RECYCLING - VECTOR OF THE CIRCULAR ECONOMY. SYSTEM ANALYSIS FROM THE BOTTLENECK THEORY PERSPECTIVE

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Abstract

The objective of the European Union, as a major player on the global socio-economic and political scene, as set out in the European Green Pact, is to achieve climate neutrality by 2050, while ensuring an equitable and socially inclusive economic framework and context.

The circular economy has thus become mainstream, attracting the attention of academia, the media and of the responsible socio-economic and political actors at a national, European and international level.

Thus, a new trajectory of consumption has emerged: buy - use - repair/recycle - reuse, a paradigm which is the very hypothesis of this study.

This is because, despite favorable auspices, the transition to the circular economy has not performed well in recent years and recycling, a key driver of the circular economy, has not performed as expected. In this context, there is a question that has not yet been clearly and generally answered - Why has the recycling process failed to reach the expected level?

Based on this situation, the general objective of the study is to identify the causes that lead to the blockage of the recycling process, which will create the prerequisites for identifying solutions that will lead to the efficiency and effectiveness of the whole system. To this end, a qualitative analysis, based on both theoretical and empirical perspectives, of the recycling system through the lens of bottlenecks theory was conducted.

Given the still precarious environmental culture and the reluctance of most producers and consumers towards the environment and the climate change threat, this study aims to contribute to identifying, raising awareness and popularising the role that circular economy stakeholders in general, and recycling stakeholders in particular, can play in ensuring sustainable micro-, meso-, macro-, euro- and global economic development. As a specific objective, the study aims to contribute to encouraging recycling and minimising waste disposal.

Keywords: *circular economy, recycling, bottleneck analysis, optimization, waste.*

1. Introduction

Environmental degradation and climate change are ongoing dangers with the potential to proliferate if national and international strategies for recovery and transition to a rational and competitive economy in terms of resource use in general and natural resources in particular, are not implemented efficiently and effectively.

In this context, the circular economy has become mainstream in the last decades, being the focus of attention of academia, the media, as well as socio-economic and political actors at national, EU and international level. This is because the circular economy advocates minimising waste and reducing resource consumption by optimising the life cycle of material economic goods. As a result, there has been a paradigm shift in resource use, production and consumption. Thus, after acquisition and use, instead of disposal and replacement, processes such as reduction, recycling, remanufacturing, reuse, reconstruction, regeneration (the well-known 'R' strategies of the circular economy) are encouraged.

But despite the media coverage, numerous scientific reports and studies, and above all the bold roadmaps for achieving climate neutrality adopted by EU and international bodies and implemented by national governments, the transition to a circular economy has slowed globally.

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According to the report „Circularity Gap 2024”[1] most of the raw materials used still come from virgin sources and the share of secondary materials, reused, has decreased over the last five years from 9.1% in 2018 to 7.2% in 2023[2] .

This raises a question that has not yet been answered clearly and generally accepted: Why has the transition to the circular economy not been as successful as expected?

Starting from this hypothesis, although the circular economy is a holistic process that aims at minimising waste and thus optimising resource use through multidirectional actions, this paper will focus on recycling, the most widely known and debated pillar of the circular economy, and will have as its overall objective to identify the causes that lead to the blocking of the expected results, which will allow the identification of solutions for optimising the whole recycling system.

To this end, a qualitative analysis, both theoretical and empirical, of the material recycling system has been carried out through the lens of bottleneck theory.

2. Circular economy - recycling - bottleneck theory. Interconnected conceptual overview

The field of circular economy is still a young[3] and growing one, both in theory and in practice. Given that there is no unanimously accepted definition of the circular economy, this paper will refer to the one formulated by Julian Kirchherr et al., after analysing 114 definitions presented in the literature, namely: „A circular economy describes an economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations.”[4] The more recently formulated definitions for the period 2017-2022 keep the same general principles (the 4 Rs and sustainable development) and adds an indispensable condition for ensuring the effectiveness of the process - collaboration between the 4 major stakeholders of this process: producers, consumers, decision-makers and academia[5].

Recycling, although intensely discussed and even disputed, is therefore a vector of the circular economy[6], the importance of the process being supported both in theory and in practice. This is because, conceptually, recycling has been and is the most frequently mentioned 'R' in the definition of the circular economy, and practically, because it makes an important contribution to the efficient management of resources and the reduction of environmental pressure through the reduction and recovery of waste and of the repeated use of resources in the economic cycle. A prime example of the usefulness of recycling is the data on recycling of paper, where the production of recycled paper generates 70% less pollution than the production of the same amount of paper from virgin raw materials[7]. Another argument in favor of making recycling more efficient is the data published in the EU Monitor, which estimates that globally in 2019, plastic production and incineration generated more than 850 million tons of greenhouse gas emissions into the atmosphere, and that these emissions could rise to 2.8 billion tons by 2050 without improved recycling.[8]

Although examples of this kind are numerous and diverse, it cannot be overlooked the fact that there are also scientific studies in which solid arguments can be found on the negative impact of recycling on the

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[1] Annual survey, conducted and published since 2019 by Deloitte and Circle Economy Foundation.

