UNITECH SELECTED PAPERS

International Scientific Conference
UNITECH`2024

PATENT ACTIVITY IN THE FIELD OF REUSE OF WASTE MATERIALS

Ventsislava Nikolova-Minkova

Technical University of Gabrovo, Bulgaria, 4 Hadzi Dimitar str.

**Corresponding author: minkova.ventsislava@gmail.com*

Abstract

This report is aimed at revealing the structure and dynamics of patent activity in the field of reuse of waste materials. The interest in this topic is influenced by the pronounced aspiration of world leaders to impose the principles of the circular economy and sustainable development goals in the fight against climate change and global pollution. As a result of the empirical analysis, the following has been achieved: technologies in the field of reuse of waste materials with the highest concentration of patent rights have been identified; the sources of patent activity are revealed and the companies with the greatest contribution to technological development in the field are ranked.

Keywords: waste, technology, patent activity, circular economy, sustainable development.

INTRODUCTION

The development of society undoubtedly leaves an imprint on the environment. Along with the opportunities for technological progress being created, more attention is paid to the amount of waste that human progress leaves behind. The reuse of waste materials is proving to be one of the methods to achieve sustainable use not only of primary resources, but also of the products produced from them. The interest in this topic is influenced by the pronounced aspiration of world leaders to impose the principles of the circular economy and sustainable development goals in the fight against climate change and global pollution.

The object of this report is technologies in the field of reuse of waste materials.

The subject of the study is the patent application activity in the field of waste reuse technologies, conducted through the European Patent Office in the period 1990-2022.

To achieve the goal defined in this way, the following **tasks** are set:

- To define and classify waste materials and products.
- To present innovative technologies in the field of reuse of waste materials.
- To track patent activity in the field of reuse of waste materials.
- To identify the sources of patent activity.

The implementation of these tasks makes it possible to identify technological developments in the field of reuse of waste materials as an element of the circular economy and to achieve the Sustainable Development Goals.

DEFINITION AND CLASSIFICATION OF WASTE TYPES

For years, researchers and organisations have sought to define the boundaries of the concept of “waste” (see Table 1) by fully covering its characteristics. However, the authors' views in this direction differ depending on the object of a particular study and its purpose, which still does not allow a single definition to be derived.

In view of the definitions cited in Table 1, for the purposes of this development, we accept as „waste“ ***unwanted material created by humans or industry, no longer used at a specific time and place for its creator***.

doi: www.doi.org/10.70456/ZJVV3857

Table 1. *Definitions of the term "waste"*

Source	Definition
EU, European Council	Waste shall mean any substance or object in the categories set out in Annex I which the holder discards or is required to discard [1].
UNEP, European Council	Wastes are substances or objects, which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law [2].
Serpell and Alarcon	Waste is defined as any material by-product of human and industrial activity that has no residual value [3].
Pongrácz and Pohjola	"…the label 'waste' does not necessarily mean that the thing is an ultimate waste, rather, it means that it will be treated as waste" [4, pp. 142]. "Waste is a man-made thing, which in a given time and place, in its actual Structure and State, is not useful to its owner, or an output that does not have any owner [4, pp. 146].
Hoornweg and Bhada-Tata [5]	Generally, waste or rubbish is known as unwanted material that results from production processes or from community and domestic activities. The material may be disposed of or accumulated, stored or treated (physically, chemically or biologically) before being disposed of or recycled. Concerning municipal solid waste, the categories into which it is classified are organic and inorganic. Waste can be divided into organic (such as food waste), paper, plastic, glass, metals, and others [6].
Silva et al. [7]	Waste is any substance that is discarded after its primary use or is valueless, defective, and of no use [6].
United Nations [8]	Waste is an "material, often unusable, left over from any manufacturing, industrial, agricultural or other human processes" [6].
Maghsoudi, Shokouhyar	"In general, waste can refer to any substance, material, or object that the holder discards, intends to discard, or is required to discard" [9, p.1].

There are several questions raised around the possibilities of using waste. Table 2 includes information on the understanding of waste as garbage or as a resource.

