PERIÓDICO TCHÊ QUÍMICA
ARTIGO DE REVISÃO

POSSIBILIDADES DE RECUPERAÇÃO DE ENERGIA PARA A MELHORIA DA GESTÃO DE RESÍDUOS SÓLIDOS MUNICIPAIS

POSSIBILITIES OF ENERGY RECOVERY FOR THE IMPROVEMENT OF MUNICIPAL SOLID WASTE MANAGEMENT

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RESUMO

Introdução: A busca por novas fontes de energia é um dos aspectos mais significativos da crescente consciência ambiental que prevalece no mundo contemporâneo. O uso onipresente de combustíveis fósseis e outras fontes prejudiciais tornou-se uma das principais preocupações das comunidades política e científica, que, desde o século passado, iniciaram uma campanha em busca de alternativas. **Objetivo:** discutir as contribuições da recuperação de energia derivada de Resíduos Sólidos Urbanos (RSU) para o panorama brasileiro de fontes elétricas, adotando a economia circular aplicada a um município. **Métodos:** Foi realizada uma revisão da literatura para reunir conceitos e casos, utilizando economia circular, gestão de resíduos e município como palavras-chave. **Resultados e Discussão:** Os artigos reunidos apresentam a proeminência da economia circular no cenário intelectual do debate ambiental; além disso, há uma lacuna no tratamento anterior dos resíduos coletados, especialmente a separação de materiais pela população, o que impacta negativamente a recuperação. Os principais aspectos do problema incluem promover o envolvimento popular no ciclo, identificado como um ativo importante para um processo bem-sucedido. Isso inclui o cenário latino-americano, que começou a mudar recentemente com planos piloto implementados em algumas regiões. A maneira eficiente é envolver tanto a indústria quanto a população no processo. **Conclusões:** Um dos panoramas mais limpos de fontes de energia, tal instalação poderia ser implementada no Brasil, seguindo uma tendência sul-americana que já possui exemplos como Santa Rosa, Peru, e Barueri, no próprio Brasil. Uma oportunidade para desenvolver regiões e municípios.

Palavras-chave: *consciência ambiental; reciclagem; recuperação de materiais; gestão municipal de resíduos; panorama de energias renováveis.*

ABSTRACT

Background: The quest for new energy sources is one of the most significant aspects of the renewed environmental consciousness that prevails in the contemporary world. The omnipresent use of fossil fuels and other harmful sources became one of the principal worries of the political and scientific communities, that since the past century started a campaign in search of alternatives. **Aims:** The aim of was to discuss contributions of

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energy recovery derived from MSU to the Brazilian panorama of electrical sources, adopting circular economy applied to a municipality. **Methods:** a revision of the literature was undertaken, to gather concepts and cases, taking circular economy, waste management and municipality as keywords**. Results:** The gathered papers present the prominence of circular economy in the intellectual scenario of environmental debate; also, a lack in previous treatment of collected residue, especially the sorting of materials by population, which impacts negatively the recovery. **Discussion:** The key aspects of the problem include promoting popular engagement in the cycle, identified as an important asset for a successful process. This includes the latin american scenario, that began to change recently with pilot plans implemented in some regions. The efficient way is to engage both industry and population in the process. **Conclusions:** One of the cleaners panoramas of energy sources, such facility could be installed in Brazil, following a south American upraising that already has Santa Rosa, Peru, and Barueri, in Brazil itself. An opportunity to develop regions and municipalities.

Keywords: *environmental consciousness; recycling; material recovery; municipal management of residue; panorama of renewable energies*.

1. INTRODUCTION

The quest for new energy sources is one of the most significant aspects of the renewed environmental consciousness of the contemporary world. The omnipresent use of fossil fuels and other harmful sources became one of the principal worries of political and scientific communities, that, since the last century, started a campaign in search of alternatives.

