from greasy material (e.g., animal fat, used cooking oil, palm oil, etc.).

The leading biodiesel-producing regions were the South and Midwest, accounting for 42% and 40%, respectively. Mato Grosso and Rio Grande do Sul were the largest producing states, together contributing to more than 40% of all national production[47].

Figure 7 **Total biodiesel production by feedstock in Brazil.**
Source: ANP, 2024

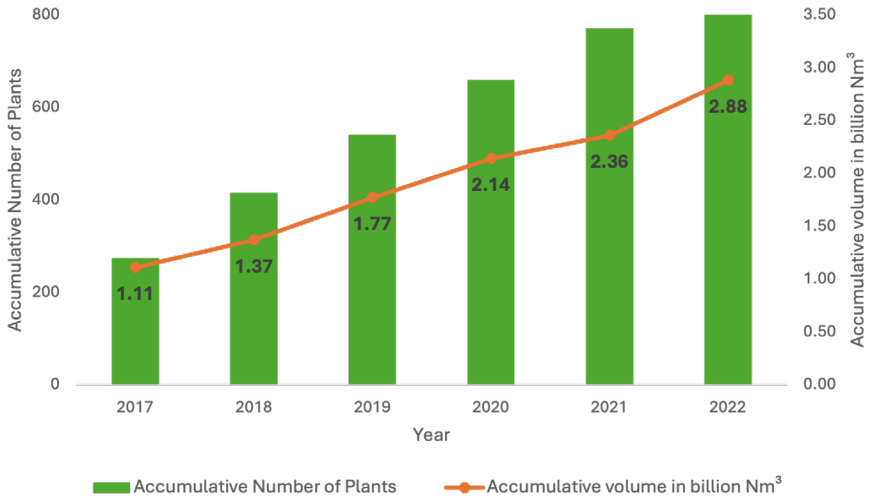


3.3 Biogas

Biogas production in Brazil is concentrated in three primary areas: agriculture, industry, and sanitation. By the end of 2022, total biogas output reached 2.9 billion cubic meters, with 114 new biogas plants launched during the year - a 15% rise compared to 2021[48].

In the industrial sector, biogas feedstock mainly comes from industrial effluents and organic residues from processing activities. The food and beverage sector leads in the number of active plants, while nearly 60% of biogas generated in this segment comes from the sugar-ethanol industry[49].

Figure 8 **Number of biogas plants and biogas production volume in Brazil in 2022**
Source: International Center for Renewable Energies - Biogas (CIBiogas), 2023

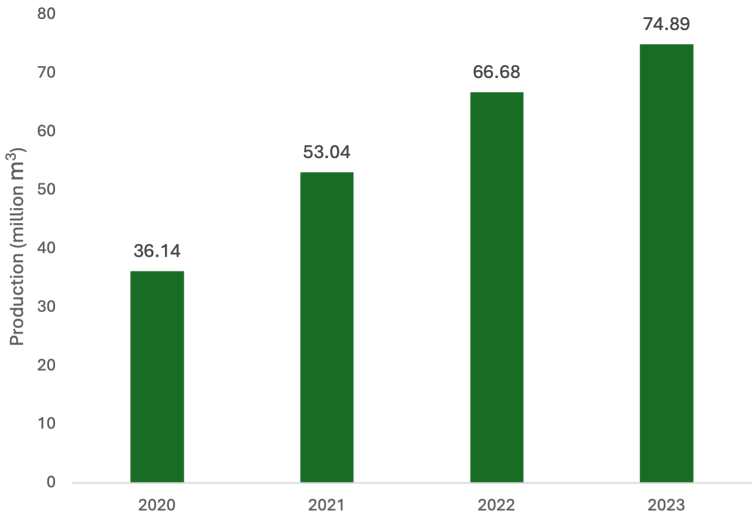


Notably, electricity generation remains the most common use for biogas in Brazil. In 2022, 86% of biogas facilities operated for power production, with an estimated 72% of the country's total biogas output being converted into electricity[50].