Table 2. *Resource-based paradigm versus waste-based paradigm [10, p.47]*

	Waste-based paradigm	Resource-based paradigm
Underlying thoughts	Waste can cause harm to public health and safety until shown otherwise	Waste is potential resource until shown otherwise
Main strategy	Safe disposal and containment	Environmentally sound processing and reuse
Language and taxonomy	Waste	Secondary materials
Operationalized metric for waste	None	Reuse potential

The definition of a material as 'waste' requires precise regulation of the sources of waste materials, as their broad definition would lead to the impossibility of reuse, while a narrow definition could cause damage to the environment. Park & Chertow. An approximate classification of waste, depending on its source, is presented in Table 3. Of fundamental importance for the possibility of reuse of waste is their distinction into two main groups – hazardous and non-hazardous waste.

Table 3. *Sources of waste [9, p. 4; 12].*

Source	Waste generators
Industrial	Such as manufacturing and processing units in the food processing industry, cement plants, power plants, textile industry, etc.
Municipal	Household waste/garbage, public places such as workplaces, schools, shops, plastic bags, plastic bottles, food waste, clothes, damaged household items, etc. Various agricultural activities include fertilizers, pesticides, agricultural residues, poultry, and abattoirs, and many more.
Agriculture	Various agricultural operations may include fertilizers, pesticides, wastes from farms, poultry houses and slaughterhouses, etc.
Medical	Hospitals, clinics, veterinary clinics, and laboratories mainly use surgical materials, needles, blood, body parts, medicines, dressings, and syringes.
Electronic (e-waste)	Telephones, TVs, music players, DVDs, CDs, computers, mobile phones, etc.
Radioactive	Nuclear explosion, nuclear/nuclear energy, mining of radioactive materials, etc.
Construction and demolition	Construction of roads, buildings, and houses and the demolition of old buildings and structures generate a lot of construction waste
Mining	Waste from mining operations, hazardous gases from explosions, etc.

Data on the nature and amount of hazardous and non-hazardous waste generated per capita for European countries is presented in Figures 1, 2 and 3 [11].

From the data presented in Figures 1, 2 and 3, it can be judged that the least waste is generated by agriculture. With the greatest negative environmental footprint, the mining industry stands out, followed by the manufacturing sector.

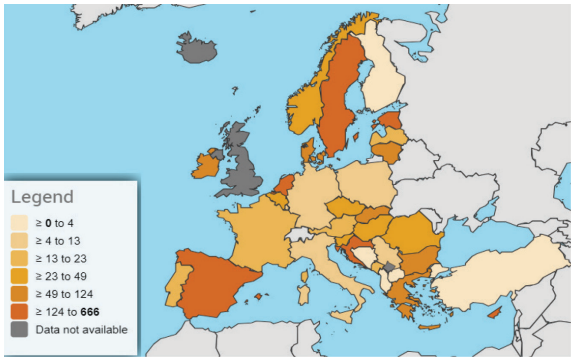

Fig. 3. *Hazardous and non-hazardous agricultural waste (2022), kg per capita [11]*

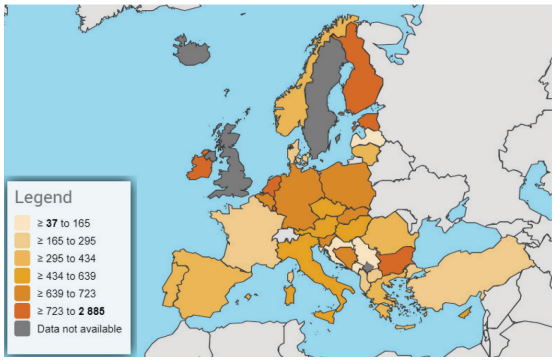

Fig. 4. *Hazardous and non-hazardous waste from the manufacturing sector (2022), kg per capita [11]*

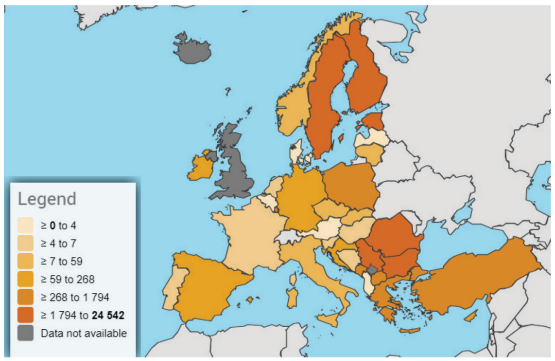

Fig. 5. *Hazardous and non-hazardous waste from the mining industry (2022), kg per capita [11]*

In the extractive industry, the initial extraction of resources takes place (the effect of which is the depletion of non-renewable resources) and their processing and subsequent use in the manufacturing sector (which is responsible for resource waste). It follows that limiting the extraction of natural resources and using them more efficiently in the production process can contribute to reducing waste reaching the environment. To achieve this objective, innovative technologies are being developed, information on which will be presented in the next paragraph.

