Uncovering barriers hindering biogas energy growth in Brazil: Insights from literature.

Ana Paula Beber Veiga[1*] and Gilberto Martins[1]

[1] Federal University of ABC, Santo André, Brazil
*Corresponding author. E-mail: ana.veiga@ufabc.edu.br

ABSTRACT

The energetic use of biogas from waste contributes to meeting global energy demand while addressing environmental issues, especially in developing countries like Brazil. Despite increased biogas production capacity, its utilization for energy remains below potential indicating the existence of bottlenecks to its development. This study reviews literature to identify relevant barriers, categorizing findings by substrate and energy use. High investment costs was the most common barrier, regardless of substrate. Lack of infrastructure, technological maturity, and knowledge were also noticeable. The study suggests decentralizing policies and targeted subsidies, based on regional specifics and environmental benefits, to enhance biogas's energy potential in Brazil.

Keywords: Anaerobic digestion; Barrier assessment; Bioenergy; Biomethane; Policy mix.

INTRODUCTION

Biogas is obtained from the decomposition of organic matter under anaerobic conditions, such as those that occur naturally in landfills where municipal solid waste (MSW) is disposed of or when different substrates (food waste, agricultural residues, manure, and others) are processed in digesters. In addition to the energetic use (electricity, thermal and mechanical), purified biogas can also be used as a substitute of natural gas from fossil origin in industrial process like production of fertilizers and plastics, and as a biofuel in the transport sector.

Due to the vast possibilities of production and use, biogas exploitation relates to different administrative sectors, such as energy, transport, sanitation, environment and agriculture, amongst others [1–3]. As a result, a coherent legal framework is one of the main institutional barriers for increasing energy use of biogas in developing countries [4] and the need for bridging this gap is seen as a necessary step towards realizing its full energy potential [1,3,5].

Brazil is a leading country concerning renewable energy production. In 2022, it was the second largest biofuel producer country [6] and over 89.3% of the country's electricity mix in 2023 was from renewable sources, mainly from hydropower plants (58.9%) [7]. Despite the growth momentum for the exploration

of biogas observed from 2016 until 2021, when more than a two-fold increase in the volume of biogas produced was observed and the number of biogas plants in the country has tripled, it still represents less than 3% of its theoretic production potential [8].

Given the unexplored potential of biogas in Brazil and the slow development of the sector, this study addressed the following research question: what are the relevant constraints, if any, affecting biogas energy exploration in Brazil? A literature review was conducted to identify the barriers reported in previous studies. Policy recommendations emerging from the systematization of the constraints identified were also explored. The results have been complemented by reports from the Brazilian government and the biogas industry in order to provide context.

MATERIALS AND METHODS

A literature review was conducted to identify relevant studies discussing the constraints related to the production and energetic use of biogas in Brazil using the Web of Science platform. The search strings considered the words "*biogas*", "*policy*" and "*Brazil*" from the title, abstract and key words fields. Only articles were included. Based on the abstracts of the selected studies, only articles that explicitly mentioned the need for establishing new policies or improving the existing ones as a possible solution to overcome the identified barrier were considered. Data from federal government and the Brazilian biogas industry were used to illustrate recent developments achieved in the energy exploration of biogas in the country. The selected studies were assessed and the most relevant barriers affecting the expansion of biogas in Brazil and related policy recommendations were discussed.

RESULTS AND DISCUSSION

The analysis of the retrieved articles revealed the most relevant hurdles and policy recommendations to accelerate the implementation of biogas projects in Brazil. High investment costs is the most frequent barrier identified for the development of biogas in Brazil. Although the first initiatives for biogas upgrade to biomethane were implemented more than ten years ago, there is still no equipment available on the national market [9]. In addition to this, the scale of the project is a relevant parameter, especially in the waste and sanitation sectors. Electricity from landfill gas is economically viable only in dense populated cities [10–12] and the insufficient rate of sewage collection in Brazil makes the

energetic exploration of biogas in waste water treatment plants (WWTP) unfeasible [13].

