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Use of agricultural waste to generate bioenergy: presentation of five ideas for industrial sectors

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ABSTRACT

Promoting the use of renewable energy sources is becoming an important political strategy worldwide to mitigate climate change and improve energy security and economic sustainability, in addition to contributing to the commitments assumed internationally by several countries to reduce carbon dioxide emissions. carbon (CO2) in the atmosphere. It is essential to use new energy sources to overcome the problems caused by non-renewable energy sources. In order to investigate and understand the opportunities for implementing new renewable energy sources, a Systematic Bibliographic Review (SBR) was planned and executed. It was found that agricultural waste has great potential to receive significant attention around the world as an alternative, sustainable and green energy source. However, in general, existing studies on agricultural residues for bioenergy generation are relatively few, and still have important gaps, compared to other renewable energy sources that have received much attention in the last ten years (2012-2022), as is the case of wind and solar energy. The use of agricultural residues to generate bioenergy is a broad and favorable scenario for exploration. Paths, almost unexplored, were identified with potential for carrying out studies that aim to contribute and stimulate researchers and industrial sectors in order to deliver technological solutions to society and industrial sectors in order to encourage the use of agricultural residues, for the production of briquettes and pellets , as a sustainable alternative, for the purpose of generating bioenergy, aiming to contribute to an increasingly sustainable energy matrix.

KEYWORDS: Biomass. Agricultural waste. Briquettes.

1 INTRODUCTION

Since the beginning of humanity, man has used energy to carry out tasks that guaranteed his survival, such as the ability to produce fire – the first form of energy dominated by man, after force. After the Industrial Revolution there was a significant increase in energy consumption, as industries multiplied creating the need to use new fuels.

A few years have passed and our dependence on energy sources is clear, which is essential for carrying out various activities (or almost all). With technological advances, different forms of exploration, generation and distribution of energy have emerged from different energy raw materials.

Renewable energy sources can reduce society's dependence on fossil fuels (non-renewable energy sources) and, therefore, reduce the emission of Greenhouse Gases (GHG) into the atmosphere - which have been changing over the years , the environment (SHEZAN et al., 2016).

There are several renewable energy sources, which are represented by natural resources available in a practically infinite way in nature: such as wind (wind energy), the sun (photovoltaic solar energy) and sugar cane bagasse (biomass energy) which can, in a short period of time, make a significant contribution to the generation of clean energy.

Fossil fuels cannot provide all the energy needed in the future due to their exhaustibility. Its use also leads to enormous environmental problems. Therefore, it is vital to find new inexhaustible and clean energy sources that can be stored and transported.

Brazil is responsible for approximately one third of the Greenhouse Gas (GHG) emissions in Latin America and the Caribbean, one third of the region's population and one third of the region's Gross Domestic Product (GDP), being, therefore, in the center stage in discussions about the global climate and the use of renewable energy sources (CARVALHO et al., 2020).

According to Jenner, Groba and Indvik (2013), it is important to highlight that the use of each renewable energy source has different advantages and disadvantages, ranging from the

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costs of the technology, to the seasonality of production and the variability of the resource. energy, and for this reason, the use of the most diverse energy sources becomes opportune.

The search for renewable energy sources guarantees the sustainable development of countries, taking into account environmental, strategic and economic aspects. Thus, there are a series of alternatives to be explored in Brazil, with a view to generating energy.

Gawel et al. (2017) consider that increased investment in renewable energy sources is necessary to meet the growth in demand for energy, in a sustainable way and with low carbon dioxide (CO2) emissions.

Leaders from different countries began to engage, pay attention and sign short, medium and long-term international policies and agreements in favor of the use of renewable energy sources for energy generation, aiming to reduce the emission of Greenhouse Gases (GHG) – contributing to the diversification of the energy matrix and, consequently, mitigating the risks of climate change and aiming to promote sustainable development (HUENTELER, 2014).

As a consequence, several environmental conferences and agreements have been signed by several countries (ZHAO et al., 2022). Figure 1 presents the milestones of the main environmental conferences as well as their main highlights.