INNOVATIVE TECHNOLOGIES FOR THE REUSE OF WASTE MATERIALS

The prerequisites for the growing importance of waste materials as a "resource" for reuse have also been considered by Baumgärtner [13] and Baumgärtner & Winkler [14]. They believe that the supply of waste materials and products is independent of their price and demand – they are generated unintentionally, but their quantity is related to the degree of development and industrialization of the region/country. Also, an alternative to reuse is the application of costly waste treatment and disposal processes. Accepting the above judgments of the authors, we are aware of the importance and necessity of revealing and developing opportunities for the implementation of waste reuse.

In their study, Park & Chertow [10] proposed the Reuse potential indicator, which determines the appropriateness and possibility of reusing a waste. The indicator is dynamic and depends primarily on the innovative development of technologies in the field. The higher the technological level achieved, the more likely it is that a waste material can be reused [10].

The Reuse Potential Indicator once again reveals the need for investment in the creation of innovative technologies. The IPC Green Inventory [15] divides waste reuse technologies into two main groups, depending on the absence or need to apply additional processing for the recovery or treatment of waste. For the purposes of this analysis, we will limit ourselves only to tracking patent activity in the field of material reuse, without applying additional treatments.

Based on the technologies grouped in this way (see Table 4) and using the indices of the International Patent Classification (IPC), an analysis of the patent application activity conducted through the European Patent Office (EPO) in the period 1990-2022 in the field of waste reuse opportunities has been prepared.

Table 4. *Technologies for the reuse of waste materials [15]*

TECHNOLOGICAL DIRECTION	IPC CLASSES
Use of rubber waste in footwear	A43B 1/12, 21/14
Manufacture of articles from waste metal particles	B22F 8/00
Production of hydraulic cements from waste materials	C04B 7/24-7/30
Use of waste materials as fillers for mortars, concrete	C04B 18/04-18/10
Production of fertilisers from waste or refuse	C05F

Figure 4 illustrates the patentable technologies applied for by year from the period 1990-2022. As can be seen, the period is highly dynamic, with the change in the application activity increasing by an average of 4.3% per year.

Examining the individual years of the period, the largest growth in the technologies applied for patent was observed in 2000 compared to 1999 (28.9%), in 2005 compared to 2004 (26.9%), in 1997 compared to 1996 (23.7%). At the same time, the most significant decline in activity was reported for the period 2001 – 2003, with an average annual rate of 21.7%, the strongest expression of which was in 2003 (37.6%). At the end of the study period, there was again a decline in activity, the expression of which from 2019 to 2022 decreased by an average of 7.7% per year.

Figure 4 also provides information on the change in the submitted applications compared to the years in which the significant international agreements in the concept of sustainable development were signed.

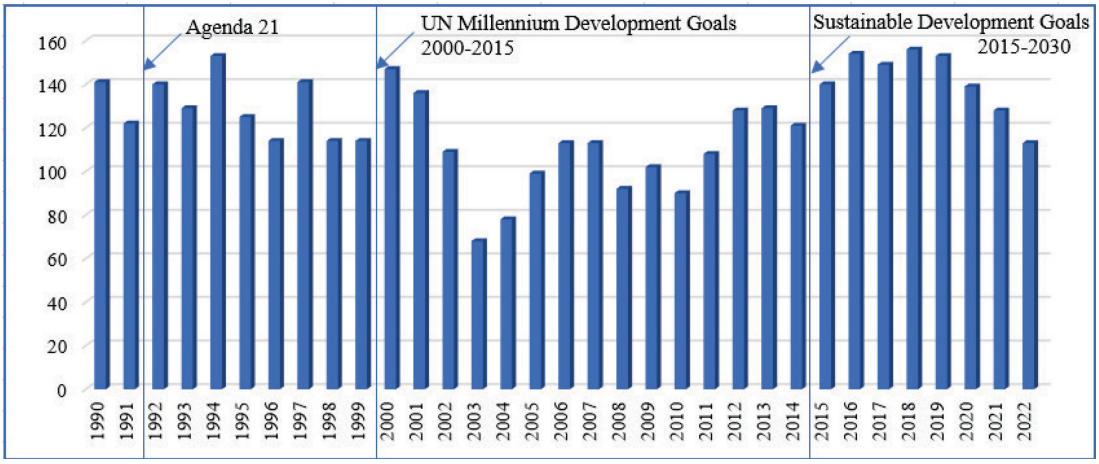

Fig. 4. *Dynamics of patent activity carried out through the EPO in the field of waste reuse technologies for the period 1990-2022 [16]*

It must be considered that waste reuse technologies represent a limited part of all possible environmentally friendly technologies, and we limit ourselves in this study to the part of them that does not apply further treatment or processing of the waste to be reused.