Biomethane

Biomethane represents a notable share of Brazil's biogas output, making up around 22% of total production. By 2023, nearly 75 million m^3 of biomethane were produced nationwide, marking a twofold increase since 2020[51]. This growth was especially significant in Rio de Janeiro, where production nearly quadrupled over this period, positioning the state as a leader with about 56% of Brazil's biomethane production by 2023[52].

Figure 9 **Biomethane production in Brazil.**
Source: National Agency of Petroleum, Gas and Biofuels, 2024




Source: Canva

4. Policy and Regulatory Framework

Brazil's bioenergy industry has deep roots, with its origins tracing back to the 1970s. The country's first major bioenergy policy, the National Alcohol Program (ProAlcohol), was launched in 1975 to reduce dependence on imported oil and enhance energy security. This landmark policy spurred sugarcane production, establishing bioethanol as a key component of Brazil's energy mix and forming the backbone of its bioenergy sector.

In 2005, Brazil introduced the National Program of Production and Use of Biodiesel (PNPB), expanding its focus beyond bioethanol to biodiesel. This program bolstered Brazil's energy security and solidified its global leadership in biodiesel production[53].

Since joining the Paris Agreement in 2015, Brazil has amplified its commitment to bioenergy. Two major policies are at the forefront: the National Biofuels Policy (RenovaBio) and the recently enacted Fuel of the Future bill. Both aiming at supporting emissions reduction targets, driving further market growth, by the creation of mechanisms like blending mandates and certification schemes[54]. Only in 2023, sugarcane and corn ethanol, biodiesel, and sugarcane bioelectricity avoided 85.6 $MtCO_2eq$ of emissions[55].

National Biofuels Policy (RenovaBio)

RenovaBio, Brazil's National Biofuels Policy, was launched by the Ministry of Mines and Energy in 2016 and formalized in 2017 through Law No. 13576. It aims to fulfill Brazil's international climate commitments, secure biofuel supply, and expand biofuel use while promoting energy efficiency and greenhouse gas (GHG) emission reductions through life cycle assessments (LCA).

Biofuels included in the program are cellulosic ethanol, sugarcane and corn ethanol, biodiesel, Hydrotreated renewable diesel (HDRD), aviation biokerosene (SAF), and biomethane[56]. The program operates on three key mechanisms:

1. **Annual Carbon Intensity Reduction targets:** Annual GHG reduction goals translated into mandatory targets for fuel distributors based on their market share.
2. **Biofuel Certification:** Biofuel producers are certified based on their GHG reduction efficiency through LCAs. Certification involves compliance with environmental regulations and the use of registered agricultural units.
3. **Decarbonization Credits (CBios):** Certified producers and importers can issue CBios, each representing one metric ton of CO_2 emissions avoided through biofuel use.

Distributors who exceed their emission caps can purchase CBios on the stock market to avoid penalties, creating a financial incentive for compliance. This system benefits biofuel producers by generating additional revenue from selling CBios while also encouraging greater biofuel use.

RenovaBio has made significant progress since it was launched in 2017. As of April 2024, 333 out of 422 licensed biofuel plants are certified under RenovaBio[57]. This includes 291 ethanol plants, 38 biodiesel plants, and four biomethane plants. From 2019 to 2023, over 105 million CBios were issued, avoiding the emission of 105 million metric tons of CO_2 equivalent. The 2024 target is set at 38.78 million CBios. However, by mid-2024, only 16% of the target had been met, influenced by cooling ethanol demand and high distributor non-compliance[58].