The implementation of the targets for wastewater collection set out in the New Sanitation Framework Policy may contribute to the expansion of these energy biogas projects [13]. In this context, there is a consensus policy recommendation that the creation of municipal consortia should be encouraged [13–16] and that the recovery of biogas from projects connected to the sanitation sector in small cities should be subsidized [10,17].

Economic instruments are recommended as means of increasing the financial attractiveness of biogas projects. The suggested mechanisms include carbon credits [13,18,19] and methane taxes [20], taxes to finance the introduction of more advanced waste treatment techniques [14,18], differentiated electricity tariffs to ensure competitiveness [14,18,19], or to minimise the effects of the sugarcane off-season on vinasse biogas [21], premium prices for the energy produced that internalize the positive externalities of producing biogas [12,22], as well as increasing financing options and implementing different loan schemes based on the environmental benefits of these activities [22,23].

Little knowledge, lack of support and technological maturity were also relevant and are linked to frustrated past experiences, mainly related to manure treatment and incentives from the Kyoto Protocol slowdown [9,22,24,25]. More recently, researchers observed that the perception of technological risk associated with biomethane production from vinasse biogas is an important bottleneck since the technology is still evolving [21,26]. Extending the deadline for achieving the objectives of the National Biofuels Policy (Renovabio) beyond 2030 and setting different prices for credits from vinasse treatment are proposed to overcome this obstacle.

Infrastructure bottlenecks were identified as obstacles to the production of biomethane, not only in terms of distribution - the gas pipeline network is inadequate [9,12,26] and is concentrated along the coast [27] - but also because of the lack of filling stations [9]. Since biomethane is a substitute for natural gas, the policy recommendations related to these barriers consists of improving the regulation of the natural gas supply chain. In this sense, new policies should focus on reducing uncertainties related to contracts and competition in the sector [9,12] - since Petrobras is the major player in the market, and also on promoting regionalization of policy design [9,12,27], starting with the identification of the most locally relevant substrates and the most prominent end uses.

Although the energy end use of biogas raises specific policy recommendations - *i.e.* tariffs for electricity projects and infrastructure for

biomethane - the need for policy decentralization and neutrality became clear when researchers addressed multiple substrates in their research [3,9,28]. If on the one hand a more targeted policy can contribute to the economic attractiveness of the projects, on the other hand it creates an imbalance of incentives between renewable energy sources and ultimately postpone the adoption of more appropriate techniques recommended by the National Solid Waste Policy for the treatment of waste, such as biodigestion [3].

CONCLUSION

This research identified key barriers to the development of biogas energy use in Brazil, with economic viability being the primary constraint, particularly when compared to other renewable energy sources. To address this, the study suggests incorporating co-benefits of biogas into policy frameworks through technology-neutral economic incentives, such as premium prices and carbon taxes.

Additionally, the analysis revealed significant regional variations in sanitary conditions and production characteristics, especially within the agricultural sector, influencing perceived barriers and policy recommendations. The findings emphasize the need for decentralization and regionalization in policy design, with a focus on local substrate availability and infrastructure to enhance biogas development in the coming years.

ACKNOWLEDGMENT

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001.

REFERENCES

[1] M. Gustafsson, S. Anderberg, Dimensions and characteristics of biogas policies – Modelling the European policy landscape, Renew. Sustain. Energy Rev. 135 (2021) 1–11. https://doi.org/10.1016/j.rser.2020.110200.

[2] L. Hjalmarsson, Biogas as a boundary object for policy integration - The case of Stockholm, J. Clean. Prod. 98 (2015) 185–193. https://doi.org/10.1016/j.jclepro.2014.10.042.

[3] W. Kanda, H. Zanatta, T. Magnusson, O. Hjelm, M. Larsson, Policy coherence in a fragmented context: the case of biogas systems in Brazil, ENERGY Res. \& Soc. Sci. 87 (2022) 102454. https://doi.org/10.1016/j.erss.2021.102454.

