Circular Economy and Patents for Treatment of Waste

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Abstract. The circular economy is established as a modern concept, reflecting environmental expectations for the future development of society. But after years of thoughtless extraction of natural resources and irresponsible disposal of excess or already used and unnecessary products and materials, changing the consciousness of enterprise managers to implement transformation and move from a linear model to a circular economy is not an easy task. This paper presents the parameters of the concept of circular economy and justifies its application in modern times. The aim is to outline the role of Environmentally Sound Technologies (ESTs) as a supporting toolkit for applying the principles of the circular economy. Using empirical methods (research, comparison, analysis) the structure and dynamics of the patents granted in the field of waste treatment as an element in the waste management process is presented. The result of the study shows the trends of patent activity, which for the studied period 2002-2022 marks a negative downward trend (an average annual by almost 7%) in several patented waste treatment technologies for which a European patent has been granted. The International Patent Classification (IPC) indices with the highest concentration of patent rights are also revealed, with Technologies for the reclamation of contaminated soil in the first place, accounting for 33.4% of the total patented waste treatment technologies. The prepared analysis of patent information on the rights to patented waste treatment technologies is indicative of the reorientation of patentees and the higher commitment to the creation and implementation of little waste or non-waste technologies.

1 Circular Economy Concept

The circular economy (CE) was born as a concept in response to the environmental and social challenges facing modern society. Its goal is to shift the linear model of the economy and implement the ideas of reuse, material recovery in production and recycling, which reduce the amount of waste reaching the environment and ensure sustainable development for generations. *"CE's main aim is to enable enterprises' sustainable growth at the micro-, meso-, and macrosystem levels and reduce the unsustainable exploitation of natural resources, energy, and materials"* [1,2].

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In addition, the focus of the circular economy concept is limiting the extraction and use of conventional natural resources and replacing them with unconventional resources, and – designing products in a way that allows subsequent processing and reuse in the production process. (see Figure 1).

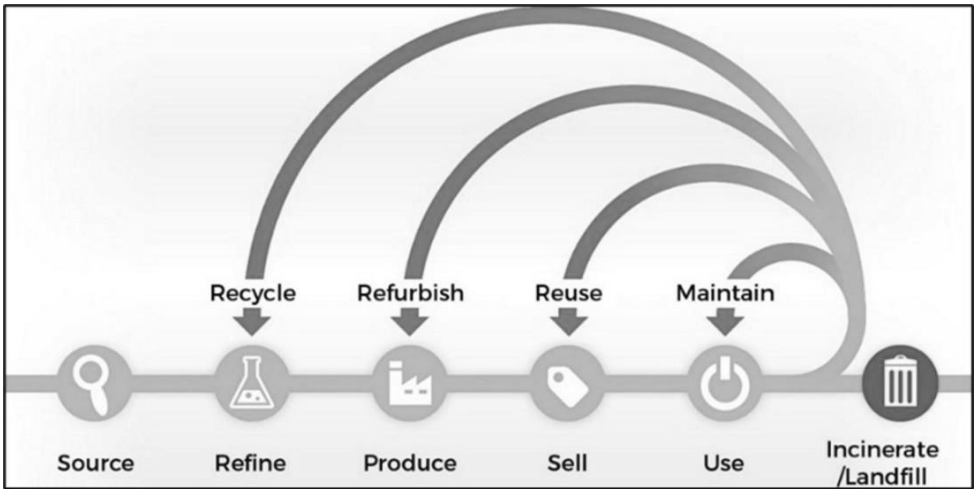

Fig. 1. Circular economy model.
Source: [3]

It is evident from Figure 1 that the life cycle of products and the material resources put into their production are extended many times through the processes of maintenance, reuse, refurbish, and recycling. Notwithstanding this, a part of the materials which is not subject to these processes becomes waste and as such needs to be treated in a certain way.

Among the more widely known definitions of the circular economy, the following stand out (see Table 1), considering the need to limit harmful waste reaching the environment.

Table 1. Definition of Circular economy.