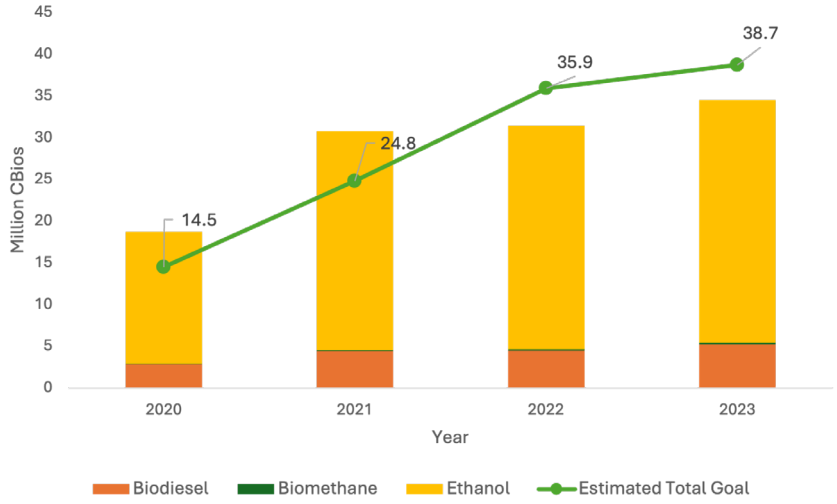
RenovaBio continues to evolve, with recent public consultations addressing certification processes, biomass custody chain, and foreign producer certification. The program's impact is further supported by fluctuating CBio prices, linked to market dynamics and blending policies.

Table 3 **Cbios issued and estimated goal from 2020 to 2023**

Year	Biodiesel	Biomethane	Ethanol	Estimated Total Goal
2020	2.8	0.05	15.8	14.5
2021	4.4	0.1	26.3	24.8
2022	4.5	0.1	26.8	35.9
2023	5.2	0.02	29.1	38.7

All values in millions

Figure 10 **Cbios issued and the estimated goal from 2020 to 2023**
Source: USDA, 2024



Fuel of the Future Bill (Combustível do Futuro)

The Fuel of the Future (Bill of Law No. 528/2020) bill aims to align domestic policies with updated NDC mitigation goals. Inspired by the success of the RenovaBio Program, the bill introduces new initiatives such as the National Sustainable Aviation Fuel Program (ProBioQAV) and the National Green Diesel Program (PNDV), both aimed at promoting sustainable low-carbon mobility.

On October 8th, 2024, the Brazilian Government officially signed the "Fuel of the Future" into law, previously approved by Brazil's National Congress[59]. The law introduces a range of measures and programs aiming to boost sustainable fuel production, including anhydrous ethanol, biodiesel, SAF (Sustainable Aviation Fuel), and biomethane. The new law proposes the following key measures:

1. **Biodiesel:** The blend in diesel will gradually increase from 14% to 20% by 2030, with voluntary additions allowed for various sectors like transport and agriculture.
2. **Ethanol:** The anhydrous ethanol blend in gasoline will be set between 22-35%, potentially increasing from the current 27%.
3. **SAF:** A new program will require airlines to reduce emissions on domestic flights using SAF, starting with a 1% reduction in 2027, aiming for 10% by 2037.
4. **Biomethane:** The law sets a gradual biomethane blend requirement in natural gas, starting at 1% in 2026 and increasing to 10%.

The bill is expected to boost investment in the sector, with companies like Atvos and Petrobras expanding their projects to meet new opportunities[60].
In terms of financing, the Fuel of the Future program aims to mobilize R260 billion (USD 45.71 billion) in clean energy financing by 2037, with over R105 billion (USD 18.46 billion) supporting biofuel policies like Renovabio and Rota 2030. It allocates R65 billion (USD 11.43 billion) for biofuels such as ethanol, biodiesel, e-fuels, and biomethane and R8 billion (USD 1.40 billion) for developing HVO refineries[61].

Source: Canva

5. Blending Mandates

Ethanol

The addition of ethanol to petrol and the use of pure ethanol were experimented with and spread in Brazil in the first decades of the last century. In 1931, a federal government decree mandated the addition of at least 5% anhydrous ethanol to petrol. Since then, all petrol consumed in Brazil has been mixed with ethanol. The ProAlcohol program in 1975 significantly boosted the industry, leading to the production of the first 100% ethanol vehicle in 1979.

The ethanol blending mandate in Brazil currently requires a 27% mix of anhydrous ethanol in gasoline C (commonly referred to as ethanol-blended gasoline), designated as E27. Existing regulations permit a blending range between 18% and 27.5%[62]. However, under the newly enacted "Fuel of the Future" law, the implementation of E35 will be authorized pending the results of technical assessments supporting its feasibility. As of April 2025, tests conducted by the Mauá Institute of Technology (IMT) and endorsed by the National Association of Automotive Vehicle Manufacturers (ANFAVEA) have approved the use of E30. This blend is currently under review by the National Energy Policy Council (CNPE) and is expected to receive approval before the end of 2025[63].

