



Fortaleza, Ceará
Centro de Eventos do Ceará

INTERNATIONAL SYMPOSIUM ON ENERGY

Optimizing renewable energy: advanced strategies for enhanced efficiency and sustainability

BIOMETANO E ECONOMIA CIRCULAR: VALORIZAÇÃO DE RESÍDUOS AGRÍCOLAS E URBANOS NA TRANSIÇÃO ENERGÉTICA

BIOMETHANE AND CIRCULAR ECONOMY: VALORIZATION OF AGRICULTURAL AND URBAN WASTE IN THE ENERGY TRANSITION

Gustavo Braz Carneiro¹, Moisés Pinto Gomes²

¹PROFNIT Master's Student, University of Brasília - gustavo.carneiro@consultingbrz.com.br;

²Master in Agricultural Engineering, Federal University of Viçosa - moises.gomes@consultingbrz.com.br

RESUMO

O estudo analisa o potencial do biometano no Brasil como vetor-chave para a transição energética. Por meio de revisão bibliográfica e documental, incluindo políticas públicas, planos nacionais e relatórios técnicos, a pesquisa destaca como o biometano produzido a partir da digestão anaeróbia de resíduos orgânicos agrícolas e urbanos, possibilita a transformação de passivos ambientais em ativos energéticos renováveis. O estudo explora as principais rotas tecnológicas de purificação, como PSA, lavagem com água e membranas, e discute as possibilidades de injeção do biometano na rede de gás existente, seu uso como combustível veicular ou na geração de eletricidade. Os resultados reforçam o papel do biometano na redução das emissões de gases de efeito estufa (GEE), na promoção da segurança energética e no desenvolvimento econômico local, por meio da produção de biofertilizantes e da valorização de resíduos. Apesar dos desafios infraestruturais e regulatórios, legislações recentes e programas nacionais vêm criando condições favoráveis à expansão do mercado. O estudo destaca o biometano como pilar da inovação sustentável, alinhado às metas de descarbonização do Brasil, à Agenda 2030 e ao desenvolvimento de modelos econômicos circulares e de baixo carbono.

Palavras-chave: Biometano; Transição Energética; Economia Circular; Resíduos; Sustentabilidade.

ABSTRACT

The study analyzes the potential of biomethane in Brazil as a key vector for the energy transition. Through bibliographic and documentary review, including public policies, national plans, and technical reports, the research highlights how biomethane, produced from the anaerobic digestion of agricultural and urban organic waste, enables the transformation of environmental liabilities into renewable energy assets. The study explores the main technological purification routes, such as PSA, water scrubbing, and membranes, and discusses the possibilities of injecting biomethane into the existing gas grid, its use as vehicle fuel, or for electricity generation. The results reinforce the role of biomethane in reducing greenhouse gas (GHG) emissions, promoting energy security, and supporting local economic development through biofertilizer production and waste valorization. Despite infrastructural and regulatory challenges, recent legislation and national programs have been creating favorable conditions for market expansion. The study highlights biomethane as a pillar of sustainable innovation, aligned with Brazil's decarbonization goals, the 2030 Agenda, and the development of low-carbon and circular economic models.

Keywords: Biomethane; Energy Transition; Circular Economy; Waste; Sustainability.



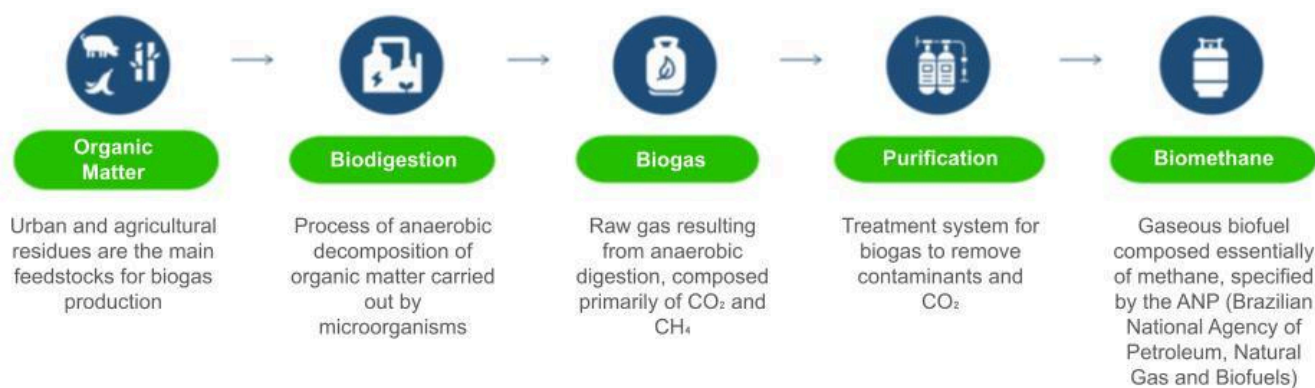
INTERNATIONAL SYMPOSIUM ON ENERGY

Optimizing renewable energy: advanced strategies for enhanced efficiency and sustainability

