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A circular economy as an alternative for Brazil's sustainable growth: analysis of the National Solid Waste Policy

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Abstract

Objective: to present a global view of the circular economy, showing the most important elements of the implementation of this concept and its inherent practices.

Methodology: the procedure chosen is qualitative, exploratory, and descriptive, based on the review of the documents and norms pertinent to the measures aimed at solid waste management in Brazil.

Relevance: the research contributes to the academic discussion about a concept that is a world's concern, based on the production and disposal of waste, investing in reuse, repair, and renovation of materials and energy, and aiming at economic growth and human development while preserving the environment and sustainable development.

Results: the results show that, in Brazil, the actions to incorporate a circular economy into production and consumption need to overcome different barriers and challenges to render it viable according to the sustainable development criteria.

Contributions: the main contributions are linked to the emphasis on the Brazilian actions to transform municipal solid waste into energy and describe the key aspects related to the regulation of reverse logistics in Brazil, in order to identify its link with the circular economy.

Conclusion: there is a need for a deep cultural change, having as its starting point environmental education, at all levels, linked to a good process of awareness raising and social communication.

Keywords: Circular economy. Environmental sustainability. Resource efficiency. Waste management. Energy recovery.

Economia circular como alternativa para o crescimento sustentável brasileiro: análise da Política Nacional de Resíduos Sólidos

Resumo

Objetivo: apresentar uma visão global do tema economia circular, tentando mostrar os aspectos mais relevantes na implantação desse conceito e as práticas a si inerentes.

Metodologia: estudo de caso, com abordagem qualitativa, exploratória e descritiva, baseado na revisão de documentos e normas pertinentes às medidas dirigidas ao gerenciamento de resíduos sólidos no Brasil.

Relevância: o trabalho contribui para a discussão acadêmica sobre um conceito que se insere no âmbito do anseio mundial, assentado na produção e eliminação de resíduos, apostando nos conceitos de reutilização, reparação e renovação de materiais e energia e visando o crescimento econômico e o desenvolvimento humano preservando o meio ambiente e o desenvolvimento sustentável.

Resultados: foi possível mostrar o movimento para incorporar a economia circular na produção e consumo no Brasil, destacando a necessidade de superar diferentes barreiras e desafios para viabilizá-lo de acordo com os critérios de sustentabilidade ambiental, conforme definido conceitualmente para a promoção da economia circular.

Contribuições: a partir da discussão teórica, associada à pesquisa empírica, as principais contribuições estão vinculadas ao fato de se dar ênfase às ações brasileiras de transformação de resíduos sólidos urbanos em energia e se descrever os principais aspectos relativos ao regulamento da logística reversa no Brasil, de modo a identificar sua vinculação com a economia circular.

Conclusão: observou-se a necessidade de uma grande mudança cultural, a partir da educação ambiental, articulada com um bom processo de sensibilização e comunicação social.

Palavras-chave: Economia circular. Sustentabilidade. Eficiência de Recursos. Gestão de resíduos. Recuperação de energia.

La economía circular como alternativa al crecimiento sostenible brasileño: análisis de la Política Nacional de Residuos Sólidos

Resumen

Objetivo: presentar una visión global del tema de la economía circular, tratando de mostrar los aspectos considerados como los más importantes en la implementación de este concepto y las prácticas a él inherentes.

Metodología: estudio de caso con enfoque cualitativo, exploratorio y descriptivo, basado en la revisión de una muestra de documentos y estándares pertinentes a las medidas dirigidas a la gestión de residuos sólidos en Brasil.

Pertinencia: el trabajo contribuye a la discusión académica sobre un concepto que forma parte del anhelo mundial, basado en la producción y eliminación de residuos, centrándose en los conceptos de reutilización, reparación y renovación de materiales y energía y apuntando al crecimiento económico y el desarrollo humano preservando el medio ambiente y el desarrollo sostenible.

Resultados: fue posible evidenciar el movimiento para incorporar la economía circular en la producción y en el consumo en Brasil, mostrando la necesidad de superar diferentes barreras y desafíos para tornarla factible según el criterio de sustentabilidad ambiental, como se define conceptualmente para la promoción de la economía circular.

Aportes: a partir de la discusión teórica, asociada a la investigación empírica, las principales contribuciones están vinculadas al énfasis en las acciones brasileñas de transformar los residuos sólidos urbanos en energía y describir los principales aspectos relacionados con la regulación de la logística inversa en Brasil, para identificar su vínculo con la economía circular.

Conclusión: se observó la necesidad de un gran cambio cultural, empezando por la educación ambiental, articulado con un buen proceso de sensibilización y comunicación social.

Palabras-clave: Economía circular. Sostenibilidad. Eficiencia de recursos. Gestión de residuos. Recuperación energética.

1 Introduction

A look at environmental policies in the international context reveals the growing worldwide concern about waste generation, due to the impacts caused by the traditional model of industrial production that is based on the extraction of raw material and its transformation into products, generating waste throughout the process and also at the end, after their consumption.

Such an economic model does not contribute to the promotion of a sustainable future, since the economy works in a linear way (extraction, production, consumption, and waste), resulting in the excessive use of natural resources at a faster pace than its capacity for regeneration, with the consequent creation of mountains of urban waste.

The concept of a circular economy has emerged to oppose this unsustainable linear economic model, which proposes a behavioral change in the way of consuming and using natural resources and waste. In practical terms, the circular economy advocates a change in the form of product design and consumption, in the process of exploring raw materials and waste, and in the conflict between environmental sustainability and economic growth. It is therefore a solution that, at least theoretically, unites the sustainable model with the technological and commercial rhythm of the modern world, minimizing the human impact on the environment.

In this context, taking into account the current stage in which the circular economy is spreading around the world, this article aims to discuss the relation between solid waste management and the circular economy in Brazil, delimited by four main concrete realities: (1) What are the sustainability strategies (regenerate and restore), developed in Brazil, covered by the three fundamental principles on which the circular economy is based? (2) How are the Brazilian initiatives, aimed at transforming municipal solid waste into energy, using reverse logistics? (3) What are the barriers that have delayed or prevented a more effective progress of these initiatives in Brazil? (4) Which aspects of the Brazilian standard for solid waste management are consistent with the circular economy principles?

Therefore, this article aims to present a global view of the circular economy theme, highlighting the main aspects of the implementation of this concept and its inherent practices. In addition to the bibliographic review, the method used is based on a qualitative, descriptive, exploratory approach, through a critical analysis employed in the study of documents and norms relevant to the measures aimed at solid waste management in Brazil. In the selection of the research sample, the fundamental role played by waste management standards was taken into account, since [depending on their legal nature] they have the power to be fully applied to any production chain, and may influence the economic growth of the country. From this perspective, the theoretical basis used in this article emphasizes the Brazilian

actions to transform urban solid waste into energy and describes the main aspects related to the regulation of reverse logistics in the country to identify its link with the circular economy.