Biodiesel

The National Program for the Production and Use of Biodiesel (PNPB), established by Law No. 11 097 in 2005, mandates a minimum blend of biodiesel in diesel fuel. Initially, the program aimed for a 5% blend (B5) by 2013 but achieved it by 2010. The program supports innovation across the biodiesel production chain and allows diverse oilseeds from both agribusiness and family farming. The National Agency of Petroleum, Natural Gas and Biofuels (ANP) oversees fuel quality and market operations.

Previously, biodiesel was sold through public auctions, but in 2022, a new over-the-counter (OTC) market model replaced this, allowing more flexibility. Law No. 13 033/2014 set the blend percentages, with adjustments by the CNPE. The biodiesel mandate reached 14% (B14) in March 2024, a year earlier than planned. The B15 blend will start in March 2025 instead of 2026[64].

Biogas/Biomethane

The Brazilian biogas and biomethane sectors are gaining momentum, driven by government policies and market dynamics. As of December 2022, 22% of the 2.9 billion cubic meters of biogas produced annually is upgraded to biomethane, reflecting an 82% increase from 2021[65].

Despite the growth potential, regulatory clarity and distribution infrastructure remain key challenges[66]. Public policies like the "Fuel of the Future" and "Zero Methane" will be critical for supporting the sector's expansion.

Source: Canva

6. Market Prices

In Brazil, fuel prices have varied significantly over the past decade due to both domestic factors and global market influences. As a market with full pricing freedom, fuel prices here are primarily driven by production costs and international price trends, while federal and state tax policies are strategically used to stabilize prices and influence supply and demand.

Gasoline prices, for example, climbed from R$2.98 per liter in 2014 to a high of R$6.11 in 2022, reflecting international oil price hikes and the Brazilian Real's exchange rate[67]. Diesel prices showed similar trends, peaking at R$6.58 per liter in 2022 before dropping to R$5.76 in 2023. Meanwhile, the cost of liquefied petroleum gas (LPG) has also increased substantially, reaching R$8.45 per kilogram in 2022[68].

Figure 11 **Fuel prices board outside Sao Paulo - October 2024.**
Photo taken by Bharadwaj Kummamuru

Biofuels, such as hydrated ethanol and biodiesel, play a unique role in Brazil's energy mix. Ethanol, which competes directly with gasoline C, saw prices vary with agricultural yields and policy changes, reaching R$4.42 per liter in 2022 before lowering to R$3.76 in 2023. Tax policy further shapes biofuel pricing, with temporary tax cuts in 2022 favoring gasoline over ethanol in some regions, impacting ethanol demand[69].

Biodiesel, largely derived from domestically produced soybean oil, saw an average price of R$4.49 per liter in 2023, 30% lower than in 2022 (6.39 R$/liter). Soybean oil accounts for approximately 69% of biodiesel feedstocks, making biodiesel production sensitive to fluctuations in international soybean oil prices, the exchange rate, and domestic soybean output. In 2024, biodiesel prices averaged R$4.45 per liter by mid-year[70]. Other feedstocks like animal fat and vegetable oils also impact biodiesel costs, as they track soybean oil price trends.

