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ENVIRONMENTAL COMPLIANCE AND THE GREEN TRANSITION: COMPARATIVE PERSPECTIVES ON WASTE MANAGEMENT IN AN EU MEMBER AND A CANDIDATE COUNTRY

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Abstract

This paper explores the importance of waste management for the effectiveness of the green transition and the path toward EU membership, guided by three research questions: the relationship between the length of EU membership and the efficiency of waste management; the extent to which candidate countries like Serbia can gain valuable insights from EU member states like Croatia to advance their green transition; and the role of community engagement in successful waste management. Research approaches included statistical databases and cluster analysis, and a survey conducted among Serbian and Croatian citizens. The results show that the EU-27 member states can be grouped into six clusters composed of countries with similar EU accession periods. Contrary to the findings of the cluster analysis − where Serbia is among the EU's worst performers in waste management − the survey results revealed a high level of public awareness regarding the importance of sustainable waste management and recycling.

Keywords: waste management, EU, green transition, Croatia, Serbia

1. INTRODUCTION

Climate change, ecological imbalances, rapid growth of the urban economy, and consumerism have affected the increasing popularity of the green transition, a process towards a new development model that ensures environmentally sustainable and fairer societies (ETF, 2023). All EU member states and candidate countries are striving to achieve a climate neutral and circular economy (Avogaro, 2024) by taking initiatives to protect biodiversity and ecosystems, improve waste management, decarbonise the EU's energy system, ensure resilient EU agriculture and lively rural areas, foster collaboration and innovation in areas of health, culture, creativity, inclusive societies, digital technologies, industry and others (GreenFacts, 2019). However, countries across Europe differ in terms of the progress made in their transition towards environmental sustainability (Fritz et al., 2024), and some of them have experienced challenged shifts in production, consumption patterns, waste management and other social and economic activities (Marino & Pariso, 2020). In this paper, we address the question of the importance of waste management for the effectiveness of a green transition and the path towards the EU. More specifically, the objective of this paper is to explore the extent to which EU candidate countries can adopt relevant knowledge and best practices from member states in the field of waste management, recognised as one of the EU's strategic priority areas. In pursuing this objective, we selected Serbia and Croatia, two neighbouring Western Balkan countries, which, according to Heemskerk (2020), both experienced a challenging transition to a market-based economy, commenced their path toward EU membership at approximately the same time, yet differ significantly in their outcomes.

Following this introduction, the next section provides the theoretical framework of the paper, discussing the concept of the European green transition and the importance of effective waste management. Moreover, the compliance of Serbian and Croatian waste prevention programmes and management initiatives with the EU waste management policies are given. The third section is the methodology section describing different research approaches used in this paper. The subsequent section presents the results and provides a discussion of the findings. The paper concludes with key insights, the study's limitations, and implications for theory, policy, and future research.).

2. THEORETICAL AND POLICY FRAMEWORK OF WASTE MANAGEMENT IN THE EU CONTEXT

2.1. The Greening of Waste Management

Since its establishment, the EU has taken initiatives for transformation towards a zero-emission economy, which was clearly outlined in the Europe 2020 Strategy (Kryk & Guzowska, 2021) and followed by the Green Deal (Vela et al., 2023). In its strategy, the EU identified the green transition as a crucial alternative

to make a balance among economic, social, and environmental development of all its members and associated countries (Ossewaarde & Ossewaarde-Lowtoo, 2020). The European Green Deal covers all sectors of the EU economy with inclusion of citizens and companies, ranging from environmental transition switching to cleaner energy use and boosting global climate actions to the social dimension of the transition supporting the most vulnerable citizens and small businesses with the green transition. The concept of the global green transition was widely discussed in the works of Markard et al. (2012), and Köhler et al. (2019), especially after the international community and policy makers recognised the importance of a shift to a less damaging system to the environment (Nacu & Jercan, 2023; Hatch et al. 2017). The scholars who explained the concept highlighted "the fundamental changes" in a broad range of different areas (Loorbach & Rotmans, 2010; Meadowcroft & Rosenbloom, 2023), a deep, systemic shift toward sustainability (Grin et al. 2010; Markard et al. 2012), a transformation of all areas of economic activity and lifestyles (ETF 2023), etc. The green transition advocates for an integrated shift towards a humane and fair financial system, with healthy ecosystems, healthcare, public services, education, and culture (Franssen & Holemans, 2020) encouraging welfare and the quality of life by establishing a sustainable economic framework that respects and maintains the limits of the planet's ecosystem (EC, 2023b). Many papers raise the question of transition in the field of energy and the industrial sector (Niu et al. 2025; Liu et al. 2025), suggesting the need for coordinated cross-sector collaboration as the green transition requires reconstruction of industry (Lu et al. 2025; McNelly & Franz, 2024), shifting from non-renewable to renewable energy sources. Aydin et al. (2024) and Nie et al. (2024) question the sustainability of the green transition idea in cases of weak governance and financials (Gharleghi et al., 2024; De Haas et al., 2024), as the green transition requires investments for the development and implementation of sustainable technologies. Song et al. (2023) and Murshed (2024) discuss the importance of the quality of economic and political institutions for green growth, because only economic growth can provide the new resources and technologies necessary for a net zero agenda (O'Donovan, 2024). Numerous studies analyse cities acting in a dual role: contributors to environmental degradation and leaders in green transition policies (Adams et al., 2023; Ehnert et al., 2018; Frantzeskaki, 2021; Moglia et al. 2021). Despite the large number of authors who identify the green transition as one of the most ambitious policy efforts (McNelly & Frantz, 2024), Grashof and Basilico (2023) have attributed controversies about the green transition to EU regional inequality. McGowan and Antadze (2023) have considered the multi-dimensional and complex nature of the concept, which is responsible for not ensuring an equally beneficial impact for all stakeholders involved. The concept of the green transition covers a broad range of different areas, such as the reduction of greenhouse emissions, reducing waste, more sustainable and energy-efficient industries, protection of the environment, (EC 2019; 2020), renewable energy sources, sustainable transportation methods (Robertson-Fall, 2023), green industrial policies, and green investments (EEA,

2023). It requires the mutual commitment of people, governments and corporations to a more sustainable economy (Nacu & Jercan, 2023).