The research is justified by bringing the academic discussion to a current topic, assuming that the effectiveness of the circular economy would not only prolong the existence of certain natural resources, but would also allow economic growth and human evolution, while preserving the environment and sustainable development.

The article is organized into four sections. In this first section, the study is contextualized, detailing its research questions, aim, justification, and relevance, in addition to the contributions it intends to provide. The second section discusses the theoretical frameworks that supported the development of the study, making a brief analysis of the main components associated with the concept of circular economy and discussing the actions to be developed for the transition of waste management to a circular economy. In this context, the regulatory aspects related to solid waste management in Brazil are also described. In the third section, an analysis is performed of the adherence of Brazilian regulatory mechanisms to the circular economy, discussing the barriers to its implementation, as there are numerous difficulties that restrict or prevent the effective promotion of a Brazilian model of circular economy. The fourth and last section presents the conclusions and final reflections on the subject, followed by the references used in the analysis.

2 Theoretical background

The current economic system, based on a linear approach (extract-consume-discard), may take the planet to a scenario of scarcity and greater environmental degradation, in view of the increase in the world population and the lack of resources to meet the current consumption needs (Almeida et al., 2016).

For Steffen et al. (2015), the economic model in force today is no longer sustainable. In part, according to Cerdá and Khalilova (2016, p. 11), because it is reaching its physical limits, by applying a linear economic model predominantly based on "picking up, making, using, discarding, relying on the availability of large quantities of cheap and easily accessible materials and energy.

In this contradiction, sustainable development can be considered the most plausible solution to the problems arising from this scarcity of natural resources and raw materials and those caused by pollution generated by human activity. With this systemic concept, an attempt is being made to find a new way of thinking about the economy, contrasting with the linear model currently in force, by incorporating the concern with nature, through the extraction of raw materials, to the aspects of a mass consumption system.

From the perspective of sustainable development, the concept of circular economy

can be conceived as a viable alternative solution to break away from the linear model paradigm, becoming an integral issue that has been taking priority on the agenda of civil society, companies, and government agencies. The circular economy has also been granted more attention in the international academic community (see Andersen, 2007; Ghisellini et al., 2016; Lieder & Rashid, 2016; Su et al., 2013), and there is already a legitimate concern for the future of humanity, if the linear economic model of production and consumption is not replaced by another that is more economically sustainable.

The strong pressure exerted by modern society to preserve the planet's natural resources requires a reorientation of the current economic model, seeking to apply a more sustainable production-consumption methodology (Simões, 2017, p. 14). If humanity continues overburdening the natural resources, it will be paramount to apply an interdisciplinary or transversal perspective and a complete reorientation of development thinking (Hogan, 1993, p. 57). Therefore, to analyze each of the elements of the circular economic process in its specific form, it is necessary to resort to a multidisciplinary approach integrating the areas linked to the social and natural sciences.

In addition, the achievement of a new alternative model for the mainstream also implies stimulating new management practices and changing society's behavior regarding the production of consumer goods and the generation of industrial waste and garbage, organic and inorganic. Waste management, in turn, is a vital issue to consider in the development of the policies and plans of a locality (Suárez et al, 2018, p. 19). For this reason, especially at industrial level, waste management has acquired significance in economic, social, and environmental perspectives, also becoming a strategic priority in countries' government policies (Almeida et al., 2016). With this, the circular economy theme proves to be a central concept in the visionary context of sustainability and sustainable development.

As the circular economy assumes the creation and maintenance of continuous flows of use of resources, both in the biological and technical cycles, the need for a more intelligent management of non-renewable resources increases in order to prolong their existence. The aim is to delay the extraction of raw materials and maximize the reuse of materials, in addition to fostering production improvement and product development, seeking a less intensive use of resources. The generation of waste in cities accounts for many of the current environmental impacts worldwide. These impacts are due both to the excessive consumption of a minority of the world population, which results in a deficit of resources, and to the effects that poor waste management has on the environment and society.

2.1 Basic principles of circular economy

The term circular economy first appeared in 1976, in a report submitted to the Energy Commission of the European Communities (today, European Commission), entitled "Potential for Substituting Manpower for Energy", by Walter R Stahel and Geneviève Reday-Mulvey, made public five years later in the book "Jobs for Tomorrow, the Potential for Substituting Manpower for Energy" (CSR Piemonte, 2019). Stahel and Reday-Mulvey (1981) defended the thesis (absolutely revolutionary for the time) that the second life of goods, until then completely undervalued, offered enormous possibilities for economic and social development, while mitigating the impacts of economic processes on the environment. According to CSR Piemonte (2019), in the report, the authors proposed that political decision makers engage in a complex change of global perspective, improving new skills and competences that could bring new life to objects, believing that there would already be customers ready to buy them.

In 1982, Stahel won the International Mitchell Award on Sustainable Development (Barbosa, 2018). In his article entitled "The Product-Life Factor", he described a closed-loop economy model, where he suggested that the service-life extension of goods would have a direct relation with the depletion of natural resources. This seminal work can be considered the first theoretical manifestation towards the concept of circular economy. The analysis of the economic model evolution adopted by companies in the last 70 years reveals a significant attempt to change course, starting in the 1980s, when began the demands to rethink market strategies and models to guarantee the competitiveness of the sectors and the heritage of natural resources, shifting the traditional model of linear economy to the circular one, as shown in the following figure:

Figure 1 - Evolution from Linear to Circular Economy

Source: Adapted by the authors, based on Ministero dell'Ambiente and della Tutela del Territorio and del Mare & Ministero dello Sviluppo Economico, 2017, p. 5.

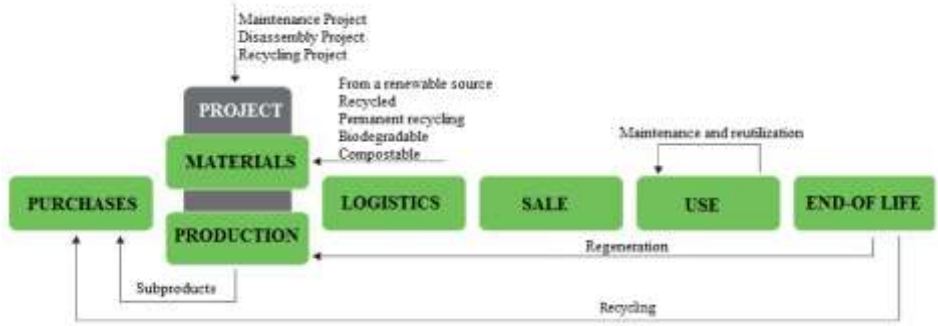
Despite being increasingly more frequent on the agenda of policy- and knowledge-makers around the world (Brennan et al., 2015; EC, 2015; Lieder & Rashid, 2016; EMF, 2013a), the conceptual relationship between the circular economy and sustainability is still unclear (Geissdoerfer et al., 2017). In practical terms, the circular economy refers to a model

of industrial economy that is, by design or intention, restorative, focusing on the concept of cradle-to-cradle principles and the sustainability of materials. Therefore, under the concept of circular economy, issues such as sustainable purchases of raw materials, ecological production and design processes, adoption of more sustainable distribution and consumption models, development of secondary markets for raw materials become key elements for business success and gradual transition towards a sustainable society.

