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SOLID WASTE AND SUSTAINABLE DESIGN – AN ANALYSIS OF RECYCLING IN THE "CIRCULAR ECONOMY" IN THE LIGHT OF THE 2030 AGENDA

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ABSTRACT

The growing concern with sustainability has driven debates on solid waste management and its reintegration into the production cycle, especially in the context of the circular economy. The UN 2030 Agenda establishes goals to ensure sustainable production and consumption patterns, reinforcing the need to reassess the linear disposal model. In this context, the research seeks to answer: how can recycling, within the scope of the circular economy, contribute to sustainable design and the reduction of environmental impact, in line with the Sustainable Development Goals (SDGs)? The theoretical foundation is based on the principles of the circular economy, as formulated by Ellen MacArthur (2013), Catherine Weetman (2019) and on the discussions on solid waste and sustainability of authors such as Boulding (1966), who introduced the idea of economy as a closed system, and McDonough and Braungart (2002), who proposed the concept of "Cradle to Cradle". In addition, it incorporates Manzini's (2006) perspective of sustainable design, highlighting the relationship between innovation and socio-environmental responsibility. The research adopts a qualitative approach based on Minayo (2016), employing the descriptive and bibliographic methodology of Gil (2010), a comprehensive analysis based on the Weberian perspective (Weber, 1969). Sources include international reports, scientific articles, and institutional documents on waste management and sustainability policies. The results indicate that recycling, when inserted in the circular economy paradigm, not only reduces environmental impacts, but also enhances innovative solutions in sustainable design. It is concluded that the implementation of articulated strategies between the productive sector, public policies and environmental education is fundamental to consolidate a more responsible development model aligned with the principles of global sustainability.

Keywords: Circular Economy. Sustainable Design. Recycling. Environmental Sustainability.

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INTRODUCTION

SOLID WASTE AND SUSTAINABILITY: CONSUMPTION CHALLENGES AND THE TRANSITION TO THE CIRCULAR ECONOMY AND SUSTAINABLE DESIGN

World consumption is growing at a fast pace, driven by an economic model based on large-scale production and planned obsolescence (Santos, *et. al.,* 2024). The throwaway culture has become a global phenomenon, with products being manufactured to have a short shelf life, encouraging constant consumption. This cycle generates an increasing volume of urban solid waste, overloading collection and disposal systems. According to Martini (2016), "[...] the increase in consumption is directly linked to the growth in solid waste generation, resulting in challenges for the sustainability of modern cities" (Martini, 2016, p. 118).

> The increase in consumption is closely related to the growth in per capita generation, placed by the current consumer society [...], as a result of the incentives to consumption, as well as the increase in product sales. In this sense, it is relevant to highlight a base phenomenon, through which these incentives and increased product sales occur, the so-called planned obsolescence (FIORILLO, 2017, apud *Resíduos Sólidos Urbanos: Teoria & Prática*, 2022, p. 68)

That said, environmental education currently plays a fundamental role in changing this scenario, but its implementation is still limited. The population's lack of awareness about the environmental impact of their consumption habits is reflected in the low adherence to recycling and proper disposal of waste. According to Benone and Medeiros (2019), "[...] the absence of an environmental culture in society prevents the adoption of sustainable practices, making it difficult to implement solid waste management policies" (Benone & Medeiros, 2019, p. 50). The absence of a culture of environmental responsibility is reflected in the irregular disposal of garbage, which pollutes soils, rivers and oceans.

> Environmental Education (EE) focuses on the need to model the attitude of human beings towards the environment and was initiated by ecological movements and later contemplated with the publication of Federal Law 9.795, of 4/27/1999, which institutes the National Policy of Environmental Education and provides other measures. In addition, another important tool for the understanding and implementation of collective awareness actions is environmental perception, which can be defined as the result of the individual's interaction with the environment and its constant transformations, through which differentiated values and importance are attributed in relation to the place in which he is inserted and leads to a new look at the present and future, favoring the introduction of new ways of proceeding and treating the environment (Fernandes *et al.,* 2004; Macedo, 2000, p. 197).

Faced with this situation, the growing concern with sustainability has driven debates about the management of solid waste and its reintegration into the production cycle. The

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concept of circular economy, proposed by Ellen MacArthur (2013), suggests an alternative model to the linear production system, promoting the reuse and recycling of materials to minimize waste and environmental impacts. According to Weetman (2019), "[...] the circular economy proposes strategies for reusing and redesigning products, reducing the need to extract new natural resources and increasing the efficiency of industrial processes" (p. 87).

> The circular economy is becoming increasingly synonymous with the Ellen MacArthur Foundation (EMF). EMF is a philanthropic institution that works with companies, governments and educational organizations in order to accelerate the transition to the circular economy, which already has many books, works and videos that explain and promote the circular economy. [...] The circular economy is inspired by nature, where the waste of one species is the food of another, and the sum provides energy. The Circular Economy 'cycles valuable materials and products, producing and transporting them using renewable energy' (Weetman, 2019, p. 87).

In view of this, the United Nations (UN), through the 2030 Agenda, established goals to ensure sustainable production and consumption patterns, reinforcing the need to reevaluate the linear disposal model. The Sustainable Development Goals (SDGs),[17] especially SDGs 11 and 12, highlight the need to reduce waste generation and promote sustainable practices in the production sector. According to the UN (2015), "[...] by 2030, countries must achieve sustainable management and efficient use of natural resources, promoting recycling and waste reduction at the global level" (UN, 2015, p. 32).

> The Sustainable Development Goals constitute a universal agenda, composed of 17 SDGs, with 169 targets for 2015 to 2030. Applicable to all countries, they reflect the economic, social, environmental and institutional dimensions, in an integrated, indivisible and transversal manner. [...] The reduction of greenhouse gas emissions by the solid waste sector, resulting from sustainable waste management, is relevant for both mitigation and adaptation to climate change, and contributes to achieving the United Nations Sustainable Development Goals (UN, 2015, p. 246).