1 INTRODUCTION

The global transition to a low-carbon economy and the pursuit of more sustainable development models are imperatives driving the redefinition of the energy future. In this context, the circular economy is established as a fundamental pillar of sustainability, advocating the transformation of waste into resources and the promotion of renewable energy use. Brazil, with its vast territory and evolving energy matrix, faces the challenge of reconciling economic growth with decarbonization and sustainability goals, in line with international commitments such as the UN 2030 Agenda and the IPCC guidelines. Within this landscape, biomethane - a gaseous biofuel purified from biogas (Figure 01) - emerges as a promising energy alternative. Its production from a wide range of residues, including agricultural waste and urban organic waste, has generated increasing academic and sectoral interest. Biomethane not only offers a renewable energy source with a lower carbon footprint but also represents an innovative solution for sustainable waste management, converting environmental liabilities into economic and energy assets. This alignment with waste valorization is central to the circular economy, highlighting the potential of biomethane in fostering innovation and sustainability. This article proposes a critical analysis of the potential of biomethane in Brazil, exploring its convergence with the principles of the circular economy and its role in promoting innovation and sustainability. Technical aspects of its production and use, logistical and infrastructure challenges, as well as the political and regulatory framework that supports its integration into the national energy matrix, will be addressed.

Figure 01 – Biomethane Production Stages from Organic Waste – Source: EPE (PIG)



2 MATERIALS AND METHODS

The methodology employed in this study is characterized by an exploratory and descriptive approach, based on a literature review and documentary analysis, with a focus on publications from the past eight years. The main objective was to build a critical perspective on the potential of biomethane in Brazil, specifically through the use of agricultural and livestock residues and municipal solid waste (MSW), within the context of the circular economy and sustainability (Figure 02). The main sources of data and information consulted included:

- . Sectoral and Technical Reports: Specialized reports from industry associations, government agencies (MME, MMA),



INTERNATIONAL SYMPOSIUM ON ENERGY

Optimizing renewable energy: advanced strategies for enhanced efficiency and sustainability

and research institutions (EPE) were examined, providing data and analyses on the biogas and biomethane sector in Brazil.

- . Official Documents and Legislation: A survey of public policies, national plans (National Circular Economy Plan, National Solid Waste Plan, Integrated National Infrastructure Plan for Natural Gas and Biomethane), laws (Law No. 14.134/2021 - New Gas Law, Law No. 14.993/2024 – Future Fuels Law, Law No. 15.103/2025 – Energy Transition Acceleration Program - PATEN), decrees, and regulatory resolutions (ANP) was conducted, which establish the regulatory framework and guidelines for the sector.
- . Scientific and Academic Production: A review and selection of scientific articles, publications in specialized journals, and proceedings from national and international conferences was carried out. The research focused on topics such as biomethane, biogas, anaerobic digestion, waste treatment, circular economy, renewable energies, energy policies, and sustainability, prioritizing the most recent developments.
- . Statistical Data: Statistical data were collected from official sources such as the Energy Research Office (EPE), the Ministry of Mines and Energy (MME), and other agencies (ANP, IRENA) to contextualize energy production and consumption, waste generation, and other relevant indicators.

Figure 02 – Municipal Solid Waste Treatment Plant with Biogas Facility, State of Rio de Janeiro – Source: Eixos



The data analysis was interpretive and critical, seeking to identify trends, challenges, opportunities, and synergies related to the development of biomethane in Brazil. The present study aimed to establish connections between technical, economic, environmental, social, and political aspects, offering a particular perspective on the subject, with an emphasis on the



valorization of agricultural and urban waste. The structure of the article follows a deductive logic, beginning with a general contextualization of the circular economy and the energy transition, and then focusing on the specific potential of biomethane, its applications, the challenges for its expansion, and the conclusions and future perspectives.

3 RESULTS AND DISCUSSION

3.1 The Potential of Biomethane in Brazil

Brazil, with its vast generation of urban and agro-industrial residues, holds significant yet underexplored potential for biomethane production. This biofuel, which can substitute natural gas, aligns with decarbonization and energy transition goals, serving as a crucial element in consolidating the circular economy by converting environmental liabilities into economic and energy assets. The Energy Research Office (EPE) estimates a national production potential exceeding 120 million m³/day—enough to supply a substantial share of heavy vehicle fuel demand (80%)—thus contributing to reduced dependence on imported fossil fuels and improving air quality in urban centers. Annual municipal solid waste (MSW) generation in Brazil is approximately 81.8 million tons, with global projections indicating an increase to 3.4 billion tons by 2050 (Carvalhaes, 2023).

