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ASSESSMENT OF MUNICIPAL WASTE MANAGEMENT IN THE SELECTED EU COUNTRIES

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Abstract – The aim of this study was to conduct an assessment of municipal waste management systems in selected European countries. Used research methods were comparative and statistical analysis. The research was conducted in May 2024.

The theoretical part contains the basics of the concept and definitions of waste management and municipal waste systems. Moreover, it provides information connected with waste management among benchmark countries in the European Union.

The empirical part of the article describes the results of the conducted research. Based on the Global Waste Index 2022, Denmark and Germany emerged as the most efficient waste management systems, with recycling rates of 35.6% and 47.8%, respectively. These countries were assigned to the first cluster of waste management systems. In contrast, Poland and the Czech Republic, with recycling rates of 26.6% and 22.0%, respectively, were categorized in the third cluster. According to Global Waste Index 2022, the best waste management systems are characterized by a high share of recycling and other beneficial waste management methods. In the second part of the study, the authors presented a graphical comparison of the Danish and Polish municipal waste management system. Denmark, with a waste market value of $817 million, translates into $139.45 million per 1 billion of population, slightly outperforming Poland's $131 million per 1 billion.

The work concludes with a summary that includes the most important elements of the described waste management analysis and trends in the European Union. It highlights the effectiveness of policy interventions and technological advancements in optimizing waste management practices. Furthermore, an example of a research gap present in economic literature is provided. These insights deliver a data-driven foundation for policymakers to enhance sustainability strategies across Europe.

Key words – European Union. Global Waste Index, municipal waste, waste management

JEL Classification – Q20, Q56, O13

INTRODUCTION

Municipal waste management has recently become a critical environmental concern across Europe. The increasing volume of waste generated and lack of awareness of its inappropriate disposal effects lead to a necessity of taking serious steps by which the damage to the environment may, if not be put to an end, be decreased. Due to urbanization, population growth, industrialization, and economic growth, a trend of increase in municipal solid waste (MSW) generation has been recorded worldwide [19]. Traditional landfill practices are reaching their limits, straining resources and posing environmental threats. The depletion of natural resources further emphasizes the need for a paradigm shift towards a circular economy, where waste becomes a valuable resource which makes waste management a multifaceted problem [8].

This study aims to identify effective strategies employed by leading European nations and assess the current state of waste management in developing countries within the region. By analyzing the contrasting approaches of countries with high recycling rates and those reliant on landfilling, this research seeks to contribute valuable insights for policymakers and waste management practitioners.

The article delves into the theoretical underpinnings of the issue, establishing a firm foundation for the analysis. It explores the core concepts and definitions of waste management and municipal waste systems, providing a common ground for understanding the complexities of the topic. Furthermore, the research examines the practices of benchmark countries in the European Union, such as Denmark, Sweden, and Germany, who have achieved significant success in sustainable waste management [28]. This analysis sheds light on the policy frameworks and assessment methodologies employed by the European Union (EU) to guide member states towards more environmentally responsible practices.

Building upon this theoretical groundwork, the research then progresses to outline the specific methods employed in the investigation. This section details the data collection and analysis techniques used to assess the strengths and weaknesses of waste management systems in various European countries. Subsequently, the research presents its findings, meticulously dissecting the data to expose the current state of waste management in both leading and developing European nations. The analysis focuses on contrasting approaches – exploring the factors contributing to the success of nations with high recycling rates and identifying areas for improvement in countries reliant on landfilling. Effective waste management is vital for environmental protection, public health, economic efficiency, and sustainable development. Analyzing waste management systems helps identify efficient practices, leading to cost optimization and promoting material reuse and recycling. The analysis results can guide policymakers in developing or modifying strategies, assist municipalities in adopting best practices, serve as educational tools to raise public awareness, and pinpoint areas for investment in new technologies and infrastructure. In summary, this analysis offers valuable insights to enhance waste management systems and achieve sustainability goals.

It is necessary to admit that comparisons of European waste management practices already exist. However, this study goes a step further by focusing on the stark contrast between leading nations and developing countries. By dissecting these opposing approaches, the research offers a more focused analysis of what works and what doesn't. This targeted approach can yield actionable insights for policymakers seeking to implement effective and replicable waste management strategies across Europe [22].