That said, if no concrete action is implemented by 2030, the planet will face severe environmental consequences. Studies indicate that solid waste generation will continue to

[17] The Sustainable Development Goals (SDGs) were established by the United Nations (UN) in 2015 as part of the 2030 Agenda, a global plan to promote sustainable development in its environmental, social, and economic dimensions. Composed of 17 goals and 169 targets, the SDGs seek to eradicate poverty, reduce inequalities, combat climate change, and encourage sustainable production and consumption patterns, among other essential goals for building a more balanced and fair future. Among the goals, SDG 11, which aims to make cities more sustainable and resilient, and SDG 12, which promotes responsible consumption and production, encouraging waste reduction and the efficient use of natural resources, stand out. In this way, the SDGs provide a guide for governments, companies and civil society to adopt concrete measures in favor of global sustainability (UN, 2015, p. 32). See: UNITED NATIONS (UN). *Transforming Our World: The 2030 Agenda for Sustainable Development.* New York: UN, 2015. Available at: https://www.un.org/sustainabledevelopment/.

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grow, overloading landfills[18] and increasing soil and water contamination. As pointed out by Boulding (1966), "[...] the economy must be thought of as a closed system, in which waste must be reintegrated into the productive cycle to avoid the scarcity of natural resources" (Boulding, 1966, p. 12).

Thus, the relationship between solid waste and sustainable design also becomes increasingly evident. Manzini (2008) highlights the need to develop products that consider their environmental impact from conception, avoiding waste and promoting the reuse of materials. The author states that "[...] sustainable design must be aligned with the principles of the circular economy, ensuring a longer life cycle for products and reducing waste generation" (2008, p. 27).

> Within the scope of industry, design has become a valuable instrument to promote the transition from linear to circular logic, as it is projected for several life cycles, economically viable and ecologically efficient, considering the feasibility of developing more durable products and services that use fewer natural and energy resources. It is considered that it is in the design phase that most of the characteristics of a product, throughout its life cycle, are defined. From the perspective of production processes, design has come to play a fundamental role, making it feasible to propose new scenarios, processes, and systems based on sustainable development guidelines, assuming new functions in the face of the current socioeconomic and environmental panorama (Dissertation - Circular Economy and Sustainability, 2020, p. 16).

In this way, in addition to environmental concern, the poor management of solid waste directly affects public health and the quality of life in cities. Jacobi (2012) points out that "[...] the accumulation of solid waste in urban areas is a risk factor for the proliferation of diseases and environmental degradation, requiring urgent planning solutions" (p. 31). The advance of urbanization without adequate planning and effective waste management policies increases the challenges for the sustainability of cities.

In this context, the active participation of the productive sector and public policies is essential to mitigate the impacts of solid waste. According to Cristóvão and Medeiros (2020), "[...] Waste management should be an integrated strategy between government,

[18] Sanitary landfills represent a technical solution for the final disposal of municipal solid waste (MSW), being designed to minimize environmental impacts and risks to public health. These enterprises operate by compacting and covering waste, avoiding direct exposure to the environment and reducing the release of polluting gases and leachate. However, the decomposition of organic matter in these landfills generates biogas, composed mostly of methane (CH_4), one of the main greenhouse gases, which requires capture and treatment systems for its conversion into energy or controlled burning. In addition, the National Solid Waste Policy (PNRS), instituted by Law No. 12,305/2010, seeks to reduce disposal in landfills by encouraging recycling, composting, and energy recovery of waste, since the expansion of these areas faces challenges such as the demand for large tracts of soil and high maintenance and monitoring costs (SENHORAS, 2022). See: LADIES, Elói Martins (Org.). *Urban Solid Waste: Theory & Practice*. Boa Vista: Editora IOLE, 2022.

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companies and civil society, aiming at the implementation of effective solutions for the reuse of materials and the valorization of waste as resources" (p. 44). Without this articulation, waste will continue to be a threat to the environmental balance. Thus, the implementation of articulated strategies between the productive sector, public policies and environmental education can consolidate a more responsible development model. As stated by McDonough and Braungart (2002), "[...] the concept of *Cradle to Cradle*[19] proposes a regenerative production model, in which waste is transformed into new resources, eliminating the logic of disposal and promoting a sustainable production cycle" (p. 56).

> The inadequate disposal of solid waste directly impacts the quality of urban life, generating soil and water pollution, in addition to contributing to the proliferation of disease vectors. The absence of integrated planning for the management of this waste compromises public health and environmental balance, highlighting the need for effective policies that promote the reduction, reuse, and recycling of discarded materials (Brasil - Gestão de Resíduos Solids, 2020, p. 87).

Thus, if urgent measures are not adopted, in 2030 the scenario could be alarming. The generation of solid waste can exceed the management capacity of municipalities, intensifying environmental degradation and public health problems. However, there are viable alternatives to reverse this situation. According to the European Commission (2015), "[...] the transition to a circular economy[20] can generate significant economic and environmental benefits, promoting efficiency in the use of resources and reducing environmental impact" (European Commission, 2015, p. 91). In this way, recycling and innovation in product design are essential tools to minimize environmental impacts and promote a more sustainable economy.

That said, the research has as its object of study the relationship between recycling, the circular economy and sustainable design, analyzing how these elements can contribute to the reduction of environmental impact. The linear model of production and disposal has

[19] The *Cradle to Cradle* (C2C) concept proposes a regenerative production model, in which waste is no longer a problem and becomes inputs for new production cycles. Developed by Michael Braungart and William McDonough, this paradigm rejects the linear logic of "extraction-production-disposal" and emphasizes the idea that all materials can be conceived as technical or biological nutrients, continuously returning to the production cycle without loss of quality. The model is based on five fundamental principles: material health, continuous reuse of materials, use of renewable energy, responsible water management, and social justice. Unlike conventional eco-efficiency approaches, which only minimize environmental damage, *Cradle to Cradle* promotes eco-efficiency by encouraging production processes that generate positive environmental and social impacts from the design of the products. See: BRAUNGART, M.; MCDONOUGH, W. *Cradle to Cradle: create and recycle unlimitedly*. Translated by Frederico Bonaldo. São Paulo: GG BR, 2013.

[20] This system will be addressed later.

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led to a growing accumulation of urban solid waste, which compromises sustainability and requires new strategies for its management. According to Weetman (2019), "[...] the circular economy proposes strategies for reusing and redesigning products, reducing the need to extract new natural resources and increasing the efficiency of industrial processes" (p. 87). In this context, the research seeks to understand how recycling can be inserted in the circular economy to enhance sustainable practices in product design and minimize environmental damage.

