

Energetic Use of Biomethane in Brazil

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Biomethane is a renewable energy source with great strategic potential for Brazil's energy transition, especially due to its compatibility with the natural gas infrastructure. Produced through anaerobic digestion of organic residues, biogas mainly contains methane (CH₄) and carbon dioxide (CO₂). After purification, the resulting biomethane reaches a methane concentration of 90–98%, making it suitable for injection into gas distribution networks or use in transportation, industry, and residential sectors. This study aims to analyze the potential, challenges, and opportunities of biomethane in Brazil, considering its contribution to the decarbonization of the energy matrix and the sustainable use of organic waste. The research adopts an exploratory and descriptive approach, based on a bibliographic and documentary review of scientific publications, institutional reports, and updated sectoral data. The results indicate that biomethane, in addition to reducing dependence on fossil fuels, contributes to waste management and the generation of carbon credits. As an advance over the current state of the art, this study systematizes recent data on production, public policies, and practical applications of biomethane in Brazil, highlighting its growing role in the national energy transition.

Keywords: Biomethane. Energy Transition. Renewable Fuel. Greenhouse Gas Emissions. Organic Waste Valorization.

The growing reliance on fossil fuels has been a major driver of greenhouse gas (GHG) emissions, intensifying the urgency for energy alternatives that are both sustainable and scalable. Among the viable solutions for decarbonizing the energy sector, biomethane stands out as a strategic renewable fuel that can support a gradual and effective transition toward a low-carbon energy matrix. While it is currently unfeasible to completely and immediately eliminate combustion-based energy sources [1], biomethane offers a practical bridge by directly substituting fossil natural gas (NG) without requiring significant changes to existing infrastructure.

Driven by mounting pressure for environmental policies and the rising global energy demand, there is a strong incentive to develop cleaner,

renewable fuel technologies [2]. In this context, scientific research, industrial innovation, and societal awareness have increasingly converged around the development of technologies that not only reduce emissions but also create value from organic residues. Among these, gaseous biofuels—particularly biomethane—have gained attention for their ability to transform waste into energy, leveraging resources such as agricultural by-products and solid or liquid urban waste to power cities, industries, and transport systems.

Biogas, the precursor of biomethane, is produced through the anaerobic digestion of organic matter, and consists mainly of methane (CH₄) [~60%] and carbon dioxide (CO₂) [~35%], along with trace gases like nitrogen, ammonia, hydrogen sulfide, and carbon monoxide [3–5]. Its exact composition depends on the type of substrate, the digestion technology used, and process conditions. After purification to remove impurities and non-combustible gases, biogas is upgraded to biomethane, achieving a methane concentration of 90–98% [7,8], as shown in Table 1. With superior calorific value and combustion characteristics, biomethane matches or even

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exceeds the quality of fossil NG, qualifying it as a fully renewable replacement, often referred to as Renewable Natural Gas (RNG) [9,10].

According to the *Panorama of Biogas in Brazil* [8], the country's theoretical biogas potential reaches 85 billion m³/year—enough to replace approximately 70% of its diesel demand and 40% of its electricity needs. These figures reveal a massive untapped opportunity.

Biomethane presents Brazil with a unique chance to integrate a renewable, decentralized, and low-emission fuel into its energy matrix. Its versatility, compatibility with existing NG infrastructure, and ability to valorize organic waste make it not only a clean energy source but also a driver of circular economy, rural development, and climate mitigation. Investing in biomethane today means advancing toward a cleaner, more resilient, and energy-sovereign tomorrow.

Materials and Methods

The methodology adopted in this work was exploratory and descriptive research, based on bibliographic and documentary research, with indirect data collection from official agencies and public and private institutions. It also considered scientific literature, technical production, sector

reports, and legal and technical standards related to biomethane in Brazil. The collected data were analyzed qualitatively and quantitatively, with the deductive method being the central vector for conducting the work. The analysis of the collected data allowed us to describe the characteristics of the biomethane sector in Brazil.

Energy Overview of Brazil

The analysis of the National Energy Balance 2025 [6] shows that combustion is responsible for 81% of the country's Internal Energy Supply (OIE) (Table 2).

BEN 2025 also shows that the transportation and industry sectors consume 65% of the energy produced in the country (Table 3).