Geissdoerfer et al. (2017, p. 759) define the circular economy as a regenerative system in which the input of resources and waste, emission, and leakage of energy are minimized by slowing, closing, and narrowing the flow of material and energy. According to the authors, this can be achieved in a long-term perspective (greater durability of products) through design, maintenance, repair, reuse, remanufacturing, restoration, and recycling.

The transition to a circular economy model will imply a paradigm shift, since it will demand a new way to conceive the production flow. Therefore, the transition from the already-consolidated linear model of economic development to a circular model comprises each of the phases that constitute the life cycle of a product - from design to production, up to the end of its useful life (CSR Piemonte, 2019, p. 9-10). In this perspective, it is necessary to: (i) minimize the consumption of natural resources; (ii) reduce energy use; (iii) avoid the generation of waste; and (iv) maximize the creation of social and environmental value. The following diagram shows how the manufacturing process should be designed in a circular economy model, from product design to final obsolescence.

Figure 2 - Design process for the development of circular products



Source: Adapted by the authors, based on Ministero dell'Ambiente and della Tutela del Territorio and del Mare & Ministero dello Sviluppo Economico, 2017, p. 27.

Looking at the economy as a circular process means the possibility of presenting the entire system of economic relations as a long road that makes a great circle and returns to the starting point (Leontief, 2007, p. 129). In concrete terms, the transition to a circular economy redirects the focus to the reuse, repair, renovation, and recycling of existing materials and products, that is, what has been seen as "waste" can be transformed into a resource (Simões, 2017, p. 15-16).

Thus, the circular economy is a response to the desire for sustainable growth in the

context of the increasing pressure that production and consumption exert on the environment and global resources (CE, 2014). It is a regenerative and restorative industrial system in principle, aiming to replace the concept of 'end of life' with renewable use, keeping products, components, and materials at their highest level of utility and value over time (EMF , 2012, p. 7). It is important to highlight the importance of Ellen MacArthur's work in this context, as this foundation has been promoting a series of publications on the topic, including a book by Webster (2015) and a series of reports (EMF, 2014; 2013a; 2013b), also acting as a collaboration center for companies, policymakers, and universities.

The following figure shows a continuous process of reabsorption and recycling, based on the reduction, reuse, recovery, and recycling of materials and energy, as proclaimed in the principles of a more circular economy.

Figure 3 - Typical Sequential Process of a Circular Economy

Source: Simões, 2017, p. 16.

The circular economy offers a platform of benefits in terms of waste management, mainly through measures that favor recycling and reuse. In the circular economy concept, the benefits obtained can be included in four macro areas, namely economy, environment, use of resources, and social aspects, as shown in the following figure:

Figure 4 - Benefits of the circular economy

Source: Adapted by the authors, based on Simões, 2017, p. 17.

2.2 Necessary measures for sustainable waste management

Lately, there has been a strong worldwide desire for sustainability and sustainable development. The concept of 'end of life' has been increasingly criticized, as it is defined in the linear economy model, which is strongly based on the production and disposal of waste. For that reason, there is an urgent need to devise a new industrial standard capable of better characterizing the concepts of reuse, repair, and renovation of materials and energy.

Consequently, there is a growing need to create a strategic reference for growth and investment based on the rational use of production, with the appreciation of natural resources and the minimization of environmental impacts. As a result, several international commitments are emerging in the light of this new mindset, to establish a regulatory model that can discipline world society in our interaction with the ecosystem and the environment in which we all live. Under this conception, there are plenty of examples of actions such as the Paris Agreement and some recent concrete proposals to promote the principles of the circular economy in terms of legislation in developed countries. China (see Geng et al., 2012; 2013) and the European Continent itself (see EC, 2014; 2015) are leading the management of this current public policy challenge, although there are still no well-organized or unified indicators to effectively measure systems that apply this concept.

In the European Union, an action plan for the establishment of a circular economy was approved in 2014 (EU action plan for the circular economy: progress so far), aiming to implement a program to put an end to waste in Europe. This package of measures sought to support the transition to a circular economy in the European Union, including legislative proposals on waste, recycling, and reuse (Santos, 2019) and a schedule for the development and adoption of a strategic policy aimed at ending waste in Europe. The actions proposed in this action plan focused on the necessary measures to implement the circular economy, in terms of production design, consumption, waste management, secondary raw materials, plastic and food materials, critical raw materials, construction and demolition waste, biomass and biomaterials (materials based on biological resources, such as wood, crops, or fibers), innovation and investment, in addition to other horizontal measures to monitor and develop a structure to address the circular economy (CE, 2015).

In Brazil, a few effective strategies have been adopted to implement the circular economy as a public policy. In practice, this theme is beginning to take its first steps in Brazil, like a 'fad', based on new approaches to waste management, but it still needs to advance further, since the circular economy, as proposed, goes well beyond the «3Rs Principle» (reduce, reuse, and recycle). In essence, this concept comprises, at least theoretically, the adequacy of the sustainable model with the technological and commercial pace of the current world; that is, it is an idea that seeks to rethink economic practices, aiming to keep

products, components, and materials in circulation, taking advantage of the maximum value and utility between technical and biological cycles.

From this perspective, waste management plays a crucial role in the circular economy, since it implements the waste hierarchy by determining an order of priority, from prevention, through preparation for reuse, recycling, and energy recovery, to discarding, as is the case of landfill disposal (CE, 2015, p. 9). The Brazilian regulatory framework regarding waste was introduced through the National Solid Waste Policy (in Portuguese: PNRS - *Política Nacional de Resíduos Sólidos*), established by Law No. 12,305, of August 2, 2010. This law contemplates the main sustainability guidelines, and among its principles and tools there stand out the shared responsibility for the product life cycle and reverse logistics, essential links to enable the reintegration of waste into a new economic cycle (Brazil, 2010a).