[2] *Circle Economy Foundation, The Circularity Gap Report 2024. Executive summary, Netherlands*, published by Circle Economy Foundation, 2024, p. 2.

[3] Although the field of circular economy took shape in the 1970s, it has seen substantial attention and development since 2012. According to Kirchherr & al in *Conceptualising the circular economy: An analysis of 114 definitions, in Resources, Conservation & Recycling,* vol. 127, December 2017, p. 226, 73% of the definitions available at that time had been formulated after 2012.

[4] J. Kirchherr, D. Reike, M. Hekkert, *Conceptualising the circular economy: An analysis of 114 definitions, in Resources, Conservation & Recycling,* vol. 127, December 2017, pp. 224-225.

[5] J. Kirchherr et al*., Conceptualising the Circular Economy (Revisited): An Analysis of 221 Definitions, Resources, Conservation & Recycling*, vol. 194, April 2023, p. 4.

[6] According to Kirchherr et al.'s 2017 and 2023 statistical analyses of the definition of the circular economy, recycling has always been a basic principle of the circular economy, even a binding element of the various approaches (until 2012 it appeared in definitions with a frequency of 90-94%, with the frequency of use dropping to 70-80%, but as the number of "R-matrix" variables increased.

[7] V. Kumar, J.S. Kalra, D. Verma, S. Gupta*, Process and Environmental Benefit of Recycling of Waste Papers,* International Journal of Recent Technology and Engineering, vol. 8, issue 2S12, September 2019, p. 104.

[8] EU Monitor, *Plastic waste and recycling in the EU: facts and figures*, published by European Parliament, on 18.01.2023, *https://www.eumonitor.eu/9353000/1/j9vvik7m1c3gyxp/vkufaw0m3zy4?ctx=vjxzjv7ta8z1*, last time consulted on 01.04.2024.

environment and society, supported by the fact that the recycling industry itself involves pollution and greenhouse gas emissions, high electricity consumption, poor quality of most secondary raw materials and the possibility of their contamination with harmful chemicals, high costs of resource management are passed on to buyers through high resource management fees and charges, etc. Under these circumstances, given that the contribution of the recycling industry to sustainable economic and social development cannot be ignored, there is a need for segment-specific cost-benefit analysis and at the same time analysis to identify bottlenecks in the process, so that optimal recycling strategies can be built and implemented to achieve environmental objectives.

„Bottlenecks" are those integral elements that limit the overall performance of the system and can manifest themselves in multiple spheres of human activity, from scientific research, economics, ecology, politics, and in general in all areas of human activity and existence. Therefore, determining bottlenecks and identifying solutions to eliminate or at least reduce these limitations is a prerequisite and a dynamic process that needs to be applied, reviewed and adjusted continuously in order to improve performance and achieve objectives.

From a recycling perspective, bottlenecks theory refers to those structural, process and cognitive elements and processes that limit its overall efficiency or effectiveness. In this sense, recycling should be approached holistically, as an integrated system, comprising intermediate processes, diverse typologies of the production process and a multifactorial matrix of actors involved. Thus, if we consider that recycling is a complex process comprising collection, sorting, processing and transformation of waste into new products, either directly or by processing the resulting secondary raw materials, the bottlenecks analysis must address each of these steps. In addition, the fact that, from a waste transformation perspective, recycling is divided into three categories - material recycling (paper, cardboard, glass, metal, aluminium, plastic), energy recycling (conversion of waste into energy) and organic recycling (conversion of organic waste into compost or biogas) - requires a separate identification of bottlenecks according to the specifics of each type of recycling. Also, in identifying bottlenecks, causal factors and remedies, the different perceptions of the various stakeholder categories (municipal, governmental and intergovernmental public institutions, recycling industry producers, producers and traders of economic goods that need to adapt their activity according to the legislative provisions) should be taken into account, consumers, education and research institutions, national and international NGOs, media, consultants, certification and standardisation organisations, investors and financial institutions interested or involved in financing initiatives to improve recycling rates).

3. Recycling system efficiency through the bottleneck view. Current context

Identifying and resolving/minimising bottlenecks is key to optimising recycling efforts and achieving environmental targets, and requires a comprehensive, multi-stakeholder approach that takes into account infrastructure, technologies used, political context, as well as culture, education and the state of stakeholder collaboration.

Given the broad spectrum and particularities of each type of recycling, this bottlenecks analysis was limited to one type, namely materials recycling, and the bottlenecks were identified by critically documenting the recycling phenomenon from the most recent primary and secondary data sources, presented centrally in the references section. In order to achieve the overall objective of the research, at least one potential solution was determined for each identified bottleneck, as will be seen below.

