

EXAMPLE OF A GOOD PRACTICE IN CIRCULAR WASTE MANAGEMENT IN THE CITY OF LUDBREG

Melita Srpak ^{1*}, Krešimir Horvat ², Ivana Matijašec – Orehovec ²

¹ Institute for Spatial Planning of Varaždin County, Mali plac 1a, Varaždin, Croatia

² Lukom Ltd., Koprivnička 17, Ludbreg, Republic of Croatia

*E-mail of corresponding author: melita.srpak@gmail.com

Abstract: In the last decade, the Republic of Croatia has witnessed a continuous increase in municipal waste, but at the same time, there has been a steady rise in the rate of recovery and recycling. However, despite the positive trends, the set goals of waste management have still not been achieved – dynamics of waste separation and processing. The City of Ludbreg, with almost 52 % of separately collected municipal waste, represents a successful model of sustainable and circular waste management, placing it among the only nine towns in the Republic of Croatia that have exceeded a 50 % rate of separately collected waste. This paper analyses the application of a circular waste management system in the City of Ludbreg and its role in achieving high recycling rates. Special emphasis is placed on the transformation of the local environment, including the elimination of illegal dumps and the creation of green spaces. The City of Ludbreg exemplifies how local communities can lead in circular economy practices by merging technological innovations with ecological awareness. Key success factors include education, local participation, and the integration of smart technologies in waste management. In conclusion, this research analyzes the challenges in separate waste collection and provides recommendations for further development and improvement of the waste management system at the local level, with the aim of achieving sustainable development goals. The result is the creation of an innovative and modern system that functionally integrates technology, infrastructure, and active participation of the local community, positioning the City of Ludbreg as an example of good and successful practice of a green and smart city.

Keywords: circular economy, waste management, city of Ludbreg, recycling, green policies.

Received: 03.06.2025. / Accepted: 12.09.2025.

Published online: 18.12.2025.

Professional paper

1. INTRODUCTION

In today's world, waste management represents a fundamental element of sustainable development and environmental protection. Waste management is an activity that includes the collection, transport, disposal, recycling, monitoring, and supervision of waste (Weghmann 2017; Weghmann 2023). Today, waste management is considered one of the sectors most vulnerable to climate change, which is why it is essential to reduce greenhouse gas emissions through the implementation of the so - called green transition. This transition entails significant infrastructural interventions and technological adaptations. According to available data, greenhouse gas emissions in the Republic of Croatia have been declining compared to 1990, particularly in the energy, industry, and construction sectors. Despite this progress, additional measures are still required to improve the waste management system in order to reduce the overall ecological footprint and achieve the goals of sustainable development (Boromisa 2023; Allwood 2014). The waste management system in the area of the City of Ludbreg is based on national strategic documents, including the Waste Management Strategy of the Republic of Croatia (Official Gazette No. 130/05), the Waste Management Plan of the Republic of Croatia for the period 2023 - 2028 (Official Gazette No. 84/23), the Waste Management Act (Official Gazette No. 84/21 142/23), and a number of by - laws that enable the implementation of these provisions. In addition to national regulations, the City of Ludbreg actively applies the guidelines from the EU Action Plan for the Circular Economy, including the 2015 "Closing the loop- EU action plan for the Circular Economy" and the 2020 "Action Plan for a Cleaner and More Competitive Europe," there by establishing the prerequisites for an accelerated transition to a circular economy. The aim of this transition is to preserve the value of resources and products within the economy while generating the least amount of waste possible. Due to the rapid development of technology and industry, there is a massive increase in waste production, posing a serious global problem. The town of Ludbreg achieves strong results in terms of waste separation, recycling, and reducing the total amount of municipal waste compared to the national average of the Republic of Croatia. Ludbreg can serve as a good practice example in both national and European contexts, given the alignment of local strategies with the objectives of EU action plans for the circular economy and waste management directives.

The systematic application of technological innovations, the engagement of the local community through educational and participatory measures, and an organizational approach with integrated collection and recycling services form the backbone of the success of Ludbreg's system. However, to maintain long - term sustainability

and fully realize the potential of the circular economy, it is necessary to continuously monitor and compare outcomes with national and EU standards, alongside a critical analysis of remaining challenges, including construction waste management and further citizen education.