Source	Definition/interpretation
Preston (2012)	"Circular economy is an approach that would transform the function of resources in the economy. Waste from factories would become a valuable input to another process – and products could be repaired, reused, or upgraded instead of thrown away" [4]
EEA (2014)	Circular economy "refers mainly to physical and material resource aspects of the economy – it focuses on recycling, limiting, and re-using the physical inputs to the economy, and using waste as a resource leading to reduced primary resource consumption" [5].
European Commission (2014)	"Pumping resources back into productive use, again and again, cutting waste and reducing dependence on uncertain supplies is a direct route to improving resilience and competitiveness. By helping to decouple economic growth from resource use and its impacts, it offers the prospect of sustainable growth that will last" [6].
Korhonen et al. (2018)	"CE is a sustainable development initiative with the objective of reducing the societal production-consumption systems linear material and energy throughput flows by applying materials cycles, renewable and cascade-type energy flows to the linear system. CE promotes high value material cycles alongside more traditional recycling and develops systems approaches to the cooperation of producers, consumers and other societal actors in sustainable development work" [7]

Source: author's elaboration based on [8, 9]

The definitions of circular economy known so far in the specialized literature allow for the purposes of this study to derive the following working definition, reflecting the place of waste management: **The circular economy is a model of the economy in which the aim is to maximize the utilization of the extracted and used resources while achieving a minimum of unusable waste.**

To achieve the objectives of the circular economy, emphasis is placed on the main processes falling within its scope (see Figure 2).

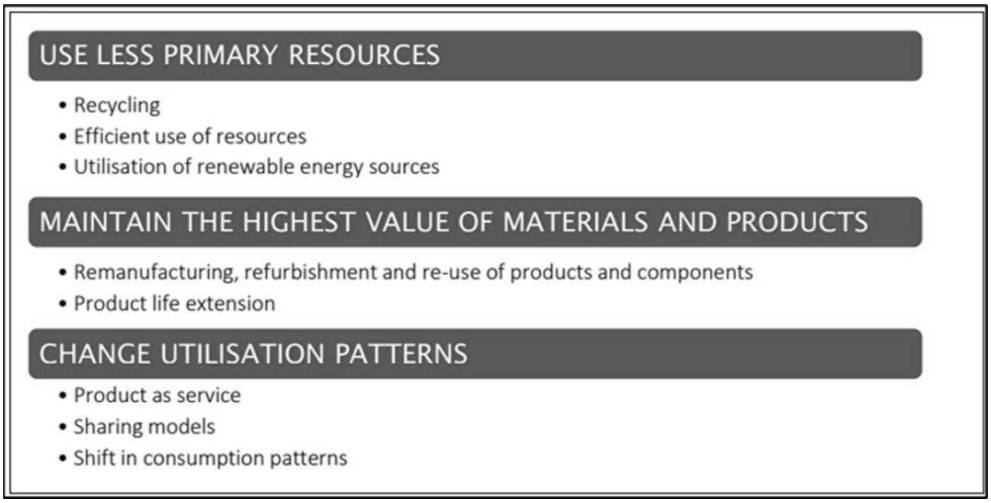

Fig. 2. Main circular economy processes.
Source: [9]

As Balinov [10] points out, one of the fundamental principles of the circular economy is the highest possible efficient use of materials and the limitation of waste reaching the environment (see Figure 2). In this regard, the European Commission proposes **Waste Framework Directive**, which defines the concept of waste management and introduces the basic concepts [11].

Fig. 3. Waste hierarchy.
Source: [11]

The waste hierarchy is presented as an inverted pyramidal structure focusing on waste prevention as an activity of paramount importance in minimizing the amount of waste reaching the environment. Prevention is related to a radical change in the activity of enterprises and the development of innovative products whose component parts can become a secondary raw material for subsequent production, thus ensuring maximum utilization of resources. Second in the hierarchical structure is the possibility of reusing the products used by changing their application or making them available for use by others. Recycling is the process by which products made from certain materials (paper, corrugated cardboard, aluminum, steel boxes, glass, plastic, organic waste, and scrap metals etc.) are processed and subsequently used as a raw material for production. Recovery as a next option refers to transforming existing products into new ones by adding recycled products and materials to extend the useful life of products and prevent their disposal.

The proposed definitions of the circular economy and the processes taking place in its scope reiterate the need to limit the volume of resources used and the place of waste management in the concept of the circular economy. Therefore, at the forefront of this paper examines the role of green technologies as a supporting toolkit for the application of the principles of the circular economy.