This paper focuses on waste management as one of the key components of the green transition. Waste management and its treatment are as old as human civilisation (Guman et al., 2020), but haven't harmed the environment until the Industrial Revolution (Barles, 2014) when mass production led to higher output and greater efficiency, economic growth and increased consumer spending (Agovino et al. 2024). Nowadays, the waste management sector faces two significant challenges: the transition from a linear to a circular waste management model (Pambudi et al., 2025), and climate change (Ackerman, 2000; Kumar et al., 2024). Both are viewed from the perspective of necessary investments in infrastructure, equipment, and the creation of new green jobs (Shayegh et al., 2023; Rajkovic & Lucic, 2023). Waste management is a basic condition to achieve a climate-neutral and resource-efficient EU economy (Tauš et al., 2023), and the EU has developed strong waste framework directives for identifying and classifying particular waste types which has initiated lively scientific discussion. Krstić and Milenković-Kerković (2017) argue about complex European legislation consisting of directives and bylaws that require strong institutional framework of the member states. However, despite this intensely regulated area, some works have been questioning the ambiguity of some definitions related to the category of waste (Johansson, 2023; Halkos & Aslanidis, 2024), while others have addressed the legal framework, particularly dealing with the mining waste (Petterson & Johansson, 2025; Pličanić et al., 2020). Often used interchangeably with extractive waste, mining waste is considered one of the most significant waste streams in the EU (EC, 2006), which could pose a risk to human health and the environment due to its composition (Garbarino et al., 2020; Mehta et al., 2018). Several valuable studies present state-of-the-art research in the field of waste management (González-Sánchez et al., 2023; Pambudi et al., 2025; Raab, 2024) highlighting topics such as e-waste (Halim & Suharyanti, 2020), plastic waste (Al-Salem et al., 2009), food waste (Flanagan & Priyadarshini, 2021), industrial waste (Mesjasz-Lech, 2025), etc., but the most scholarly attention is drawn to municipal solid waste. Akther et al. (2025) and Maalouf and Mavropoulos (2022) consider EU enlargement to be the primary reason for this topic of interest. Pires et al. (2011) found differences among waste management systems across Europe, where southern EU member states must enhance measures for integrated solid waste management to meet EU directives, while central EU countries require tools to optimise their technological and strategic decisions.

A direct link between economic development and waste generation is evident (Agovino et al., 2024; Sajid et al., 2022), and waste management is considered crucial to enabling the green transition (Di Vaio et al., 2023; Tauš et al., 2023). In the context of economic prosperity, studies have shown a correlation between improved living standards (Liu et al., 2019), rising consumption (Minelgaitė & Liobikienė, 2019; Taušova et al., 2019) and waste generated. It is precisely community involvement that plays a crucial role in waste separation and

reuse (Rogowska et al., 2024; Knickmeyer, 2020), as studies have confirmed waste treatment is influenced by the socioeconomic conditions of a given society (Dong et al., 2022). Eurobarometer survey (EC, 2014) found a high level of agreement on the concern about waste generation and management among European consumers. However, similar to Flanagan and Priyadarshini (2021) and Triguero et al. (2016), some differences in the attitudes towards waste management and resource efficiency between member states are shown. These differences are mainly due to lack of required technology, infrastructure, adequate legislation, more qualified staff and public commitment to efficient waste management (Laureti et al., 2024; 2023; Dong et al., 2022). Further to the above, three research questions arose:

RQ1: Is there a relationship between the duration of EU membership and efficient waste management, i.e. whether EU countries with "longer membership" are more successful in their green transition compared to others, especially to candidate countries?

RQ2: Can the knowledge of EU member states regarding the green transition and waste management provide guidance to candidate countries such as Serbia, more specifically, can candidate countries learn from EU member states, such as Croatia, about the effectiveness of waste management?

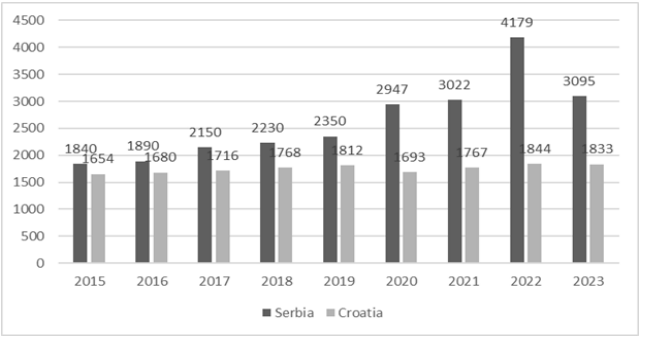
RQ3: To what extent is the community involved in achieving effective waste management on the path toward a green and sustainable Europe?

2.2. Compliance with EU waste management policies

Harmonising waste management policies with EU standards is essential for both Member States and candidate countries (Petrović-Ranđelović & Radukić, 2015; Todić, 2021). It promotes sustainable development, environmental protection, and circular economic goals for EU members, all the while granting access to EU financing and technologies. For Serbia and other aspirant countries, alignment represents a necessary step toward accession and a mechanism to strengthen institutional integrity and environmental sustainability. Croatia and Serbia have aligned their legal frameworks with EU waste directives (Tankosić, 2023; Stojanović et al., 2022), while their implementation techniques differ. Croatia's Law on Sustainable Waste Management (2013) and its National Waste Management Plan (2023-2028) aim to increase recycling rates to 55% by 2025 and reduce landfill disposal to 10% by 2035.The initiative supports the European Green Deal and the Circular Action Plan (Sudar et al., 2024). Serbian legal framework includes the Waste Management and Environmental Protection Law. In Chapter 27 of EU negotioations, Serbia refined its goals, prioritising improved recycling, reduced illegal landfilling, and infrastructure advancement. Both Croatia and Serbia follow the waste hierarchy, encompassing prevention, reuse, recycling, energy recovery, and landfilling, and also use the „polluter pays" principle. Croatia has a centralised system characterised by involvement of

national funds and over 550 municipal units. Serbia has delegated more authority to local governments (Todić, 2021; Crnčević et al., 2011) monitored by national and local inspectors. Croatia has invested in eleven regional Waste Management Centres, eqquipped with Mechanical Biological Treatment facilities, landfill cells, and transfer stations in order to improve recycling and reduce landfill utilisation. However, it still faces challenges meeting recycling targets and enhancing infrastructure. On the other hand, Serbia has delays in infrastructure development due to its financial and technological constraints (Čepić et al., 2022; Nikolić et al., 2017). It has to accelerate investment, strengthen enforcement (Martin, 2024; Džuverović & Milošević, 2021), and promote public awareness of sustainable waste management practices to meet EU standards. The following Figures 1-4 display statistical data on municipal waste generated (in tonnes), per capita, recycled, and landfilled from 2015 to 2023, in accordance with EU targets.