This hypothesis encourages a deeper evaluation of the role of local governments in implementing effective waste management models based on circular principles and emphasizes the importance of alignment with higher-level regulations and policy initiatives.

The quantity and composition of waste depend on a society's level of economic development, meaning that more developed countries generate more waste per capita. Developed countries are faced with larger quantities of waste per person, which is a result of increased consumption and lifestyle. However, it is paradoxical to note that despite efforts to reduce municipal waste, this trend is increasing not only in developed countries but also in developing ones (Simončić 2001; Nejašmić & Toskić 2013). The development of fast and efficient recycling methods is becoming imperative in order to reduce landfill disposal and to reuse materials (Harada 1995; Briški 2016; Szpilko et al. 2023). In the context of circular waste management, although it is usually quite clear what constitutes waste in terms of materials or objects, in certain cases it may still be questionable what should be reported as waste. This often applies to industry, where production residues are not always considered waste. Such materials are most commonly reused or recycled at the site of origin (Kalambura et al. 2018; Kiš & Kalambura 2018). To ensure effective waste management, the proposed methodology includes a case study of the City of Ludbreg, based on waste monitoring through empirical research and both quantitative and qualitative analysis in the period from 2018 to 2023. The research results indicate that an integrated waste management system, as a good example of circular practice, can significantly reduce greenhouse gas emissions and the ecological footprint in local communities. In addition, the introduction of advanced technologies and continuous public education increases the recycling rate and reduces the amount of waste sent to landfills, thereby achieving the goals of sustainable development. These findings confirm the importance of a circular approach to waste management, particularly in local communities such as the City of Ludbreg. The City of Ludbreg is located in Varaždin County, on the border with Koprivnica - Križevci County and Međimurje County. The local self-government units bordering the City of Ludbreg within Varaždin County include the Municipality of Martijanec, the Municipality of Sveti Đurđ, the Municipality of Veliki Bukovec, and the Municipality of Mali Bukovec. To the south, the City of Ludbreg borders the Municipality of Rasinja in Koprivnica - Križevci County.

2. WASTE MANAGEMENT IN THE AREA OF THE CITY OF LUSBREG

Municipal waste management in the area of the City of Ludbreg is based on the public waste collection service, which encourages waste producers and holders to separately dispose of different types of waste in order to reduce the amount of mixed municipal waste and biowaste in the generated mixed municipal waste. The Republic of Croatia fulfills its obligation to separately collect and recycle paper, cardboard, glass, metal, plastic, biowaste, wood, textiles, packaging, electronic waste, batteries, accumulators, and bulky waste such as mattresses and furniture, including special categories of waste regulated by specific regulations governing the management of special categories of waste, with the aim of reducing the amount of waste disposed of in landfills (Sofilić 2015; Srpak 2017). In the area of the City of Ludbreg, the organized waste collection and transport service is performed by the municipal company Lukom d.o.o. The company collects and transports mixed municipal waste from the city area to another legal entity (Piškornica - Sanitary Landfill d.o.o.), which disposes of the waste at the Piškornica landfill in Koprivnički Ivanec (Srpak et al. 2022).

The organized collection and disposal of municipal waste from households and non-hazardous industrial waste similar to municipal waste includes the City of Ludbreg and 12 suburban settlements, covering a total of 8,098 residents in 3,275 households (data from 2023), as well as 245 business entities. The coverage percentage of 95% was calculated as the ratio of the number of residents covered by the organized waste collection system (8,098 residents in 2023) to the estimated total population of the City of Ludbreg. This calculation is based on available official data on system users and demographic estimates, representing a standard method for determining the level of service coverage. It is important to emphasize that the reliability of this estimate depends on the accuracy and consistency of the relevant data, as official population estimates may vary due to demographic changes and methodological differences in data collection. Therefore, the analysis also includes the official 2021 population census, which recorded 8,477 residents and serves as the most recent and highest-quality demographic reference source.