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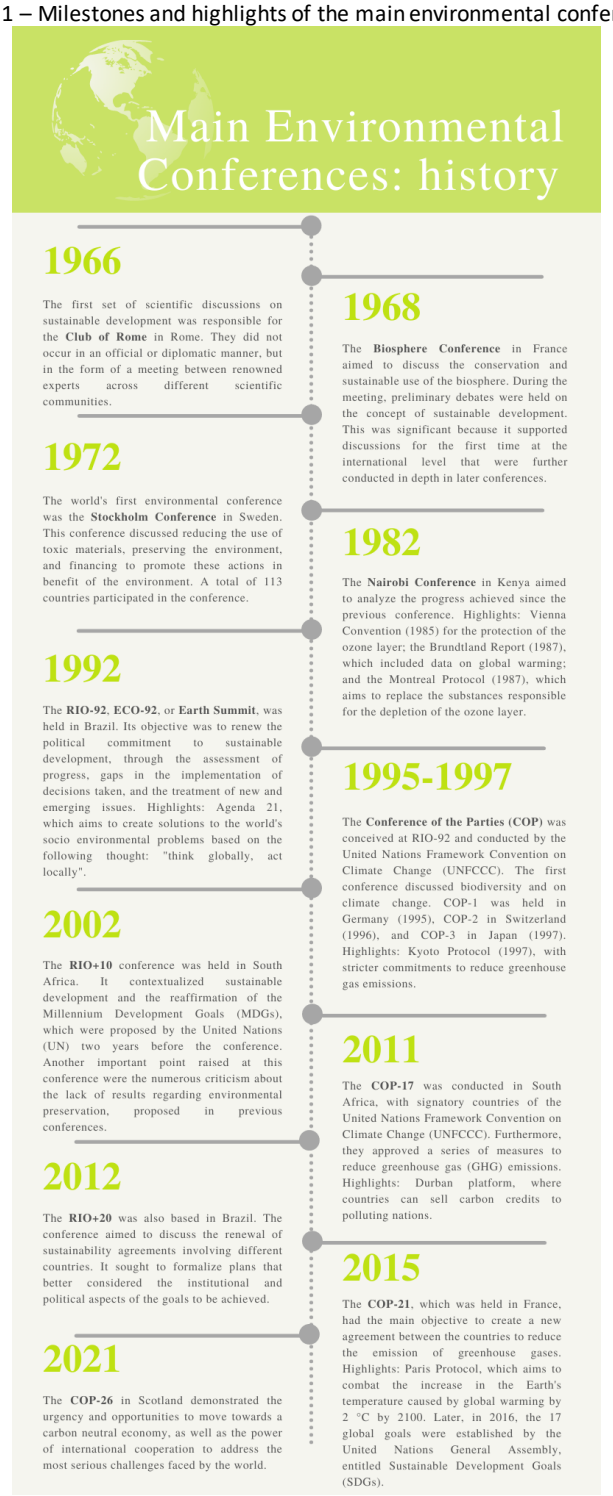
Figure 1 – Milestones and highlights of the main environmental conferences



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The great challenge of these agreements is to develop new energy matrices from alternative sources for low-cost energy generation, making them economically competitive. Faced with this situation, several research centers in the country have made efforts to develop new alternative renewable energy sources.

Among the various possibilities, the use of biomass waste to generate energy through

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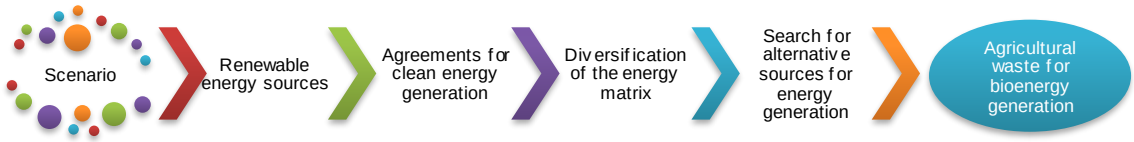
their combustion stands out. And, as a result, briquettes and pellets produced from agricultural waste (which is considered a type of biomass) for the purpose of generating bioenergy have several advantages and are extremely useful.

In Figure 2, based on the main concepts involved in this article, the central theme of this research is presented – which is the use of agricultural waste to generate renewable energy.

Figure 2 – Concepts of the central theme of the research



Source: Own Authorship

With concerns about sustainable development, it is extremely important to carry out studies aimed at multiplying practices for using renewable resources. In other words, guarantee changes to enhance initiatives and contribute to the process of transforming this agricultural waste into clean energy. Thus, it can be said that there are favorable conditions for using agricultural residues, as renewable energy sources, to generate bioenergy, and this topic becomes extremely important and relevant, in addition to opening paths and discussions so that an energy matrix can be achieved increasingly sustainable.