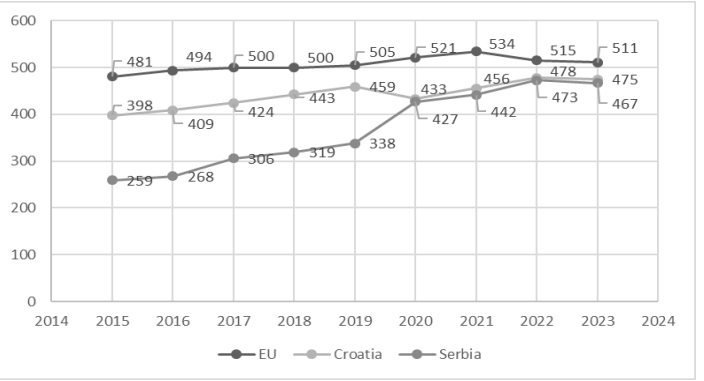
Figure 1 Municipal waste generated in Croatia and Serbia (2015-2023) (000 tonnes)



Source: The authors adapted from: Eurostat (2024).

Steady growth of municipal waste generated in Croatia (Figure 1) is the result of its obligation as an EU member to maintain extensive reports, leading to the increase of recorded data and statistics. Furthermore, such an increase can be attributed to the rise in living standards and consumption, as well as improvement in data collection regarding municipal waste generated in Croatia. The recorded decrease in municipal waste generated in Serbia should not be interpreted as an indicator of improved environmental performance. Instead, it reflects structural shortcomings in waste monitoring, data collection and reporting systems, as well as the prevalence of informal disposal practices and incomplete coverage of rural areas. In contrast, Croatia's increasing waste figures partly reflect more comprehensive reporting obligations as an EU member state, alongside higher levels of consumption.

Figure 2 Municipal waste generated in Croatia and Serbia (2015-2023) (kg per capita)

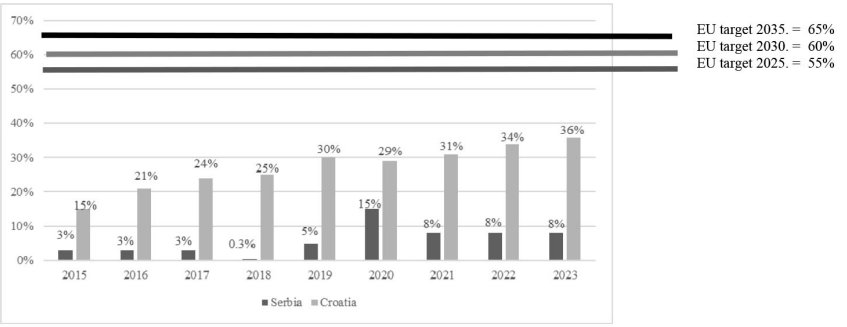


Source: The authors adapted from: Eurostat (2024).

Municipal waste generated (kg per capita) shows different paths for Croatia and Serbia. Croatia reports values ranging between 400-500kg per capita annually, broadly aligned with EU average, while Serbia reports lower levels, between 300-350kg per capita (Figure 2). Figure 1 and 2 should be interpreted with caution, as per capita values are influenced by polulation estimates, revisions in reporting methodologies and degree of formal waste collection coverage. Difference between Figures 1 and 2 arise from annual population adjustments and revisions in Eurostat data, which affect per capita calculation.

While Croatia has adhered mainly to EU norms, Serbia still needs to implement a reliable system supported by public education on waste disposal and sorting. In recent years, Serbia has been actively working on public education regarding waste disposal and sorting. As part of its cooperation with Serbia's government, the Japan International Cooperation Agency (JICA 2025) is implementing projects that include public awareness campaigns, training programs for employees of public utility companies, and the promotion of the 3R principles (Reduce–Reuse–Recycle). Sekopak (2025), the authorised packaging waste operator, in cooperation with the Ministry of Environmental Protection (2025–2029), is implementing the Packaging Waste Reduction Plan through educational campaigns, the installation of recycling infrastructure, and the organization of public events (Eco Days, workshops for children).

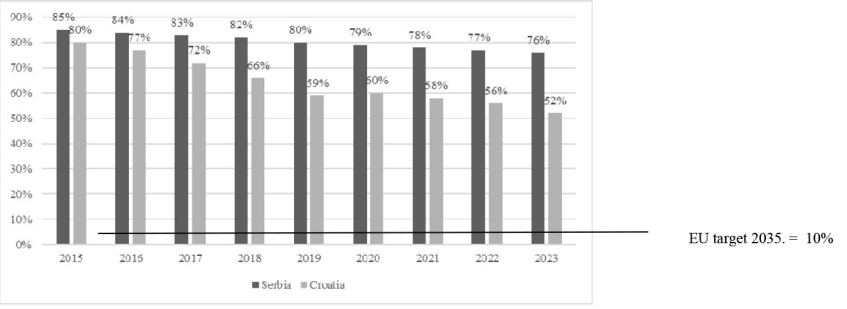
Figure 3 The share of municipal waste recycled in Croatia and Serbia (2015-2023)



Source: The authors adapted from: Ministry of Environmental Protection of Croatia (2024); Ministry of Environmental protection of Serbia (2022); Eurostat (2024).

Figure 3 presents Croatian and Serbian recycling rates from 2015 to 2023, alongside EU targets of 55% by 2025, 60% by 2030, and 65% by 2035. Despite its progress in recycling efficiency since 2023, Croatia remains below the 55% target, indicating the need for intensified work, especially in rural infrastructure development. However, Serbia has exhibited inadequate and inconsistent recycling rates, with a rise to 15% in 2020, followed by a decline to 8%. This unpredictability indicates fundamental structural issues, such as ineffective infrastructure, limited public awareness, and weak local capabilities. Moreover, the stated outcomes have been affected by data inconsistencies and postponed the deployment of tracking devices. Unlike Croatia, which is making progress towards EU standards, Serbia is lagging behind, while setting lower national targets of 25% by 2025 and 35% by 2030. Serbia must improve its infrastructure, enhance public education, and establish reliable monitoring systems to meet EU criteria.

Figure 4 The share of municipal waste disposed in Croatia and Serbia (2015-2023)



Source: The authors adapted from: Ministry of Environmental Protection of Croatia (2024); Ministry of Environmental protection of Serbia (2022); Eurostat (2024)

Figure 4 presents the trend of municipal waste percentage designated for landfills in Croatia and Serbia, both displayed in comparison to the EU's 2035 target of a maximum of 10%. Although Croatia has reduced landfilling, the rate is still above the EU objective, signifying insufficient recycling initiatives. To achieve the goal, it is essential to close non-compliant landfills, improve mechanical-biological treatment (MBT) facilities, and refine source waste separation. Serbia has witnessed a modest decline in landfill usage, but it still remains well below the EU target. Progress is hindered by outdated infrastructure, reliance on inadequate landfills, and lack of waste separation. Key challenges include insufficient sanitary landfills, inefficient selective collection systems, limited public awareness, and limited budgetary resources. Accordingly, Serbia should invest in infrastructure, increase recycling, and improve waste monitoring through sustainable funding and strategic partnerships.