Bottleneck - underdeveloped collection infrastructure leading to low collection rates of recyclables.

Solutions:

- improving collection methods by making collection points more accessible and simplifying conditions (in addition to dedicated collection streams, wider use of mixed waste sorting);
- increasing individual awareness and responsibility, promoting social responsibility, involving local communities in protecting the environment through sustained and accessible information adapted to the behavioral profile of each category of users of recyclable products;
- as well as stimulating recycling behavior by providing rewards by stakeholder category.

Bottleneck - most secondary raw materials from recycled materials[9] are of poor *quality* and can only be used for the production of lower quality economic goods (*e.g.*, plastic chairs, flowerpots, packaging).

Solutions:

[9] Recyclable materials are those materials that can be transformed into new products (paper, plastic, glass, aluminium, metal, etc.).

- expanding advanced mechanical[10] recycling, as it allows even contaminated waste to be recycled and gives secondary raw materials a higher quality, similar to virgin raw materials, which will allow them to be used to produce higher quality economic goods (in the automotive, cosmetics, beverage, etc. industries);
- improving waste recovery by expanding Research & Development and innovation in this sector, leading to the modernization of recycling facilities.

In this respect, S&P Global Platts Analytics[11] estimates that by 2030, more than 1.7 million tons of virgin polymers will be replaced by mechanically recycled plastics (a significant increase compared to the 688 000 tons produced in 2020)[12].

Bottleneck - dependence on primary (virgin) raw materials due to low recycling rates

For example, a report on the circularity of PETs[13] in Europe, carried out in 2022 by Eunomia at the request of Zero Waste Europe[14], shows that the recycling rate for all PETs[15] (bottles, packaging, even textiles and car parts) was 23% and the rate of use of recycled[16] PETs (rPETs) in the production of other PETs was 24%**.**

Solutions:

- efficient collection of recyclable materials through large-scale implementation of landfill returns systems which is a global best practice;
- facilitate access to finance for the purchase and large-scale use of advanced technological sorting and treatment facilities for household and industrial waste (as per European Parliament Report A9-0290/2022 A2A, AVR and EEW facilities) that ensure the decontamination and use of materials previously considered non-recyclable.

Bottleneck - major bottlenecks in the availability of recycled content as demand for high quality recycled materials has increased substantially, as companies, as a result of legislation but also voluntary commitments, are also targeting environmental objectives such as increasing the proportion of recycled content.

At EU level, it was decided to implement a directive[17] in 2022 setting a collection target of 90% recycling of single-use plastic bottles by 2029 (with an interim target of 77% by 2025). These bottles should contain at least 25% recycled plastic in their manufacture by 2025 (for PET bottles) and 30% by 2030 (for all bottles).

Solution: closed-loop recycling, in as many production cycles with the same destination, would ensure a more efficient supply of recyclable materials by reducing the time needed for the whole recycling process, reducing the degree of contamination and therefore waste (for example, although each recycling decreases the quality of the paper, it can be recycled 6-7 times, aluminium and glass can be recycled indefinitely).

Bottleneck - recycling in this closed loop is done at a low rate.

For example, of the 1.8 million tons of flakes from recycled bottles, only 31% were put back into the recycling loop as new containers, with the remaining 69% being converted into other products, usually of lower quality and even non-recyclable.[18]

Solutions:

- increasing the quantities of recycled products recovered in all waste streams;
- introduction of extended producer responsibility (EPR) schemes.

Bottleneck - negative publicity regarding the recycling process by publicising and promoting the idea that the use of recycled products has negative effects on health, but also about the negative influence on the environment of the production of technologies needed for the recycling process and even the recycling process itself.

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[10] Recycling method that can be applied to paper, plastic, glass, textiles or metal and that consists of grinding, washing, separating, drying, regranulating and finally recompiling the collected materials. It is the most popular method, but other methods are also used in recycling: composting, incineration, anaerobic digestion, chemical recycling (specific to plastics).

[11] A leading independent provider of data and analysis for commodity and energy markets, founded in 1909.

[12] S&P Commodity Insights, *Recycled plastics market becoming more liquid and globalised as demand soars*, 2021, *https://commodityinsights.spglobal.com/Download-Asset-Recycled-Plastics.html*, last time consulted on 01.04.2024.

[13] Andy Grant *et al.*, *How circular is PET,* Brussels, published by Eunomia & Zero Waste Europe, February 2022, p. 18.

[14] Zero Waste Europe is an NGO Supported by the EU LIFE Programme.

[15] The weight of packages entering the recycling operation versus the weight of packages placed on the market (equivalent of the EU measurement method for recycling).