Another view of application activity, with a focus on technology developments during the IPC class study period, is presented in Figure 5.

Figure 5 presents a comparative analysis of the development of the top 20 IPC classes that are similar in essence or in applied technology/manufactured product to the classes analysed in this paper (see Table 4). As can be seen, only classes *C04B Production of hydraulic cements from*

waste materials and *C05F Production of fertilizers from waste* fall into the analysis, with the highest concentration of application activity reported in the *C05F strand.*

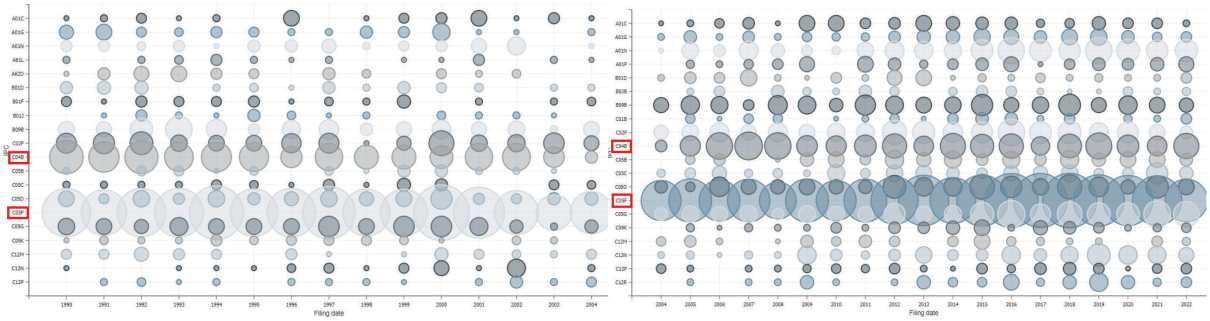

Fig. 5. *Development of application activity by technological areas for the period 1990-2022 [16]*

A more detailed look (see Figure 6) shows those classes in which there is the greatest interest. The displayed information covers only the first 20 positions of the ranking.

#	IPC subgroup	Documents
1	C05F17/02	797
2	C05F11/08	498
3	C04B18/08	338
4	C04B18/04	259
5	C05F9/02	235
6	C05F9/04	234
7	C05F11/02	201
8	C04B28/02	174
9	C04B7/24	170
10	C05F3/06	160
11	C05F11/10	156
12	C04B18/06	153
13	C12N1/20	147
14	C04B18/10	133
15	C05D9/02	130
16	C04B18/14	98
17	C04B28/04	96
18	C05D3/02	85
19	C02F11/12	82
20	C04B18/02	79

Fig. 6. *Number of applications by classes of the IPC for the period 1990-2022 [16]*

Drawing attention to the source of patent application activity (see Figure 7), we also identify the persons (natural or legal) who contribute to the highest degree to the development of technologies in the field of waste reuse.

In class *C05F,* the top three applicants are: Herhof Umwelttechnik GMBH (26) – Fertinargo Biotech SL (21) –Whirlpool Cooporation (16). In class *C04B*, the top 3 applicants are Lafarge (16), Halliburton Energy Services Inc. (14) and Pelt Hooykaas BV (12).