3. METHODOLOGY

3.1. The First research approach

In order to achieve the objective of the paper and address the research questions, two research approaches were applied. The first involved analysing available data from Eurostat (2024; 2025) and Sustainable Development Goals Index-SDG Index (Sachs et al. 2024). Similar to D'Adamo et al. (2024), we used Eurostat (Table S4), regarding Serbia and 27 EU Member States during the period 2015–2023, and collected the following variables:

- municipal waste treatment and generation (in kilogrammes per capita)
- municipal waste disposed of by energy recovery, landfill, and incineration (in kilogrammes per capita);
- municipal waste recycling rate (in percentage of total waste generated).

Relying on collected data, six corresponding tables with time series of analysed variables (2015-2023) were created, and the mean values of variables were calculated for each country. A dataset created consisting of those values, reflected the efficiency of the waste management systems in selected countries. To mitigate the limitations of our analysis caused by the unavailability of specific data, we enriched this dataset with the Sustainable Development Goals Index-SDG Index (see Table 4 in the Appendices). SDG Index assesses countries' progress towards achieving the 17 Sustainable Development Goals (Sachs et al., 2024). Subsequently, using the statistical software R, cluster analysis was performed, clustering countries with similar waste management indicators. Due to lack of data on incineration disposal per capita for many countries, we excluded this indicator from further analysis.

In light of the fact that we have considered the length of EU membership, we can determine how certain EU countries (and Serbia as a candidate country) are grouped based on the success of their transition process

towards a sustainable Europe. Similar to Jano (2022), the length of the membership was observed using accession-wave groupings. Following Laureti et al. (2024), we applied the K-means algorithm. The Elbow Method and Silhouette Analysis were used to identify the optimal number of clusters. To assess whether the identified clusters differ significantly on selected variables, a series of one-way ANOVAs were conducted, each followed by Tukey's HSD post-hoc test identifying which specific cluster pairs vary considerably in terms of the variable being tested (Pocol et al., 2020).

3.2. The Second research approach

The second research approach involved an online survey conducted among respondents from Serbia and Croatia from October 2024 to January 2025. To maximise participation, the survey was distributed via Google Classroom with the support of the Faculty of Economics Niš and the Faculty of Economics and Business Zagreb.

A non-probabilistic convenience sampling approach was employed, distributed through university-supported digital platforms. This approach resulted in an overrepresentation of younger respondents, reflecting higher responsiveness of students to online questionnaires and their greater engagement with sustainability-related topics. Consequently, the findings primay reflect attitudes of younger, educated populations and should not be interpreted as representative of the general population.

A sample of 334 valid answers was obtained, and characteristics of the respondents can be found in Table 5 in the Appendices. Similar to other studies dealing with waste management and sustainability, most respondents in this study were women (75.7%). The largest share of respondents (85.6%) were younger individuals (18-24 years), which Pocol et al. (2020) explain by the fact that they are more inclined to complete online questionnaires and are more interested in this topic. Following Pontis et al. (2017), we decided not to include income in our research, as questions about income often cause discomfort among respondents and lead to non-responses.

Besides the five demographic questions, the questionnaire included a set of questions adapted from Coscun (2022), and Mosnegutu et al. (2025), focusing on respondents' attitudes toward waste management, sustainability and the green transition. The questionnaire comprised closed-ended questions and a series of statements in which respondents were offered 1-5 Likert-type scales (1="total disagreement" to 5="total agreement"). The questionnaire items showed good reliability (*Cronbach's* $\alpha = 0.824$), indicating a high level of internal consistency among the items. The response distribution, the values of Pearson's Chi-square and the associated significance level (Asymp. Sig.) were necessary to find a statistically significant association between certain demographic variables and specific Likert-scale items related to waste management. Multiple t-tests,

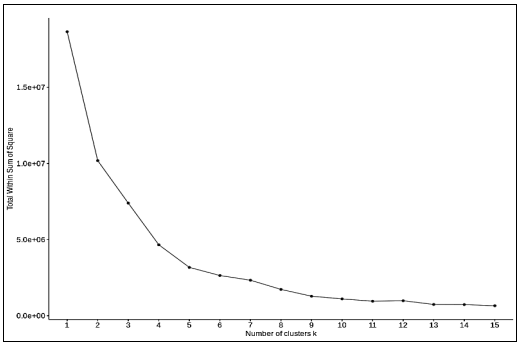
including Levene's test for equality of variances, were conducted to deepen the analysis. The statistical software package SPSS 20 was used to analyse the data obtained from the survey.

4. RESULTS AND DISCUSSION

4.1. The results of cluster analysis

In determining the number of clusters, we first applied the Elbow method to obtain an initial estimate (Figure 5), followed by a Silhouette analysis for further validation (Figure 6).

Figure 5 Elbow plot



Source: Author's calculation based on Table 4 (in the Appendices).

The scree plot in Figure 5 (number of clusters on the x-axis, within-cluster sum of square on the y-axis) shows an evident decline in the within-cluster sum of squares (WCSS) up to k=5 and k=6, after which the curve flattens. Based on the assumption (Fa'rifah & Pramesti, 2022) that the silhouette coefficient is the best criterion for determining the optimal number of clusters, we carried out its calculation (Table 1).

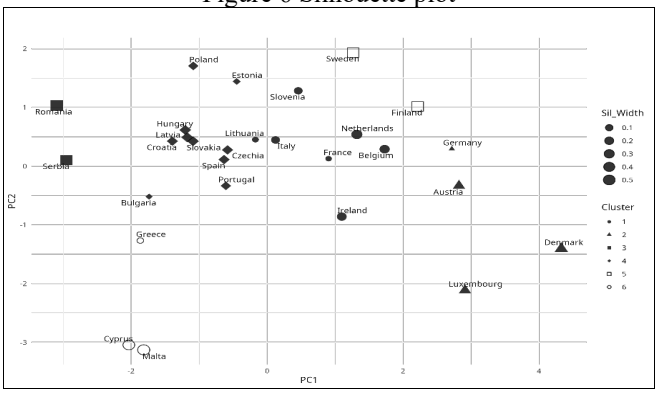
Table 1 Silhouette Coefficients of Each Scenario

Scenarios	Silhouette Coefficient
I (4 clusters)	0.289
II (5 clusters)	0.311
III (6 clusters)	0.331
IV (7 clusters)	0.298

Source: Author's calculation based on Table 4 (in the Appendices).