Based on this regulation, solid waste management in Brazil started to reduce waste generation and combat pollution as its most relevant guidelines for sustainability. In addition to the National Environmental Education Policy (in Portuguese: PNEA - *Política Nacional de Educação Ambiental*), established in 1999, the PNRS is articulated with the Water Resources Policy (in Portuguese: PNRH - *Política Nacional de Recursos Hídricos*), 1997, the National Policy on Climate Change (in Portuguese: PNMC - *Política Nacional de Mudanças Climáticas*), 2009, and the Brazilian National Plan for Basic Sanitation (in Portuguese: PNSB - *Plano Nacional de Saneamento Básico*). The latter, sanctioned by Federal Law No. 11,445, of January 5, 2007, establishes the national guidelines for basic sanitation, and determines, in Article 7, that they include among their public service activities, the treatment of household waste, and the management of solid waste from the cleaning of roads and public areas (Brazil, 2007).

In its article 33, the Federal Law No. 12,305 determines who is obliged to structure and implement post-consumer reverse logistics systems, in order to avoid incorrect disposal, in other words, increasing recycling and reducing the deposit of municipal waste in landfills. This must be done independently of the urban cleaning service and solid waste management. Manufacturers, importers, distributors, and traders are the agents responsible for the return of pesticide containers and their residues, common and electric batteries, tires, used lubricating oils and packaging waste, in addition to the waste resulting from the disposal of electronic devices (Brazil, 2010a).

The "3Rs Principle" is based on changing consumption habits, which must be carried out with more awareness, reducing the demand for natural resources, with the consequent reduction in the generation of waste disposal in the environment (Machado, 2015, p. 186). The paradox is that this behavior implies an expected individual responsibility to provide a solution to a collective problem; in other words, it will be necessary to change personal habits.

In addition to the federal legislation, states and municipalities also act autonomously in establishing their own regulations, standardizing waste management and reverse logistics, within the limits established in the PNRS. Thus, the development of integrated solid waste management plans follows a priority order of action: (i) non-generation; (ii) reduction; (iii) reuse; (iv) recycling and treatment of residual waste (including mixed); v) the environmentally appropriate final disposal of residual waste, which are residues whose possibilities of use have been exhausted, since they were considered unsuitable for any other type of use. Therefore, from the perspective of advancing towards a sustainable economy, it is necessary that waste be reused in some way, according to its characteristics and specificities, that is, its reinsertion in the production processes or reuse in other companies or utilities.

According to the PNRS, in order to favor the return of materials in the right conditions for their reintegration back into production, the optimization of the process requires an articulation between all those involved in the whole value chain, taking into account the entire product life cycle, from producer to consumer. From the perspective of reverse logistics, in the cascading of materials in other applications, it is necessary that the reverse logistics chains be optimized from start to finish. Thus, it is essential to develop competencies, skills, and infrastructure in order to move towards greater circularity (Ellen MacArthur Foundation, 2015, p. 18).

Based on these considerations, the Brazilian move towards the establishment of a national policy aligned with the concept of circular economy would demand the adoption of some strategic actions in terms of policies to promote the efficient use of resources: in the management and appreciation of specific waste streams, energy efficiency, and green growth. For this purpose, in Chart 1, a follow-up and monitoring protocol is developed, defining the seven macro-level actions that contain the main elements to be considered in the context of the development and implementation of the circular economy. Based on the European Union's Action Plan for the Circular Economy (CE, 2014; 2015) and the Action Plan for the Circular Economy of Portugal (PAEC, 2017), the macro level has as its central elements product, consumption, waste or secondary raw materials, and knowledge. In macro-level actions, it can be seen that it will be precisely the fifth action (New Life for Waste), which will be used as an object of comparison with Brazilian initiatives in the reverse logistics segment (in view of the current legislation), given that Brazil is still in the early stages towards the circular economy.

Table 1 - Action Plan for Adoption of Circular Economy

Macro-level actions	Main Elements	Action Title
Action 1	Production + Consumption	Designing, repairing, and reusing: increased producer responsibility.
Action 2	Consumption	Encouraging circular market: sustainable investment, production, use, and consumption.
Action 3	Consumption + Knowledge	Educating for the circular economy: knowing, learning, communicating, and raising awareness.
Action 4	Consumption + Waste	Combating and reducing food and organic waste.
Action 5	Waste	Generating new life for waste, by-products, and secondary raw materials.
Action 6	Consumption + Waste	Regenerating resources: water reuse and sustainable use of nutrients
Action 7	Knowledge	Research and innovation in circular economy.

Source: Own elaboration based on the analysis of Interministerial Circular Economy Group, 2017, p. 34-45.

The proposed planning enables us to identify the necessary measures for the effective and efficient implementation of the circular economy, mainly in the areas of product design, production processes, consumption, waste management, secondary market for raw materials, and innovation, as defined by the European Commission (EC, 2015). According to Gonçalves (2017, p. 12), this planning also identifies priority materials and sectors, notably the industry that produces plastic. The planning also includes global commitments aimed at specific actions in areas such as food waste, critical raw materials (biomass and bioproducts), industrial and mining waste, consumption, and public purchases (construction and demolition).

From such a strategic plan, it is possible to move towards a circular economy model, obtaining economic, social, and environmental benefits with better management of urban waste, with a series of legally binding measures and objectives that will improve resource efficiency and increase recycling and reuse and will lead to the progressive elimination of landfill deposition, mainly in the large urban centers of the country.

3 Analysis and discussion

The results are shown below, divided into two steps, where: (i) we analyse the adherence of Brazilian regulatory mechanisms to the circular economy model regarding the theoretical and practical assumptions present in the debate on circular economy; and (ii) we discuss the main barriers to the implementation of this new economic concept in Brazil.

3.1 Brazil's adherence to the circular economy

To determine the adherence degree of the PNRS to sustainable development, a descriptive analysis of the impacts of its content was performed to link them to the principles of the circular economy.

Efforts to achieve environmentally sustainable conduct in Brazil, according to the concept of circular economy, are being developed, notwithstanding many current challenges in public policies and economic strategy. Today, there are initiatives that show the Brazilian commitment to boost habits and consumption which are more aligned with sustainable development, where the guidelines of public and private entities, albeit in a relatively slow way, motivate the movement towards of a circular economy scenario.

From the perspective of rational use of resources and generation of waste, the more they are recovered and reused, the less the need to extract them and produce their components. Consequently, the degree of contamination will also be less and, in turn, the stock of resources for future generations, greater. However, in this context of circular economy, the Brazilian instruments, mechanisms, and regulations on waste management are still trying to contemplate some characteristics of these principles of socially sustainable behavior.