An analysis of the energy consumption structure in the industrial sector indicates that combustion supplies 80% of the energy consumed by industry, and electricity only 20%. In the transportation sector, combustion accounts for 99% of the energy consumed by industry, and electricity contributes 1% [6].

Biomethane Production in Brazil

The country's biomethane production capacity is 667,000 m³/day (Table 4).

Table 1. Composition range of combustible gas mixtures.

Compounds	Concentration (Volume %)		
	NG	Biogas	Biomethane
Methane (CH ₄)	91	50-70	90-98
Carbon Dioxide (CO ₂)	0,61	25-40	0
Hydrogen Sulfide (H ₂ S)	< 0,001	0,5-1	0
Nitrogen (N ₂)	0,32	< 0,001	0
Ammonia (NH ₃)	< 0,001	< 0,01	0
Carbon Monoxide (CO)	0	< 0,01	0
Calorific Value [MJ/ Nm ³]	27	20–25	35–39
Directly replaces NG?	-	No	Yes

Source: Prepared based on Coelho and Colleagues [5] and Empresa de Pesquisa Energética [6].

Table 2. Breakdown of internal energy supply-OIE.

SOURCES	[%]
Combustion - Oil and Derivatives	34
Combustion - Sugarcane Biomass	17
Combustion - Natural Gas	10
Combustion - Firewood and Charcoal	8
Combustion - Black Liquor and Other Renewables	8
Combustion of Mineral Coal	4
Hydraulic Power	12
Wind Power	3
Solar Power	2
Uranium	1
Other Non-Renewables	1
Total	100

Source: Prepared based on data from EPE [6].

Table 3. Breakdown of internal energy supply by sector (%).

Sector	[%]
Transportation	33
Industrial	32
Residential	11
Energy	9
Non-Energetic use	6
Agriculture	5
Services	4
Total	100

Source: Prepared by the Authors based on data from [6].

Energetic Use of Biomethane

Biomethane can be used in the same applications as natural gas (NG), meaning it is a natural and

Table 4. Companies authorized to sell biomethane / ANP.

TOTAL	Production Capacity By Raw Material			
	MSW	ASP	SUGARCANE	TOTAL
Nm ³ /d)	433	230	4	667

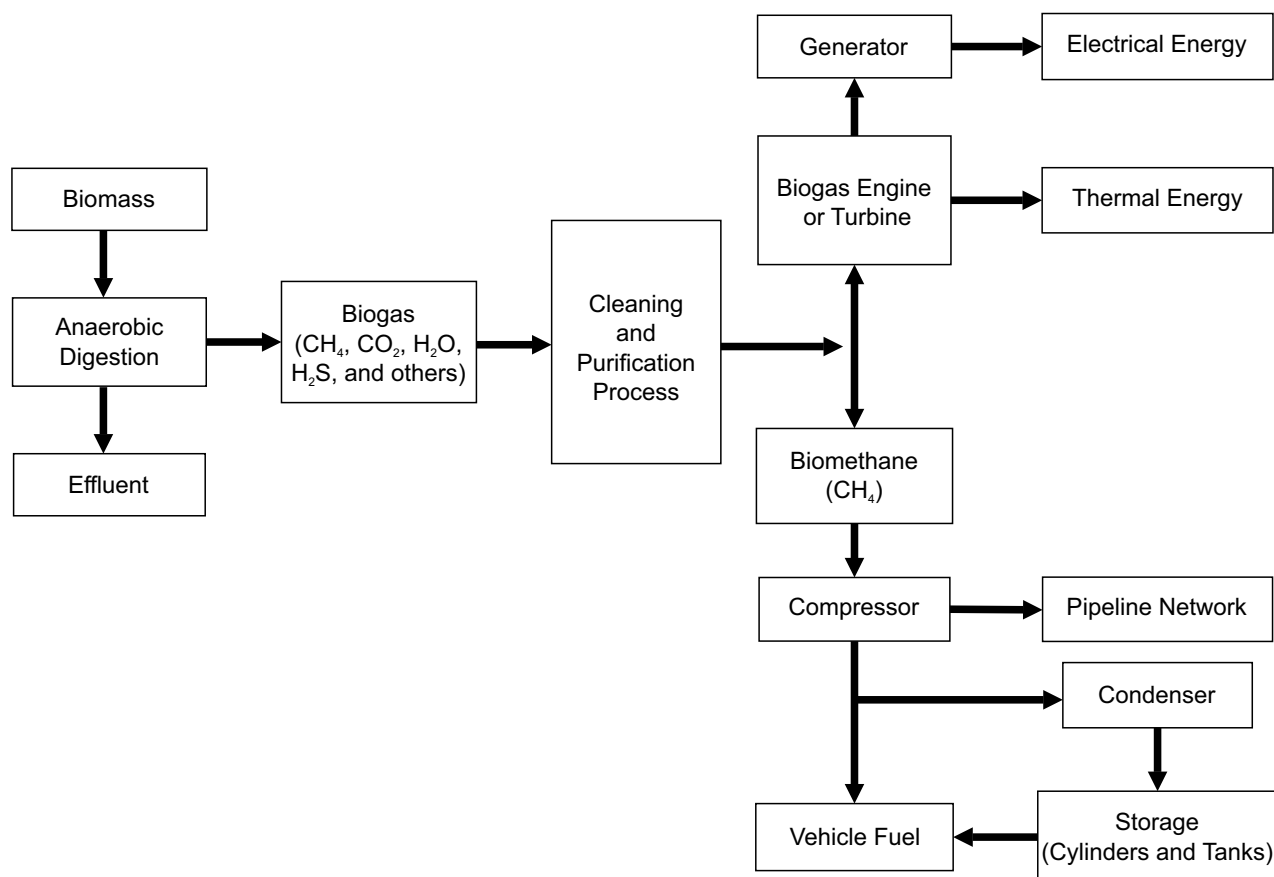
Source: Prepared by the authors based on data from the ANP's Biomethane Producers Dynamic Panel [11].