2 Environmentally Sound Technologies (ESTs) and patent information

The importance of ESTs has increased in recent years precisely in the context of two interrelated and complementary concepts – those of the circular economy and sustainable development. ESTs are defined as technologies that *„protect the environment, are less polluting, use all resources in a more sustainable manner, recycle more of their wastes and products, and handle residual wastes in a more acceptable manner than the technologies for which they were substitutes“*. [12, p. 305] Environmentally sound technologies are not limited to a single technology, they represent comprehensive systems that cover both the know-how created and the management and organizational procedures applied [12]. Their scope is defined in the United Nations Framework Convention on Climate Change (UNFCCC) by the Committee of Experts of the International Patent Classification (IPC), which differentiates the following categories: **Alternative energy production**; **Transportation**; **Energy conservation**; **Waste management**; **Agriculture/forestry**; **Administrative, regulatory or design aspects; Nuclear power generation** [13].

The scope of green technologies corresponds to the principles and objectives set out in the circular economy concept, so it can be assumed that the degree of development of technology testifies to the progress of society in the practical implementation of circular economy ideas and pollution reduction. In this context, environmentally sound technologies are *„process and product technologies" that generate low or no waste, for the prevention of pollution. They also cover "end of the pipe" technologies for treatment of pollution after it has been generated* [12, p.305]

For the purposes of this paper and analysis, ESTs have been studied only in *the waste treatment* part (see Table 2).

Table 2. Scope of ESTs in the field of waste treatment.

Treatment of waste	IPC
Disinfection or sterilisation	A61L 11/00
Treatment of hazardous or toxic waste	A62D 3/00, 101/00
Treating radioactively contaminated material; decontamination arrangements therefor	G21F 9/00
Refuse separation	B03B 9/06

Reclamation of contaminated soil	B09C
Mechanical treatment of wastepaper	D21B 1/08, 1/32

Source: [13]

The information presented shows that waste treatment contains different groups of technologies, for which their assigned indices from the IPC are presented. The IPC extends to all areas of human knowledge whose objects can be protected by patent.

A patent is a protected document certifying the exclusive rights of the patent owner in an invention. The patent documentation prepared by the patent applicant contains information about the specific field of knowledge to which the invention is directed and which corresponds to a specific classification index. An invention may be assigned more than one IPC index.

When examining the databases with patent information on the classification indices included in Table 2, information is obtained on all patented technologies in the field of waste treatment. In this regard, it can be argued that patent information provides knowledge about the development of technology at a given time and assists inventors in their research developments by stimulating innovative thinking and the development of innovation. Patent information becomes *"a valuable information resource of strategic importance for individual companies, for the national economy, as well as for the whole society"* [14, p. 37]. The quoted statement gives us reasons to accept patent information as a reliable and significant source of data on technological advances in the field of waste treatment, which cannot be covered by maintenance, reuse, repair, and recycling processes and must be disposed of and processed accordingly to avoid environmental pollution.

3 Structure and dynamics of patent activity in the field of waste treatment

The research on patent activity in the field of waste treatment is limited in the period 2002-2022. The data are obtained from the database of the European Patent Office – EPO [15] and cover the IPC codes derived in Table 2.

Tracking the number of patents granted in the study period (see Figure 4) reveals trends in the field of innovative waste treatment technologies.

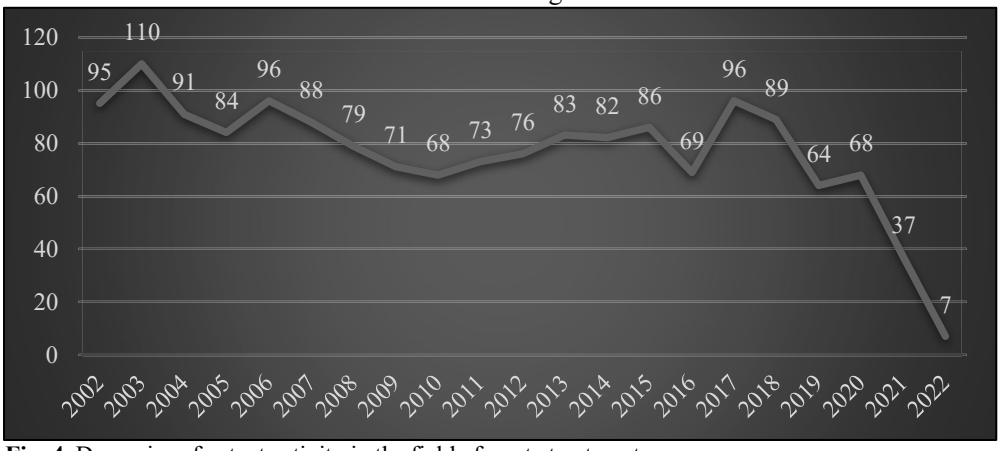

Fig. 4. Dynamics of patent activity in the field of waste treatment.
Source: PATSTAT, Author's calculations