[4] T. Nevzorova, V. Kutcherov, Barriers to the wider implementation of biogas as a source of energy: A state-of-the-art review, Energy Strateg. Rev. 26 (2019) 100414. https://doi.org/10.1016/j.esr.2019.100414.

[5] IEA, Renewables 2019., IEA, Paris, 2019.

https://www.iea.org/reports/renewables-2019 (accessed May 21, 2021).
[6] EIA, International Energy Statistics, Biofuels Prod. 2022. (2022). https://www.eia.gov/international/data/world (accessed September 3, 2024).
[7] EPE, Balanço Energético Nacional: Relatório síntese 2024, ano base 2023., 2024. https://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/balanco-energetico-nacional-2024 (accessed September 3, 2024).
[8] CIBiogás, Panorama do Biogás no Brasil 2021., CiBiogás, Foz do Iguaçu, 2022.
[9] T. Sinigaglia, V.B. Pedrozo, F.F. Rovai, R.T. Gondim Guilherme, T.D. Metzka Lanzanova, M.E. Santos Martins, Current scenario and outlook for biogas and natural gas businesses in the mobility sector in Brazil, Int. J. Hydrogen Energy. 47 (2022) 12074–12095. https://doi.org/10.1016/j.ijhydene.2022.01.234.
[10] R. Mambeli Barros, G.L.L. Tiago Filho, T.R. da Silva, R.M. Barros, G.L.L. Tiago Filho, T.R. da Silva, The electric energy potential of landfill biogas in Brazil, Energy Policy. 65 (2014) 150–164. https://doi.org/10.1016/j.enpol.2013.10.028.
[11] G.L. Fernandes, I.F.S. Santos, H.L. Castro E Silva, R.M. Barros, Power generation using landfill biogas in Brazil: a study of energy potential and economic viability in terms of the population, Eng. Sanit. e Ambient. 27 (2022) 67–77. https://doi.org/10.1590/S1413-415220200210.
[12] I.F. Silva dos Santos, N.D. Braz Vieira, L.G.B. de Nóbrega, R.M. Barros, G.L. Tiago Filho, Assessment of potential biogas production from multiple organic wastes in Brazil: Impact on energy generation, use, and emissions abatement, Resour. Conserv. Recycl. 131 (2018) 54–63. https://doi.org/10.1016/j.resconrec.2017.12.012.
[13] I.F.S. Dos Santos, R.M. Barros, G.L. Tiago Filho, Electricity generation from biogas of anaerobic wastewater treatment plants in Brazil: An assessment of feasibility and potential, J. Clean. Prod. 126 (2016) 504–514. https://doi.org/10.1016/j.jclepro.2016.03.072.
[14] R.E. dos Santos, I.F.S. dos Santos, R.M. Barros, A.P. Bernal, G.L. Tiago Filho, F. das G.B. da Silva, Generating electrical energy through urban solid waste in Brazil: An economic and energy comparative analysis, J. Environ. Manage. 231 (2019) 198–206. https://doi.org/10.1016/j.jenvman.2018.10.015.
[15] R.M. Lima, A.H.M. Santos, C.R.S. Pereira, B.K. Flauzino, A.C.O.S. Pereira, F.J.H. Nogueira, J.A.R. Valverde, Spatially distributed potential of landfill biogas production and electric power generation in Brazil, Waste Manag. 74 (2018) 323–334. https://doi.org/10.1016/j.wasman.2017.12.011.
[16] B.V.R. Pin, R.M. Barros, E.E. Silva Lora, I.F.S. dos Santos, Waste management studies in a Brazilian microregion: GHG emissions balance and LFG energy project economic feasibility analysis, Energy Strateg. Rev. 19 (2018) 31–43. https://doi.org/10.1016/j.esr.2017.11.002.
[17] A.T.A. Felca, R.M. Barros, G.L. Tiago Filho, I.F.S. dos Santos, E.M. Ribeiro, Analysis of biogas produced by the anaerobic digestion of sludge generated at wastewater treatment plants in the South of Minas Gerais, Brazil as a potential energy source, Sustain. Cities Soc. 41 (2018) 139–