1. THEORETICAL BACKGROUND

Human activities have always contributed to generating waste, although it was not always as a big source of concern as it is nowadays. In recent times, the rate and quantity of waste generation have been on the increase. Unlike the prehistoric period, where wastes were merely a source of nuisance that needed to be disposed of. Proper management was not a major issue as the population was small and a vast amount of land was available to the population at that time. In those days, the environment easily absorbed the volume of waste produced without any degradation. A substantial increase in the volume of waste generation began in the sixteenth century when people began to move from rural areas to cities as a result of the industrial revolution. This migration of people to cities led to a population explosion that in turn led to a surge in the volume and variety in composition of wastes generated in cities [1]. It was then that materials such as metals and glass began to appear in large quantities in municipal waste streams. The large population of people in cities and communities gave rise to indiscriminate littering and open dumps [13].

Therefore, the need to amend this state has led among others to the creation of definitions for waste management and municipal waste systems. As for waste itself, it arises in many different forms and its characterization can be expressed in several forms. Some common characteristics used in the classification of waste include the physical states, physical properties, reusable potentials, biodegradable potentials, source of production, and the degree of environmental impact. It can be classified broadly into three main types according to their physical states; these are liquid, solid and gaseous waste [29].

Waste management is a process by which waste is gathered, transported, and processed before disposal of any remaining residues. It is the effective supervision and handling, keeping, collection, conveying, treatment and disposal of waste in a manner that safeguards the environment and the public. Solid waste management utilizes skills and knowledge from various disciplines such as legal, financial, administration, among others, in the day-to-day running of waste management issues. Analyzing the entire material flow across the board of human activities can also help solve root problems with waste management. Every influence affecting each material is isolated and analyzed for each environment. Environment may be private household, industries or means of transport [21]. Municipal waste systems are essential infrastructures that manage the collection, transportation, treatment, and disposal of waste.

The municipal waste system can be considered to be a common good system, having in mind two aspects of the notion: classic common pool resource and a system in which the common pool resource is the environment, and any actions aimed at reducing the amount of waste or its nuisance are resources conservation actions that protect the resource [10]. There are several components of the described systems that need to be included. Waste collection is the initial stage involving the gathering of waste from various sources using appropriate vehicles and containers. Efficient collection systems are crucial for preventing litter and reducing odors and pests. The next step is the transportation to processing or disposal facilities. This often involves transfer stations where waste is consolidated before being transported to larger facilities. The processing stage focuses on treating waste to reduce its volume, recover valuable materials, or convert it into energy. Common processing methods include recycling, composting, incineration, which in short means burning waste to generate energy, and landfilling. The final stage involves the safe and environmentally sound disposal of waste that cannot be recycled or treated. Landfills are the most common method, but other options include deep-well injection and ocean dumping, though the latter is highly regulated and restricted [3].

Speaking of waste management in specific EU countries, there should be mentioned such as Germany, Denmark, and Sweden since these are often cited as benchmarks for effective waste management in the European Union. These countries have implemented comprehensive strategies that prioritize waste reduction, recycling, and resource recovery and have adopted a variety of strategies to achieve their waste management outcomes.

Extended Producer Responsibility in Denmark became to hold responsible Danish producers of packaging, batteries, and electronic waste for the entire lifecycle of their products, including recycling and disposal. This has driven innovation in product design for recyclability. What is more, Denmark's deposit-return system for beverage containers has led to high recycling rates, with consumers receiving a refund for returning empty bottles and cans [11]. The Amager Bakke waste-to-energy plant in Copenhagen is a prime example of how Denmark has transformed waste into a resource, generating electricity and heat for the city.

Taking Sweden for example, this country has implemented strict regulations on landfilling, incentivizing recycling, composting, and waste-to-energy. Sweden has achieved high recycling rates for paper, metal, and glass, as well as extensive composting programs for organic waste and has been a pioneer in promoting a circular economy, with initiatives focused on reusing and repairing products to minimize waste [24].