2 OBJECTIVES

Aiming to meet the needs of diversifying the energy matrix and, as well as advancing research into the use of agricultural waste to generate bioenergy, this research has the following objectives:

2.1 General objective

Aiming to elucidate the research problem presented, the General Objective was established: **To present promising ideas, to the industrial sectors, for using agricultural waste to generate bioenergy.**

2.2 Specific objectives

a) Carry out a Systematic Bibliographical Review (RBS) to identify the themes, important suggestions and gaps to advance research in relation to the use of agricultural waste to generate bioenergy;

b) Highlight possible promising opportunities for collecting agricultural waste and producing briquettes and pellets from them;

c) Propose five ideas and possibilities involving everything from the collection of agricultural waste, to operational aspects such as production, marketing and use of briquettes and pellets.

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It is also worth mentioning that this research is also justified by the fact that it contributes to four of the 17 Sustainable Development Goals (SDGs) of the United Nations (UN), highlighting that two of them are directly related to the research theme here. presented, they are: **7) clean and affordable energy** and **13) action against global climate change**. And although, according to the subsequent directions with the ideas that will be presented, this research will provide suggestions that will contribute to two other Sustainable Development Goals (SDGs), namely: **9) Industry, innovation and infrastructure** and **11) City and communities sustainable**.

3 METHODOLOGY

To classify the research, Gil (2008) was used. From the point of view of the object, the research is classified as bibliographic and field. Bibliographic, through the use of technical literature relevant to the topic addressed for the elaboration of the basic theory, in this case, predominantly journal articles. And in the field, as it involved data collection with a significant group of experts on the problem studied, participation in scientific events in the area, and technical visits to then obtain conclusions on the ideas presented.

From the point of view of its nature, this research is classified as applied research, as it will serve to generate knowledge for practical application in solving a specific problem, in addition to being characterized as an investigation conceived by the interest in acquiring new knowledge. Applied research is the combination of available knowledge and its expansion.

From the point of view of the way of approaching the problem, this is a qualitative research, as the method used in data analysis considers experiences, perceptions and intuitions logical and complete from experts, that is, it seeks to get closer to reality including and measuring all qualitatively measurable factors, tangible or intangible.

From the point of view of its objectives, it assumes the research profile as exploratory, which is a type of research that is in line with other sources that will provide a basis for the subject covered, as is the case of the research presented here, which uses bibliographies (technical literature) and interviews with experts and technical visits.

From the point of view of technical procedures, the research presents characteristics of bibliographical research and survey. Bibliographical, as it is necessary to explore studies on the use of agricultural waste to generate bioenergy. Survey, as it follows the following steps: definition of the research objective, experts who were interviewed and technical visits carried out.

Figure 3 shows, in general, the research classifications. The characteristics adopted in this research, in each research classification, are highlighted.

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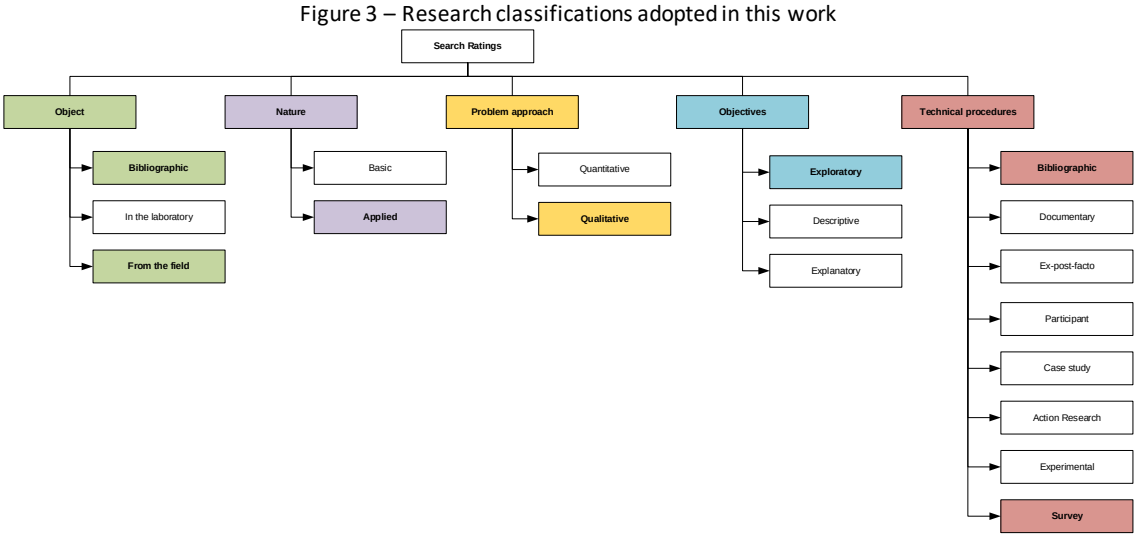
Figure 3 – Research classifications adopted in this work



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Initially, an Initial Bibliographic Review (RBI) was carried out, which aimed to obtain knowledge of the application of the stages of a Systematic Bibliographic Review (RBS) as a research methodology to serve as a basis for the organization and development of the Systematic Bibliographic Review (RBS) presented here.

