

## Technological Propection and Flowchart for Production of Biogas Enriched with Hydrogen: A Proposal for Renewable Energy Sources

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Over time, environmental issues have taken on significant proportions worldwide, making using renewable energy sources increasingly trivial, notorious, and indispensable. Projects focused on sustainability enable the expansion and diversification of current energy matrices, such as the potential use of biogas as an alternative source. Therefore, the project aimed to develop a flowchart proposal through technological propection, given the production of biogas enriched with hydrogen through anaerobic digestion of solid waste. Thus, a technological prospecting of patents and quantitative analysis of scientific articles was carried out to show an overview of the production of biogas associated with hydrogen from 2012 to 2022, based on the studies that analyzed the viability and efficiency of the use of hydrogen for biogas production.

**Keywords:** Biogas. Biohydrogen. Anaerobic Digestion. Biofuel.

### Introduction

The topic of energy is a significant issue in the world, as it is directly linked to the economy of countries. There is still a dependence on the oil industry as a source of energy production. Fossil fuels, oil, and natural gas are the primary raw materials for energy. However, this scenario has caused adverse environmental, social, and health impacts due to the high emission of greenhouse gases, promoting adverse effects, such as increased global warming and climate change. Faced with this, sanctions imposed at international conferences, such as the 1997 Kyoto Protocol, the 2015 Paris Agreement, and COP27, put pressure on reducing carbon and methane emissions and developing renewable energy sources [1,2].

According to Dorning (2015) [3], bioenergy production has become a viable and necessary alternative for energy production. The growth of renewable energies in Brazil's energy matrix has been evident, remaining among the highest in the world. In times of growing ecological problems,

the need for sustainable technologies linked to bioenergy has been the subject of many studies worldwide [4,5].

Biogas is a renewable biofuel source composed of methane gas (CH<sub>4</sub>) and carbon dioxide (CO<sub>2</sub>). It is obtained through anaerobic digestion of solid or liquid waste. This process has 4 phases, where solid waste is digested and decomposed by bacteriological microorganisms following criteria of fermentation, temperature, humidity, and pH. The amount of gas produced depends on the organic matter used and may vary in composition [6].

Although the production of hydrogen-enriched biogas is a promising technology for generating energy from renewable sources, some gaps still need to be addressed to make it more efficient and viable. These gaps include Cost, Efficiency, Raw Material Availability, Infrastructure, and Regulation. The work aims to identify an optimal route to produce biogas enriched with hydrogen. Therefore, the objective is to evaluate the feasibility of producing biogas enriched with hydrogen through anaerobic digestion of solid waste.

### Materials and Methods

In the project, a bibliographical review and technological prospecting of the biogas production scenario were developed, so patent searches and works were carried out to identify technologies

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that addressed the production of biogas associated with hydrogen. To this end, data collection was carried out regarding technologies on a national and global scale, using the resources of the Derwent World Patents Index bases, which is a database that contains patent applications and concessions of 44 from the world's patent-issuing authorities and to publications in databases such as Google Scholar, SciELO, ACS publications, and Elsevier. Publication data

They were exported to Microsoft Excel® and transformed into graphs to better present and interpret the results. The terms biogas production, Biogas production, biogas and hydrogen, biogas production, Biomethane Production, Biomethane production, and Biomethane production are in the Title or abstract field. As a research strategy, 653 patent filings were found between 2012 and 2022. In addition, a preliminary flowchart of the biogas production process was created using the SUPERPRO Designer software.

## Results and Discussion

As a result, we have carried out technological prospecting for biogas production, followed by the proposal of a preliminary flowchart of the production process using the SUPERPRO software.

In Figure 1, there was an increase in scientific production on the proposed topic. Through analysis of the selected patent documents, Figure 2 illustrates that several countries submitted patents on the topic, but the ones that stood out were China, Korea, and the United States.

China is in a prominent position as the largest applicant of patents related to researched technology, having almost all of the patent deposits protected in the country (267). This high number indicates that the technologies mentioned can be used in other countries that are not protected, leaving those who use them accessible from any sanctions. Concerning national participation, Brazil needs to present relevant quantified data regarding patents. They

highlighted the need for more significant national scientific investments to develop patentable products and techniques. This technological prospecting shows a strong trend towards growth in studies and research, demonstrating that the current scenario is quite dynamic and that there is a tendency for positive changes to occur in the short and medium term.