Recyclable waste is sent for recovery to companies such as Univerzal d.o.o., CE-ZA-R d.o.o. Mechanical-biological treatment (MBT), Wang-X d.o.o., Unimer d.o.o., GKP Komunalac d.o.o. and the social cooperative Humana Nova. Hazardous waste types (problematic and construction waste) collected at the recycling yard in 2023 were delivered for recovery to companies such as Kemokop d.o.o., Komunalno poduzeće d.o.o. Križevci, and Friš d.o.o. Electrical and electronic waste from the recycling yard was taken over by UNIMER d.o.o. Packaging covered by the deposit refund system (PET, glass, and metal packaging) collected manually at the recycling yard was taken over by the company Lotus d.o.o. Until 2016, the City of Ludbreg operated a landfill site called "Meka" (remediation completed), which today serves as a model of best practice and can be used as an example for other institutions - such as local and regional governments, public interest organizations, and private

entities in the environmental protection and sustainable development sectors interested in solving landfill problems and preserving nature.

The “Meka” landfill remediation project positively impacted the local environment by improving soil, groundwater, surface water, and air protection, and by reusing the space for urban revitalization with new community facilities, significantly improving living conditions (World Development Report 2019; Srpak, et al. 2024). A recycling yard named “Meka” has been built in the City of Ludbreg, where citizens can dispose of waste in accordance with the Waste Management Ordinance (Official Gazette No. 81/20). The owner of the recycling yard is the City of Ludbreg, and it is managed by Lukom d.o.o. In 2023, the City of Ludbreg recorded a significant amount of waste received at the recycling yard, totaling 92.50 tons. This figure not only reflects the activity of citizens in waste disposal but also the importance of the recycling system for the local community.

Figure 1 presents the distribution of different types of waste collected at the Recycling Yard in 2023. The largest portion of waste falls under the category of "Other waste," accounting for 66.14% of the total. Construction waste represents 14.35%, followed by hazardous waste at 12.86%, and recyclable waste constitutes the smallest share at 6.65%. This distribution highlights the predominance of non-recyclable and construction-related materials in the waste stream managed at the facility during the year.

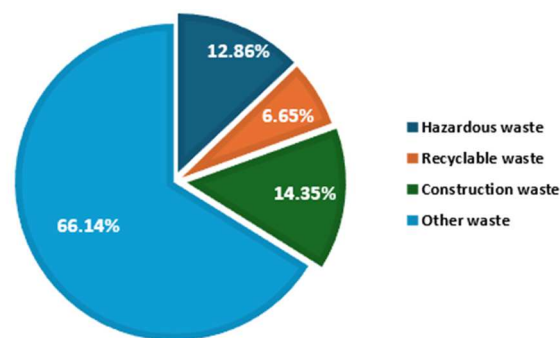


Figure 1. Types of waste at the Recycling Yard in 2023 (Lukom d.o.o. Ludbreg)

Figure 2 illustrates the proportion of hazardous and non-hazardous waste collected at the Ludbreg Recycling Center in 2023. The majority of the waste, 72.73%, is classified as non-hazardous, while hazardous waste comprises 27.27% of the total. This distribution indicates that while most waste handled at the facility is non-hazardous, a significant portion consists of hazardous materials, which require careful management and disposal to ensure environmental safety.

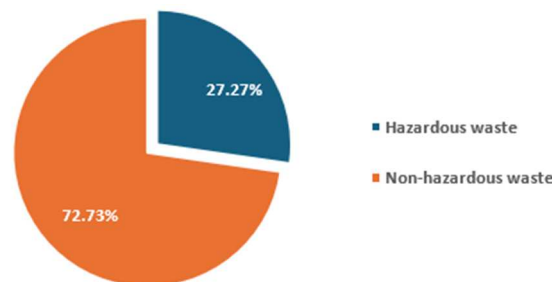


Figure 2. Share of hazardous and non-hazardous waste at Ludbreg recycling center in 2023 (Lukom d.o.o. Ludbreg)