Next, a Preliminary Bibliographic Review (RBP) was carried out, which served as initial knowledge for carrying out the research, that is, a first familiarization with the themes and the definition of search strings and keywords suitable for carrying out the Systematic Bibliographic Review (RBS).

In order to investigate and understand agricultural waste as a source of renewable energy, as well as identify works related to this research, a Systematic Bibliographic Review (RBS) was planned and executed.

A step-by-step Systematic Bibliographic Review (RBS) was carried out, which was based on the work presented by Conforto, Amaral and Silva (2011), with some adaptations. The model was based on good practices of Systematic Bibliographic Review (RBS) adopted by different researchers, such as: Levy and Ellis (2006); Biolchini et al. (2007) and; Dybå and Dingsøyr (2008).

The Systematic Bibliographic Review (RBS) was organized into 15 steps distributed in 3 phases (Input, Processing and Output). The detailed description of each of the stages of the Systematic Bibliographic Review (RBS) is available in Ribeiro and Braghini Junior (2022).

In Graph 1, the number of references used in RBS is presented, as well as the type of origin: theses, dissertations, books, national periodicals, congresses, websites and articles published in recognized periodicals – with a high impact factor (periodicals international).

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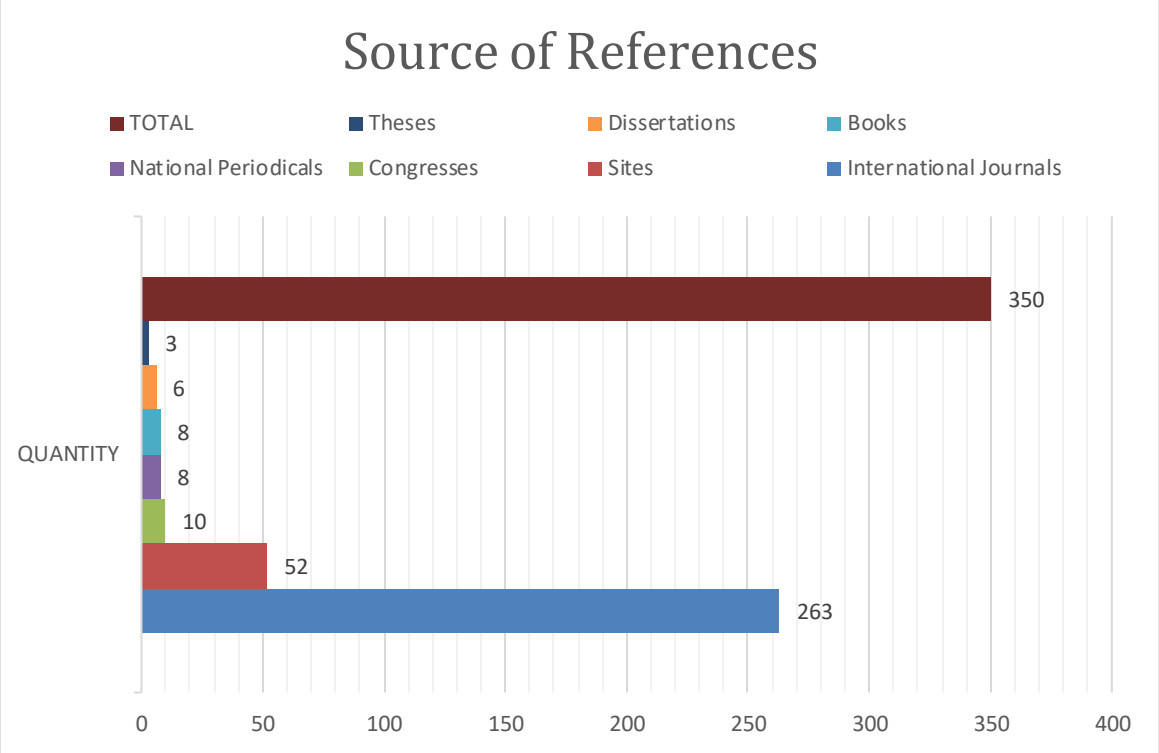
Gráfico 1 – Número de referências da RBS e suas origens



Source: Own Authorship

In Graph 1, it can be seen that, of the total of 350 references cited in RBS, 263 references are international – which correspond to a total of approximately 75% of the references.