According to the results in Table 1, the silhouette coefficients generated from the four scenarios used in the k-means clustering analysis are close to 0.3. Since the literature (Mooi & Sarstedt, 2011; Fa'rifah & Pramesti, 2022) points out that silhouette measure between 0.20 and 0.50 a fair solution, we can conclude that almost all scenarios produce a fair number of clusters. Of the four scenarios, scenario III (k=6) is the best solution (silhouette coefficient = 0.331), which is consistent with the Elbow method choice (k=6). A silhouette plot was generated to visualise the clustering quality for scenario III (Figure 6). The plot displays the silhouette coefficient (silhouette width score) for each country, grouped by cluster, allowing an assessment of cluster cohesion and separation.

Figure 6 Silhouette plot



Source: Author's calculation based on Table 4 (in the Appendices).

As shown in Figure 6 (silhouette width values indicating cluster cohesion and separation), the six clusters consist of European countries with similar characteristics related to waste management (Table 2).

Table 2 Membership of four Clusters in III Scenario

Cluster 1	*Cluster 2*	*Cluster 3*	*Cluster 4*	*Cluster 5*	*Cluster 6*
Belgium	Austria	Serbia	Slovakia	Finland	Cyprus
Ireland	Denmark	Romania	Bulgaria	Sweden	Greece
Netherlands	Luxembourg		Latvia		Malta
Lithuania	Germany		Czechia		
France			Spain		
Italy			Portugal		
Slovenia			Poland		
			Croatia		
			Hungary		
			Estonia		

Source: Author's calculation based on Table 4 (in the Appendices).

To verify the validity of our decision to retain six clusters, an ANOVA test was conducted (as shown in Table 6 in the Appendices). It indicates statistically significant differences between clusters across all six variables, suggesting that the chosen clustering solution captures meaningful distinctions among the observed groups. Post-hoc comparisons conducted using Tukey's HSD suggest which pairs of clusters are significantly different. Large effect sizes ($\eta^2 > 0.50$) (Cohen, 1988) for several waste management indicators suggest that over 50% of the variability in these outcomes is accounted for by cluster membership.

Based on the cluster analysis results and the grouping according to the waves of EU accession, a relationship can be observed between the length of EU membership and the effectiveness in waste management and the implementation of EU's planned green transition. The results align with Hondroyiannis et al. (2024) and Giannakitsidou et al. (2020), indicating that Northern European EU member states exhibit higher Circularity Rates compared to their Southern European counterparts. The member states that the literature (Jano, 2022) considers EU founders, as well as those belonging to the "pre-2000 enlargements", are found in the same clusters (clusters 1, 2 and 5 in Table 2), apart from Greece, Spain and Portugal. Spain and Portugal are characterised by regional disparities in the implementation of waste management measures, with significant differences in their application, the availability of necessary infrastructure, and public awareness across regions, particularly between urban and rural areas (Touza et al., 2025). Greece continues to struggle with insufficient governmental interest, weak enforcement of regulations, and a lack of resources and expertise at the local government level. The most pressing concern is the orientation of the national waste-to-energy strategy towards the construction of six incineration plants across the country, which is entirely contrary to the objectives of the EU (Plitharas, 2024; Lialios, 2025).

Despite the varying approaches to assessing the effectiveness of waste management and progress in the green transition across EU member states, Denmark, Sweden, Finland, Germany, Austria, and Luxembourg are examples of the best-performing countries in waste management. They are located in clusters 2 and 5 (Table 2), and have made considerable progress in the green transition, serving as a benchmark for other member states and candidate countries. Cluster 5 includes countries with well-established systems for waste collection separation, a strong regulatory framework that promotes recycling, and active efforts in reducing landfill disposal. At the same time, these countries are still challenged by waste management - for example, the Netherlands, Belgium and France incinerate a large amount of their waste with energy recovery. While this decreases the volume of waste sent to landfills, it does not match EU priorities, which place reuse and recycling above incineration. Zero Waste Europe (2025) has highlighted large levels of dioxins, PFAS, and heavy metals in environments near waste incinerators. Ireland is challenged by limited municipal waste management infrastructure, resulting in continued substantial dependence on landfilling. In contrast, Italy faces a similar problem of pronounced regional

disparities in available infrastructure and waste volumes as in most Southern European countries. Comparable findings were reported in the studies by Laureti et al. (2024), D'Adamo et al. (2024), and Peyravi et al. (2024), apart from Spain's better positioning. Clusters 3, 4, and 6 encompass countries at risk of failing to meet the EU's municipal waste management targets within the green transition framework. Due to similar challenges in waste management, Romania and Serbia have been placed in the same cluster. Both countries have significantly lower recycling rates compared to the EU average and other member states, and they face a high number of illegal dumping sites and landfills that often do not meet minimum sanitary standards (Dumitrescu, 2023; Jovanović, 2019). The EU has already imposed sanctions on Romania for failing to comply with directives on the closure and remediation of illegal landfills and for the unlawful import of waste from other countries (Dumitrescu, 2023). Valenćiková (2022) and EEA (2021) warn that waste management in Serbia faces challenges of shortage of trained personnel, inadequate financial sustainability of operations, insufficient investment in infrastructure, low levels of public awareness, and ineffective enforcement of relevant legislation. Alongside Romania and Greece, Malta and Cyprus also rank among the poorest-performing EU countries in waste management (D'Adamo et al., 2024; Laureti et al., 2024) due to limited infrastructure and a continued dependence on landfilling. The fourth cluster includes countries from the "large wave of EU enlargement" and is also the largest in terms of the number of countries. These countries characterise inadequate infrastructure, a significant portion of waste landfilled, low recycling levels, poor control and tracking waste flows, and a lack of data transparency. Croatia is also included in this cluster, with problems of a weak enforcement mechanism for waste management in line with the principles of the waste hierarchy, a significant reliance on landfilling (Smoljko & Sedlar 2024), a lack of financial resources for facilities and equipment for proper waste management and insufficient public interest in this matter (Barbir & Dabić, 2024). Building upon our research question, we can see (Table 4 in the Appendices) that Croatia achieves higher recycling rates than Serbia. However, Croatia still needs to make significant efforts to meet the EU targets for waste treatment, as it is listed among the countries that the EEA has identified as unlikely to meet the targets for municipal and total packaging waste (EC, 2023a).