Thus, the central objective of the research is to investigate how recycling, integrated with the concept of circular economy, can contribute to a sustainable design aligned with the Sustainable Development Goals (SDGs). The starting question that guides this study is: how can recycling, within the scope of the circular economy, contribute to sustainable design and the reduction of environmental impact, in line with the SDGs? This issue is part of a broader debate on the need to transition to production models that minimize waste and value the reuse of materials. As Manzini (2008) states, "[...] sustainable design must be aligned with the principles of the circular economy, ensuring a longer life cycle for products and reducing waste generation" (p. 27).

QUALITATIVE AND BIBLIOGRAPHIC METHODOLOGY: A COMPREHENSIVE ANALYSIS OF SOLID WASTE FROM THE CIRCULAR ECONOMY AND SUSTAINABLE DESIGN

Qualitative research is essential to understand complex phenomena that involve social, environmental and economic aspects, such as the impact of excessive consumption and planned obsolescence on the generation of solid waste. According to Minayo (2006), "[...] qualitative research is concerned with a level of reality that cannot or should not be quantified, because it works with the universe of meanings, motives, aspirations, beliefs, values and attitudes" (p. 21). Thus, by addressing the problem of urban solid waste, this research allowed us to analyze not only the volumes generated, but also the subjective factors that influence the behavior of the consumer society, showing how public policies and sustainable practices can be implemented more effectively.

> Qualitative research, unlike the quantitative model, seeks to interpret and understand social dynamics, analyzing contexts and meanings attributed by individuals. It allows the capture of nuances, subjectivities and relationships that can hardly be reduced to numbers and statistics (Minayo, 2006, p. 24).

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Based on this perspective, the study was formulated from the need to understand the relationship between consumption, circular economy and sustainable design, seeking to identify strategies to minimize environmental impacts. As Gil (2010) points out, "[...] Every investigation begins with a question, a problem, a question, a doubt. The response to this movement of thought is usually linked to previous knowledge or demands the creation of new references" (p. 17). Thus, the study was structured in a qualitative approach, analyzing documents, scientific articles and institutional reports to understand how recycling and sustainable design can contribute to the reduction of urban solid waste. This design allowed the research to delve into the processes that involve the disposal and reuse of materials, considering both the social and environmental contexts.

> The methodology adopted for the development of the research is descriptive, carried out through consultation with various authors in scientific productions, such as articles, books, dissertations and theses, as well as specialized journals and materials available on the internet, in order to obtain data on the subject. 'It is used to identify and obtain information about the history and characteristics of a particular problem or issue (Collis & Hussey, 2005, p. 24).

In order for this analysis to be conducted efficiently, the development of the research adopted a descriptive qualitative methodology, enabling the critical evaluation of environmental policies and the impacts of planned obsolescence. According to Minayo (2006), "[...] fieldwork is such a central phase for the knowledge of reality that Lévy-Strauss calls it the 'wet nurse' of all social research" (p. 61). Thus, data collection and analysis were conducted based on the triangulation of methods, including literature review and specific case studies related to solid waste management and circular economy. This approach allowed a broad view of the problem, associating different theoretical and empirical perspectives to support the discussion.

In addition, the methodological steps followed a structured investigative cycle, which involved theoretical exploration, data collection and critical analysis of the findings. As Gil (2007) points out, "[...] the analysis of data in qualitative research starts to depend a lot on the capacity and style of the researcher" (p. 176). In this way, the research not only identified the challenges faced in solid waste management, but also proposed practical recommendations for sustainable design and the circular economy to be incorporated more effectively into environmental and business policies. With this, it has become possible to establish guidelines for reducing waste production and promoting more responsible consumption.

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> Data analysis in qualitative research involves a systematic and reflective process, which includes the organization, categorization, and interpretation of the information collected. Unlike the quantitative approach, which is based on the measurement of variables, qualitative research seeks to understand meanings, contexts and interrelationships, allowing a more in-depth view of the phenomenon studied (Gil, 2007, p. 176).

Thus, the qualitative research allowed a broad and contextualized understanding of the problem, revealing the interactions between economic, social and environmental factors that influence waste generation. According to Minayo (2006), "[...] Qualitative research answers very particular questions. It works with the universe of meanings, motives, aspirations and beliefs, aspects that can hardly be translated into numbers" (p. 21). In this way, the study reinforces the importance of adopting interdisciplinary approaches to face the challenges of sustainability, proposing solutions that integrate innovation, responsible consumption and effective public policies. In the end, the knowledge generated by the research translates into a fundamental instrument to transform production and disposal practices, guiding the path to a more sustainable future.

On the other hand, the bibliographic research, in turn, played an essential role in the theoretical foundation of this study, allowing an in-depth analysis of the relationship between solid waste, circular economy and sustainable design. As Gil (2010) points out, "[...] The bibliographic research is developed from material already prepared, consisting mainly of books and scientific articles. Although in almost all studies some type of work of this nature is required, there are studies developed exclusively from bibliographic sources" (p. 51). Thus, the literature review made it possible to identify consolidated theoretical approaches and to survey scientific evidence that supports the analysis of recycling and its relationship with the principles of the circular economy. In addition, it allowed a broad view of the challenges and opportunities of implementing more sustainable practices in the productive sector.

In this context, the comprehensive analysis inspired by Weber was essential to critically interpret the information collected and establish relationships between the different factors that influence solid waste management. According to Weber (1969), "[...] comprehension refers to the meaning subjectively aimed at by actors, in the course of a concrete activity" (p. 110). This theoretical framework allowed us to go beyond the technical aspects of recycling, also addressing the social, cultural, and economic motivations that impact the adoption of sustainable practices. Thus, the circular economy was not only analyzed as an efficient production model, but also as a social construction, where different

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agents, such as companies, governments, and consumers, play key roles in its consolidation.

In addition, the bibliographic research was organized according to a descriptive and exploratory method, allowing a detailed approach to the challenges of sustainability and sustainable design. As described in the Dissertation on Circular Economy and Sustainability, "[...] the methodology adopted for the development of the research is descriptive, carried out through consultation with various authors in scientific productions, such as articles, books, dissertations and theses, as well as specialized journals and materials available on the internet, with the purpose of obtaining data on the subject" (Collis & Hussey, 2005, p. 24). This approach ensured the systematization of the central concepts and the understanding of the practices already implemented in different contexts, evidencing both the advances and the difficulties encountered in the transition to a more sustainable model.