Legend: MSW = Urban Solid Waste Deposited in Sanitary Landfills; ASP = Agroforestry and Commercial Organic Products and Waste; SUGARCANE = Vinasse and Sugar and Ethanol Production Waste.

direct substitute for fossil natural gas (NG), but with renewable sources (NGR). However, its production for use as a NG substitute requires biogas purification, a process that reduces the concentrations of moisture, CO₂, and other lower concentrations, resulting in a methane-rich gas (biomethane) with similar physical and chemical properties to natural gas. After compression, biomethane can be used directly in the pipeline for supply in various applications, including vehicles. After compression, condensation, and storage in tanks or cylinders, it can also be used in various applications, including vehicles (Figure 5).

The transportation sector is the largest CO₂ emitter in Brazil, according to the BEN 2025 (Table 5), which causes environmental problems that can be reduced with the use of alternative energy sources such as biomethane.

For vehicle use, adjustments may be necessary due to methane's high octane rating, but the biggest problem is its energy density, much lower than that of diesel [19]. This requires tanks that can withstand the operating pressure and offer satisfactory range. Furthermore, biomethane functions as a vehicle fuel in the same way as natural gas (or fossil methane) and, therefore, can be used in conventional natural gas (NGV) vehicles. Different types of biomethane engines can be used: A specific biomethane gas engine - operates on 100% biomethane; a gasoline/biomethane flex-fuel engine; a diesel/biomethane flex-fuel engine; and a tri-fuel engine - a combination of a flex-

Figure 5. Simplified flowchart of the production and end use of biogas and biomethane.**Table 5.** Total emissions (2023) in Mt CO₂-eq.

Sectors	Mt CO ₂ -eq	%
Transportation	214	50%
Industry	75	17%
Residences	19	4%
Other Sectors	124	29%
Total	431	100%

Source: Prepared by the Authors based on data from the BEN 2025 – Summary Report [6].

fuel vehicle with a natural gas (NGV) vehicle. A flex-fuel vehicle uses gasoline and ethanol, either exclusively or as a blend. Thus, a tri-fuel vehicle runs on gasoline, ethanol (or both), and natural gas or biomethane. Perhaps it is the most appropriate choice for Brazil, which has had a consolidated and efficient fuel ethanol program for 50 years.

Advantages of Using Biomethane

The Gross Calorific Value (GCV) of biomethane ranges from [9.47 to 11.94] kWh/m³ [12] and is equivalent to the GCV of natural gas. In energy terms, 1 Nm³ of biomethane is equivalent to 0.87 liters of diesel [8].