3. ANALYSIS AND ASSESSMENT OF THE WASTE MANAGEMENT SITUATION IN THE AREA OF THE CITY OF LUDBREG

The City of Ludbreg has established a waste management system that meets all criteria, standards, and objectives of waste management. By choosing a door - to - door waste collection system direct collection from households all the prerequisites have been created for further progress toward achieving the targets set by national and European legislation. The current waste management system should be further improved through the following components:

- implementation of door - to - door separate biowaste collection across the entire city area, with the option for home composting;
- implementation of a pay-as-you-throw system based on the total volume of waste generated, in accordance with the Regulation on Municipal Waste Management;
- establishment of a construction waste management system;

d) provision of in house waste treatment capacities (sorting facility and composting plant).

The City of Ludbreg is meeting the targets set out in the Ludbreg Waste Management Plan for the period 2018 - 2023, and is doing so in accordance with legal requirements, primarily due to the successful cooperation with the company LUKOM d.o.o., as well as significant support from local businesses and residents. Citizens are increasingly recognizing the importance of waste separation and are participating more actively in sorting their waste. In terms of its waste collection and disposal system, the City of Ludbreg stands out positively compared to the national average in the Republic of Croatia.

3.1. Municipal waste

An analysis of data from the period 2018 to 2023 reveals a significant downward trend in both the total amount of waste and the amount of waste per capita (**Table 1**). This result can be attributed to recycling efforts, public education, and stricter regulations that encourage waste reduction. All of these changes represent a positive step toward more sustainable waste management practices. The amount of waste per capita was calculated based on the official 2021 population census data (8,477 inhabitants), as this represents the most recent and most reliable demographic source available for the City of Ludbreg. Although population estimates for 2023 are available, they have not yet been officially confirmed or published by the relevant statistical authorities and may therefore carry some uncertainty. To ensure methodological consistency and comparability of the data, the calculations presented in the Tables rely exclusively on verified census data. rability of data, the calculations presented in Tables rely solely on verified census data.

Table 1. Total collected municipal waste in the period 2018–2023.¹ (Lukom d.o.o. Ludbreg)

YEAR	AMOUNT OF WASTE (t)	AMOUNT OF WASTE PER CAPITA (kg/person)
2018	1,137.99	134.24
2019	987.76	116.52
2020	994.76	117.35
2021	970.74	114.51
2022	938.02	110.65
2023	945.00	111.48

3.2. Mixed municipal waste

In 2023, the total amount of mixed municipal waste collected as part of the public service decreased by 115,79 tons, compared to 2018. Similarly, the amount of waste generated per capita decreased by nearly 13,66 kg/person (**Table 2**). These data indicate good efficiency in waste management and increased environmental awareness among citizens.

Table 2. Quantities of collected municipal waste in the period 2018-2023.² (Lukom d.o.o. Ludbreg)

YEAR	AMOUNT OF WASTE (t)	AMOUNT OF WASTE PER CAPITA (kg/person)
2018	682.79	80.55
2019	592.66	69.91
2020	596.86	70.41
2021	583,64	68.85
2022	562.81	66.39
2023	567.00	66.89

The amount of collected biowaste has been increasing year by year, rising by 60.35% from 2018 to 2023. The reason for this increase is the introduction of door - to - door separate biowaste collection throughout the entire city area, as well as the collection of green waste, such as branches. Users still have the option to compost independently at home in their own garden or yard, and the amount of waste generated this way is unknown and is not included in the total recorded biowaste quantities (**Table 3**).

¹ Per capita waste was calculated based on the 2021 population data, as the official 2023 population data are not yet available.

² Per capita waste was calculated based on the 2021 population data, as the official 2023 population data are not yet available

Table 3. Quantities of collected biowaste in the period 2018-2023.³ (Lukom d.o.o. Ludbreg)

YEAR	AMOUNT OF WASTE (t)	AMOUNT OF WASTE PER CAPITA (kg/person)
2018	278.57	32.86
2019	253.02	29.85
2020	251.71	29.70
2021	353.41	41.69
2022	380.94	44.94
2023	446.70	52.69

3.3. Paper, plastic, glass and metal

A positive trend has also been observed in the collected quantities of all types of recyclable waste over the past six years. The greatest increases were recorded for plastic (78.30%), glass (55.52%), metal (47.90%) and paper (13.61%) (Table 4).