Thus, the articulation between the theoretical data and their practical applicability became a fundamental aspect of the study. Minayo (2006) emphasizes that "[...] interpretation consists of relating the semantic structures (signifiers) with sociological structures (meanings) of the utterances present in the message" (p. 90). In other words, it was not enough just to gather information about circular economy and sustainable design, but also to understand how these strategies are applied in everyday life and what challenges need to be overcome to make them more accessible and effective. From this analysis, it was possible to propose recommendations to strengthen public policies and encourage changes in the behavior of consumers and companies.

Thus, Weber's comprehensive approach was crucial for the interpretation of the results and the formulation of recommendations that were more aligned with the observed reality. As Minayo (2006) states, "[...] qualitative analysis is not limited to the description of data, but seeks to understand the interrelations and meanings attributed by the subjects to the phenomenon studied" (p. 91). In this way, the research reinforces the need to integrate different perspectives in solid waste management, promoting a holistic view that considers environmental, economic and social aspects. Thus, it is concluded that recycling, when inserted in the logic of the circular economy, not only reduces environmental impacts, but also drives innovation and strengthens socio-environmental responsibility, contributing to a more sustainable and balanced future.

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ANALYSIS OF SOLID WASTE RECYCLING IN THE "CIRCULAR ECONOMY" IN THE LIGHT OF THE 2030 AGENDA.

Neoliberalism, by transforming all spheres of life into merchandise, intensified consumption and reinforced the logic of planned obsolescence[21], stimulating the rapid disposal of products. As Weetman (2019) states, "[...] neoliberal economics encourages the maximization of immediate profit, neglecting long-term environmental impacts and promoting an accelerated production and disposal cycle" (p. 52). This model of accumulation is also reflected in the financialization of life, where essential goods are treated as financial assets, promoting social inequalities and aggravating the exploitation of natural resources.

> The increase in consumption is closely related to the growth in per capita generation, placed by the current consumer society [...], as a result of the incentives to consumption, as well as the increase in product sales. In this sense, it is relevant to highlight a base phenomenon, through which these incentives and increased product sales occur, the so-called **planned obsolescence** (*emphasis added*) (Fiorillo, 2017, p. 68).

In this way, globalization and the financialization of the economy have driven the adoption of the neoliberal model in several nations, leading to the accelerated exploitation of natural resources. According to Jacobi (2012), "[...] neoliberal economic growth drives the uncontrolled extraction of raw materials, resulting in irreversible environmental impacts" (p. 45). The financialization of life stimulates consumption via credit and indebtedness, perpetuating a cycle of purchase and disposal. According to Weetman (2019), "[...] the incentive to exaggerated consumption creates an unsustainable demand for disposable products, overloading natural ecosystems" (p. 60).

> Society gives prestige to the purchasing power of the individual and takes it as an indicator of success and happiness. The act of consuming is linked to personal fulfillment, professional success, social ascension, among other attributes. The incentive to consumption comes from all sides: marketing and the media that create new needs and even from the State that provides tax and credit incentives so that household consumption and GDP increase, thus increasing economic development. In this way, our society promotes unbridled consumption, thus characterizing consumerism (Dissertation - Circular Economy and Sustainability, 2020, p. 34).

[21] Planned obsolescence is a deliberate strategy adopted by manufacturers to reduce the shelf life of products, encouraging continuous consumption and premature disposal. This practice emerged in the 1930s, during the Great Depression, as a mechanism to stimulate the economy by increasing demand for consumer goods. Currently, it manifests itself in several ways, such as the introduction of components with limited lifespans, software updates that make devices incompatible, and aesthetic changes that induce consumers to replace products that are still functional. This production model has significant impacts on the generation of solid waste and the consumption of natural resources, contributing to environmental and social problems. See: MARTINEZ, J. *Urban Solid Waste: Theory & Practice*. São Paulo: Editora Ambiental, 2017.

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In this way, this economic system drives the accumulation of goods, generating an increasing volume of solid waste. According to Fernandes et al. (2004), "[...] the current economic model leads to an exponential increase in waste, without guaranteeing effective alternatives for its management" (p. 215). With the rise of neoliberalism, several environmental services have been privatized, making it difficult to have equal access to sustainable waste management. According to the UN (2015), "[...] the commodification of environmental services compromises their universalization, resulting in disparities in the sustainable management of urban waste" (p. 89). Thereby

> Despite the measures and the commitment to public policies, there is still a long way to go to have the effective structuring of these actions, both in the collective aspect as a society, and in the individual aspect, since the generation of waste in the country grows exponentially and that a large part of what is generated is still not correctly disposed of according to the guidelines imposed by the waste hierarchy determined by the PNRS[22] (ABRELPE, 2019, p. 118).

That said, transnational corporations have incorporated the logic of financial capital into the exploitation of natural resources. According to Cristóvão and Medeiros (2020), "[...] the financialization of nature allows corporations to accumulate wealth while externalizing environmental costs" (p. 55). In the neoliberal context, many companies adopt green marketing strategies[23] without structural changes in their production. According to Jacobi (2012), "[...] the discourse of corporate sustainability often serves only to reinforce the logic of unbridled consumption" (p. 75).

[22] The National Solid Waste Policy (PNRS), instituted by Law No. 12,305/2010, represents a milestone in solid waste management in Brazil, establishing guidelines for reducing waste generation, encouraging recycling and reuse, as well as the environmentally appropriate disposal of waste. The PNRS adopts the waste management hierarchy, prioritizing non-generation, followed by reduction, reuse, recycling, treatment and environmentally correct final disposal. In addition, it establishes shared responsibility for the life cycle of products, involving manufacturers, importers, distributors, traders, consumers and holders of public urban cleaning services. One of the main challenges for the effective implementation of this policy has been the eradication of dumps and the replacement by adequate sanitary landfills, in addition to the need to expand selective collection and the involvement of society in the sustainable management of waste. See: BRAZIL. *Law No. 12,305, of August 2, 2010*. Establishes the National Solid Waste Policy, amends Law No. 9,605, of February 12, 1998, and provides other provisions. Diário Oficial da União, Brasília, 3 ago. 2010. Available at: http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2010/lei/l12305.htm. Accessed on: 12 Feb. 2025.