The use of biomethane as a renewable fuel helps mitigate GHG emissions, and its production from organic waste prevents the release of methane into the atmosphere [13] and uses urban solid waste and agro-industrial byproducts for energy. Through anaerobic digestion, this waste is converted into biogas, which, after purification, results in biomethane. This process not only reduces the amount of waste sent to landfills but also generates biofertilizer as a byproduct, contributing to soil fertility and closing the nutrient cycle.

Opportunities for Biomethane Growth in Brazil

Brazil has vast potential to expand biomethane production, especially by integrating new economic sectors and exploring different biomass sources.

Sugarcane Sector

The sugarcane industry presents significant opportunities for biomethane production. Waste such as filter cake and vinasse can be used to generate biogas, which, after purification, results in biomethane. Studies indicate that, by 2034, it is possible to produce approximately 3.3 billion Nm³ of biomethane from this waste, meeting approximately 39% of the agricultural sector's diesel demand [14].

Urban Solid Waste (MSW) Sector

Municipal waste management represents another frontier for the expansion of biomethane. The anaerobic decomposition of organic waste in landfills and sewage treatment plants generates biogas, which can be converted into biomethane.

The waste sector is responsible for the emission of 3.17 Mt of methane [15], and biomethane production can address emissions from the waste sector in Brazil if it uses municipal solid waste (MSW), domestic and industrial liquid effluents, and agricultural waste as raw materials. With the New Regulatory Framework for Basic Sanitation, established by Law 14,026 of July 15, 2020, which reinforces the National Solid Waste Policy, an increase in waste collection and treatment is expected, expanding the potential for biomethane production in this sector [16].

Animal Protein Sector

Brazil is one of the world's largest producers of animal protein, generating large volumes of organic waste. This waste, from slaughterhouses and farms, can be used to produce biogas and,

consequently, biomethane. The use of this waste contributes to the sustainability of the sector and the diversification of the energy matrix [7].

Carbon Credit Generation in Biomethane Production

Biomethane production involves the capture and purification of biogas resulting from the anaerobic decomposition of organic waste, a process that prevents methane emissions into the atmosphere, allowing the generation of carbon credits. For each ton of CO₂ equivalent not emitted, it is possible to generate a biofuel decarbonization credit (CBIO), a tradeable security on the stock exchange. According to the National Biofuels Policy (RenovaBio), established by Law 13,576/2017 [17], which established a carbon credit program linked to the fuel distribution sector, biomethane regulation is considered one of the eligible routes for generating decarbonization credits (CBIO) under ANP Resolution 758/2018 [18]. Integrating biomethane production into carbon credit generation mechanisms represents an effective strategy for promoting environmental and economic sustainability in Brazil. With appropriate public policies and investments in infrastructure and technology, the country can establish itself as a leader in the production of renewable biofuels and in mitigating climate change.

Conclusion

Biomethane represents a key opportunity for Brazil to accelerate its transition toward a low-carbon, diversified, and circular energy matrix. As a renewable fuel with physical-chemical properties and calorific value comparable to those of fossil natural gas, biomethane can be seamlessly integrated into the existing gas infrastructure, avoiding the need for costly system adaptations. Its production from organic residues—agricultural, industrial, and urban—transforms environmental liabilities into strategic energy assets.

The environmental benefits of biomethane are particularly significant: it reduces methane

emissions from waste, mitigates overall greenhouse gas (GHG) emissions, and contributes to achieving international climate targets. Moreover, its production process generates valuable co-products such as biofertilizers and green CO₂, supporting the circular economy and sustainable agricultural practices.

Economically, biomethane offers new revenue streams through the generation of decarbonization credits (CBIOs), in line with Brazil's RenovaBio program. This not only improves its financial viability but also attracts investments in renewable energy and infrastructure, especially in rural areas where feedstock availability is high.

Technologically, biomethane enables energy decentralization and strengthens energy security by providing a reliable, renewable, and local energy source. Its use in transportation—especially in heavy-duty vehicles—can significantly reduce Brazil's oil dependency and pollution in urban centers.

In summary, biomethane is not just a fuel—it is a catalyst for innovation, environmental restoration, and sustainable development. Its large-scale adoption offers Brazil a rare convergence of environmental responsibility, energy resilience, and economic opportunity. By embracing biomethane, Brazil positions itself as a global leader in renewable gas and paves the way for a just and efficient energy transition.

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