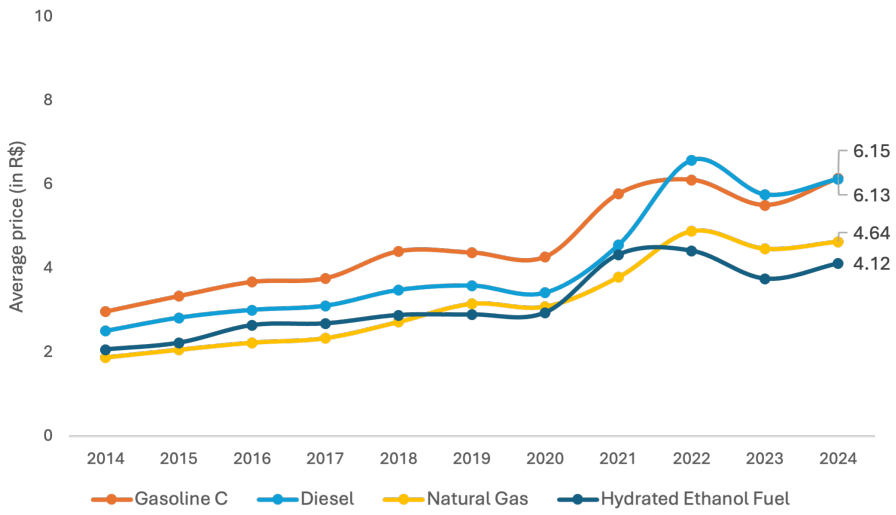
Ultimately, Brazil's fuel pricing landscape reflects a blend of market dynamics, government policy, and strategic tax interventions, supporting a balance between fossil fuel and biofuel production while aiming to keep consumer prices stable amid economic fluctuations.

Table 4 **Average price to the consumer of keys fuels in Brazil**
Source: National Agency of Petroleum, Natural Gas and Biofuels, 2024.

Average price to the consumer	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Gasoline C	2.98	3.34	3.68	3.77	4.41	4.38	4.28	5.78	6.11	5.51	6.15
Diesel	2.51	2.83	3.01	3.11	3.49	3.59	3.42	4.56	6.58	5.76	6.13
Natural Gas	1.88	2.06	2.23	2.34	2.73	3.16	3.09	3.80	4.89	4.47	4.64
Hydrated Ethanol Fuel	2.07	2.23	2.65	2.69	2.89	2.90	2.95	4.33	4.42	3.76	4.12

All prices in R$/liter except Natural Gas (R$/m³).

Figure 12 **Average price to the consumer.**



All prices in R$/liter except Natural Gas (R$/m³)

Source: Canva

7. Case Studies

7.1 Study Visit to Iracema Sugar Mill

As part of the BBEST IEA Bioenergy Conference 2024, participants visited the Iracema Mill, a key facility of the São Martinho Group, one of Brazil's largest sugar and ethanol producers. The BBEST (Brazilian Bioenergy Science and Technology) conference brought together global experts in bioenergy to discuss advancements in sustainable energy solutions. WBA was one of the supporters of the conference. The site visit held on 25 October 2024, provided firsthand insights into sugarcane-based biofuel production, industrial processes, and innovative agricultural practices in Brazil.

The study visit took place in the city of Iracema (180 km Northwest of Sao Paulo), home to approximately 40,000 people. This region, located about 2,000 km from the Amazon, is one of Brazil's two major sugarcane-producing areas. The Iracema Mill, part of the São Martinho Group, plays a crucial role in the country's bioenergy sector. The group operates four mills, three of which are in São Paulo state, processing a total of 24 million tons of sugarcane annually.

Sugarcane Production & Challenges

Brazil cultivates 9 million hectares of sugarcane, with 5 million hectares concentrated in São Paulo state. Recently, the representatives informed that the region has faced severe droughts lasting six to seven months, significantly reducing sugarcane yields and driving up prices. Moreover, mechanized harvesting is prohibited during wet conditions, leading to operational disruptions. High-slope areas present additional harvesting challenges, but technological advancements, including AI-driven pest control and precision agriculture, are improving efficiency. On average, each harvester processes 959 tons of sugarcane per day, with a typical yield of 80 tons per hectare.

Due to the perishable nature of sugarcane, unharvested cane deteriorates within three days, leading to fermentation. It is critical to transport sugarcane as soon as harvested to preserve it.

Figure 13 **Iracema Sugar Mill**
Source: São Martinho

Industrial Processes at Iracema Mill

The Iracema Mill follows a structured industrial process with no on-site storage, requiring continuous truck deliveries every minute. Sugarcane undergoes quality control before crushing, followed by juice extraction and purification through heating, chemical treatment, and decantation. The process then moves to evaporation, crystallization, and centrifugation, ultimately producing raw sugar for storage.

The mill does not clean sugarcane before processing, relying on a two-plate loading system. Three types of sucrose products are derived from processing: crystal sugar, ethanol, and molasses. Mills operate for nine months (April–October/November) before undergoing maintenance (November–March).