[23] Green marketing is a strategy that seeks to align business practices with sustainable development, promoting products and services with less environmental impact. This approach involves the use of renewable raw materials, eco-efficient production processes, and transparency in communication with the consumer, avoiding *greenwashing*—a marketing practice that conveys a false impression of sustainability. Companies that adopt green marketing seek to add value to their products, meeting a growing demand for conscious consumption and socio-environmental responsibility. However, for this strategy to be effective, a real commitment to sustainability is needed, integrating circular economy principles and innovation into product design. See: WEETMAN, C. *Circular Economy: concepts and strategies to do business in a smarter, more sustainable and profitable way*. São Paulo: Autentico Business, 2019.

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> The rhetoric of sustainability has been widely appropriated by the market, where the concept of 'green marketing' often hides predatory and ineffective practices for reducing environmental impact. The corporate discourse on sustainability often prioritizes the brand image to the detriment of structural changes in production processes (Loschiavo dos Santos, 2012, p. 31)

Thus, neoliberal policies reduced state action in solid waste management, compromising sustainable actions. According to the UN (2015), "[...] neoliberal deregulation weakens the capacity of governments to implement effective environmental policies" (p. 110). Neoliberalism also affects water management, making it an increasingly commodified resource. According to Weetman (2019), "[...] the financialization of water resources compromises efficiency in waste management and intensifies environmental inequality" (p. 135).

In the face of evidence that neoliberalism has negative effects on the environment, sustainable alternatives must be explored. According to Cristóvão and Medeiros (2020), "[...] the transition to a sustainable economic model requires the implementation of public policies that challenge the neoliberal logic" (p. 190). Thus, the need for a new economic paradigm that balances development and sustainability becomes necessary to ensure a viable future for the next generations.

SOLID WASTE RECYCLING AND THE USE OF THE "CIRCULAR ECONOMY"

Solid waste represents one of the main environmental and urban challenges in Brazil. According to the National Solid Waste Policy (PNRS), instituted by Law No. 12,305/2010[24], solid waste is defined as "[...] materials that can be recycled or reused, whether domestic, industrial, electro-electronic, among others, and also waste, which cannot be reused and must be disposed of correctly" (Brasil, 2010). The proper disposal of these materials is essential to avoid environmental and social impacts resulting from improper disposal.

[24] Law No. 12,305/2010, which institutes the National Solid Waste Policy (PNRS), establishes guidelines for the integrated management and environmentally appropriate management of solid waste in Brazil. The standard defines shared responsibilities between the government, the business sector and civil society in minimizing waste generation and promoting reverse logistics and extended producer responsibility. In addition, the legislation prioritizes the non-generation, reduction, reuse, recycling and treatment of waste, as well as the environmentally appropriate final disposal of waste. The PNRS also encourages the inclusion of recyclable material collectors in production chains and prohibits practices such as the improper disposal of waste in dumps, reinforcing the need to implement technically viable landfills. See: Brazil. (2010). *Law No. 12,305, of August 2, 2010*. Establishes the National Solid Waste Policy; amends Law No. 9,605, of February 12, 1998; and makes other provisions. Federal Official Gazette, Brasília, DF. Retrieved from http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2010/lei/l12305.htm.

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> The PNRS specifically provides for solid waste. This emphasis is due to the potential of waste to be reused, recycled, subject to reverse logistics or any other technique that can serve as a base raw material. Unlike garbage, defined by the Brazilian Association of Technical Standards (ABNT) as being leftovers from activities arising from human conduct, it is characterized by being useless or undesirable, and treatment is not possible. In the same sense, there is the definition of waste where all possibilities for recycling or reuse have been exhausted, with the only plausible destination being disposal in landfills (Vasconcelos & Vasconcelos, 2016, p. 71).

Thus, the National Solid Waste Policy (PNRS) plays a fundamental role in Brazilian environmental management, establishing guidelines for the proper disposal of waste and promoting sustainability. According to the legislation, "[...] in the management and management of solid waste, the following order of priority must be observed: non-generation, reduction, reuse, recycling, treatment of solid waste and environmentally appropriate final disposal of waste" (Brasil, 2010). This hierarchy seeks to minimize environmental impacts and maximize the use of discarded materials.

Indeed, the differentiation between solid waste and garbage is essential for efficient environmental management. As defined by the Brazilian Association of Technical Standards (ABNT), "[...] solid waste is material that can be recycled or reused, while garbage is characterized by being useless or undesirable, without the possibility of adequate treatment" (ABNT, 1996). This distinction justifies the importance of developing public policies aimed at the valorization of waste and its reinsertion into the production chain.

That said, the classification of solid waste is a central element of the PNRS, allowing different categories to be treated according to their physical, chemical, and biological properties. According to Fiorillo (2017), "[...] waste considered hazardous is part of Class I, while non-hazardous waste is divided into Class II A, which contains biodegradable or combustible materials, and Class II B, which is inert" (p. 71). This categorization[25] makes it possible to adopt specific strategies for each type of waste, ensuring greater efficiency in its management.

[25] According to Fiorillo (2017), solid waste can be classified based on its origin, composition, and hazardousness. As for the origin, the waste can be household, commercial, industrial, health services, civil construction, agricultural and public services. Regarding composition, they can be organic and inorganic, with the former being biodegradable and the latter generally recyclable. As for hazardousness, waste is classified as hazardous and non-hazardous, according to the risks it poses to human health and the environment. The classification of solid waste is essential for the definition of appropriate management, treatment and final disposal strategies, ensuring environmental preservation and public health. See: Fiorillo, C. A. P. (2017). *Curso de direito ambiental brasileiro* (18th ed.). Editora Saraiva.

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Table 1 – Classification of Solid Waste according to Fiorillo

	Classe	Descrição	Exemplos
1	Classe I	Resíduos perigosos, contendo características de inflamabilidade, corrosividade,	Baterias, solventes, tintas, pesticidas, resíduos hospitalares.
2	Classe II A	Resíduos não perigosos, biodegradáveis ou combustíveis, como restos de	Restos de comida, papel, madeira, tecidos.
3	Classe II B	Resíduos não perigosos e inertes, como entulho, vidro e certos plásticos que não	Vidro, entulho, plásticos não recicláveis.

Source: Obtained from the work of Fiorillo (2017).