In order to verify the level of adherence to the principles of the circular economy of proposals contained in the Brazilian waste management guidelines, the PNRS is studied and evaluated in comparison with the action plan for the adoption of the circular economy proposed in Table 1. In this sense, the points of convergence will be identified with the objective of knowing what has already started and what still needs to be covered in the future regulatory framework in Brazil to adapt to the development of the circular economy.

As already mentioned, at the macro level, the PNRS contemplates only actions directed to waste (Action 5), in terms of the useful life of waste, by-products, and secondary raw materials. Regarding the level of commitment of Brazilian waste management standards to the principles of the circular economy, Table 2 presents seven indicators of adequacy control or verification to calculate the degree of transition to a circular economy, classified in the dimension transform waste into added-value products.

Table 2 presents a summary of the adherence of the Brazilian waste management regulations to the concepts of the circular economy. In a way, practically all indicators are contained in the Brazilian norm, whether as a principle, guideline, or objective. The indicators that deal with the generation and deposition in dumps are still being addressed predominantly in theoretical terms in the current regulations, considering the characteristics and difficulties to establish goals and control or inspect these activities locally. The other three indicators are related to recycling and are determined more clearly in the Brazilian norm. They can be evaluated in their practical results, although still timidly.

Table 2 - Analysis of the adherence of the National Solid Waste Policy (PNRS, in Portuguese) to the indicators for measures to transform waste into resources

	INDICATOR	MEASURE
1	Generation of waste, excluding mining residues, dredged waste, and contaminated soil (kg/per capita)	Based on the information provided by municipalities on the volume of waste per capita, efforts are encouraged to prevent its generation and reduce current levels of waste emission; but there are no deadlines or indicators for such control (Art. 7, II; Art. 30, III; Art. 38, among others).
2	Landfill deposit rate (%), excluding mining residues, dredging, and soil contamination [defined as the volume of waste sent to the landfill deposit (directly or indirectly) divided by the volume of treated waste (excluding mining, dredging, and contaminated waste) from soil]	The deposits in sanitary landfills are considered environmentally adequate and justified for the residues, including mixed waste (art.3, VIII; art.9, §1; art.54; among others). It is still the main methodology for the final waste deposit. The norm establishes that municipalities are responsible for the management, control, and creation of performance indicators. There is a signed long-term commitment, but it has not been kept. For this reason, class entities and environmental agencies provide the data, albeit underestimated.
3	Generation of municipal waste (kg/per capita)	Efforts are encouraged to prevent the generation of waste, fostering its reduction (Art. 7, II). However, there are no indicators in the legislation, as it is the duty of municipalities to create them, and class entities and environmental agencies provide a ballpark estimate.
4	Rate of municipal waste disposal in landfills (%)	The landfill deposit is considered environmentally suitable for urban waste, including mixed waste (art.3, VIII; art. 9, §1; art. 54; among others). The main methodology is the final waste deposit. Selective collection and recycling are encouraged (art. 9, §1; among others). Performance indexes must be created by municipalities.
5	Municipal waste recycling rate (%)	Reuse and recycling are actions considered priority by law (art. 6, VIII; art. 7, II, VI; art. 19, X; among others). There are no indicators in the legislation, as to the duty of municipalities to create them; however, class entities and environmental agencies provide a ballpark estimate.
6	Packaging waste recycling rate (%)	The recycling of packaging materials (paper, glass, plastic, metal, and wood) is a relevant regulatory concern in recycling programs and in the reverse logistics system (Art.12; Art.14; Art.18; Art. 32; Art.33; among others). The establishment of goals, indicators, and control mechanisms was left to municipal plans. However, these measures are based on estimates from class entities and environmental organizations, which in turn end up providing underestimated data.
7	Recycling rate of waste from electronic devices (%)	Municipal plans will include commitments aimed at developing and implementing goals, indicators, and mechanisms to control the waste from electronic devices. However, responsibility will be shared, implemented individually and in chains, between market participants and owners of public services. Electronic waste is inserted in the selective collection, recycling programs, and the reverse logistics system. The systems of increased producer responsibility must be structured and maintained by manufacturers, importers, distributors, and traders (Art.33; Art.18; among others). Sectorial agreements must establish progressive, intermediate, and final goals. Performance analysis data and rates are either unavailable or shown to be undervalued by estimate.

Source: Own elaboration based on the analysis of PNRS and PAEC documents.

The first four indicators are the-smaller-the-better type. They focus on waste management in general (from industrial and hospital sources) and urban waste (domestic and municipal). For the circular economy, if there is a reduction in the generation of this waste, it may mean that the materials are being treated as raw material or by-product by economic activity and also that industrial processes can become more sustainable, reducing waste generation to a minimum. If landfill deposition rates decrease, it may mean that reuse is becoming more intense and the economic value of these materials will be preserved. According to the European Commission (EU, 2015, p. 2), the essential contribution in the effort to achieve a sustainable, efficient, and competitive economy in the use of resources occurs when the value of products, materials, and resources remains in the economy as long

as possible and where the generation of waste is minimized. As a result, it seems logical that waste would become a resource, as the circular economy principles advocate.

The last three indicators monitor the recycling process and are of the "bigger, better" type. It is assumed that technological developments could allow 100% of the containers and electronic devices to be recycled in a few years. As a long-term objective, the Brazilian norm aims to increase the preparation for reuse and recycling of waste. At the same time, the proposed actions support the efforts in the field of sustainable development, considering that the rates also present higher recycling volumes, demonstrating strong adherence to the principles of the circular economy. In the case of urban organic waste, its disposal today represents one of the biggest problems that is interesting to discuss from an environmental point of view. Currently, there is a growing interest in the use of organic waste as energy recycling; for example, in the use of energy in the recovery of ecosystems (they can be returned to the soil as fertilizers). For this reason, this initiative has been the best economic and environmental option, despite being always complementary, as food waste must be avoided. Inorganic waste (glass, plastic, paper, cardboard, metals, wood, cloths, fabrics) can also be recycled. Yet, when they are contaminated, they can only be incinerated to generate energy to obtain an economic value from them, for example, as a source of thermal energy in unconventional kitchens.

For all these reasons, it appears that the Brazilian legislation is already reasonably adhering to the concept of circular economy, although the scope of the PNRS has not yet been effectively implemented in all regions of the country. In short, three of the seven indicators proposed in Table 2 are adequately covered by waste regulation in Brazil. This means that the country, in theory, adheres to 43% of the circular economy indicators. Thus, the transformation of waste into resources is examined under the approach of recycling within Brazil, despite its small volume. To better understand this Brazilian dilemma, it seems important to briefly describe the solid waste scenario in the country, since it is partially adherent to the principles of the circular economy, but in a still insufficient proportion.