The rise of these concerns follows a renewal of the human conception of environment, started by the romantic thinkers in 19th century. Its branches were amplified in the 20th, when various institutions and governments organized themselves politically around this new understanding of the question, brought up by the works of scientists like Rachel Carson, Roderick Nash, Donald Worster and others, that both pioneered research approaches, strategies of scientific vulgarization and academic disciplines concerning environment (Drummond, 1991). The focus of the actions then taken was to preserve the planet, causing the least environmental damage as possible, what is identified in the prohibition of CFCs, Kyoto's protocol, agenda 21.

Given this new perception, different scientific endeavors took place in the last decades. Approaches like circular economy, that understand a link between the technological processes of production as interconnected by the waste, that is to say: the residue of one is the source for another, the material before understood as waste can be inserted in another technological route and receive another treatment, generating new products.

This research takes part in this effort, following the application of the concepts of circular economy and energy recovery in the management of Municipal Solid Waste. The aim of this paper was to discuss the possible contributions of energy recovery derived from MSU to the Brazilian panorama of electrical sources, adopting as perspective circular economy applied to a municipality. Therefore, a revision of the literature was undertaken, to gather concepts and cases, taking circular economy, waste management and municipality as keywords.

First, in the revision of the literature, the guiding concepts with which the gathered papers were analyzed. Then, the contributions of each case to the research were presented, and at last the general inferences obtained by the examination of the spectrum of concepts.

2. METHODS

Therefore, a revision of the literature was undertaken, to gather concepts and cases. The researched terms were "circular economy", "city", "municipality" and "waste management", inserted in *Google Scholar*'s research tool. The criteria of selection of papers were either to present case studies or concepts interesting for composing a theorical background.

The research was conducted from January 1 to July 30. The period searched on the databases was from 2000 to 2023.

3. RESULTS AND DISCUSSION

3.1. Results

Table 1 presents the selected papers, according to their types and contributions to this study.

Table 1. Review Results

Selected Studies		
Authors	Type	Contribution
Barboza *et al.* (2019)	Theorical	Presentation of management's strategies
Holmgren and Henning (2004)	Case Study	Analysis of two cases of application of energy recovery.
Shorokova-Palolahti and Tawosoli (2021)	Case study	Analysis of energy recovery in a bigger context, with more cities involved.
Quispe *et al.* (2023)	Case study	Analysis of waste situation on a Peruvian city.
Oliveira (2018)	Case study	Description of a recovery plant's implement process

3.1.1. Renewal of the Environmental Consciousness

The human conception of nature has changed widely through the course of history, as described in various historical sources, varying from the Bible and classical literature to the romantic writings and further. Nash (2014) gathers some of them and offers some considerations. At first, man faces the untouched nature as an enemy, because of its unpredictable character: he is a weak animal when faced by the unknown menaces of wild environments, then recurring to multiple tricks to guarantee his survival. By consequence, the good nature, the one seen as friendly, is that who was tamed by his hands. Examples of this vision can be found in the works of Greeks and Romans, like the bucolic poetry, representing the beauty of the pastoral fields. Every mention of the desire to exchange the city for a better life in nature, it's about these rural environments they are talking. Still considering this dialectical approach, the authors of the Bible tell of a God that can express both anger and bliss through nature, that will provide rest in the promised land or cause ruin through various plagues. The prophets and narrators take the environment's perceivable strength as an analogy of the ineffable actions of God, henceforth making of it an instrument of description and an image of symbolical power. This can be noticed in the relevance of the image of the garden, present in two crucial moments of the Judeo-Christian cosmogony: Eden, in the creation of men, and Gethsemane, place of the epiphany that precedes the capture and consequent crucifixion of Christ (Nash, 2014).

Seeing nature's dynamic as an indicator of God's will, this theological approach also gives basis to a utilitarian vision. Given to the usage of men, this gift of God can be explored in as many ways as there are applications to its aids in improving men's lives. This vision also derives from the notion of docile and subjugated nature to man, that will remain beyond Greek and pre-Christian times. Keith Thomas (2010) lists several sources that attest to the use of the Christian worldview as a justification for the subjection of the natural world to man. Therefore, the human approach towards nature had always the possible benefits in mind, whether it was the use of animals for traction and plow, or search for food. Research on plants aimed to discover species with medicinal properties, so that they could be cultivated, or, if necessary, transported and acclimatized, notably a feature of botanical gardens (Fraga; Monteiro; Cavalcanti, 2021).