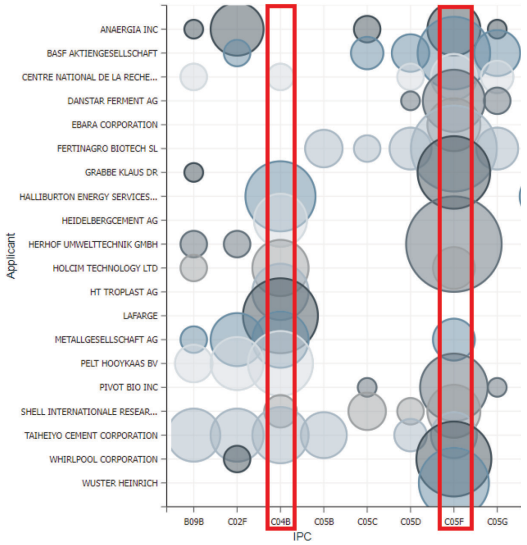

Fig. 7. *Source of application activity by technological areas for the period 1990-2022 [16]*

CONCLUSION

Through this study, an attempt is made to present the importance of waste reuse as a means of achieving sustainable development of society.

As a result of the analysis of the research in the field of normative definition of the nature and essence of the category "waste", the classification of waste and the patent application activity in the field of technologies for the reuse of waste, we can conclude that: **The absence of management policies for the reuse of waste materials leads to inefficient production practices, shortage of**

resources and growth in waste. On the other hand, investments in innovative developments in the field of waste reuse and their successful implementation in production processes can contribute to reducing organizations' dependence on primary resources and help protect the environment.

Acknowledgments: This work is supported by the Technical University of Gabrovo under grant 2415C/2024

REFERENCE

[1]. European Council. Council Directive 75/442/EEC modified by Directive 91/156/EEC on waste, 1991.

[2]. European Council. Council Regulation (EEC) No 259/93 of 1 February 1993 on the supervision and control of shipments of waste within, into and out of the European Community, 1993.

[3]. Serpell A, Alarcon L.F. Construction process improvement methodology for construction projects. Int J Project Manag 1998; 16(4):215–21.

[4]. Pongrácz, E., & Pohjola, V. J. Re-defining waste, the concept of ownership and the role of waste management. Resources, Conservation and Recycling, 2004; 40(2), 141–153. https://doi.org/10.1016/S0921-3449(03)00057-0

[5]. Hoornweg, D., and Bhada-Tata, P. What a waste: A global review of solid waste management, in Urban development series; knowledge papers no. 15. World Bank, Washington, DC. 2012; http://hdl.handle.net/10986/17388.

[6]. Giurea R, Carnevale Miino M, Torretta V and Rada E.C. Approaching sustainability and circularity along waste management systems in universities: an overview and proposal of good practices. Front. Environ. Sci. 2024; 12:1363024. doi: 10.3389/fenvs.2024.1363024

[7]. Silva, A., Rosano, M., Stocker, L., and Gorissen, L. From waste to sustainable materials management: three case studies of the transition journey. Waste Manage 2017; 61, 547–557. doi:10.1016/j.wasman.2016.11.038

[8]. United Nations On multilateral environmental agreements (InforMEA). Glossary: waste management. 2023; Available at: https://www.informea.org/en/terms/waste management

[9]. Maghsoudi, M., Shokouhyar, S., Khanizadeh, S., & Shokoohyar, S. Towards a taxonomy of waste management research: An application of community detection in keyword network. Journal of Cleaner Production, 2023; 401, 136587. https://doi.org/10.1016/j.jclepro.2023.136587

[10]. Park, J. Y., & Chertow, M. R. Establishing and testing the "reuse potential" indicator for managing wastes as resources. Journal of Environmental Management, 2014. 137, 45–53. https://doi.org/10.1016/j.jenvman.2013.11.053

[11]. Eurostat, Data Browser, Generation of waste by waste category, hazardousness and NACE Rev. 2 activity, https://ec.europa.eu/eurostat/databrowser/view/env_wasgen/default/map?lang=en)

[12]. Lone, G.H., Buchh, F., Shah, N.I., Social causatums of improper waste management. In: Innovative Waste Management Technologies for Sustainable Development, 2020; pp. 1–17. https://doi.org/10.4018/978-1-7998-0031-6.ch001

[13]. Baumgärtner, S., Price ambivalence of secondary resources: joint production, limits to substitution, and costly disposal. Resour. Conserv. Recyl. 2004;43, 95e117.

[14]. Baumgärtner, S., Winkler, R., Markets, technology and environmental regulation: price ambivalence of wastepaper in Germany. Ecol. Econ. 2003;47, 183e195.

[15]. WIPO, IPC Green Inventory, Available at:https://www.wipo.int/classifications/ipc/green-inventory/home

[16]. EPO's Worldwide Patent Statistical Database, PATSTAT, Available at: https://www.epo.org/searching-for-patents/business/patstat.html