Data from the study by the Brazilian Association of Public Cleaning and Special Waste Companies (in Portuguese: ABRELPE - *Associação Brasileira de Empresas de Limpeza Pública e Resíduos Especiais*), 2018, show that the amount of waste sent to landfills has increased for the second consecutive year in Brazil. According to this study, in 2017, waste production in the country reached 78.4 million tons. This corresponds to a collection coverage rate of 91.2% for the country, which shows that 6.9 million tons of waste were not collected and, consequently, were improperly disposed of, being deposited without any kind of care in uncontrolled landfills. The total generation of waste in the same period reached a total of 214,868 tons/day in the country, corresponding to a generation per capita of 1.035 (kg/inhabitants/day). Of this total, 196,050 tons/day had their destination distributed

as follows: i) 59.1% were destined for landfills; ii) 22.9% for controlled landfills; and iii) 18% were transferred to large dumps.

Regarding recovery, despite a relatively careful elimination, it remains irregular. It is noteworthy that inadequate units such as dumps and controlled landfills, present in all regions of the country and with a high potential for promoting environmental pollution and negative health impacts, receive more than 80 thousand tons of waste per day. According to the National Health Information System (in Portuguese: SNIS - *Sistema Nacional de Informação Sanitária*), 2017, 842,496 tons of recyclables were recovered, with 826,926 tons being received at recycling centers, with a difference of 15.6 million tons not used and without information about their destination. It is emphasized that information on the correct disposal of waste varies according to sources. The country has 5,570 municipalities; however, not all of them have made their information available. The Brazilian Association of Public Cleaning and Special Waste Companies released data only from 3,352 municipalities in the period. On the other hand, 3,670 municipalities disclosed information through the National Sanitation Information System of the Ministry of Cities (in Portuguese: SNIS - *Sistema Nacional de Informações sobre Saneamento do Ministério das Cidades*).

Part of this recovery was based on reverse logistics, which in Brazil operates through regulations and sectorial agreements started in 2016, between the government and manufacturers, importers and everyone involved in the reverse-cycle process, as defined in the PNRS and Decree No. 7,404, of 2010. However, some products are still in the implementation phase of the agreement, such as used or contaminated lubricating oils, batteries, tires, and electrical and electronic products.

About the shared responsibility of final consumers, in relation to products with mandatory reverse logistics (lamps, batteries, etc.), the orientation is that delivery be made to establishments that sell these products. They will guide the manufacturers to give them a correct destination. That is, they will be responsible for collecting, transporting, and shipping to their final disposal.

According to Andrade et al. (2017, p. 53), the recovery of waste in industry facilitates the achievement of a maximum degree of substitution of non-renewable materials. The measures proposed in the Brazilian regulatory framework try to minimize the generation of hazardous waste and there are already some advances in reverse logistics in Brazil that can be highlighted:

Lubricating oils: For the reverse logistics of these products, the National Union of Fuel and Lubricant Distribution Companies (in Portuguese: SINDICOM - *Sindicato Nacional das Empresas Distribuidoras de Combustíveis e Lubrificantes*), the entity responsible for complying with the first sectorial agreement signed with the Ministry of the Environment, in

late 2012, created the Fair Play Institute. As of January 1, 2020, this association, which represents the largest fuel distribution companies in the country, has been called "Plural - National Association of Fuels, Lubricants, Logistics, and Convenience Distributors" (in Portuguese: *Plural – Associação Nacional das Distribuidoras de Combustíveis, Lubrificantes, Logística e Conveniência*). Currently, the program is present in 15 states (Alagoas, Bahia, Ceará, Espírito Santo, Mato Grosso, Minas Gerais, Paraíba, Paraná, Pernambuco, Rio de Janeiro, Rio Grande do Norte, Rio Grande do Sul, Santa Catarina, São Paulo, Sergipe), and the Federal District, covering 4,153 municipalities, with 41,755 registered generating points and 25,780 active generators (Abrelpe, 2018). According to data from the National Agency of Petroleum, Natural Gas, and Biofuels (in Portuguese: ANP - *Agência Nacional de Petróleo, Gás Natural e Biocombustíveis*), after two years of falling demand due to the contraction of the economic activity, there was a small increase of 2.6% in relation to 2016, since the national market of lubricants experienced a resumption of growth and there was an increase in the minimum level of quality of automotive lubricating oils provided by the ANP Resolution 22/2014 (Plural, 2018).

Lamps: The reverse logistics of lamps started with the "Reciclus" Program. Created in 2014, through a sectorial agreement signed by the Ministry of the Environment (MMA: in Portuguese *Ministro do Meio Ambiente*), representing the Brazilian State, with the Brazilian Lighting Industry Association (in Portuguese: ABILUX - *Associação Brasileira da Indústria da Iluminação*). Also participating in this sectorial agreement were the Brazilian Association of Importers of Lighting Products, (in Portuguese: ABILUMI - *Associação Brasileira de Importadores de Produtos de Iluminação*) and 24 other manufacturing companies, in addition to importing firms, traders, and lamp distributors. This agreement aims to implement the reverse logistics system for fluorescent lamps of sodium and mercury vapor and mixed light. However, the reverse logistics of lamps formally started in 2016. In 2017, 43 tons of waste were collected, equivalent to 96 thousand lamps, corresponding to approximately 28 tons of compact lamps and 15 tons of tubular bulbs, totaling around 296 thousand units, of which 192 thousand compact and 104 thousand tubular ones. The breakage rate remains close to zero, reinforcing the collectors' efficiency and safety. The collection system occurred at 500 delivery points in operation in 80 cities in 21 Brazilian states, in addition to the Federal District, amounting to 543 points installed from north to south of the country (Reciclus, 2018, p. 2).

Common batteries and electric batteries: Manufacturers and importers of products that incorporate batteries should inform consumers about how to remove these products after use, allowing for their separate destination from the devices. In addition, establishments that