Table 4. Quantities of collected paper, plastic, glass, and metal in the period 2018–2023. (Lukom d.o.o. Ludbreg)

YEAR	AMOUNT OF WASTE (t)			
	PAPER	PLASTIC	GLASS	METAL
2018	149.69	102.03	41.68	19.56
2019	155.40	138.42	65.52	16.89
2020	153.61	148.50	63.58	18.74
2021	154.15	149.98	66.60	22.20
2022	178.46	173.95	63.52	29.04
2023	170.06	181.92	64.82	28.93

3.4. Textiles

Separate collection of textiles is also conducted, although no significant quantities have been recorded.

Table 5. Quantities of collected textiles in the period 2018–2023. (Lukom d.o.o. Ludbreg)

YEAR	AMOUNT OF WASTE (t)
2018	0.60
2019	0.48
2020	0.00
2021	0.00
2022	1.56
2023	2.65

3.5. Bulky Waste

The largest increase in collected bulky waste was recorded at 107.69% in the period from 2018 to 2023. Users are entitled to one free bulky waste collection per year upon request (Table 6).

³ Per capita waste was calculated based on the 2021 population data, as the official 2023 population data are not yet available.

Table 6. Quantities of collected bulky waste in the period 2018–2023. (Lukom d.o.o. Ludbreg)

YEAR	AMOUNT OF WASTE (t)
2018	63.44
2019	56.96
2020	49.02
2021	66.78
2022	101.54
2023	131.76

3.6. Special Waste Categories

3.6.1. Tires

In 2018, a minimal amount of waste was recorded at 0.026 tons, while in 2023 the largest increase was noted at 8.08 tons (**Table 7**).

Table 7. Quantities of collected tires in the period 2018-2023. (Lukom d.o.o. Ludbreg)

YEAR	AMOUNT OF WASTE (t)
2018	0.026
2019	3.09
2020	1.65
2021	3.76
2022	4.68
2023	8.08

3.6.2. Waste batteries and accumulators

In 2019, a small amount of waste was recorded (0.071t), followed by a slight increase to 0.10t in 2020 and 0.086t in 2021 (**Table 8**). Smaller quantities of batteries and accumulators were also collected at the recycling yard.

Table 8. Quantities of collected batteries and accumulators in the period 2018–2023. (Lukom d.o.o. Ludbreg)

YEAR	AMOUNT OF WASTE (t)
2018	0.00
2019	0.071
2020	0.10
2021	0.086
2022	0.053
2023	0.24

3.6.3. Waste Lubricating Oils and Waste Edible Oils

No amount of waste lubricating oil has been recorded over the years, while the quantity of waste edible oils shows a gradual increase (**Table 9**). Waste edible oils are collected at the recycling yard, up to approximately 100 liters annually.

Table 9. Quantities of collected waste lubricating oils and waste edible oils in the period 2018–2023. (Lukom d.o.o. Ludbreg)

YEAR	AMOUNT OF WASTE (t)	WASTE EDIBLE OILS
2018	0.00	0.014
2019	0.00	0.15
2020	0.00	0.37
2021	0.00	0.67
2022	0.00	0.08
2023	0.00	0.093

3.6.4. Construction Waste

The amount of waste started at 3.00t in 2018 and has continuously increased each year, as shown in **Table 10**.

Table 10. Estimated quantities of generated construction waste in the period 2018-2023. (Lukom d.o.o. Ludbreg)

YEAR	AMOUNT OF WASTE (t)
2018	3.00
2019	11.00
2020	20.00
2021	22.00
2022	23.00
2023	25.00

A waste management system for construction waste in the area of the City of Ludbreg still needs to be established. Citizens, users of the city's waste management services, can currently deliver up to 200kg of construction waste to the recycling yard within six consecutive months.