4.2. The results of the survey

Since the literature (Barbir & Dabić, 2024; Ivanović et al., 2025) suggests that both Croatia and Serbia lack public awareness regarding the importance of proper waste separation, disposal, and recycling – which is one of the key prerequisites for improving waste management – this section aims to examine that issue. The findings indicate that while most respondents report engaging in waste separation, 22.5% cannot due to the lack of appropriate waste bins. Among them, the greatest percentage of Serbian respondents (34%) stated that they would separate waste but do not have adequate waste bins, compared to

only 8% of Croatian respondents. These differences may result from local infrastructure availability, urban planning policies, and investment priorities, as noted by Šundov et al. (2025), who emphasize the role of spatial efficiency and infrastructure in enabling effective waste management. Furthermore, 32.3% of respondents buy products aligned with EU waste management policies, whereas a notably high proportion (67.7%) do not consider such things when making purchasing decisions. Only 16.2% of respondents reported changing their purchasing preferences in response to implementing new waste management policies. Respondents demonstrated a low level of awareness in response to other questions related to sustainability in waste management and the green transition because 17.1% of participants reported a preference for companies that implement the zero-waste concept, while 24.3% stated that they encourage their family members to separate waste properly. Some more positive results were observed regarding recognising the importance of recycling (30.3%) and avoiding plastic bags during shopping (46.7%). One third of the respondents consider education a key solution for improving the current situation, specifically by raising public awareness about the importance of sustainable waste management, while another third of the respondents view penalties for those who neglect this issue as a practical measure. This aligns with Tuškan Sjauš et al. (2024), who point out the influence of social factors on sustainable behavours and corporate responsibility.

Following the approach of Emmanouil et al. (2025), we conducted a Chi-square test, which revealed statistically significant associations between certain demographic variables and items related to waste management. Cramér's V and Phi coefficient (φ) were used to test the strength of the associations. Only statistically significant associations are presented in Table 3, which are generally not strong.

Table 3 Chi-square test results, Cramér's V or φ

Demographic variable	*Likert items – WM variables*	*χ^2 (df)*	*p*	*Cramér's V or (φ)*	*Strength of association*
Gender	Changes in purchasing preferences due to new WM policies	19.97(3)	.000	.24	Weak
	Willingness to pay more for products aligned with WM policies	11.45(4)	.022	.18	Weak
	Reusable vs. plastic bag preference	14.36(4)	.006	.21	Weak
	Support for recycling	19.12(4)	.001	.24	Weak
	Promoting waste separation within the household	13.84(4)	.008	.20	Weak
Age	Willingness to pay more for products aligned with WM policies	17.33(8)	.027	.16	Weak
Employment	Waste selection	17.16(9)	.046	.13	Weak
	Changes in purchasing preferences due to new WM policies	28.18(12)	.005	.17	Weak
State	Waste selection.	34.25(3)	.000	.32	Moderate
	Willingness to pay more for products aligned with WM policies	14.29(4)	.006	.21	Weak
	Support for companies implementing zero waste practices.	15.7484)	.003	.22	Weak
	Support for recycling	16.27(4)	.003	.22	Weak
	Promoting waste separation within the household	9.90(4)	.042	.17	Weak

Source: Survey findings

To examine differences between Croatian and Serbian respondents, independent samples t-tests were conducted on Likert-scale items related to waste management. Serbian respondents ($M = 2.03$, $SD = 0.85$) reported significantly higher waste selection preferences than Croatians ($M = 1.63$, $SD = 0.75$), $t(331) = –4.50$, $p < .001$; equal variances were assumed ($F = 2.64$, $p = .105$). Serbians also showed greater willingness to pay more for products aligned with waste management policies ($M = 2.79$, $SD = 1.13$) than Croatians ($M = 2.34$, $SD = 1.13$), $t(331) = –3.63$, $p < .001$; equal variances were met ($F = 0.75$, $p = .389$). Moreover, Serbians expressed higher support for companies adopting zero-waste practices ($M = 2.79$, $SD = 1.19$) than Croatians ($M = 2.28$, $SD = 1.11$), $t(331) = –4.00$, $p < .001$; $F = 0.04$, $p = .846$. They also reported stronger support for recycling ($M = 3.03$, $SD = 1.30$ vs. 2.59, $SD = 1.28$), $t(331) = –3.10$, $p = .002$; $F = 0.97$, $p = .325$, and for household waste separation ($M = 2.86$, $SD = 1.21$ vs. 2.51, $SD = 1.16$), $t(331) = –2.63$, $p = .009$; $F = 0.47$, $p = .492$. These findings indicate that Serbians consistently demonstrate greater support for key pro-environmental behaviours compared to Croatians across various domains, including recycling, zero waste practices, and willingness to support environmentally aligned products and companies.

Based on these results, several concrete policy recommendations can be proposed to improve the efficiency of waste management systems in Croatia and Serbia. First, both countries should prioritize investments in municipal waste infrastructure, ensuring sufficient availability of bins, collection points, and recycling facilities, especially in areas with limited infrastructure. Second, public awareness campaigns and educational programs should be intensified to increase citizen engagement in waste separation and recycling. Third, financial incentives and penalties could be introduced to encourage both households and companies to adopt sustainable waste practices, such as supporting zero-waste initiatives or purchasing environmentally friendly products. Finally, local governments need to enhance enforcement mechanisms and regulatory compliance to reduce illegal dumping and improve adherence to EU waste management standards.

5. CONCLUSION

The objectives outlined in EU directives require both member states and candidate countries to improve resource efficiency and transition toward a circular economy, while focusing on climate change and reducing pollution. While some EU member states, such as Denmark, Sweden, Finland, and Germany, have achieved significant success in waste management and the implementation of sustainable practices, others, including Bulgaria, Greece, and Romania, face a considerable risk of not meeting the EU Green Deal targets. Croatia falls into this latter group of countries that still struggle with structural challenges, particularly in coordination between governance levels, infrastructure investment, and coherent policy implementation. Its waste management system is predominantly centralized, with strategic planning, regulatory frameworks, and

funding largely determined at the national level, while local authorities are primarily responsible for implementation. On the other hand, Serbia's system demonstrates more decentralized characteristics, with a stronger role of municipalities in organizing waste collection, local campaigns, and citizen engagement, often supported by EU accession initiatives. These structural differences offer valuable context, but empirical data, presented in this paper do not allow causal conclusions about the effectiveness of centralized versus decentralized approaches.

The survey results reveal important and somewhat unexpected findings. Although Croatia performs better in terms of recycling rates, and overall compliance with EU waste management targets, Serbian respondents demonstrate stronger pro-environmental attitudes, including a higher willingness to separate waste, support zero-waste practices, and pay more for environmentally friendly products. This mismatch suggests that favourable attitudes do not necessarily translate into better overall system outcomes, highlighting the importance of institutional capacity, governance, infrastructure, policy enforcement, and public engagement in achieving effective green transition outcomes. The findings have clear policy implications. In Croatia, priorities include public education, expanding recycling infrastructure, and improved coordination between national and local authorities. In Serbia, policy actions should prioritize strengthening citizen engagement, enhancing municipal services, and supporting local initiatives through targeted funding. In both countries, incentives for circular economy practices and effective monitoring can help translate positive public attitudes into measurable environmental outcomes.