sell batteries must necessarily contain adequate collection points. However, the generation of waste resulting from the presence of dangerous substances is an emblematic case in Brazil, since in PNRS the company is not necessarily considered responsible for its product destination (reverse engineering). Currently, in Brazil, there is only a requirement for the manufacturer to collect packages of pesticides and lubricating oil. The waste of electrical and electronic products, plastic containers, fluorescent lamps (containing sodium, mercury, or mixed vapor), expired medicines, and batteries depend on the manufacturer's non-mandatory environmental awareness. Concerns about the danger posed by improper disposal of batteries are necessary, since some are manufactured with large quantities of hazardous metals, such as, for example, mercury (Hg), a very dangerous element for life (Reidler & Günther, 2002). Brazil needs to develop specific guidelines, in particular with regard to the treatment of non-recoverable hazardous waste, to launch a series of initiatives to promote compliance with the PNRS, thus ensuring a better application of this legislation in selective collection and in increasing socio-environmental awareness at national level, thereby reducing environmental problems. This will serve to create a better link between waste legislation and broader actions in support of the circular economy in the future. As disclosed in the *Exame* Sustainability Guide, although there is a high percentage of battery recycling, companies in the sector, such as *Baterias Moura,* the largest battery manufacturer in South America, are now advancing in initiatives that seek to achieve zero generation of batteries waste in their industrial process, eliminating the disposal in urban dumps (*Exame*, 2019, p. 68). Due to the application of reverse logistics in Brazil, most of these companies' waste is generated in the process of transporting batteries, since the plastics and wooden pallets that pack the products are disposed of in the environment by distributors and consumers. According to the *Exame* (2019), companies such as Nestle, PepsiCo, and Unilever have entered into partnerships with startups aiming to accelerate innovation and sustainability in their products and to prevent the disposal of waste, reusing all the waste possible in the business chain, not sending the garbage to landfills.

Tires: Art. 16 of Conama Resolution No. 416, of September 30, 2009, provides for the prevention of environmental degradation caused by unusable tires and their environmentally appropriate destination, establishing the mandatory presence of collection points in municipalities with a population above 100 thousand inhabitants. In 2007, new tire manufacturers (Bridgestone, Goodyear, Michelin, & Pirelli) created Reciclanip to develop the collection and disposal of waste tires. In 2010, Continental joined the organization and, in 2014, it was Dunlop's turn. Data from the Brazilian Environment Institute (in Portuguese: IBAMA - *Instituto Brasileiro do Meio Ambiente*), 2017, show the creation of 1,718 collection points throughout Brazil, with the collection and correct disposal of about 4.2 million tons of

waste tires, a volume equivalent to 857.2 million sedan car tires. The main destination of these waste tires is recycling for reuse in rubber, asphalt-rubber, lamination and, given their high calorific value, for co-processing (about 70%).

Electronic devices: The Brazilian Association of the Electrical and Electronic Industry (in Portuguese: ABINEE - *Associação Brasileira da Indústria Elétrica e Eletrônica*) created, in 2016, GREEN Eletron, Manager for Reverse Logistics of Electronic Equipment (in Portuguese: *Gestora para Logística Reversa de Equipamentos Eletroeletrônicos*), aiming to develop a collective system for the reverse logistics of electrical and electronic products. Another aspect that is emerging in this regard is the companies' concern with the reuse of materials and part of device components discarded by consumers, working on the concept of circular economy (National Confederation of Industry, 2017 - in Portuguese: *Confederação Nacional da Indústria*). Companies such as Whirlpool, owner of the brands Brastemp and Consul, and Embraco, a Brazilian manufacturer of compressors for refrigeration appliances, have been working on the development of products manufactured in a sustainable way throughout the product's life cycle, reducing the amount of waste sent to landfills.

Packaging in general: The sectorial agreement, signed at the end of 2015, for the implementation of the reverse packaging logistics system in general, started to monitor from 2016. Its objective is to guarantee the environmentally appropriate destination of packaging throughout the country. According to the agreement, the first phase of application will last for 24 months and, in the end, it should guarantee the recovery of just over 3,800 tons of containers per day (Brazilian Association of Public Cleaning and Special Waste Companies, 2016).

Aluminum packaging: Brazil has been leading aluminum recycling since 2001 and remains with very high efficiency rates, above the world average, recycling practically all available scrap. In 2015, the country recycled 602 thousand tons of aluminum. Of this total, about 293 thousand tons refer to aluminum-scrap cans for drinks, which corresponds to 97.9% of the total packaging consumed in 2015, an index that has kept Brazil among the main countries in terms of can recycling since 2001 (Brazilian Aluminum Association, 2017; in Portuguese: ABAL - *Associação Brasileira do Alumínio*). In Brazil, a whole new market for aluminum recyclers has arisen. The good price paid in stores by scrap dealers ended up creating the "profession" of can pickers in the country. Today, it has become an individual collection activity in several locations, reaching expressive numbers of around 540 million tons of recycled aluminum. Therefore, this informal practice has made Brazil one of the first countries in the world to recycle aluminum cans, with about 98% of recycled products. The

recycling process generally begins with the purchase of aluminum cans by junkyard stores and the subsequent shipment of collected aluminum to large warehouses. From there, it is transported to recycling industries that melt scrap and produce secondary aluminum ingots. In practice, there is a more specific recycling chain, including the manufacturer of square profiles and the supplier of the billet used in the profiles production (Filleti & Santos, s.d.). The *Pesquisa Exame* (2019, p. 139) shows that the structuring of a reverse logistics chain was fundamental to render the concept of circular economy in the area of aluminum packaging recycling tangible. Novelis, the largest producer of aluminum sheets for beverage cans, plays a key role in the management of this chain.

Plastic materials: The use of plastics in Brazil has grown very sharply, but only 1.2% of plastic waste is recycled, amounting to 11.3 million tons produced. A large portion of the plastic waste generated is deposited in lfills, since there is a lot of inadequate disposal areas in the environment [large amounts of plastic end up in the oceans, impairing the survival of marine species and the performance of sectors such as fishing and tourism]. In order to have the transition to sustainable development completed by 2030, according to the circular economy concept, it is essential to increase the recycling of plastics and significantly reduce marine pollution of any kind, including marine litter (European Commission, 2014, p. 15). According to data from the World Bank, Brazil is the country with the lowest recycling rate in the sample of the 15 countries that produce the most plastic waste in the world. Brazil is the fourth largest generator of plastic waste in the world, behind only the United States, China, and India (World Wildlife Fund, 2019). It is estimated that plastic production will continue to grow in Brazil and there are no PNRS incentives for industry and civil society to replace this high socioenvironmental-impact material, nor properly discuss its handling, such as establishing a national target for its reduction, recycling, control, and management (Grandelle, 2019). Due to increasing pressure from environmentalists and Brazilian consumers for measures that prevent the disposal of plastic in the environment, companies in this industrial segment have begun, albeit timidly, to try to make their processes and products more sustainable, aligned with the concepts of the circular economy. According to the *Exame* (2019), companies like Basf and Dow have been adopting initiatives and actions regarding the circular economy in the chemical industry supply chain, in order to reduce the environmental impact of this type of production in Brazil. The HP company (Hewlett-Packard) has implemented a project focused on circular production that includes cooperatives of waste pickers in the state of São Paulo in the reverse logistics and electronics recycling chains, through the development of a digital platform that connects these cooperatives to final consumers (*Exame*, 2019, p. 101).