The total patent activity for the entire survey period 2002-2022 (see Figure 4) marks a negative downward trend (annual average of almost 7%) in the number of technologies for

waste treatment granted legal protection under a European patent. For the period 2002-2017, patent activity maintained relatively stable levels, with an increase in granted patents on average by 1.06% per year. In the same period, the highest activity of 110 patents in 2003 was measured. At the end of the analyzed period, from 2018 to 2022, there was a sharp decline in activity, an annual average of 31.2%.

Analysing the IPC classes assigned to patented technologies in the study period, Figure 5 reflects the top twenty indices most included in patent documents. It also contains information on IPC classes outside the scope of environmentally sound technologies, due to the multifaceted nature of certain inventions and their ability to be used in different technological fields.

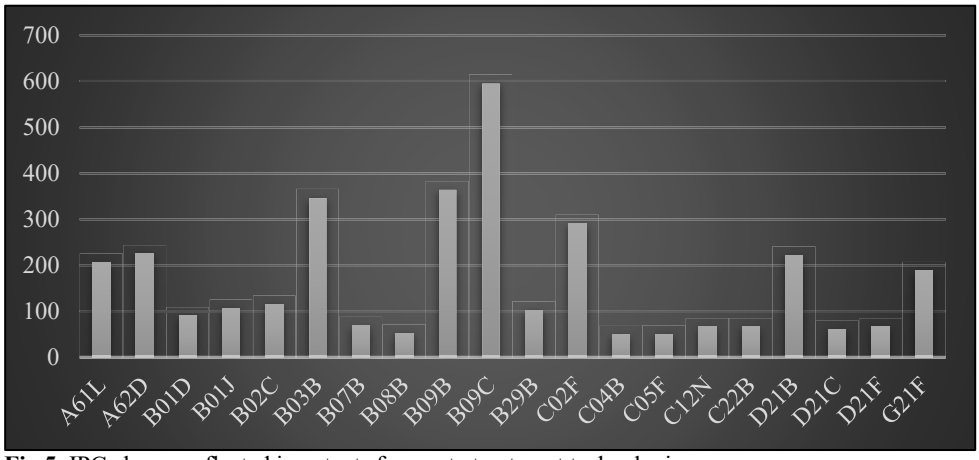

Fig.5. IPC classes reflected in patents for waste treatment technologies.
Source: PATSTAT, Author's calculations

With the greatest concentration of patent rights (see Figure 6) stands out B09C *Technologies for the reclamation of contaminated soil*, which account for 33.4% of the total patented waste treatment technologies. The next classes in which patentees show an increased interest are: *B03B Refuse separation,* with 19.4% patent activity*; A62D Treatment of hazardous or toxic waste* (12.6%); *D21B Mechanical treatment of waste paper* (12.4%); *A61L Disinfection or sterilization* (11.6%); *G21F Treating radioactively contaminated material; decontamination arrangements therefor* (10.6%).

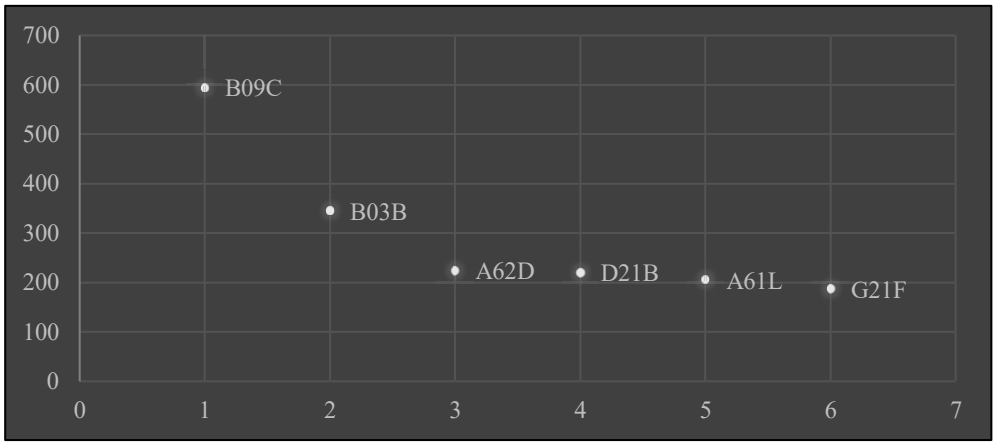

Fig. 6. Concentration of patent rights on the indices from the IPC in the field of waste treatment.
Source: PATSTAT, Author's calculations