The attitude of human superiority lasts, through different forms, until the 19th century, that saw the birth of romanticism, and with it a desire to preserve nature, to restore some kind of primeval relation between man and the environment, a felling recognizable in the works of such authors as Henry Dadid Thoreau Thoreau (1817-1862), John Muir (1838-1914), Aldo Leopold (1887-1948) (NASH, 2014), George Perkins March (1801-1882), Gifford Pinchot (1865-1946) (Stoll, 2016); in the Brazilian context: Rodrigo de Souza Coutinho (1755-1812), Alexandre Rodrigues Ferreira (1756-1815) and José Bonifácio de Andrada e Silva (1763-1838) (Pádua, 2002). A lot of names lack in this little hall, but even though there was a plenty of names giving contribution to this new vision, it only reaches the cultural mainstream in the 20th century, takin its part as a relevant theme in the panorama social and political discussion.

The turning point came with the work of the biologist Rachel Carson, Silent Spring, published in 1963, that brought to the public, in one of the masterpieces of science vulgarization, the results of her research on the harmful implications of DDT and other pesticides on various species, especially the Bald Eagle. Her enterprise brought this theme to public discussion, an impact that mobilized the public and the government to look nature with another eyes

(Ramos, 2001). What succeeded was the emergence of organizations dedicated to preserve and fight for the environment and the realization of congresses worldwide dedicated to discussing the theme. This mentality, therefore, is ideally founded on the search for a sustainable and balanced interaction with the environment, always with the homeostasis of the system in perspective, with man being a part of it, not a distant observer (Pádua, 2010).

Among the notable implications of this new approach towards environment lies the research for new sorts of energy, that although demonstrate a good deal of efficiency cause less harm than the ones currently in use. There's also a quest for new technological routes, aspiring a reconfiguration of industry. Of course, new energetical sources are part of this process, but the remaking aims further objectives, from new strategies of obtaining material sources to reimagining and integrating processes to mitigate the problem of waste (Leitão, 2015). These and other characteristics are part of the theoretical background of Circular Economy, that will be presented further. Another notable aspect is the rethinking of the role individual action plays in this new context. Looking at the beginnings of this discussion, the second half of twentieth century, the actions taken were collective and of wide range, as were its agents: governments, organizations, coalitions between countries and so on (Ramos, 2001).

Half a century later, although the activities of these grand coalitions is still perceived, new kinds of though emerged, that deviate the field of action from them to the tinier parts of the mechanism. It's possible to state that the effectiveness of broad campaigns concerning a good relationship with nature, or of environmental education itself, can only be attested when the individual's approach to the environment becomes more conscious: all the propaganda is worthless if the human action is not affected. This vision is presented, for instance, by philosopher Roger Scruton (2016), according to whom the only effective action in benefit of the environment comes from the individual, came from his understanding of the question. It is to say: all human activities towards nature, either harmful or not, are based on their conceptions — and the only effective way to change them is dealing with the misconceptions within learned over the years. It's the duty of environmental educators to deal with it (Fraga; Chaché; Cavalcanti, 2022). Unless the person's action is changed, all political efforts are vain.

3.1.2. Circular Economy and Energy Recovery

Between the modes of approaching environment that came from this renewed vision is Circular Economy. Its principal idea is a modification in the form of seeing the models that sketch the process from production to consumption of materials. The concept is old, even though this terminology is relatively new (Sillanpää; Ncibi, 2019): primitive societies did not know the waste of elements, because the material they had at their disposal, from wood to animal leather, in addition to being difficult to acquire, and therefore used until exhaustion, was easily degraded in nature. So, it was part of the instincts of these individuals in dealing with the environment, with whom they lived in full synergy — man was a part of nature as everything else (Sillanpää; Ncibi, 2019). Further in time, this concept is not completely abandoned: in the Middle Ages, for example, food had to be prepared and served on the same day, as it could not be kept for a long time, so what was not eaten in the nobles' residences was given to the servants, so they could take It home and throw it away. Their cauldrons. There was no cutlery: it was served on bread, which was either eaten or given, also to the servants. There were no disposable napkins: hands were cleaned with the fur of the animals in the house (Elias, 1990).