This paper contributes to the existing knowledge by highlighting the gap between public attitudes and actual waste management performance, as well as by providing comparative insights into two institutional contexts at different stages of EU integration. In this way, the paper builds on prior research exphasizing the importance of spatial organization and infrastructure (Šundov et al., 2025), socio-behavioural determinants of sustainable practices (Tuškan Sjauš et al., 2024), and the role of awareness and knowledge in advancing practices of circular economy (Lovrenčić Butković & Mihaljević, 2021).

Several limitations should be acknowledged. Despite extensive analysis of the literature and EU databases on waste management and the green transition, data gaps for some countries and time periods have affected indicator accuracy. The survey component is also subject to potential response bias and limitations inherent in self-reported data, while the sample size constrains generalizability. Moreover, there is a limited number of prior studies addressing the relationship between institutional frameworks, public attitudes, and actual waste management performance in Croatia, Serbia, and other EU candidate countries, emphasizing the need for further research. Future research should expand the range of indicators, increase the dataset, include other EU candidate countries, and apply mixed methods and longitudinal approaches to gain deeper insights into these relationships.

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APPENDICES

Table 4 Country-Level Mean Values of the Six Waste Management Variables and SDG Index

	SDG Index	Waste treatment per capita	Waste generated per capita	Recycling rate of MW	Incineration disposal per capita	Disposal landfill per capita	Disposal, incineration and energy recovery
European Union – 27 countries		496.00	506.78	47.41	5.22	122.44	132.11
Belgium	80.04	546.67	547.78	54.06	3.00	2.89	245.00
Bulgaria	75.54	438.50	447.88	31.24	-	259.13	17.25
Czechia	81.26	458.29	464.43	34.96	-	219.86	71.43
Denmark	85	806.00	814.38	49.13	-	9.13	397.13
Germany	83.45	622.89	622.89	67.98	14.78	5.33	194.22
Estonia	80.46	349.56	380.33	31.46	-	52.89	171.11
Ireland	78.72	592.20	601.00	39.40	-	112.20	231.60
Greece	78.71	507.00	507.00	18.24	-	407.88	6.71
Spain	80.7	470.22	470.22	37.91	-	238.67	53.00
France	82.76	536.33	545.11	41.24	1.43	138.22	173.00
Croatia	82.19	407.44	441.67	27.69	-	282.44	2.75
Italy	79.29	450.50	494.63	49.48	13.00	107.88	95.75
Cyprus	72.92	554.00	652.89	16.11	-	440.78	8.00
Latvia	80.99	411.63	434.25	34.94	-	246.13	11.88
Lithuania	78.12	436.67	460.22	46.54	-	109.56	109.67
Luxembourg	76.81	758.89	758.89	51.48	-	32.22	335.89
Hungary	79.53	398.56	398.11	34.26	-	207.22	53.44
Malta	76.95	628.33	644.44	12.10	-	545.00	10.60
Netherlands	79.21	507.00	507.00	55.94	5.11	7.00	216.67
Austria	82.55	660.38	666.63	59.45	0.25	14.75	246.75
Poland	81.69	327.22	336.00	35.22	4.11	137.89	70.78
Portugal	80.22	496.22	495.56	29.53	-	250.89	99.00
Romania	76.7	257.25	278.38	12.35	0.22	207.88	13.75
Slovenia	81.34	400.56	485.44	58.67	12.00	48.78	65.44
Slovakia	79.35	417.11	423.89	37.39	11.00	213.56	36.56
Finland	86.35	540.00	540.00	42.07	2.67	10.78	302.44
Sweden	85.7	429.00	429.89	43.57	-	2.78	237.67
Serbia	77.03	329.89	366.56	8.34	-	281.00	1.33

Note: For incineration disposal per capita, unavailable countries' data were marked with -.

Source: Author's calculation based on Eurostat (2025; 2024) and Sachs et al. (2024).

Table 5 Demographic characteristics

		N	%
Gender	Male	81	24.3
	Female	253	75.7
Age	18-24 yrs	286	85.6
	25-34 yrs	20	6
	35-44 yrs	3	0.9
	45-54 yrs	11	3.3
	55+	14	4.2
Education	high school	183	54.8
	college	151	45.2
Occupation	student	283	84.7
	pensioner	4	1.2
	employed	38	11.4
	unemployed	9	2.7
Country	Croatia	151	45.2
	Serbia	183	54.8

Source: survey findings (N=334)

Table 6 ANOVA and Post-hoc test for WM variables Across Country Clusters

Variable	F	p	η2	Post-hoc (sig.diff.)
SDG Index	F(5,22)=6.45	0.000	0.59	Cluster 5>Cluster 1, 3, 4 Cluster 6<Cluster 2, 5
Waste treatment per capita	F(5,22)=16.68	0.000	0.79	Cluster 2>Cluster 1 Cluster 3<Cluster 1, 2 Cluster 4<Cluster 2 Cluster 5<Cluster 2 Cluster 6>Cluster 3, 4
Waste generated per capita	F(5,22)=18.37	0.000	0.81	Cluster 2>Cluster 1 Cluster 3<Cluster 1, 2 Cluster 4<Cluster 2 Cluster 5<Cluster 2 Cluster 6>Cluster 3, 4
Recycling rate of MW	F(5,22)=36.88	0.000	0.89	Cluster 3<Cluster 1, 2 Cluster 4<Cluster 1, 2 Cluster 4>Cluster 3 Cluster 5>Cluster 3 Cluster 6<Cluster 1, 2, 4, 5
Disposal landfill per capita	F(5,22)=30.07	0.000	0.87	Cluster 3>Cluster 1, 2 Cluster 4>Cluster 1, 2 Cluster 5<Cluster 3, 4 Cluster 6>Cluster 1, 2, 3, 4,5
Disposal, incineration and energy recovery	F(5,22)=15.23	0.000	0.76	Cluster 2>Cluster 1 Cluster 3<Cluster 1, 2 Cluster 4<Cluster 1, 2 Cluster 5>Cluster 3, 4 Cluster 6<Cluster 1, 2, 5

Note: Detailed ANOVA table output with Tukey HSD in Table 7 and 8.

Source: Author's calculation based on Table 4.