A look at the dynamics of patent activity by individual IPC classes for the period 2002-2022 (see Figure 7) largely recreates the general patent activity in the field of waste treatment technologies (see Figure 4). And here there is a downward trend in the activity of patentees, strongly expressed in the last years of the period. Although in some years there is an increase in patent activity by individual classes, there are periods of decline and again increased activity. Only in technologies for *the treatment of hazardous or toxic waste* there has been a steady downward trend in the number of patented technologies since 2006.

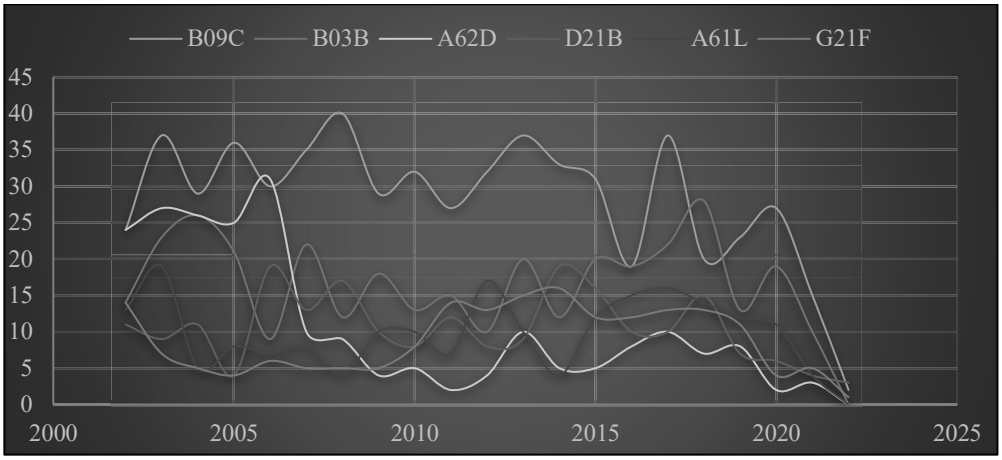

Fig. 7. Dynamics of patent activity by IPC classes for the period 2002-2022
Source: PATSTAT, Author's calculations

The overview of patented waste treatment technologies in the period 2002-2022 is indicative of the decreasing activity of patentees in this area. Reasons for the results obtained can be sought in the desire of inventors to create more waste-free technologies. While initially after the establishment of the concept of sustainable development [12] the efforts of enterprises are focused on developments limiting the harmful impact on the environment, which are applicable to existing production systems and products, in recent years there has been a reorientation. Morally obsolete production is being replaced by innovative small waste or waste-free technologies that allow the application of circular economy principles and maximise the use of materials falling into production. As a result, products compatible with the objectives of the circular economy are created, environmentally friendly and ensure the sustainable development of society.

4 Conclusion

The information discussed in this paper on the essence of the circular economy concept and the priorities it presents to society, along with the trends in the development of innovative green technologies contributing to reducing the harm of human activity to the environment, highlight the role of the circular economy in achieving sustainable development. Sustainable development is *"a process of change in which the exploitation of resources, the direction of investment, the orientation of technology and institutional change are in harmony with each other and increase the current and future potential with which to provide human needs and aspirations."* [16, p.43]. In this direction, the goals set for the circular economy are also oriented: to ensure sustainable development of enterprises while reducing the use of conventional resources.

The presented classification of categories of environmentally sound technologies outlines the directions in which research should be directed to achieve sustainable and responsible

development of the activities of enterprises and minimize the negative effect on the environment and man. This makes green technologies a valuable tool for promoting the principles of the circular economy.

The prepared analysis of patent information on the rights to patented waste treatment technologies is indicative of the reorientation of patentees and the higher commitment to the creation and implementation of little waste or non-waste technologies.

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