The rise of the concept of waste comes with the revolution of the industrial capacities, driven by both science and technology, that made possible to produce materials of constitution and quantity that nature could not reabsorb in a human time interval. Circular Economy proposes to replace the understanding of the production process as a Cradle-to-Grave model, that is the use of a given input to manufacture a product and the consideration of the surplus as waste from the process, by a Cradle-to-Cradle model, which disregards the concept of residue, treating the surplus as an input for a new process (Leitão, 2015). It is intended to increase the useful life of materials through recycling, reuse, repair, and remanufacturing (Shokorova-Palolahti, 2021). This circular vision eliminates the concept of waste from the production cycle, since, in this philosophy, materials are used as much as possible, and when their application to a given situation is exhausted, they are inserted into a new process, starting a new cycle, creating an ecosystem healthy to the maintenance of both environment and society (Lacy; Long; Spindler, 2020).

One of the related strategies is material recovery, focused on extracting valuable

resources from waste materials through various methods such as sorting, separation, and processing. The goal of material recovery is to reduce waste, conserve natural resources, and minimize environmental impacts, since the recirculation of recovered resources in the life cycle allows the use in new construction applications, avoiding the use of virgin raw materials (Antoniou; Zabaniotou, 2013). The underlying question is the demand for energy: either reuse or recycling are possibilities of recovery, but the former consumes much more energy in processing, since it must break down used items to make new materials and objects, therefore used as source for another processes. Thus, reuse is the low energy alternative (Ginga; Ongpeng; Daly, 2020).

It's possible to create an overall summary of recovery kinds, which may vary depending on the type of material being recovered and the specific recovery method being used. Here are some general steps involved in the material recovery process:

1. Collection: Waste materials are collected from various sources such as households, businesses, and industries. The collection process may involve curbside pick-up, drop-off centers, or recycling facilities.

2. Sorting: Once the waste materials are collected, they are sorted into different categories based on their composition and properties. This step is important because different materials require different processing methods.

3. Separation: The sorted materials are then separated using various techniques such as mechanical sorting, magnetic separation, and density-based separation. For example, metals can be separated from plastics using magnetic separation, while paper and cardboard can be separated using air classification.

4. Processing: The separated materials are then processed to extract the valuable resources. The processing methods may include shredding, crushing, grinding, and melting, depending on the type of material and the desired product.

5. Purification: The extracted resources may need to be purified further to remove any impurities or contaminants. For example, recycled metals may be purified by smelting and refining to remove any impurities.

6. Reuse or sale: Once the extracted resources are purified, they can be reused in manufacturing new products or sold to other industries that require those resources.

Energy recovery is in line with this proposal because it understands that, in process waste, there is an energy amount that can be reused or reused. There are various methodologies for doing so, but the most common is incineration (Holmgren; Henning, 2004): the waste is subjected to high temperature combustion, resulting in a reduction in volume and mass of around 85 to 90 percent, in addition to the reduction of dangerous characteristics that such residues may present. The energy recovery process, roughly speaking, takes place, initially, through the segregation of materials, so that the gravimetric and energy characterization can be carried out, and these residues are then taken to the incinerator. This process generates some solid emissions, ashes, gases, exhaust gases, and liquids, which are related to cleaning systems, and such emissions must be considered in the preparation of projects so that they can be controlled (Rossi, 2014). Holmgren and Henning (2004), however, point to the existence of other methodologies for conducting energy recovery, for example, letting waste degrade in controlled and appropriate environments, in order to collect the gas resulting from these processes and use it. As fuel. The pyrolysis process, in which the material undergoes combustion without access to oxygen, the products are basically gas and carbonized waste. When applied to organic materials, the products may involve a variety of oxygen-carrying organic compounds. These gases can be condensed into a mixture of two phases, containing several hydrophilic compounds, and an organic one, called bio-oil, a mixture of insoluble organic compounds, such as waxes, oleic acids, phenols, among others (Misailidis; Demetri Petrides, 2021).