The Green Dot, which is Germany's packaging recycling system, has been highly successful in increasing recycling rates for packaging materials. Germany also implemented the dual waste collection system, with separate bins for recyclable and non-recyclable waste that has simplified waste sorting for residents. Last but not least, Germany imposes high taxes on landfilling, discouraging this practice and incentivizing recycling and waste reduction [9].

Regarding the take on the waste management issue by the European Union, it is said that 5 tons of waste is generated by the average European each year, only 38% of waste is recycled in the EU, and over 60% of it, in some countries, still goes to landfill [17]. By far, petrifying data forces the EU to take actions which result in creating specific waste policies. In general, the implemented waste policy aims to protect the environment and human health and help the EU's transition to a circular economy [2]. It sets objectives and targets to improve waste management, to stimulate innovation in recycling and to limit landfilling. Taking as an example, the European Green Deal aims to promote growth by transitioning to a modern, resource-efficient and competitive economy. Moreover, the Waste Framework Directive, which is the EU's legal framework for treating and managing waste in the EU, introduces an order of preference for waste management called the "waste hierarchy".

Measuring the effectiveness of a waste management system is crucial for understanding its performance, identifying areas for improvement, and making data-driven decisions [15]. Certain indicators can be used for such purposes, such as the Global Waste Index which has been described in the research methods section. Other than that, worth mentioning are the Environmental Performance Index and Sustainable Development Goals concerning the matter of waste.

The first one was developed by Yale University and Columbia University with the focus on evaluating country-level environmental performance on a wide range of policy goals. It includes waste management metrics, such as material recovery, hazardous waste management, and treatment. In its methodology it combines policy and institutional commitments with on-the-ground performance [7].

Developed by United Nations Environment Program, the Sustainable Development Goals initiative has also created indicators regarding waste management with each having a specific methodology. Those addressing waste are the following [26]:

- 11.6.1: Municipal Solid Waste Management
- 12.3.1: Food Loss and Waste
- 12.4.1: Information Transmitted under Chemicals and Waste Conventions
- 12.5.1: National Recycling Rate
- 14.1.1: Coastal Eutrophication and Plastic Debris Density

Through a combination of methods and indicators, a thorough assessment of waste management system performance can be achieved, enabling the identification of improvement opportunities. This comprehensive evaluation facilitates the development of targeted strategies to enhance waste reduction, recycling, and recovery efforts. Furthermore, it allows for the optimization of resource utilization and the minimization of environmental impacts.

2. RESEARCH METHODS

This study aimed to conduct an assessment of municipal waste management systems in selected European countries. Used research methods were comparative and statistical analysis. The research was conducted in May 2024. The primary objective of the research was to compare waste management systems in selected European Union countries. The specific objectives were:

– presentation of the quantitative state of waste management in European Union countries,
– identification of best practices in waste management based on the Global Waste Index 2022.

This analysis is significant for several reasons. Effective waste management is crucial for environmental protection, as it minimizes negative impacts by reducing pollution of soil, water, and air. Additionally, proper waste handling is essential for public health, preventing the spread of diseases and health hazards. From an economic perspective, analyzing waste management systems allows for the identification of the most efficient practices, leading to cost optimization in waste management operations. Moreover, such comparisons support the pursuit of sustainable development by promoting the reuse and recycling of materials, thereby facilitating the transition to a circular economy. Policymakers can utilize the findings to develop or modify waste management strategies, incorporating proven solutions from other countries to enhance policy and regulation development.

The source materials for the research were secondary and included data from: Eurostat, OECD, Central Statistical Office of Poland (GUS).

A comparative analysis method was used to process the research results, comparing the waste management systems in Poland, the Czech Republic, Denmark, and Germany in the year 2020. The countries were purposefully selected based on GDP, the annual amount of waste generated per capita, and the Global Waste Index 2022. Global Waste Index (GWI) 2022 is a comparative analysis of waste management in 38 member countries of the Organization for Economic Co-operation and Development (OECD). Moreover, it focuses on the generation and management of municipal waste. Global Waste Index includes the following aspects of municipal waste management systems in countries [18]:

– Waste generated: Mass in kilograms per inhabitant and year,
– Recycling: Mass in kilograms per inhabitant and year that is declared to become new raw materials,
– Waste incineration: Mass in kilograms per inhabitant and year that is incinerated in a controlled manner,
– Landfill: Mass in kilograms per inhabitant per year that is landfilled in a controlled and uncontrolled manner,
– Illegal waste disposal: Mass in kilograms per inhabitant per year of waste disposed of illegally,
– Other waste: Mass in kilograms per inhabitant per year that is generated without being recorded.