A distinctive advantage of the Brazilian context lies in the diversity of feedstocks. In the agricultural sector, animal manure (from swine, poultry, and cattle production) represents abundant and continuous sources of biogas. Biomethane production from these substrates not only generates renewable energy but also provides an environmentally sound solution for waste treatment, preventing soil and water contamination while mitigating methane emissions, a potent greenhouse gas (GHG). Integrating biomethane production with agricultural activities can create additional revenue streams, enable soil biofertilization through digestate (a by-product of anaerobic digestion), and increase the energy self-sufficiency of rural properties.

In urban contexts, solid waste and sewage sludge from wastewater treatment plants (WWTPs) are equally promising. Anaerobic digestion of these residues for biogas and biomethane production aligns with the National Solid Waste Plan (PLANARES) and circular economy principles, which emphasize waste prevention, reduction, reuse, recycling, and proper treatment. Biomethane derived from organic waste can significantly reduce landfill volumes, extend their operational lifespan, and generate clean energy for cities. Industrial effluents - particularly from the food and beverage, pulp and paper, and meat processing sectors - also hold considerable potential for biogas and biomethane generation, simultaneously lowering organic loads discharged into water bodies and producing energy for the industries themselves.

3.2 Technical Aspects of Biomethane Production and Use

The production of biomethane from biogas requires technological processes to remove impurities and enrich methane (CH₄) content, reaching specifications that render it interchangeable with natural gas (Santos, 2024). Key purification technologies include pressurized water scrubbing, pressure swing adsorption (PSA), membrane



INTERNATIONAL SYMPOSIUM ON ENERGY

Optimizing renewable energy: advanced strategies for enhanced efficiency and sustainability

separation, and chemical adsorption. The choice of technology depends on biogas composition, production scale, and purity requirements of the biomethane. End-use applications are diverse, including vehicle fuel (compressed natural gas – CNG), injection into the natural gas grid, electricity generation, and industrial heat production.

3.3 Challenges and Opportunities

Despite its vast potential, the consolidation of the biomethane value chain in Brazil faces technical, logistical, economic, and regulatory challenges. Transport and distribution infrastructure represents one of the main bottlenecks, particularly in regions with high biogas production potential but limited or absent gas pipeline networks. The economic feasibility of biomethane projects depends on factors such as feedstock costs, conversion technology efficiency, market prices for biomethane, and government incentives. The absence of a consolidated regulatory framework and long-term policies may discourage investment. Nonetheless, the Future Fuels Law (2024) and the ongoing development of the Integrated National Infrastructure Plan for Natural Gas and Biomethane (PNIIGB) represent important steps toward sectoral advancement.

Opportunities lie in the rising demand for renewable energy, the pressing need for sustainable waste management, and the pursuit of decarbonization strategies. Valorization of digestate as a biofertilizer, the generation of carbon credits, and the creation of new business models based on circular economy principles exemplify pathways that could drive the development of biomethane in Brazil.

4 CONCLUSIONS

Biomethane represents a strategic and promising solution for Brazil, aligning with the objectives of energy transition, energy security, and the circular economy. The valorization of agricultural and urban residues for biomethane production not only provides a renewable and low-carbon energy source but also contributes to sustainable waste management, the reduction of greenhouse gas (GHG) emissions, and the creation of value within new production chains. Despite challenges related to infrastructure and the regulatory framework, Brazil's biomethane potential is vast, and recent government initiatives indicate a favorable pathway for its consolidation. Continuous research and development, combined with public policies to foster the sector and investments in infrastructure, will be crucial for biomethane to achieve its full potential as a driver of innovation and sustainability within the Brazilian circular economy.

REFERENCE

ANP - AGÊNCIA NACIONAL DO PETRÓLEO, GÁS NATURAL E BIOCOMBUSTÍVEIS. Resolução ANP N° 886, de 18 de agosto de 2022. Estabelece a especificação do biometano oriundo de aterros sanitários e de estações de tratamento de esgotos, destinado ao uso veicular e às redes de distribuição de gás canalizado, e dá outras providências. Diário Oficial da União, Brasília, DF, 2022.



Fortaleza, Ceará
Centro de Eventos do Ceará

INTERNATIONAL SYMPOSIUM ON ENERGY

Optimizing renewable energy: advanced strategies for enhanced efficiency and sustainability

BORGES, M. M. P.; et al. Aproveitamento Energético de Biogás de Aterros Sanitários de Resíduos Sólidos Urbanos. Caderno Pedagógico, v. 22, n. 7, p. 01-22, 2025.

BORSCHIVER, S.; et al. Catalisando a Economia Circular: Conceitos, Modelos de Negócios e sua Aplicação em Setores da Economia. O Setor Energético na Economia Circular. Rio de Janeiro. Ed. UFRJ. p. 143-152, 2022.