3.1.3. Presentation of cases

Barboza *et al.* (2019) object of interest is the amount of waste generated by construction sector in Brazil. Their aim is to identify strategies applicable to the management of this sort of residue, considering the logistics problems it can create to the maintenance of urban operation. They are obstruction of sidewalks or street by endurant presence of containers, indiscriminate deposit among common trash, interference on the overall management of urban residue, large occupation of municipal landfills and so on.

From this scenario, an approach based on circular economy would seem the better option, since it would create no impediment to waste collection. A new strategy of collecting the material and redirecting it to such facilities that will use as source to their production processes.

Searching through literature, they identified applications of circular economy in different countries and contexts. It's revealed a prosperous practice, because, even though the model applied is the same for every case, reinsert the waste of a process as raw material of another, there are specialties concerning each one. Two of the most interesting are the European Union and England in special. For the first, its actions are inclined toward creating a mass of knowledge produced around the theme of circular economy, investing in universities and in their post-graduation courses to produce knowledge and state-of-the-art technology. For England, its industry did bet on procession, treatment, and reintroduction of waste in the same process — interesting facts to consider for implementation.

Holmgren and Henning (2004) present the situation of waste management in Sweden. Changes in management regulations brought new criteria for disposable elements in landfills: for example, since ordinance (2001:512), no combustible residue was allowed to be placed inside them, also valid for organic material (Sweden, 2001). These new standards are the roots of investments in technology of incineration, since it's capable of recovery these materials energetically, what would provide sources of heat or even electricity to some districts.

Considering this scenario, the authors investigate the situation of two municipalities, Skövde and Linköping, to identify the effectiveness of both material and energy recovery and which one is the better alternative considering each necessity. Given their geographic conditions, Swedish cities demand production of heat. These facilities work with different kinds of fuels, and the authors propose an analysis focused on the replacement of at least a percentage of them by waste. Material recovery is the preferred method, since the substitution of virgin material in processes saves a considerable amount of energy, but some interesting results on previous investigations led to consider this new approach as an improvement both to municipal waste management, since combustible material no longer would be deposed on landfills, and energetical supply, following that residue would become source of heat and electricity.

Their analysis first identifies the current situation of material and energy recovery for each location. In Skövde, the current method was the first, since the city had no waste incineration plant, although there were prospects of investment. Linköping, on the other hand, has one, but it's old, so demands of improvement have been pointed out. The prospect for both cases is the investment on a hybrid system, capable of converting waste into both heat and electricity.

Rather than a comparative, Shorokova-Palolahti and Tawosoli (2021) present a scenario of cooperation, the so called six-city strategy, an industry congregating Vantaa City, the core of the scheme, and five surrounding municipalities. Other interesting distinction between this and the other selected papers is the methodology: qualitative research. What seems odd at first reveals as an adequate complement to all the data brought up by the quantitative methodologies.

The situation they present follows: the coalition between the six municipalities already has a circular economy project implemented; what concerned them was how it was planned and why the taken options and strategies were adopted — a reverse engineering kind of research question. Thus, the methodology adopted: a semi-structured interview with strategic representatives of the entities involved, aiming to identify the ideas behind the decision making, for they could give insights of the reasonings that link, in practice, all the available information that is clustered around circular economy, but has no practical synthesis.

Quispe *et al.* (2023) provide the most recent scenario of this discussion. Being a post-pandemic paper, it indicates the structural changes inflicted on the world's modus vivendi. It's not a surprise that it had an influence on environmental situation, especially on waste generation. The necessity of isolation gave rise to a growth in the production of packaging, used mostly to enable the circulation of groceries and food, since it was not recommended for people to go to restaurants and markets.