4. RESULTS AND DISCUSSION ON TYPES AND QUANTITIES OF GENERATED WASTE, SEPARATELY COLLECTED WASTE, DISPOSAL OF MUNICIPAL AND BIO-DEGRADABLE WASTE, AND ACHIEVEMENT OF TARGETS

The City of Ludbreg, as a small town in continental Croatia, has achieved good results in waste management in recent years and can serve as an example to other towns. The total amount of municipal waste in 2018 was 1,736.08t, of which 34.45% was separately collected waste. Although the total amount of collected municipal waste increased to 1,976.04t in 2023, the separate collection rate rose to 52.18%. In 2023, residents produced more municipal waste (262kg per capita) than in 2018 (235kg per capita), but more than half of the generated waste was separated, and the amount of waste per capita remains significantly lower than the Croatian average of 474kg per capita. It is important to note that from 2018 to 2023, the amount of mixed municipal waste sent to the landfill decreased by 17%. The City of Ludbreg has not paid penalties or incentive fees for collected mixed municipal waste exceeding the threshold amount. However, further efforts are needed to reduce the amount of waste disposed of and to separate even more recyclable waste from the mixed municipal waste bins. Through an analytical approach that includes legislative changes, citizen education, and infrastructure improvements, an efficient waste management system can be ensured that reduces negative environmental impacts and contributes to the conservation of natural resources (Report on the Implementation of the Waste Management Plan in the City of Ludbreg for the Period 2018–2023, 2024).

Population growth and urbanization significantly affect the volume of municipal waste (Mannu et al. 2019; Zhou et al. 2022). This increase can have serious environmental consequences, including greater pressure on landfills and increased greenhouse gas emissions. On the other hand, it presents major challenges for the waste management system, such as the need for stronger legislation, improved infrastructure, and the development of more effective waste reduction strategies. According to research, effective municipal waste management requires integrated approaches that include waste prevention, recycling, and responsible disposal (Salau et al. 2017).

Quantities of paper, plastic, and glass waste have been steadily increasing, which can be attributed to changes in consumer habits, including increased use of packaging and single use products. Since paper and plastic represent a significant portion of municipal waste, their increased presence demands improvements in recycling systems and innovations in packaging design (Ghisellini et al. 2016). The implementation of circular economy strategies, focused on reuse and recycling of materials, is becoming increasingly important in this context. Plastic, as one of the most problematic materials, requires urgent measures to reduce its use and increase recycling rates. Research shows that plastic recycling can significantly reduce environmental footprints and the consumption of natural resources, while glass, as a material that can be recycled indefinitely without loss of quality, represents an important component of sustainable waste management (Hopewell et al. 2009). The trend of collected waste lubricating oils and waste edible oils from 2018 to 2023 indicates an increasing awareness of the ecological consequences of improper disposal, as well as the growing availability of infrastructure for collection and recycling. In the context of sustainability, proper management of waste oils is crucial for reducing water and soil pollution (Hopewell et al. 2009). Ensuring proper disposal of biodegradable waste can be achieved through the implementation of composting systems, which not only reduce the volume of waste but also represent a sustainable practice that contributes to nutrient cycling and improves soil quality, thereby reducing the need for chemical fertilizers.

In light of these data, there is a clear positive trend in the recycling of paper, plastic, and glass, indicating successful waste management measures. However, to ensure the long-term sustainability of these practices, it is necessary to continue developing educational programs, improving infrastructure, and encouraging innovations in recycling. It is important to involve all stakeholders consumers, industry and authorities to make recycling an integral part of everyday life. This trend can be attributed to a combination of educational campaigns, improved infrastructure solutions for waste collection, and incentive policies implemented at local and national levels. Research shows that increased public awareness of environmental issues directly correlates with increased recycling rates, emphasizing the importance of education and community information (Geissdoerfer et al. 2017). Data from the period 2018 to 2023 show significant progress in separate collection and recycling practices, confirming the effectiveness of existing initiatives and policies aimed at educating and raising citizen awareness about the importance of recycling, especially in the City of Ludbreg. However, although positive improvements in recycling rates are evident, it is important to emphasize that sustainable waste management requires an approach that goes beyond recycling alone and includes a comprehensive strategy based on circular economy principles. The introduction of measures encouraging waste reduction at the source, prolonging product lifespans through reuse systems, and optimizing resources through innovative waste processing technologies can, in the long term, reduce the overall negative environmental impact of waste (Hasan 2004). Such an approach assumes the involvement of various stakeholders: from legislative bodies that shape the regulatory framework, through industrial sectors implementing environmentally conscious production processes, to the citizens of Ludbreg who adopt sustainable consumption patterns.