Pesticide packaging: In 2016, 44,528 tons of empty containers of pesticides were disposed of in an environmentally friendly manner throughout the country, representing 94% of the total primary packaging sold, of which 90% was sent for recycling and 4% for incineration. Compared to 2015, the volume of recovered material fell by approximately 2%. Nevertheless, despite the drop in the index, Brazil maintains leadership and is a world reference on the subject (Brazilian Association of Public Cleaning and Special Waste Companies, 2017).

Although the survey by the *Exame* (2019) shows that eight out of ten participants in the *Exame* Sustainability Guide 2019 use the Sustainable Development Goals (United Nations, 2018) as a guideline for their business strategies, the sustainability actions identified are still going at a slow pace towards the circular economy if confronted with the urgency of the topic. This means that the circular economy in Brazil still has a long way to go to be effective. However, some isolated actions that are already being developed show signs that the waste management sector has advanced, although still below the levels that would be recommended to move towards a circular economy.

3.2 Barriers to the implementation of the circular economy in Brazil

There are numerous difficulties that restrict or prevent the possibility of implementing the circular economy in the country, since it is still a movement with little visibility and representativeness in the segments that could promote its incorporation in the best business and political practices in force today.

The challenges to the adoption of the circular economy generally arise from the need for profound cultural changes in companies, governments, as well as citizens. These challenges are even greater for certain products, as in the case of parts composed by many suppliers or suppliers in various locations, and the products that undergo constant changes in composition or features (House of Commons, 2014).

To move forward, the movement to incorporate the circular economy in production and consumption needs to overcome different barriers and challenges, with emphasis on:

Insufficient household waste segregation: many families and companies, despite calls for recycling, end up mixing the waste in a single container; that is, products, their components, and packaging are combined with food waste, tree pruning, sweeping waste, and other household waste. This makes recycling more difficult and makes reuse more expensive, or simply prevents it from being carried out, due to contamination.

This process involves a series of necessary changes, including revolution in product design, encouraging aspects such as longevity, durability, repair potential, possibility of upgrading, reuse, remanufacturing, and recycling (Ribeiro and Kruglianskas, 2014).

Little acceptance of recycled products by consumers and companies: a certain degree of distrust can be identified regarding the quality of products that use recycled, restored, used, or reused materials. As for the company, there are doubts about ensuring the supply of recycled material in adequate volume, quality, and term. As for the consumer, it is known that some are willing to pay for green products. They are environmentally friendly, but most don't seem to care much about it.

Lack of investment and political incentives: in the recycling segment, as a rule, companies are medium- or small-sized, some are cooperatives, and many operate informally. So far, investors interested in solid waste recovery projects are rare; perhaps because they realize that the technologies available today are not yet able to solve all the problems in the sector, especially contamination and pollution, or because they think the return on investment tends to be slower than in other businesses. In addition, taxation is an aspect that can compromise the efficiency of the circular economy. Discussions on this issue result from the occurrence of double taxation, including Federal Decree No. 7,619, of October 2011, which was issued to boost the recycling sector and stimulate reverse logistics with the granting of presumed Industrialized Products Tax credit (in Portuguese: IPI - *Imposto sobre Produtos Industrializados*), in the acquisition of solid waste for use as an input or intermediate product in the manufacture of other products (Brazil, 2011).

Geographic dispersion of companies of the same cycle: the companies established themselves in the Brazilian territory according to their interests, mainly the proximity to the consumption centers. As a result, suppliers of different materials can be spread across all Brazilian regions, away from their customers. Therefore, the country's territorial extension represents an important identified barrier, since, not always will companies of the same cycle find suppliers of recycled material close to them. As a result, geographic dispersion can further increase the cost of these materials; that is, the longer the cycle, the higher the cost. Thus, the attractiveness of the business may be compromised due to inadequate economic viability.

Other barriers: knowledge transfer and the need for investments for the adoption of new technologies, mainly for the agricultural sector, can also hinder the implementation of the circular economy in Brazil. Barriers related to the need for asset sharing, distribution of by-products to small producers and difficulties in public and private financing are also identified (C100Brasil, 2017). Governments must encourage the integration of the circular economy and systemic thinking in education programs at the fundamental, middle, and higher levels (Ellen MacArthur Foundation, 2015, p. 18). There is a need for a profound cultural change,

starting with environmental education, combined with a good process of awareness raising and social communication.

4 Final considerations

The literature review demonstrates the growth of the circular economy concept in management practices and in society in general. However, it also signals the need to ripen and integrate it fully into economic development and corporate culture. Moreover, there are still many challenges to render the circular economy more effective for sustainability and sustainable development.

In structuring an industrial model that is non-destructive and not predatory of natural resources, where the industry tries to be fully regenerative, some companies are already beginning to be granted institutional benefits (including economic and financial) provided by the opportunity to establish a sustainable business model to successfully face an increasingly competitive market with greater ecological and social demands.

However, despite the positive impacts on corporate image, the financial investments of a company in a circular economy model have no immediate return, but rather a long-term return. In creating a system that promotes the circular economy, it should be noted that at first this seems a burden (cost) that most of the times takes time to disappear. Nevertheless, the alignment of companies' business strategies with issues related to the environment and sustainable development, mainly guaranteeing a production-consumption model based on the circular economy seems to show a path of no return in contemporary society.

The analysis of the relationship between solid waste management and sustainable development in Brazil, compared to the principles identified in the circular economy concept, enables the discussion of four main aspects: (i) sustainability initiatives in Brazil; (ii) measures adopted for the transformation of waste into energy; (iii) barriers that delay the application of the circular economy; and (iv) adequacy of the PNRS aspects in relation to the concept of circular economy.

The degree of adherence of Brazilian waste management norms to the actions for the circular economy was determined based on seven indicators identified in the converting-waste-into-a-resource dimension. Three of them are related to recycling, included in the Brazilian standard of reverse logistics, which demonstrates that the Brazilian legislation is quite adherent to the concept of circular economy when specifying the deepening of the issue of waste management. After seven years of the enactment of this federal law in Brazil, research on the subject (solid waste) has increased, but the scope of this norm has not yet been effectively applied in all regions of the country, where much remains to be done to ensure that the reality is consistent with the current legislation.

Despite this, Brazil has advanced in waste management, albeit slowly as compared to the impact that waste causes on the environment, on people, and on the economic field. In practice, it is possible to identify actions that are being consolidated, as is the case of the sectorial agreement for reverse logistics, and initiatives that address the PNRS proposals for the use and transformation of waste into energy, as is the case of biogas. Although partially adhering to the circular economy, this guideline is presented as an important process for closing the production cycle, since all waste will be reused, showing that the country is on the right path for the circular economy, and presents aspects of similarity with the principles that govern this concept.

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