Of the 350 references, 3 are theses (approximately 1%), 6 are dissertations (approximately 2%), 8 are books (approximately 2.5%), 8 are national periodicals (approximately 2.5%), 10 are conferences (approximately 3%), 52 are websites (approximately 14%), which correspond to approximately 25% of the references. The significant number of websites is due to the fact that many documents (reports), extremely important for the topic presented here, are available on them.

Thus, with the development of the Systematic Bibliographical Review (RBS), relevant studies were observed on the contributions to the energy matrix, from agricultural residues, as a source of renewable energy, with the aim of advancing existing research, seeking to identify how to actually use agricultural waste to produce briquettes and pellets for bioenergy generation.

To innovate appropriately, the researcher needs to be in tune with the current scenario. In this sense, this study aims to contribute and show the real ways to produce briquettes and pellets, from agricultural waste, for the purpose of generating bioenergy. These results can stimulate the development of new technologies and new studies in the generation of green energy.

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4 RESULTS

In order for agricultural residues to be used for bioenergy production and, as well, for them to be part of the diversification of the global energy matrix, there are a set of questions that must be answered in order to contribute and benefit society in general, not necessarily only linked to academia, but also so that companies can develop and generate new technologies so that society can benefit from these renewable sources, such as:

1) It is coherent to study biomass from agricultural waste, in pellets or briquettes, to be used for residential purposes (for heating fireplaces and used in kitchens in wood burning stoves, the latter being able to be related to the use and consumption of Liquefied Petroleum Gas – LPG), commercial (barbecues and wood-burning ovens in restaurants and pizzerias), industrial (steam boilers – which is used in turbines to move equipment, heat products and generate electricity, wood-burning ovens, food industries, ceramic and brick factories, blast furnaces as an aid for charcoal). Even in agriculture itself, in ovens for drying stored grains and temperature control in cold regions, or even in poultry houses for thermal control of chickens on farms, that is, pellets or briquettes as solid fuel for bioenergy production;

2) It is also encouraged to carry out a comparison between the two technological routes for obtaining pellets or briquettes from agricultural waste: the pelletization or briquetting-carbonization option and the carbonization-briquetting or pelletization option. In the first option, the biomass is compacted to obtain a briquette. Then the briquette is carbonized to produce a charcoal briquette. In the second option, the biomass is first carbonized and crushed to obtain charcoal, which is then briquetted. Being able to relate: results and yields, calorific value, environmentally friendly option, suitable for small, medium and large scale production;

3) It is advantageous to carry out a study involving the importance of pelletization or briquetting, as a densification technology that converts waste with a low heating value per unit volume into high-density fuels and energy concentrates (increased energy efficiency, as due at the compaction pressure there is an increase in the calorific value), demonstrating that pelletization or briquetting can positively influence the physical-chemical properties of waste, offering advantages such as increasing the density of the waste, improving their storage, and preventing their possible scarcity during off-season periods, as well as the conditions for transporting pellets or briquettes, allowing waste to reach energy generation sites more easily, that is, analyzing whether pellets or briquettes are a better way of handling this waste agricultural as a source of energy;

4) It is necessary to analyze the technical, economic, environmental and social feasibility of producing pellets or briquettes from agricultural waste directly in the field of rural properties, immediately after harvest, and present a viable production layout (detailing all necessary investments and equipment to carry out pelletizing or briquetting), from the beginning to the end of the production of these pellets or briquettes to carry out this activity for the producer's own consumption or for commercial purposes. Present the spot prices of pellets or briquettes and the net revenues that can be generated in a layout for small, medium and

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large-scale production, proposing different physical arrangements and layouts, based on the amount of agricultural waste available in the location or region. An analysis of the Return on Investment (ROI) and Operational Expenditure (OPEX) and Capital Expenditure (CAPEX) and variable costs for each proposed physical arrangement and layout is encouraged;

5) A fundamental practical study is to propose a set of flowcharts, as an optimization scheme, to assist in the decision-making process, based on the type of agricultural residues (crop), available quantities of these residues – as well as whether it is a small or medium production. or large scale, identifying the best energy conversion routes that are most suitable for each type of agricultural waste – in relation to their calorific value, also relating to the location and distribution of these final products (pellets or briquettes) to potential consumers – optimization in relation to the supply chain and distribution logistics, and also its most appropriate applications in relation to the processes and equipment that will be used. A scheme that can be proposed is the best methods for storing these agricultural residues in natura, in pellets or briquettes, aiming to reduce losses. It can also carry out a simulation of the best decision routes proposed for some scenarios studied.