Countries were ranked based on their waste management practices by assigning scores reflecting their environmental impact, specifically CO2 emissions. Scores for each factor were standardized from 0 to 10 and summed up, then further standardized on a 0-100 scale. The country with the lowest score (0) had the greatest environmental impact, while the highest score (100) indicated the least impact. Other countries were ranked between 0-100 based on their scores, resulting in the Global Waste Index 2022 ranking. The results of the study were presented in both graphical and descriptive form.

3. RESULTS AND DISCUSSION

Progressive urbanization, economic development, rising living standards, and changing lifestyles have led to a significant increase in the amount of waste generated [19]. The majority of European Union countries experienced an increase in waste generation between 2004 and 2020. The amount of waste varies depending on a country's population and GDP (Figure 1 and 2). Literature reviews [3, 23] indicate that waste management assessments and comparisons between countries can be conducted based on statistical data and policy [29].

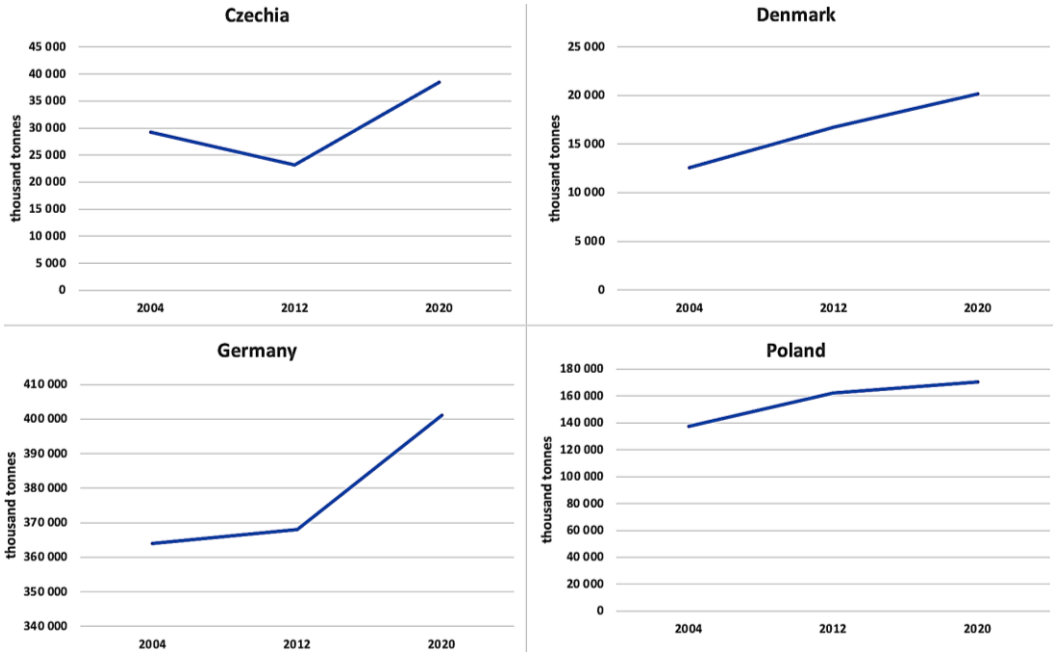

Fig. 1. Annual waste generation in selected EU countries 2004-2020. Source: Own elaboration based on Eurostat (2020)