Data also point to the need to continue education on sustainable practices and to establish concrete programs for waste reduction. Initiatives such as "zero waste," "Green Cleanup - One Day for a Clean Environment," as part of the global "World Cleanup" movement, and campaigns like "Take Care of the Environment and Manage Waste" can empower the community to realize their contribution to waste reduction, promoting alternative consumption forms such as borrowing, reuse, and product repair instead of replacement and disposal.

Given the existing trends, it is crucial that further waste management policies encompass the entire product life cycle. The development of environmentally friendly materials, promotion of responsible product design, and ensuring the economic viability of recycling can significantly reduce waste quantities and improve the sustainable waste management system (Vieira & de M 2018; Srpak & Zeman 2017). Only through an integrated approach that includes prevention, reduction, reuse, and recycling is it possible to achieve long-term sustainable resource management and environmental protection. The City of Ludbreg has surpassed a 50% municipal waste separation rate, placing it among the leading local communities in the Republic of Croatia (City of Ludbreg, 2023, 2024). This study is based on the hypothesis that an integrated approach, encompassing infrastructural investments, educational measures, and technological innovations, enables local governments to achieve and maintain high waste separation rates in line with national and European targets.

The City of Ludbreg exemplifies successful fulfillment of the objectives set by the National Waste Management Plan for the period 2023–2028. Compared to the national average, Ludbreg demonstrates above-average results, which are the outcome of effective local policies and community engagement (Municipal Waste Report 2023). Within the framework of the European Union, especially concerning the provisions of the Waste Framework Directive (EU 2018), Ludbreg is close to meeting the minimum target of 55% household waste recycling by 2025, indicating strong progress but also the need for further efforts.

Critical analysis highlights several areas for improvement. Construction waste management is still not fully systematized, representing a challenge shared by other Croatian local communities and strictly regulated at both the national and EU levels. Furthermore, it is necessary to develop local capacities for sorting and composting biodegradable waste and to provide stronger incentives for waste reduction at the source. Public awareness and participation are increasing; however, long-term engagement requires continuous educational programs and transparent communication regarding the achievements and benefits of waste separation. Compared to more advanced EU systems that employ pay – as – you - throw models and digital monitoring technologies, Ludbreg's

system has room for modernization that could further improve efficiency and economic sustainability. By adopting such approaches, Ludbreg can continue to align its practices with best examples from across the European Union.

In conclusion, the experience of the City of Ludbreg confirms that local communities can achieve high standards of waste management in line with national and EU goals through integrated and multisectoral approaches. However, success depends on addressing remaining challenges and fostering innovation, making Ludbreg a valuable example and reference for other Croatian cities striving to achieve the goals of the circular economy.

5. CONCLUSION

Due to increasingly stringent legal requirements, it is essential to establish a high - quality, long-term sustainable, and economically viable municipal waste collection system that respects the principles of environmental protection, sustainable development, and proper waste management. Considering the continuous increase in waste volume, there is an urgent need to introduce innovations into the system, which can be achieved by following successful best practice examples already implemented in the Republic of Croatia. This approach will not only ensure more efficient waste management but also better adapt to new challenges arising from changes in the legislative framework and community needs. In this context, to achieve the goals of sustainable waste management, it is crucial to focus efforts on waste reduction, which includes developing and implementing educational programs to raise awareness among the citizens of the City of Ludbreg about the importance of waste reduction and recycling. Research shows that community education plays a key role in changing behavior and encouraging sustainable practices. In this sense, integrating educational initiatives with existing waste collection systems can further strengthen efforts to reduce waste volume and improve recycling rates, thereby contributing to achieving sustainable development goals and adapting to new legislative frameworks. Studies have shown that citizens, together with associations, should be actively involved in initiatives that promote responsible environmental behavior through activities such as workshops, campaigns, and public events. Active participation not only increases awareness of the importance of waste reduction and recycling but also strengthens collective engagement in achieving sustainable waste management goals. Through such initiatives, citizens can adopt sustainable practices and better understand their environmental impact.