Ethanol & Bioenergy Production

Ethanol production at the Iracema Mill is flexible, with at least 30% of output dedicated to sugar. The decision to produce more ethanol or sugar depends on market conditions. Currently, 70% of the output is sugar and 30% ethanol. Ethanol is produced in fermentation tanks, with a production capacity of 500 m^3 per day with a product mix ratio of 50%/50% (sugar/ethanol). The ethanol categories produced in the mill include anhydrous for fuel, industrial grade for food and cosmetics, and hydrous for fuel.

Molasses, rather than cane juice, is the primary ethanol feedstock. A byproduct of

ethanol distillation, vinasse, is concentrated up to seven times to facilitate transport and application as fertilizer for the farms where the sugarcane is harvested, as it is rich in potassium. Each liter of ethanol generates 10–13 liters of vinasse. Additionally, 75 cubic meters of wastewater per hour is treated and reused for re-irrigation.

Sustainability & Innovation

São Martinho is a leader in agricultural innovation, integrating drones and AI for pest control, precision harvesting, and smart weather prediction. The group operates a 2 MW solar plant and employs advanced boiler systems to optimize energy use. Organic fertilizers, derived from ash, chicken manure, and filter cake (a subproduct of sugar processing), enhance soil health.

The company owns 70% of its sugarcane land, spanning 350,000 hectares, and employs 13,000 people.

For more information, visit: www.saomartinho.com.br

7.2 Atvos

Atvos is one of the largest biofuel producers in Brazil, standing out as the second-largest ethanol producer in the country, harnessing sugarcane as its primary raw material. In addition to biofuel, the company produces and exports VHP sugar and generates electricity from biomass.

As a key player in the production of clean and renewable energy, Atvos is recognized as one of the leading issuers of Decarbonization Credits (CBIOs) in Brazil, achieving some of the highest scores in energy and environmental efficiency under the criteria of the National Biofuels Policy (RenovaBio).

With more than 10,000 team members, the company operates eight field and mill operations strategically located in the states of Goiás, Mato Grosso, Mato Grosso do Sul and São Paulo. Since its inception in 2007, sustainability has been the central pillar guiding all our operations, products and business strategies.

The commitment to sustainable practices is reflected in ability to power millions of vehicles with clean fuel, while also fostering socioeconomic development in the communities where Atvos operate by empowering people and creating jobs.

By constantly investing in technology and innovation, Atvos strive not only to meet current energy demands through best field and mill practices but also to pave the way for a greener, more prosperous future, reaffirming the role as leaders in the transition to a more sustainable energy matrix in Brazil and the world.

Certifications

Aligned with the company's long-term vision, Atvos developed a plan to certify units in accordance with international standards and norms. These certifications are essential to achieving strategic objectives such as accessing new markets, driving continuous improvements in operational processes, mitigating socio-environmental impacts, and promoting Brazilian ethanol and biofuels as effective solutions for decarbonizing global economies.

- 8 field and mill operations recertified to International Sustainability and Carbon Certification (ISCC).
- 8 field and mill operations recertified to RenovaBio.
- 2 plants, Conquista do Pontal and Santa Luzia, certified to the Bonsucro EU RED Production and Chain of Custody Standard.

Figure 14 **Atvos Ethanol Plant**
Source: Atvos

New cycle of growth

Atvos has begun the process of building a new biomethane plant, which will use vinasse and filter cake as raw materials. This initiative will diminish the company's ecological footprint by replacing diesel in its fleet with gas produced from waste. The project is currently in the engineering analysis phase, pending final approval, with production expected to begin in 2026.

The medium- to long-term project envisions the construction of a plant to produce SAF (Sustainable Aviation Fuel) using ethanol-to-jet (EtJ) technology, which con-

verts sugarcane-based ethanol into aviation fuel. A key feature of this project is the industrial-scale production of SAF, with a secured raw-material supply and a competitive cost in terms of carbon emissions avoided.

Atvos is planning to invest upwards of R$ 10 billion over the next eight years in projects focused on new products. These investments reflect the company's vision of leveraging ethanol as a central element in the sustainable chemical industry, given its versatility as a building block for developing various technological pathways that significantly contribute to global decarbonization.