Anaerobic digestion is a process that has 4 phases: Hydrolysis, acidogenesis, acetogenesis, and methanogenesis, where solid waste is digested and decomposed by anaerobic microorganisms under controlled conditions to produce biogas.

In the acetogenesis phase, hydrogen will be produced to be consumed, stored, and consumed in the methanogenic stage along with the byproduct CO<sub>2</sub> to form CH<sub>4</sub>. A preliminary flowchart of this biogas production process was created using the SUPERPRO DESIGNER software (Figure 2).

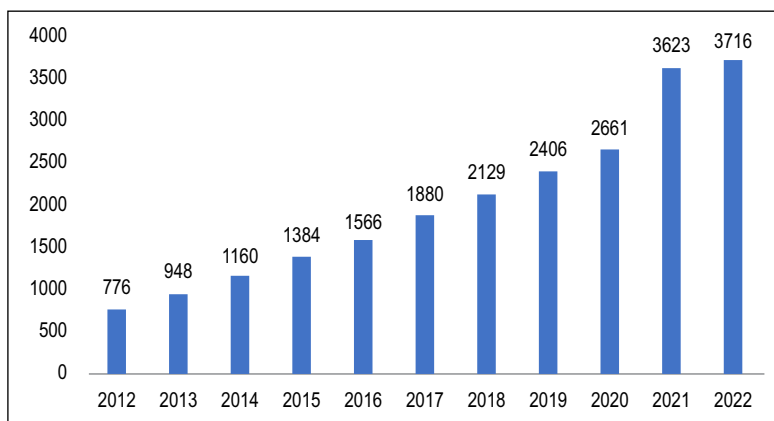
In Figure 3, there are two bioreactors in the series; the first in the fixed bed will be pre-treated without methanogenic microorganisms, in which the chosen substrate will enter, and hydrogen will be produced, and in the second bioreactor with the sludge without pre-treatment will produce the biogas from the substrate coming from the first bioreactor. Studies are underway to identify the best flowchart and, therefore, simulate the production process and analyze the economic viability of the process.

The production of a greater quantity of hydrogen in the acetogenesis phase allows the optimization of the result, as it will result in a more outstanding production of biogas in the methanogenesis phase and the possibility of storing hydrogen. Thus, although there are several processes to be applied to biogas, all of these processes require more time and additional costs to obtain biogas and do not generate a favorable amount of biogas.