In Brazil, solid waste management is a persistent challenge, especially due to the lack of infrastructure and informality in the sector. As pointed out by Mendonça et al. (2017), "[...] the PNRS innovated by assigning shared responsibilities between the public and private sectors, including the mandatory use of waste management plans and the implementation of reverse logistics" (p. 88). However, despite this innovation, the application of these guidelines still faces structural obstacles, such as the low adherence of municipalities to the formulation of management plans. This scenario highlights the need for more effective strategies to ensure the correct disposal of waste.

In this context, reverse logistics emerges as one of the main tools of the PNRS for the recovery of discarded materials and their reintegration into the production chain. According to the Ministry of the Environment (MMA, 2019), "[...] Reverse logistics is the process of adding value by planning, implementing and controlling the flow of materials, from the point of consumption to the point of origin, for the purpose of recapturing value or proper disposal". In this way, this approach promotes co-responsibility between manufacturers, distributors, and consumers, reducing environmental impacts and increasing efficiency in the use of resources.

In addition, the growing generation of municipal solid waste aggravates the challenges of waste management, making the adoption of innovative solutions even more urgent. As noted by Martini (2016), "[...] the generation of waste has reached such a significant stage that it has been addressed in different Brazilian and international public policies" (p. 118). The increase in population and consumption intensifies the production of

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waste, requiring initiatives that not only optimize collection and disposal, but also reduce the generation of waste at the source.

To address this challenge, solid waste management in Brazil is regulated by environmental standards that establish guidelines for collection, transportation, treatment, and final disposal. According to the PNRS, "[...] in the management and management of solid waste, the following order of priority must be observed: non-generation, reduction, reuse, recycling, treatment of solid waste and environmentally appropriate final disposal of waste" (Brasil, 2010). This hierarchy aims to minimize environmental impacts and maximize the use of discarded materials, promoting a more sustainable consumption culture.

Within this scope, recycling emerges as one of the main strategies to mitigate the environmental impacts of solid waste. According to Vasconcelos and Vasconcelos (2016), "[...] waste has great potential to be reused, recycled, subject to reverse logistics or any other technique that can serve as a base raw material" (p. 70). Thus, in addition to reducing the demand for virgin raw materials, recycling contributes to reducing the amount of garbage sent to landfills, avoiding the overload of these spaces and reducing the emission of greenhouse gases.

Faced with the need to restructure the production and disposal system, the circular economy emerges as a sustainable alternative to the linear consumption model. According to the European Commission (2015), "[...] the European Union's action plan for the circular economy establishes 54 measures to close the life cycle of products, promoting sustainable growth and reducing waste generation" (p. 91). This concept proposes the continuous reuse of materials, minimizing waste and encouraging innovation in production.

To make this transition viable, the circular economy requires the integration of sustainable practices throughout the production chain, from product design to final disposal. According to Weetman (2019), "[...] the circular economy proposes strategies for reusing and redesigning products, reducing the need to extract new natural resources and increasing the efficiency of industrial processes" (p. 87). By rethinking the way goods are designed and consumed, this model favors innovative solutions that extend the life of materials and avoid waste.

However, despite advances in legislation and the development of sustainable technologies, several challenges still persist in solid waste management in Brazil. According to the IBGE (2014), "[...] only 33.5% of Brazilian municipalities were able to

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prepare a Municipal Plan for Integrated Solid Waste Management, essential to receive federal resources". The absence of adequate planning compromises the implementation of effective policies, making it more difficult for the country to adapt to a circular economy model.

In addition, informality in the collection and recycling sector represents another obstacle to be overcome. According to ABRELPE (2014), "[...] Every day, more than 20,000 tons of waste are not collected in the country, probably having an improper destination." This demonstrates the importance of strengthening selective collection and valuing the work of waste pickers, who play a key role in the recovery of recyclable materials and in reducing improper disposal.

Given this scenario, it is essential to expand investment in public policies and business initiatives that encourage sustainable practices and the transition to a circular economy model. As Gama (2020) points out, "[...] the reduction in the generation of waste in general, reuse and recycling provide for the modification of consumption patterns and contribute significantly to reducing the use of raw materials and environmental impacts" (p. 239).

In this context, in the face of the growing generation of waste, the circular economy emerges as an alternative to the linear model of production and disposal. As Weetman (2019) points out, "[...] the circular economy proposes strategies for reusing and redesigning products, reducing the need to extract new natural resources and increasing the efficiency of industrial processes" (p. 87). This system emphasizes the continuous reuse of materials, minimizing environmental impacts and promoting a more sustainable production cycle.

> The circular economy appears as a desirable alternative to the traditional model, as it advocates the use of resources with less waste. In addition, it allows companies to reduce costs and losses, generate alternative sources of revenue, and decrease dependence on virgin raw materials (Andrade, 2019).

The circular economy emerges as an urgent alternative to the linear model of production and disposal, which has historically led to the accumulation of waste and the depletion of natural resources. According to Weetman (2019), "[...] the circular economy proposes that we rethink our production and consumption systems, ensuring that products, materials and resources are kept in use for as long as possible, reducing the generation of waste" (p. 34). This approach not only minimizes environmental impacts, but also drives

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innovation by encouraging sustainable practices at all stages of the production chain. In this sense, the author reinforces that "[...] the transition to a circular system requires a restructuring of value chains, where each phase of a product's life cycle is planned to minimize environmental impacts and maximize resource efficiency" (p. 42).

Given this scenario, one of the main global challenges is the growing production of urban and industrial solid waste. The improper disposal of these materials has generated serious environmental problems, in addition to representing a significant loss of resources that could be reintegrated into the economy. Weetman (2019) emphasizes that "[...] The circular economy not only reduces waste, but also generates new business and innovation opportunities by encouraging practices such as reuse, remanufacturing, and recycling" (p. 67). In this way, in addition to contributing to the reduction of environmental impacts, this model also promotes the generation of jobs and the strengthening of the competitiveness of companies. To this end, a change in the business mentality is essential, because, as the author points out, "[...] The logic of the circular economy requires a new approach, in which the focus is not only on selling products, but on maximizing value through continuous cycles of use and reuse" (p. 75).

In this context, the circular economy presents itself as a concrete solution to minimize dependence on landfills and incineration processes, which, in addition to being environmentally harmful, are financially costly. Weetman (2019) highlights that "[...] companies are increasingly adopting circular economy principles, such as the use of recyclable and renewable materials, designing products to last longer and be easily repaired" (p. 125). This paradigm shift requires a coordinated effort to restructure production and logistics chains, ensuring that products are reintegrated into the production cycle. For this, it is essential to create adequate infrastructure for the collection and reuse of waste, because, as Weetman (2019) emphasizes, "[...] For this approach to be successful, it is essential to develop an efficient collection and sorting system, ensuring that materials return to the production cycle in an optimized way" (p. 132).