To perceive these impacts, the authors studied a city of Peru. The country is characterized by a population divided between rural and urban areas, which imposes limits to the range of actions related to public policies. Thus, the inadequate management of its residues, generating health problems in some communities. In this sense, the elaboration of measures to mitigate a set of factors that influence the generation of SR became of absolute relevance in the Peruvian scenario.

In the study, the authors, based on pre-

sorting strategies, proposed the elaboration of policies and appropriate systems of organic management of RS to obtain a better understanding and extension of each one of the sub-stages involved in the District of Santa Rosa, Ayacucho. The focus on the district was due to the lack of effective collection service in the municipality, which left 42 communities without it.

Following the Latin-American scenario, Orlando (2018) presents the current situation of Brazil: municipalities with no independent management system. Barueri, set in the so called Big São Paulo, an ensemble of highly industrial cities around the capital, faces this situation: it has a working strategy of waste destination, but it depends on facilities localized in another municipality twenty kilometers away, namely the landfill of Santana de Parnaíba, and transportations costs, in face of the amount of residue produced per day, are becoming high, to the point that is more beneficial, both strategically and financially, to Barueri to construct its own facility.

But the plan is not to construct a landfill of their own: on the contrary, following tendencies of various cities worldwide and according to Brazilian restrictions to constructing new facilities as such, the administration prepared the construction of a plant of energy recovery. Although waste-to-energy technology has been widely used in several countries, for several decades, in Brazil this is a pioneering effort, which can be considering a great advance for the consolidation of an even more diverse energy spectrum, characteristic of this country (Castilho *et al.*, 2020). The relevance of this project is its capacity of treatment since the municipality generates about 300 t/day and about 8,500 tons/month.

3.2. Discussion

One of the fundamental facts inferable from all papers is the prominence of circular economy (CE) in the intellectual scenario concerning environment. Barboza et al. (2019) emphasize the importance of enhancing and developing the concept of the CE for the sustainability of the planet, stating that its implementation is directly linked to the policies practiced in each country. Industrial processes planned as natural cycles, with a focus on regenerative processes, increase efficiency in production and the use of by-products, contributing to the local biosphere. In China, the CE is considered part of a broader transformation policy, and the country has invested in socio-economic development to promote its implementation. However, policy interventions supporting the adoption of circularity principles at the macro level are perceived as less effective than at the micro or medial proportions.

In the European Union (EU), strategies for the CE are developed with the aim of facilitating sustainable economic growth while observing the rational use of limited environmental resources. However, the EU's action plan for the circular economy faced difficulties in implementing conventional issues such as material recovery and waste recycling (Barboza *et al.*, 2019), as can be noted in Holmgren and Henning (2004), since they state the fundamental problem: the costs facing effectiveness. Even though it's environmentally justifiable to do such a thing, how it will be presented as a good alternative to the entrepreneur when some authors state that the costs are superior to the benefits of these actions? It's the core of the discussion. Although technologies had their advances, some processes remain economically inviable.

Besides, the lack of success in the overall approach of the plan is due to the lack of promotion of resource-saving behaviors and the absence of a common vision of environmental ethics. In the EU, positive results have been achieved through incentives for interdisciplinary research and cooperation across different disciplines. That's the reason some of the professionals interviewed by Shorokova-Palolahti and Tawosoli (2021) point that the participation of people is fundamental. As stated by Fraga, Chaché e Cavalcanti (2022), the individual plays an important role in the whole process, at a point where their exclusion can make the strategy so expensive that it becomes inviable. The professionals consulted suggested politics of environmental education within the management strategy, considering the relevance of pre-sorting of residue to the general efficiency of it all. Costs become imperatively high when the material is not correctly separated, because of two factors: some of the elements present in the combustible mass are in an adequate state, that would permit recycling, therefore these that could be used as source to other processes are not destroyed by incineration; and the machinery capable of segregating the elements before burning is expensive to the point of making this option inviable. Taking this perspective, engaging the population in such matters is fundamental for their success.