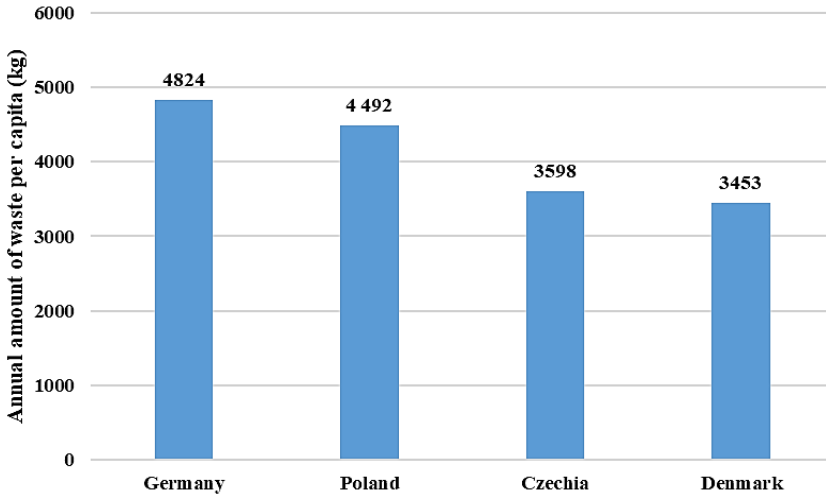

Fig. 2. Annual waste generation in selected EU countries per capita in 2020 (kg). Source: Own elaboration based on Eurostat (2021), https://ec.europa.eu/eurostat/databrowser/view/env_wasgen$defaultview/default/table

In the case of the compared countries, Germany and Poland generate the largest amounts of waste. Denmark, on the other hand, records a steady increase in waste generation, partly due to its high GDP leading to excessive, irresponsible consumerism. However, Denmark and Germany, according to Global Waste Index 2022, are the most efficient countries in Europe in terms of waste management (Table 1). Leading country in the world is South Korea with a score of 100, which means it is supposed to be a benchmark waste management system for others.

Table 1. Global Waste Index 2022 results for selected EU countries

Rank	Country	Generated waste (kg)	Recycling (kg)	Incineration (kg)	Disposal (kg)	Open dumping (kg)	Unregistered waste (kg)	Recycling (%)	Score
1	**South Korea**	400	243	88	46	0	0	60,80%	100
2	**Denmark**	845	300	382	7	0	0,2	35,60%	94,9
3	**Germany**	632	302	204	5	0	13	47,80%	90,4
13	**Poland**	346	92	74	138	0	0	26,60%	79,5
20	**Czechia**	499	110	76	231	0	0	22,00%	71

Source: Sensoneo. (2022). Global Waste Index 2022. Retrieved from https://sensoneo.com/global-waste-index/

Denmark and Germany were selected as the most efficient countries in municipal waste management and assigned to the first cluster of waste management systems in the European Union. Poland and the Czech Republic were representatives of the third cluster. According to the Global Waste Index 2022, the best waste management systems are characterized by a high share of recycling and other beneficial waste management methods. The high share of landfilling as a waste management method is present in Poland and the Czech Republic. It should be emphasized that in Denmark and Germany, a system of returnable packaging with a deposit has been developed, which has a positive impact on the efficiency of waste collection and processing. Lower availability of waste processing infrastructure in Poland and the Czech Republic may negatively affect waste management efficiency.

Other important aspects of waste management systems are population, Gross Domestic Product, and policy of the analyzed country (Table 2). Most European countries introduce their policies according to European Union standards. However, not all of them use waste stream record systems like BDO (ang. Database on products, packaging and waste management) in Poland [6].

Table 2. Comparison of waste management systems in 2020 for selected EU countries

Country	**Poland**	**Czechia**	**Denmark**	**Germany**
Population (mln)	37,9	10,07	5,831	83,16
GDP (Gross Domestic Product) per capita ($/year)	15793	22984	60927	46712
Annual waste generation (tones/year)	170 233 670	38 486 186	20 135 564	401 156 266
Waste generated per capita (kg/year)	4 492	3598	3453	4824
Main waste treatment method (%)	Recycling (37%)	recycling (48%)	Recycling (58%)	recycling (42%)
Waste management system (record of waste streams)	BDO	ISPOP	-	LUCID
Year of issue and name of the main legal act in the area of waste management	2012 (Ustawa o odpadach)	2001 (Zákon o obalech)	1997 (Danish Statutory Order on Waste)	2012 Germany's Waste Management Act (KrWG)