However, for this transition to occur effectively, the role of public policies is fundamental. Regulatory measures can accelerate the adoption of circular practices, creating incentives for the efficient use of resources and penalizing excessive waste generation. Weetman (2019) highlights that "[...] government regulation can accelerate the adoption of circular practices, creating incentives for the efficient use of resources and penalizing excessive waste generation" (p. 178). One of the most effective examples is

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extended producer responsibility, which obliges companies to collect and recycle products after their use, significantly reducing the volume of waste. In addition, as the author observes, "[...] legislation can play an essential role in establishing minimum standards for recycling and reuse, fostering an environment of innovation for the development of more sustainable materials" (p. 184).

In addition to regulation, one of the central principles of the circular economy is the change in the perception of waste, which should be seen as valuable resources and not just as disposable. Weetman (2019) endorses that "[...] waste should not be seen as a problem, but rather as an opportunity for innovation and value creation" (p. 203). This implies investments in new technologies for advanced recycling, composting of organic waste, and the development of biodegradable materials. In addition, the author argues that "[...] the adoption of circular models can generate significant economic benefits, reducing raw material costs and increasing the competitiveness of companies that invest in sustainable solutions" (p. 210). Thus, the circular economy not only protects the environment, but also offers concrete economic advantages for the productive sectors.

That said, it is essential to recognize that the transition to the circular economy requires not only structural changes, but also a profound cultural transformation. Weetman (2019) argues that "[...] educating consumers and companies about the benefits of the circular economy is essential for change to occur in an effective and lasting way" (p. 256). This involves everything from sustainable design to the adoption of new business models based on sharing, repair, and reuse, promoting more conscious consumption. In addition, the author concludes that "[...] For this change to materialize, collaboration between governments, companies and civil society is essential, ensuring an environment conducive to the implementation of circular solutions" (p. 263). Therefore, the circular economy is not just a trend, but an urgent need to ensure a more sustainable and balanced future for the next generations.

SOLID WASTE AND SUSTAINABLE DESIGN IN THE LIGHT OF THE 2030 AGENDA

Sustainable design plays a crucial role in solid waste management, as it makes it possible to create products with a lower environmental impact from conception to disposal. According to Manzini and Vezzoli (2016), "[...] Eco design[26] is the activity that, by

[26] *Eco design* is an approach to design that integrates environmental considerations into all stages of a product's life cycle, from conception to disposal, with the aim of minimizing negative ecological impacts.

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connecting the technically possible with the ecologically necessary, gives rise to new proposals that are socially and culturally acceptable" (p. 47). This concept implies the use of recyclable materials, efficient production processes, and the reduction of waste, promoting a more circular and sustainable economy. In addition, as Cardoso (2008) points out, "[...] sustainable design has its roots in the late 1960s, when environmental movements began to influence industrial production and consumption models" (p. 46). Thus, it is clear that the concern with the environmental impact of products is not recent, but has become increasingly relevant in the face of climate challenges and the growth of waste production.

> The essence of EC lies exactly in the design and in the well-planned industrial process, maintaining closed cycles, in which the resources used are subject to infinite circulation, without the need for new extractions. While there is always a certain amount of unavoidable dissipation, the design intent becomes to enable a continuous, balanced circuit. The commercialization of 'sustainable' products, partially made from recycled materials or more energy-efficient than their previous versions, is not enough (Manzini & Vezzoli, 2016, p.126).

In this sense, the relationship between sustainable design and the circular economy reinforces the importance of choosing less impactful materials and production processes. Braun and Gomez (2007) state that "[...] design starts to have as its main objective the design of products and services that, in some way, reduce the use of resources and minimize negative externalities" (p. 50). Thus, the careful selection of materials and the adoption of modularity and reuse techniques become fundamental strategies to ensure sustainable production. Complementing this idea, Stefano and Ferreira (2013) highlight that "[...] design ensures that a product is derived from the conscious use of energy, water and raw materials, providing advantages linked to cost reduction, less waste generation and attraction of new consumers" (p. 50). Therefore, it is evident that sustainability in design not only reduces environmental impacts, but can also generate economic value for companies and consumers. Like this

> The reduction of environmental impact is achieved by the adoption of guiding principles such as the careful selection of materials, efforts for energy efficiency,

According to Manzini and Vezzoli, this practice seeks to connect the technically possible with the ecologically necessary, creating solutions that are socially and culturally acceptable. Eco *design* considers the selection of sustainable materials, energy efficiency, waste reduction and modularity of products to facilitate their reuse and recycling. In this way, this approach aligns with the principles of the circular economy and the need to reduce the consumption of natural resources, becoming an essential element for the transition towards more sustainable production models. See: MANZINI, E.; VEZZOLI, C. *The Development of Sustainable Products: the environmental requirements of industrial products*. São Paulo: Edusp, 2002.

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> quality, durability, adoption of modularity techniques, as well as the reuse and reuse of products (Brones *et al.,* 2014, p. 50).

In addition, sustainable design plays an essential role in reducing the generation of urban solid waste, one of today's main environmental challenges. According to Martini (2016), "[...] the generation of waste has reached such a significant stage that it has been addressed in different Brazilian and international public policies" (p. 118). In view of this, the development of products with less environmental impact is in line with the guidelines of the National Solid Waste Policy (PNRS), which establishes the waste hierarchy and encourages non-generation, reduction, reuse and recycling. Brones et al. (2014) reinforce this perspective by stating that "[...] the reuse and reuse of products are essential to minimize environmental impacts and reduce the need for virgin raw materials" (p. 50). Thus, for waste management to be efficient, it is essential that the design is thought out from the beginning of the life cycle of the products.

> The PNRS defines principles such as prevention, and coefficient and life cycle of products, as well as objectives such as sustainable production standards and the use of raw materials derived from recycled materials. This demonstrates that sustainable design is a strategic element to enable the recapture of waste value, ensuring that products are designed to minimize environmental impacts and facilitate their reintegration into the production cycle (Circular economy and sustainability, 2021, p. 74).