In a strictly technological point of view, however, the debate lies on the option for the

correct strategy. The case of the two Swedish cities presented by Holmgren and Henning (2004) sticks around a dilemma: if either material or energy recovery is the best option to adopt. The second consists in replacing the current fuel by waste; on the other hand, when the orientation is material recovery, it replaces virgin material and saves energy at the same time, because the energetical consumption when processing a recovered material is inferior. This brings back the problem already discussed problem of sorting materials: only where it is practiced such strategy as this can be applied. Considering some improvement made in the heating system of the cities, they concluded that although it's possible, and effective, to use biomass from cardboard and biodegradable waste as fuel to the heating systems, this being an application of energy recovery, materials as paper and hard plastic are more suitable to material recovery, at least considering the treatment methodology used by them.

Quispe *et al.* (2023) continue this inquiry for the best plan, this time in a Latin-American context. Also, they take pre-sorting as axiom for a proficient approach. Considering they had a blank slate to work on, the option for organization, quantification and segregation of waste was, although seemingly conservative, very effective. From the guidelines proposed, it was possible to conclude that the largest amount of solid waste that arrives at the dump is waste of biogenic origin and that its recovery would be able to minimize the amount of organic material that is inappropriately arranged. In this case, the option for material recovery is the most adequate.

Setting up the first pilot plan for the recovery of organic waste of the region, during a period of six months more than four tons of organic compost were obtained, being promptly directed to be converted in compost, that was destined for different green areas of the city, to produce forest seedlings for different projects in the district and as an incentive in ecological contests. In this context, such a plan could be suggested to several municipalities in developing countries, such as Brazil, which has the characteristic of garbage composed of 50% of biogenic origin.

Considering the adequacy of the parameters, such facility could be installed in Brazil, following a south American upraising that already has Santa Rosa, Peru, and Barueri, in Brazil itself. In this case, according to Orlando (2018), the Environmental Impact Study (EIA) prepared under the responsibility of SGW Services states that the plant, based on thermal energy generated by burning, has capacity to process approximately 825 t/day of waste generated in the city itself and in neighboring cities, and energy recovery capable of generating 17MW of electricity, having a useful life of approximately 30 years, considering the operation of 8,000 hours/year. Its sophisticated technology has a gas filtration and neutralization system to meet air quality standards. In addition, all solid waste formed during the incineration process must be disposed of in landfills, which would extend their useful life, all according to the new parameter established in legislation.

4. CONCLUSIONS

This paper's intent was to identify the possible contributions of adopting a circular economy approach in Brazilian municipal waste management. Considering the works collected, several possibilities were identified, also the challenges behind each and some scenarios that brought parameters and data to establish comparisons.

First, all these strategies consider nature and its circles as a system, therefore are engaged in the renewed environmental consciousness; they also match with the impetus of developing new forms of interaction between man and nature, especially in the urban context. Thus, it's plausible to consider the achievements of the cases considered as evidence of the prosperous scenario of this philosophical approach, and that its application in a Brazilian municipality may be prosperous. Even though there are legal aspects that guarantee the correct disposal of waste and related aspects, the distance between paper and action is enormous. Based on the results presented, the application of circular economy may be a more suitable strategy, reducing the necessities of long-distance logistics and improving the financial necessities of this kind of management. Such methodologies could also improve the energetical spectrum of Brazil, already one of the most diverse in the world.

Although the concern with the destination of the generated residues presents an evolution, there is still a lack of investments for the popularization of efficient and environmentally correct technologies for reuse. It is essential to discuss the change in the perception of waste as an expensive product for a source of electricity and so many other possibilities for reuse.

Thus, this study exposed a promising alternative not only for the final treatment of MSW but also in the decentralization of an energy matrix that is still very dependent on hydroelectricity.

Considering the population growth and, consequently, the increased energy demand, in addition to generation of urban solid waste, waste-to-energy technology becomes an interesting option for the environmentally development of Brazilian municipalities.

5. DECLARATIONS

5.1. Study Limitations

This study is limited to the references and methods it has used.

5.2. Funding source

The authors funded this research.

5.3. Competing Interests

There's no conflict of interest regarding this paper.

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