153. https://doi.org/10.1016/j.scs.2018.04.035.
[18] M.M.V. Leme, M.H. Rocha, E.E.S. Lora, O.J. Venturini, B.M. Lopes, C.H. Ferreira, Techno-economic analysis and environmental impact assessment of energy recovery from Municipal Solid Waste (MSW) in Brazil, Resour. Conserv. Recycl. 87 (2014) 8–20. https://doi.org/10.1016/j.resconrec.2014.03.003.
[19] S.M. Loureiro, E.L.L. Rovere, C.F. Mahler, Analysis of potential for reducing emissions of greenhouse gases in municipal solid waste in Brazil, in the state and city of Rio de Janeiro, Waste Manag. 33 (2013) 1302–1312. https://doi.org/10.1016/j.wasman.2013.01.024.
[20] D.T. Michalovicz, P. Bilotta, Impact of a methane emission tax on circular economy scenarios in small wastewater treatment plants, Environ. Dev. Sustain. 3 (2022). https://doi.org/10.1007/s10668-022-02317-3.
[21] J.V. Silva Neto, W.L.R. Gallo, Potential impacts of vinasse biogas replacing fossil oil for power generation, natural gas, and increasing sugarcane energy in Brazil, Renew. Sustain. Energy Rev. 135 (2021) 110281. https://doi.org/10.1016/j.rser.2020.110281.
[22] P.A.C. de S. Bernardes, G. Aquila, E. de O. Pamplona, L.C.S. Rocha, P. Rotella Junior, Net metering and tax incentives for distributed generation in Brazil: Economic impact analysis for swine biogas, J. Clean. Prod. 375 (2022). https://doi.org/10.1016/j.jclepro.2022.134138.
[23] J.F. Cirino, M.A.M. Ferreira, L.V.P. de Faria, Financial and economic analysis under risk conditions for investment projects on biodigester for generation of electric energy from pig farming: A case study for a farm in Minas Gerais, Custos e Agronegocio. 13 (2017) 155–182.
[24] I.D. Cielo, M.C.P. Ribeiro, W.F. da Rocha Júnior, R.M. de S. Fragoso, C.M. Schmidt, Generation of Renewable Energy (Biogas) in the Western Region of Paraná/Brazil—A Multicase Study from the Viewpoint of Contracts, Sustain. 15 (2023). https://doi.org/10.3390/su15021458.
[25] C.P. Borges, J.C. Sobczak, T.R. Silberg, M. Uriona-Maldonado, C.R. Vaz, A systems modeling approach to estimate biogas potential from biomass sources in Brazil, Renew. Sustain. Energy Rev. 138 (2021). https://doi.org/10.1016/j.rser.2020.110518.
[26] N. Hughes, V.M. Mutran, J. Tomei, C. de Oliveira Ribeiro, C.A. Oller do Nascimento, Strength in diversity? Past dynamics and future drivers affecting demand for sugar, ethanol, biogas and bioelectricity from Brazil's sugarcane sector, Biomass and Bioenergy. 141 (2020) 105676. https://doi.org/10.1016/j.biombioe.2020.105676.
[27] A.P.B. Veiga, R. Stramieri Silva, G. Martins, Geographic Information Systems based approach for assessing the locational feasibility for biomethane production from landfill gas and injection in pipelines in Brazil, Eng. Sanit. e Ambient. 27 (2022) 41–46. https://doi.org/10.1590/s1413-415220210075.
[28] R. Galbieri, T.L.F. Brito, D. Mouette, H.K. de Medeiros Costa, E. Moutinho dos Santos, M.T.W. Fagá, Bus fleet emissions: new strategies for mitigation by adopting natural gas, Mitig. Adapt. Strateg. Glob. Chang. 23 (2018) 1039–1062. https://doi.org/10.1007/s11027-017-9771-y.