The importance of this process is highlighted by the 2030 Agenda, which establishes a global commitment to promote sustainable production and consumption patterns. Sustainable Development Goal (SDG) 12 proposes that by 2030 "[...] sustainable management and efficient use of natural resources is achieved" and that "[...] substantially reduce waste generation through prevention, reduction, recycling and reuse" (UN, 2015, p. 32). These goals highlight the need for design focused on sustainability, promoting solutions that minimize waste and favor the reuse of materials. In this context, ABNT (2004) highlights that "[...] more organizations are becoming aware that there are substantial benefits in integrating environmental aspects into product design and development" (p. 3). In other words, the transformation of production processes is essential to achieve global sustainability goals.

> The 17 Sustainable Development Goals make up 169 associated targets that are integrated and indivisible. Never before have world leaders committed to common action and effort via such a broad and universal political agenda. It is a path towards Sustainable Development, collectively dedicated to the search for social

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> evolution and win-win cooperation, which can bring enormous gains to all countries (UN 2030 Agenda Platform, 2015, p. 32).

Another relevant aspect is the influence of sustainable design on industrial waste management and reverse logistics, which are fundamental for recycling and recovery of materials. According to the Ministry of the Environment (MMA, 2019), "[...] Reverse logistics is the process of adding value by planning, implementing and controlling the flow of materials, from the point of consumption to the point of origin, for the purpose of recapturing value or proper disposal". This approach reinforces the shared responsibility between businesses and consumers, ensuring that discarded products are repurposed or recycled. Gontijo and Dias (2010) complement this view by stating that "[...] Reverse logistics must be planned from the product design phase, as the material generated in post-consumption can define and make the reverse channel viable" (p. 23). Therefore, thinking about the circularity of products from their conception is essential to make reverse logistics more efficient.

> Reverse logistics must be planned from the conception of the products, ensuring that their materials can be reused in subsequent production cycles. This planning includes everything from the selection of recyclable materials to the feasibility of efficient return channels, allowing waste to be transformed into inputs for new productions (Circular economy and sustainability, 2021, p. 71).

In addition to the environmental impact, sustainable design also has strong social relevance, promoting green jobs and improving the quality of life of populations. According to the UN (2015), "[...] the generation of employment and income through the collection, treatment and disposal of solid waste is fundamental for the eradication of poverty and sustainable development" (p. 247). This shows that sustainability in design not only reduces environmental impacts, but also creates socio-economic opportunities. Gregson et al. (2015) reinforce this idea by pointing out that "[...] The circular economy should be seen as not only an environmental strategy, but also a social one, promoting inclusion and job opportunities" (p. 218). Thus, the circular economy and sustainable design go hand in hand in building a fairer and more balanced future.

> Design can be an essential element for the generation of economic, social and ecological prosperity that is sustained in the long term, considering the recommendations evidenced, the use of biodegradable, durable, renewable, recycled and recyclable materials, for the thought of closing the cycle, with less toxicity, less impact, less waste and less waste (Circular economy and sustainability, 2021, p. 138).

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In this way, sustainable design proves to be an essential tool to transform the current linear production model into a more circular and resilient system. According to Weetman (2019), "[...] the circular economy proposes strategies for reusing and redesigning products, reducing the need to extract new natural resources and increasing the efficiency of industrial processes" (p. 87). As a complement, Mackenzie apud Giudice et al. (2006) point out that "[...] the design for disassembly maximizes recycling sources and minimizes the potential for product pollution" (p. 133). Therefore, by integrating sustainable practices from the conception of products to their disposal, sustainable design consolidates itself as one of the pillars for building an environmentally responsible and socially inclusive future.

> The Circular Economy (CE) has been presented as an important change for companies, as it forces them to rethink beyond their ecological footprints, resource consumption and energy efficiency. It is a model that allows us to reassess the economic practices of today's society and that is inspired by the functioning of nature itself, promoting the regeneration of materials and the restoration of technical resources (Circular Economy and Sustainability, 2021, p. 76).

CONCLUSION

The research showed that recycling, when inserted in the circular economy paradigm, plays a fundamental role in the transition to a more sustainable production and consumption model. Throughout the investigation, it was possible to understand that the current linear model of disposal, characterized by the excessive use of raw materials and the waste of resources, imposes environmental, social and economic challenges that compromise the quality of life and planetary sustainability. In this sense, the circular economy emerges as a viable alternative for the reintegration of waste into the production cycle, minimizing environmental impacts and promoting the efficient use of natural resources.

The findings point out that recycling not only reduces the extraction of new resources, but also enhances innovative solutions in sustainable design. As demonstrated, the approach based on the circular economy proposes the reconfiguration of production processes, favoring the reuse, remanufacturing, and reuse of materials, ensuring that products have longer life cycles and reduced environmental impacts.

In addition, it was found that sustainable design plays an essential role in this transition, as it enables the design of products that consider their destination from the initial phase of development. The incorporation of principles such as modularity, the use of

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biodegradable materials, and the elimination of toxic substances are key strategies to ensure that products are easily disassembled and recyclable. The survey also revealed that, without a real commitment from the productive sector, efficient public policies and a broad awareness of society, the implementation of these concepts may be limited.

Another relevant aspect identified throughout the study was the relationship between recycling and the Sustainable Development Goals (SDGs), particularly SDGs 11 and 12, which emphasize the need to ensure sustainable production and consumption patterns. The challenges identified in the implementation of the circular economy reinforce the importance of investments in infrastructure for waste collection and sorting, as well as the creation of incentives that promote shared responsibility between consumers, companies, and governments.

In addition, the research reinforces that recycling, by itself, is not enough to solve the problem of urban solid waste. Without the adoption of an integrated approach that includes product redesign, reverse logistics, and effective public policies, waste will continue to be disposed of inappropriately, compromising the environmental balance. Thus, in order to consolidate a more responsible development model aligned with the principles of global sustainability, it is essential to articulate the productive sector, policymakers, and civil society.

Therefore, it is concluded that recycling, combined with sustainable design and the circular economy, is a key element for mitigating environmental impacts and building a more sustainable future. The transition to this new model, however, requires collective efforts and structural investments, as well as cultural changes that favor more responsible consumption and disposal practices. Only through the coordinated implementation of innovative and sustainable strategies will it be possible to achieve a balance between economic development and environmental preservation, ensuring a more livable planet for generations to come.

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