[16] The weight of recycled PET versus the weight of virgin PET in packaging.

[17] Directive (EU) 2019/904 on the reduction of the environmental impact of certain plastic products and Implementing Decision (EU) 2022/162.

[18] Eco Synergy*, PET, marea decepție eco: de ce nu se reciclează cel mai reciclabil tip de plastic ?,* 13.04.2022, *https://ecosynergy.ro/pet-marea-deceptie-eco-de-ce-nu-se-recicleaza-cel-mai-reciclabil-tip-de-plastic/*, last time consulted on 01.04.2024.

There are concerns from users of economic goods containing recycled materials about the toxicity of the resulting products, and these concerns have even been confirmed by recent scientific studies. For example, the presence of chemicals in food and beverages bottled in PET containers is widely publicised and debated, and is caused by multiple factors, from the actual production process to the conditions of filling, storage, distribution, sorting or reprocessing for a new life cycle.

A negative contribution to the perception of the usefulness of the recycling process is also made by the inequality with which measures to achieve sustainable development goals are applied, which creates inequality and unfair competition for fair play actors. A good example of this is the EU's goal of becoming the first climate-neutral continent by 2050, which forces European investors to make much greater financial efforts than their competitors in China or the US, and this financial pressure is of course reflected in the prices of the offered products.

Solutions:

- firstly, reviewing the rules on the use, labelling, traceability and chemical stability of recycled materials (*e.g.*, EU Regulation 10/2011 on plastic materials and articles intended to come into contact with food);
- investing in technologies for more efficient cleaning;
- stricter monitoring of storage conditions;
- investment in research and innovation in emerging technologies (chemical depolymerization);
- encouraging certification to increase both industry and consumer confidence;
- encouraging EU countries to consider reducing VAT on recycled products.

In recent years, efforts and progress have been made to improve recycling infrastructure, increase awareness and involvement of the population in the recycling process, and collaboration between stakeholders throughout the value chain. Although there are shortcomings in the way the process works, there are still measures and tools that can be further diversified and applied to increase the efficiency and effectiveness of the process, the difficulty is that to be truly sustainable and have lasting effects, they must be implemented in a harmonised and equitable way on a global scale, always taking into account the social, economic and environmental implications. In order to respect the principle of equity, solutions may vary depending on the region and local context.

4. Conclusions

There are no general solutions to ensure circularity in the economy, they may vary depending on the region and the local context, but increasing the efficiency and effectiveness of the waste recycling process can only be ensured by treating it as a holistic process, which means supporting investments in the whole infrastructure of the system, *i.e.*, collection, sorting, recycling and creating end markets for secondary raw materials.

An overview of the analysis of the bottlenecks reveals the following general conclusions: bottlenecks occur at every stage of recycling, resolving the bottleneck at the waste collection level is a first solution for the bottlenecks at later stages as well, but the unblocking solutions must be applied synchronously otherwise bottlenecks of the opposite nature - pressure from the supply side of waste or recycled raw materials - may occur.

As a result, complementary solutions such as: large-scale development and implementation of easy waste return systems (a worldwide best practice), but also of mixed waste sorting, increasing the quantities of recycled products recovered in all waste streams, reducing contamination of recyclable products, extended producer responsibility systems, harmonising quality standards for secondary raw materials and encouraging their certification in order to increase user confidence, financial motivation for stakeholders (reduced VAT for recycled products, easier access to finance for all entrepreneurs involved in the recycling process, generalisation and streamlining of the guarantee-return system).

The creation and implementation of fair and comprehensive binding rules is also a necessary market intervention with a decisive role to play in achieving sustainable development goals through greener, more circular economies. The outcome of the European Parliament elections in June 2024 also poses a risk to the future direction of European legislation, including from an environmental policy perspective. This is because, for the first time in the history of the European Parliament, polls show a strong chance of a majority for right-wing populist parties, parties which, in addition to their neo-nationalist and anti-globalization doctrine, are also associated with anti-environmental ideologies, which puts the future of the EU's agenda, including the Environmental Action Program, in doubt.

Given that bottlenecks, as we have already pointed out, make their presence felt in all spheres of human activity, the present study also faced a number of limitations. Thus, the analysis was limited to recycling as a vector of the circular economy, since the article aimed at identifying and eliminating or at least moderating the factors that cause bottlenecks in this process, but it could be extended to all the traditional 4 Rs (reduce, reuse, recycle, recover), or even to the more detailed framework of the modern circular economy, the 9 Rs (refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, recover).

Moreover, this study is limited to one „B" out of the 3 of the analysis of the optimization matrix of any human activity in general, in this case, the recycling of materials. Therefore, the aim is to continue the scientific approach to extend the analysis of the recycling process from a complex perspective, taking into account the correlation between all the 3 quadrants of the „3 B" analysis - bottleneck, blind spots, and blended finance.

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