In April 2025, Atvos signed a letter of intent with Tsubame BHB, a Japanese startup, to jointly develop a green aqueous ammonia production plant in Mineiros, Goiás, Brazil. The plant will be located at the Morro Vermelho, which is currently dedicated to ethanol production.

Atvos will invest over BRL 70 million in the new plant, which will have an annual installed capacity of 20,000 tons of aqueous ammonia. The product will be used to replace fossil-based nitrogen fertilizers currently applied in the agricultural areas of Morro Vermelho and Alto Taquari, located in the municipality of Alto Taquari, in the state of Mato Grosso. With this initiative, the company estimates that it will avoid emitting approximately 11,000 tons of CO_2 per year, thereby significantly reducing its carbon footprint.

Atvos, a member of the World Bioenergy Association, is leading the energy transition to move the world and transform lives. For more information, visit: www.atvos.com.


Source: Canva

8. Conclusions

Brazil is a bioenergy powerhouse. The country with a population of 200 million people is a great example of a holistic approach to decarbonizing all end use sectors with the support of bioenergy. In all sectors including fuels, power, and heat, bioenergy solutions are a cornerstone of the social, economic and environmental progress of the country over the past few decades.

Renewable energy sources already account for half of the energy supply while sugarcane biomass (predominantly bagasse for power and ethanol for fuel) make up 35% of the RE mix while other products such as black liquor, biodiesel and biogas combine to account for another 15% of the renewable energy supply. In terms of consumption, both biodiesel and fuel ethanol account for 17 – 19% of their respective fuel mix. Considering the size and population of the country, this is truly a remarkable achievement. In comparison, EU's renewable energy share in transport was less than 11% in 2023. Remarkably, renewables accounted for half of the total energy consumption in the country – where bioenergy dominates with a share of 31%.

Ethanol remains the primary driver for transport decarbonization in the country. Brazil is the world's 2nd largest ethanol producer – predominantly from corn and sugarcane. The support and uptake of flex fuel vehicles was one of the primary drivers for increasing use of renewable fuel in the country, with current production at 37 billion litres. Biodiesel is also seeing rapid growth with a 21% increase over the previous year and a total production of 9 billion litres in 2024. Finally, biogas and biomethane (upgraded biogas) are receiving increasing attention in the country with a 12 - 15% increase over previous year.

A primary enabler for the biofuels sector to grow is consistent and reliable regulatory framework. Brazil – over the past decades since 1970's – had benefited from broad political support for biofuels development in the country which translates to

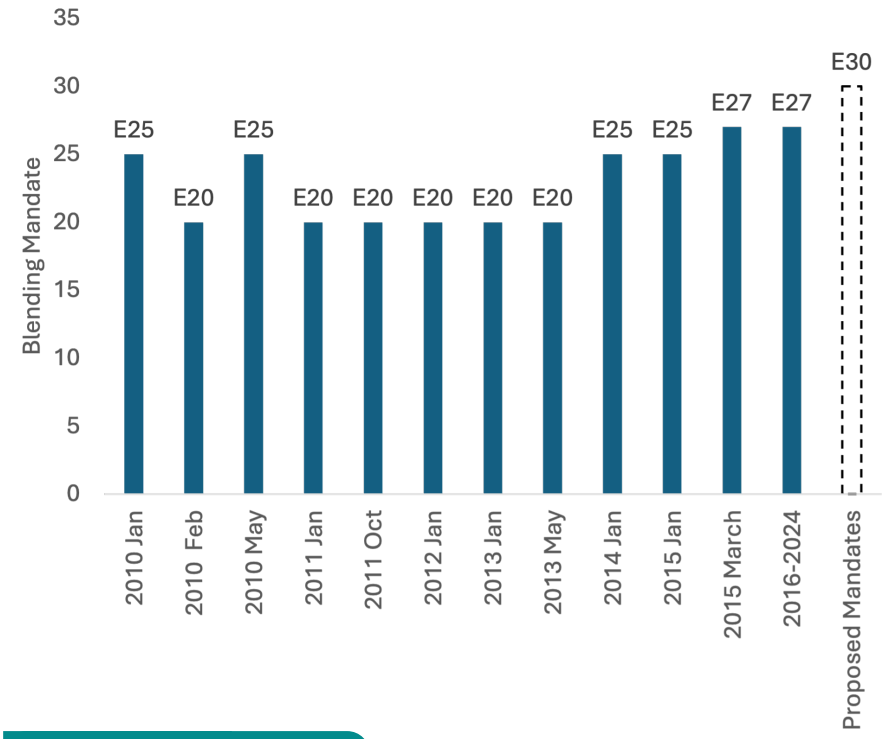
ambitious policies and supportive incentives for biofuels in the country including tax credits, blending mandates, investments to flex fuel vehicles, GHG reduction targets etc. Recent laws such as “Fuel of the Future” further incentivize the production of biofuels due to support for emerging sectors such as SAF – Sustainable Aviation Fuels.