BRASIL. Ministério do Meio Ambiente - MMA. Secretaria de Qualidade Ambiental. Plano Nacional de Resíduos Sólidos - PLANARES. Coord. FRANÇA, A. L. F., et. al. Brasília, DF, 2022.

BRASIL. Lei nº 14.134, de 8 de abril de 2021. Dispõe sobre o novo mercado de gás natural e dá outras providências, de 26 de abril de 2002. Diário Oficial da União, Brasília, DF, 2021.

BRASIL. LEI Nº 14.993, de 08 de outubro de 2024. Institui o Programa Nacional de Combustível Sustentável de Aviação (ProBioQAV), o Programa Nacional de Diesel Verde (PNDV) e o Programa Nacional de Descarbonização do Produtor e Importador de Gás Natural e de Incentivo ao Biometano e dá outras providências. Diário Oficial da União, Brasília, DF, 2024.

BRASIL. Lei nº 15.103, de 22 de janeiro de 2025. Institui o Programa de Aceleração da Transição Energética (Paten). Diário Oficial da União, Brasília, DF, 2025.

BRASIL. Ministério do Desenvolvimento, Indústria, Comércio e Serviços - MDIC. Secretaria de Economia Verde, Descarbonização e Bioindústria. Plano Nacional de Economia Circular - PLANEC, 2025.

CARVALHAES, T. R. Produção de Biogás através de Aterros Sanitários: Uma Alternativa para Economia Circular. TCC, 42f. Universidade Estadual Paulista, 2023.

COELHO, S. T.; et al. Tecnologias de Produção e Uso de Biogás e Biometano: Part. I Biogás; Part. II Biometano. São Paulo: IEE-USP, 2018.

EMBRAPA - EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA. Caracterização e Purificação do Biogás. Curso Energias Renováveis. Concórdia, 2017.

EPE - EMPRESA DE PESQUISA ENERGÉTICA. Nota Técnica Metodológica - Plano Nacional Integrado das Infraestruturas de Gás Natural e Biometano, 2025.

EPE - EMPRESA DE PESQUISA ENERGÉTICA. PIG 2024 - Plano Indicativo de Gasodutos de Transporte - Nota Técnica EPE/DPG/SPG. Rio de Janeiro, 2025.

EPE - EMPRESA DE PESQUISA ENERGÉTICA. Potencial Técnico do Biogás de Resíduos. Análise para o Período de 2021 a 2031. Rio de Janeiro, 2023.

EPE - EMPRESA DE PESQUISA ENERGÉTICA. Recursos Energéticos Distribuídos: Potencial Técnico do Metano da Pecuária Bovina. Rio de Janeiro, 2020.



Fortaleza, Ceará
Centro de Eventos do Ceará

INTERNATIONAL SYMPOSIUM ON ENERGY

Optimizing renewable energy: advanced strategies for enhanced efficiency and sustainability

GUEDES, M. T. J. C.; et al. Geração de Biogás e Biometano através da Digestão Anaeróbia de Resíduos de Casca de Laranja em Diferentes Formatos. LUME Repositório Digital UFRGS, 2023.

IEA - INTERNATIONAL ENERGY AGENCY. Disponível em: <https://www.iea.org/>. Acesso em: 12 agosto 2025.

IPCC - INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE. The Intergovernmental Panel on Climate Change. Disponível em: <https://www.ipcc.ch/>. Acesso em: 11 agosto 2025.

LEMOES, G. L.; et al. C. Biogás e Biometano no Brasil: Panorama e Perspectivas. Desenvolvimento e Meio Ambiente. UFPR, 2024.

NASCIMENTO, M. C. B. et al. Estado da Arte dos Aterros de Resíduos Sólidos Urbanos que Aproveitam o Biogás para Geração de Energia Elétrica e Biometano no Brasil. Engenharia Sanitária e Ambiental, v.24, n.1, p.143-155, 2019.

ONU - ORGANIZAÇÃO DAS NAÇÕES UNIDAS. Agenda 2030 - Objetivos do Desenvolvimento Sustentável. 2015. Disponível em: <https://brasil.un.org/>. Acesso em: 09 agosto 2025.

PEREIRA, R.; et al. Produção de Biometano a partir de Resíduos Sólidos Urbanos utilizando Biodigestores. In: Anais do XXVIII Encontro de Iniciação Científica da UNIVAP. São José dos Campos: UNIVAP, 2024.

SANTOS, S. A. V. Purificação do Biogás: Influência dos Parâmetros Operacionais em Torres de Absorção. Dissertação de Mestrado, 68f. Universidade Federal de São Paulo. Programa de Pós-graduação em Bioprodutos e Bioprocessos, 2024.

TEIXEIRA, C. A. N.; et al. A Hora do Biometano no Brasil. Textos para Discussão. BNDES, 2024.