Source: Own elaboration based on Sensoneo. (2022). Global Waste Index 2022. Retrieved from https://sensoneo.com/global-waste-index/; Eurostat (2021) Waste treatment in Europe, https://ec.europa.eu/eurostat/databrowser/view/env_wastrt/default/table?lang=en

The average recycling rate in Europe was approximately 46% in 2020, and 48% in 2022 [14]. Data from the Czech Republic and Denmark indicate a well-developed material recovery network in the recycling process. Germany and Poland have slightly lower recycling rates. The high GDP per capita in Denmark and Germany may lead to the generation of excessive amounts of municipal waste; however, the average amount of municipal waste produced per person was highest in Germany and Poland. The data indicate varying degrees of waste management development in the discussed countries.

The authors compared waste management in Poland and Denmark due to the different levels of development in their waste management systems according to the Global Waste Index 2022. The literature review identified key variables for assessing waste management, such as GDP, Waste Market Value, and costs of waste management (Table 3).

Table 3. Comparison of waste management systems in Poland and Denmark

Country	Poland	Denmark
Population (mln)	37,9	5,831
GDP per capita ($/year)	15793	60927
Waste market value (mln $)	4 970	817
Waste market value per 1 bilion of population (mln $)	131	139,45
Fee for the collection and disposal of municipal waste (EUR/year)	90,60	69,18
GWI (Global Waste Index)	79,5	94,9
Share of disposed waste (%)	~25	~8

Source: Own elaboration based on Sensoneo. (2022). Global Waste Index 2022. Retrieved from https://sensoneo.com/global-waste-index/; Eurostat (2021) Waste treatment in Europe https://ec.europa.eu/eurostat/databrowser/view/env_wastrt/default/table?lang=en

The waste management system in Denmark does not differ in its fundamental structure from the Polish system. Both systems include the stages of waste collection, waste stream management, waste processing, and disposal. However, the key differences lie in the methods used for waste processing and efficiency. In Denmark, the primary methods of waste processing are incineration with energy recovery and recycling. The country has developed advanced infrastructure that allows for the efficient incineration of waste, which not only reduces the volume of waste that needs to be landfilled but also generates energy in the process. Additionally, Denmark has a robust recycling system that effectively separates and processes recyclable materials, contributing to higher recycling rates.

In contrast, Poland lacks the necessary infrastructure for efficient waste disposal. The country faces challenges in implementing effective waste incineration and composting processes. This absence of infrastructure means that a significant portion of waste in Poland cannot be processed in an environmentally friendly manner. Consequently, a larger share of waste ends up in landfills, and the recycling rates are lower compared to Denmark. These differences highlight the need for Poland to invest in and develop its waste processing infrastructure to improve its waste management system.

Denmark has a significantly higher GDP per capita and a more efficient waste management system, as reflected by its higher GWI score and lower percentage of disposed waste. Poland, despite having a larger population and total waste market value, has a lower per capita waste market value and higher disposal rates. Waste management costs are lower in Denmark, which also has a smaller share of waste being disposed of compared to Poland. Moreover, the returnable packaging system implemented in Denmark contributes to better separation of waste fractions, resulting in improved quality of secondary materials.

CONCLUSIONS

Human activities have always generated waste, but the concern about waste management has grown significantly over time. The rate and quantity of waste generation have increased, especially since the industrial revolution, which led to urbanization and a surge in waste volume and variety. Modern waste management involves collecting, transporting, processing, and disposing of waste to protect the environment and public health. It includes methods like recycling, composting, incineration, and landfilling. European countries like Germany, Denmark, and Sweden are benchmarks for effective waste management, focusing on waste reduction, recycling, and resource recovery. The European Union implements policies to transition to a circular economy, reduce landfill use, and promote recycling. Key indicators like the Global Waste Index, Environmental Performance Index, and Sustainable Development Goals help measure and improve waste management systems' performance.