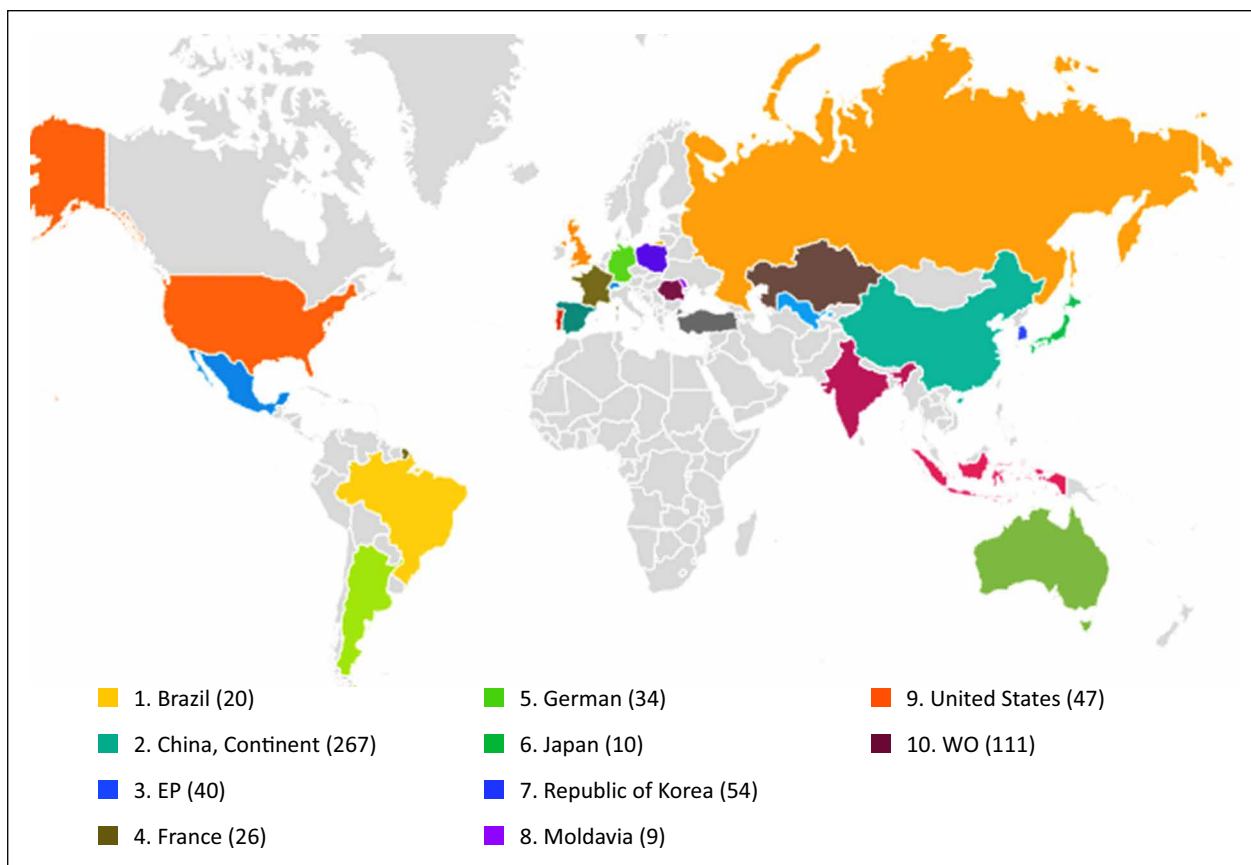
## Final Considerations

The study of the biogas production process with hydrogen shows promise in Brazil due to the opportunity to take advantage of the energy matrix

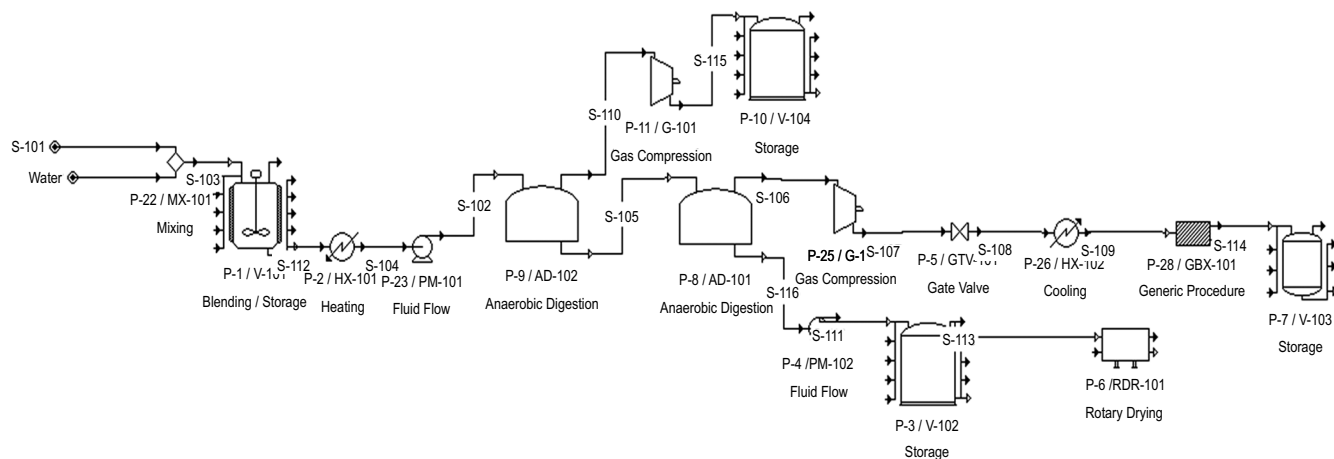
**Figure 1.** Number of article publications per year.



**Figure 2.** Number of patents by Country/Offices where they were filed.



Source: Derwent, 2022.

**Figure 3.** Flowchart of the hydrogen-enriched biogas production process.

since we have different resources as a source for the biotransformation of this product.

Furthermore, the data collected during this essay objectively demonstrates the growing advancement in research. The increase in recent years in the development of scientific production and patents related to biogas was also highlighted, being a genuine alternative within the sustainable aspect and renewable energy on a global scale. Concerning national participation, it became clear during this work that Brazil needs to present relevant quantified data regarding patents.

Studies are underway to identify the optimal flowchart and simulate the process. In the following steps, the study will consider the technical-economic feasibility of producing more efficient biogas as it is enriched with hydrogen.

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