Table 7 One-way ANOVA test in R

		Df	Sum Sq	Mean Sq	F value	Pr(>F)
SDG Index	as.factor(df_clustering$Cluster) Residuals	5 22	150.93225 103.02822	30.18645 4.683101	6.4458	7.87E-04***
waste treatment per capita	as.factor(df_clustering$Cluster) Residuals	5 22	343285.32 90536.14	68657.065 4115.2791	16.683453	7.668E-07***
waste generated per capita	as.factor(df_clustering$Cluster) Residuals	5 22	331729.01 79458.562	66345.803 3611.7528	18.369419	3.377E-07***
recycling rate of municipal waste	as.factor(df_clustering$Cluster) Residuals	5 22	5647.2528 673.73554	1129.4506 30.624343	36.88081	5.573E-10***
disposal landfill per capita	as.factor(df_clustering$Cluster) Residuals	5 22	498890.14 73000.243	99778.029 3318.1928	30.069991	3.921E-09***
disposal incin., energy recovery	as.factor(df_clustering$Cluster) Residuals	5 22	277730.71 80211.431	55546.142 3645.9741	15.234925	1.634E-06***

Signif. Codes: 0 '***'; 0.001 '**

Source: Author's calculation based on Table 4.

Table 8 Tukey HSD Post-hoc test in R (cluster differences)

	comparison	diff	lwr	upr	p adj
SDG Index	5-1	6.0992857	0.694217717	11.50435371	0.02099159
	5-3	9.16	2.418695801	15.9013042	0.0040476
	5-4	5.832	0.610208221	11.05379178	0.02274386
	6-2	-5.759167	-10.9079228	-0.610410537	0.02247869
	6-5	-9.831667	-15.9856073	-3.677726038	0.0007007
waste treatment per capita	2-1	216.33502	91.0802904	341.589749	0.00027101
	3-1	-202.13373	-362.360118	-41.9073419	0.00818704
	3-2	-418.46875	-591.533029	-245.404471	2.15979E-06
	4-2	-294.56379	-412.7892	-176.33838	1.3327E-06
	5-2	-227.53819	-400.602474	-54.4739152	0.0055752
	6-3	269.541667	87.1158987	451.967435	0.0016953
	6-4	145.636706	14.0876143	277.185798	0.02432878
waste generated per capita	2-1	195.525794	78.1837903	312.867797	0.00042314
	3-1	-197.703373	-347.807768	-47.598978	0.0054812
	3-2	-393.229167	-555.360444	-231.09789	2.05705E-06
	4-2	-286.46131	-397.218057	-175.704562	7.22107E-07
	5-2	-230.75	-392.881277	-68.618723	0.00252627
	6-3	278.979167	108.077795	449.880538	0.00054265
	6-4	172.21131	48.9725778	295.450041	0.00305305
recycling rate of municipal waste	3-1	-38.9891865	-52.8110878	-25.1672852	1.66611E-07
	3-2	-46.6638889	-61.5932486	-31.7345292	2.73594E-08
	4-1	-15.8741667	-24.3696089	-7.37872444	9.71048E-05
	4-2	-23.548869	-33.7475633	-13.3501748	4.47124E-06
	4-3	23.1150198	9.76179458	36.4682451	0.00026343
	5-3	32.4729167	15.233977	49.7118564	8.70722E-05
	6-1	-33.8500661	-45.7460647	-21.9540676	1.43345E-07
	6-2	-41.5247685	-54.6912262	-28.3583109	2.328E-08
	6-4	-17.9758995	-29.3239588	-6.62784011	0.00077425
	6-5	-27.3337963	-43.0707232	-11.5968694	0.00025237
disposal landfill per capita	3-1	169.220437	25.3454788	313.095394	0.01503599
	3-2	229.079861	73.6771455	384.482577	0.00173868
	4-1	135.649206	47.2184351	224.079978	0.00111937
	4-2	195.508631	89.3483659	301.668896	0.00011793
	5-3	-237.659722	-417.103322	-58.2161228	0.00519759
	5-4	-204.088492	-343.084907	-65.0920776	0.00181448
	6-1	389.333862	265.506015	513.16171	2.46043E-08
	6-2	449.193287	312.140974	586.2456	1.15858E-08
	6-3	220.113426	56.3045806	383.922271	0.00451723
	6-4	253.684656	135.560418	371.808894	1.34806E-05
	6-5	457.773148	293.964303	621.581993	1.95708E-07
disposal incineration and energy recovery	2-1	131.049702	13.1531026	248.946302	0.0235902
	3-1	-154.905159	-305.718996	-4.09132153	0.04180491
	3-2	-285.954861	-448.852423	-123.057299	0.0002205
	4-1	-103.727579	-196.423238	-11.0319209	0.02240773
	4-2	-234.777282	-346.057502	-123.497062	1.75349E-05
	5-3	262.513889	74.4159862	450.611792	0.00309254
	5-4	211.33631	65.6363006	357.036318	0.00206818
	6-1	-154.00873	-283.808615	-24.2088457	0.01397792
	6-2	-285.058433	-428.720579	-141.396286	4.24346E-05
	6-5	-261.61746	-433.326567	-89.9083531	0.00120797

Note: Only statistically significant differences between clusters are shown.

Source: Author's calculation based on Table 4.

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USKLAĐENOST S PROPISIMA ZAŠTITE OKOLIŠA I ZELENA TRANZICIJA: USPOREDNI POGLED NA GOSPODARENJE OTPADOM U ČLANICI EU-A I ZEMLJI KANDIDATKINJI

Sažetak

Ovaj rad istražuje važnost gospodarenja otpadom za postizanje učinkovitosti zelene tranzicije i put prema članstvu u EU-u vodeći se trima istraživačkim pitanjima: odnosom između duljine članstva u EU-u i učinkovitosti gospodarenja otpadom; stupnjem do kojeg zemlje kandidati kao što je Srbija mogu od zemalja članica EU-a poput Hrvatske steći vrijedna saznanja za unaprjeđenje procesa zelene tranzicije; te ulogom uključenosti zajednice u uspješnost gospodarenja otpadom. Istraživački pristupi obuhvaćali su baze statističkih podataka i klaster analizu te anketno istraživanje među građanima Hrvatske i Srbije. Rezultati su pokazali da je članice EU-27 moguće grupirati u šest klastera sastavljenih od zemalja sa sličnim razdobljima pristupanja EU-u. Suprotno nalazima klaster analize – prema kojima se Srbija nalazi u grupi zemalja članica EU-a s najlošijim gospodarenjem otpadom – rezultati ankete pokazali su visoku razinu osviještenosti javnosti glede važnosti održivoga gospodarenja otpadom i recikliranja.

Ključne riječi: gospodarenje otpadom, EU, zelena tranzicija, Hrvatska, Srbija.

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