Urbanization, economic development, rising living standards, and lifestyle changes have led to increased waste generation in Europe. According to the Global Waste Index 2022, Denmark (GWI score: 94.9) and Germany (GWI score: 90.4) demonstrate the highest efficiency in waste management within the EU, while Poland (GWI score: 79.5) and the Czech Republic (GWI score: 71) lag behind. Recycling rates further illustrate this disparity: Denmark (35.6%) and Germany (47.8%) outperform Poland (26.6%) and the Czech Republic (22%). Additionally, landfill dependency remains a significant issue, as Poland and the Czech Republic dispose of 25% and 46% of waste, respectively, compared to only 8% in Denmark. Despite generating 845 kg of waste per capita annually, significantly higher than Poland (346 kg per capita) Denmark effectively manages its

waste through high recycling rates (35.6%) and extensive incineration (45.2%), reducing its landfill burden. In contrast, Poland and the Czech Republic face higher landfill rates, indicating inefficiencies in waste processing infrastructure.

A key economic indicator, waste market value per 1 billion of population, is higher in Denmark ($139.45 million) than in Poland ($131 million), reflecting greater investment in waste management technologies and infrastructure. Surprisingly, the fee for waste collection and disposal is lower in Denmark (69.18 Euro/year) than in Poland (90.60 Euro/year), suggesting that Denmark benefits from economies of scale, efficient policy frameworks, and well-developed recycling markets.. Poland and the Czech Republic have similar waste management systems, which do not meet the standards of Denmark and Germany. Despite efforts to improve, both countries face challenges such as budget constraints and the need for better public awareness. To improve, Poland and the Czech Republic can adopt best practices from Denmark and Germany, invest in modern technologies, implement stringent recycling regulations, and enhance public education. Collaborative efforts within the EU and leveraging digital technologies can further optimize waste management. Embracing a circular economy approach can also reduce waste and promote sustainability.

The main limitation of the study was the European waste management data for selected countries. Future research should aim for an in-depth analysis of the efficiency of waste management in EU countries based on the latest data related to the EU waste market.

OCENA GOSPODARKI ODPADAMI KOMUNALNYMI W WYBRANYCH KRAJACH UE

Celem badania była ocena systemów gospodarki odpadami komunalnymi w wybranych krajach europejskich. Zastosowane metody badawcze to analiza porównawcza oraz statystyczna. Badania przeprowadzono w maju 2024 roku.

Część teoretyczna zawiera podstawowe pojęcia i definicje związane z gospodarką odpadami oraz systemami gospodarki odpadami komunalnymi. Ponadto, przedstawiono informacje dotyczące gospodarki odpadami w wybranych krajach Unii Europejskiej.

W empirycznej części artykułu opisano wyniki przeprowadzonych badań. Na podstawie wyników Global Waste Index 2022, Dania i Niemcy plasowały się jako najbardziej efektywne systemy zarządzania odpadami, z poziomem recyklingu odpadów komunalnych wynoszącymi odpowiednio 35,6% i 47,8%. Kraje te zostały przypisane do pierwszego klastra systemów gospodarki odpadami. Z kolei, Polska i Czechy, z poziomem recyklingu odpowiednio 26,6% i 22%, zostały sklasyfikowane w trzecim klastrze. Według Global Waste Index 2022, najlepsze systemy gospodarki odpadami charakteryzują się wysokim udziałem recyklingu oraz innych korzystnych, z punktu widzenia środowiska, metod zarządzania odpadami. W drugiej części badania autorzy porównali duński i polski system zarządzania odpadami komunalnymi. Dania, z wartością rynku odpadów wynoszącą 817 milionów dolarów, co przekłada się na 139,45 miliona dolarów na 1 miliard mieszkańców, nieznacznie przewyższa Polskę z 131 milionami dolarów na 1 miliard mieszkańców.

Artykuł zakończono podsumowaniem, zawierającym najważniejsze wnioski dotyczące przeprowadzonych badań oraz aktualne trendy w obszarze gospodarki odpadami w Unii Europejskiej. Przykładem może być wdrażanie gospodarki o obiegu zamkniętym, która promuje minimalizację odpadów i efektywne wykorzystanie zasobów. Jednakże, w literaturze ekonomicznej nadal istnieją luki badawcze dotyczące kompleksowej oceny wpływu tych interwencji na różne sektory gospodarki.

Słowa kluczowe: Unia Europejska, Indeks Global Waste, odpady komunalne, gospodarka odpadami.

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