And, as in any area of research: it is essential to propose a study presenting the limitations and possible disadvantages of using agricultural waste for bioenergy production.

Finally, and less expressive, but perhaps interesting, biomass and agricultural residues from the roots were never mentioned, on the contrary, they were considered as practical difficulties in their use and a lack of information on their use for the production of bioenergy, it is believed that this is due to the difficulties in relation to the collection, accumulation and separation of soil, and also that they remain and are sufficient to contribute to soil correction, thus guaranteeing the removal of other residues without interfering in the process of nutrients available in the solo, that is, it also becomes an opportunity to be explored.

To overcome the energy crisis, energy generating capacity must be developed from alternative sources, aiming to diversify the sources of energy consumption as much as possible. Therefore, studying and understanding the evolution of energy sources and demands over time is essential to project possible future scenarios and prepare for them, in order to have sufficient energy to guarantee socioeconomic advancement.

In general, currently, it is clear that the great challenge is related to the collection of these agricultural residues and also the logistical and distribution issue of them as raw materials for the production of pellets or briquettes, which enable the presentation of different solutions and opportunities as mentioned in the various future research directions cited above.

Discussing these recommendations and opportunities, presenting problems and proposing solutions, new ideas and innovative technologies, aiming to contribute to the scientific community, the private sector and policymakers and decision makers, allows us to reach conclusions to support the transition to a future of low carbon and achieve global emissions targets as established in international conferences and agreements and, as a consequence, economic and sustainable growth in the short, medium and long term. It is worth highlighting that all the opportunities listed can be researched in isolation, or even a combination of the various gaps identified.

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5 CONCLUSION

The Systematic Bibliographical Review (RBS) carried out indicated strong evidence of possibilities for substitution between biomass and fossil fuels, indicating that countries can continue with their growth and sustainability policies using more biomass and less fossil fuels.

The Systematic Bibliographical Review (RBS) also helped the scientific community working on energy generation from agricultural waste to build a common understanding of the challenges that must be faced when investigating the energy potential of these wastes.

The share of biomass in the energy matrix is increasing, which shows a trend towards global market acceptance of these renewable energy sources. Biomass also offers the possibility of being produced from a wide variety of materials, providing flexibility and security to the market, unlike fossil fuels themselves, mainly oil.

A large amount of agricultural waste biomass is generated from production and agribusiness activities and, partially, remains in the field of rural properties after harvest. Removing excess agricultural waste after harvest can increase a farmer's income, contributing to value addition, as well as providing raw material that can be used for industrial and energy purposes. Another point is that, by using agricultural waste to produce bioenergy, it is receiving a more sustainable destination than simple disposal.

Even so, the use of agricultural residues for bioenergy production aims to contribute to the diversification of the energy matrix, mainly aiming to increase the share of renewable energy sources from biomass, since it has been identified that there are numerous problems and large concerns regarding hydro, solar and wind energy sources (cited as unstable renewable energy sources), which lead the sustainable energy matrix.

It is observed that more studies are needed to investigate the relationship between the use of agricultural waste for bioenergy production and renewable energy sources as a means of contributing to an increasingly diverse energy matrix.

It is also clear that the use of renewable energy sources has a positive impact on environmental sustainability. The use of renewable energy sources, in particular biomass from agricultural waste, will reduce energy dependence on fossil fuels, reducing Greenhouse Gas (GHG) emissions, thus reducing environmental pollution and contributing to the reduction of global warming .

The main objectives of this article were achieved, as an overview of the current panorama was presented with the possibilities of carrying out research involving the replacement of fossil fuels with renewable and sustainable energy, that is, critical thinking – such as This is the case with the numerous opportunities cited in relation to the potential for using agricultural waste for bioenergy production.

Furthermore, it is also observed that the challenges mentioned in the previous section portray what still needs to be developed so that agricultural waste can also become a representative source of renewable energy in the global energy matrix.

Despite the recognized amount of research published on the topic of renewable energy sources, it was found that research involving agricultural waste for bioenergy production is a promising topic, with countless opportunities, as it encompasses several topics to be

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explored that are still quite restricted, In other words, the use of agricultural waste for bioenergy production is a broad and suitable scenario for exploration.

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