One of the critical aspects for uptake of biofuels in the transport mix is the price at the pump. In Brazil, blended ethanol and diesel can compete with gasoline and diesel respectively in terms of price. In favourable situations such as high yields and increased supply, blended biofuel can be 30% - 40% lower in terms of cost compared to their fossil fuel alternative. The availability of flex fuel vehicles provides customers to choose the right blend depending on the price of both renewable and fossil fuel.

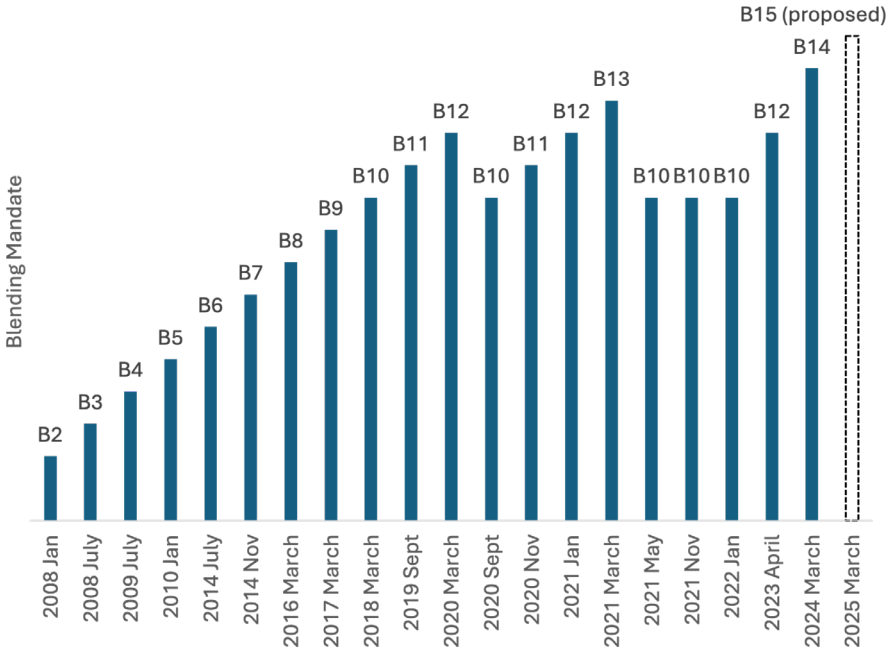
To conclude, Brazil has shown the way with exceptional progress on the path towards decarbonization of multiple sectors such as power, heat, fuels using biomass along with other renewable energy technologies. A strong and stable political and regulatory framework has ensured great success for the sector and is an excellent case study for the rest of the world. As the world moves towards ambitious targets and climate change mitigation becomes even more crucial with every passing year, Brazil can lead the way in mobilizing international efforts in achieving critical goals enshrined in the Paris Agreement. The upcoming COP30 conference in Belem, Brazil is a great opportunity to showcase the success of bioenergy in the country and share the knowledge to the rest of the world.

Appendix

Supplementary Figure 1 Anhydrous Ethanol Blending Mandates



Supplementary Figure 2 Biodiesel Blending Mandates



Currency exchange rate:
1 USD = 5.68801 (xe.com) Consulted 25 April 2025

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Endnotes

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