Besides education, it is important to improve waste collection systems to facilitate separation and recycling. Based on research results, we can conclude that introducing more bins for separated waste collection in public spaces in the City of Ludbreg, as well as providing accessible information on proper disposal, can contribute to higher recycling rates. Collection systems should be supported by legal frameworks that ensure the responsibility of all participants in the process, including producers, consumers, and local authorities. Promoting the circular economy, based on the reuse and recycling of materials, can significantly reduce pressure on resources and the environment in the long term. The joint effort of all stakeholders, including citizens, local authorities, and organizations in the City of Ludbreg, is crucial for achieving long-term sustainability goals. Approaches combining education, infrastructure improvements, and policy can create the synergy needed for effective waste management, thereby ensuring a healthier environment for future generations.

6. REFERENCES

- Allwood J M (2014) Squaring the Circular Economy: The Role of Recycling within a Hierarchy of Material Management Strategies. In: Handbook of Recycling: State-of-the-art for Practitioners, Analysts, and Scientists. Oxford: Elsevier, pp.445–477. <https://doi.org/10.1016/B978-0-12-396459-5.00030-1>.
- Boromisa A (2023) Klima i rad. Prilagodbe radnih mjesta i radnika na klimatsku krizu. Savez samostalnih sindikata Hrvatske i Zaklada Friedrich Ebert. <https://www.sssh.hr/pdf/whatwedo-publications/klimairad.pdf>.
- Briški F (2016) Zaštita okoliša. Zagreb: Element, Fakultet kemijskog inženjerstva i tehnologije.
- Geissdoerfer M, Savaget P, Bocken N, Hultink E J (2017) The Circular Economy – A new sustainability paradigm? Journal of Cleaner Production, 143(6), pp.757–768. <https://doi.org/10.1016/j.jclepro.2016.12.048>
- Ghisellini P, Cialani C, Ulgiati S (2016) A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. Journal of Cleaner Production, 114, pp.11–32. <https://doi.org/10.1016/j.jclepro.2015.09.007>
- Grad Ludbreg (2024) Izvješće o provedbi Plana gospodarenja otpadom na području Grada Ludbrega za razdoblje 2018.–2023. godine u 2023. godini. Ludbreg: Grad Ludbreg.
- Grad Ludbreg (2023) Strategija krajobraznog uređenja Grada Ludbrega do 2027. Ludbreg: Grad Ludbreg.
- Harada M (1995) Minamata disease: methylmercury poisoning in Japan caused by environmental pollution. Crit Rev Toxicol 25(1):1–24. <https://doi.org/10.3109/10408449509089885>
- Hasan S (2004) Public awareness is key to successful waste management. Journal of Environmental Science and Health Part A: Toxic/Hazardous Substances & Environmental Engineering, 39(2), pp.483–492. <https://doi.org/10.1081/ESE-120027539>
- Hopewell J, Dvorak R, Kosior E (2009) Plastics recycling: challenges and opportunities. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1526), pp.2115–2126.

<https://doi.org/10.1098/rstb.2008.0311>

Kalambura S, Kiš D, Guberac S (2018) Gospodarenje otpadom II. Osijek: Poljoprivredni fakultet u Osijeku, Sveučilište J.J. Strossmayera Osijek.

Kiš D, Kalambura S (2018) Gospodarenje otpadom I. Osijek: Poljoprivredni fakultet u Osijeku, Sveučilište J.J. Strossmayera Osijek.

Mannu A, Ferro M, Di Pietro ME, Mele A (2019) Innovative applications of waste cooking oil as raw material. *Science Progress*, 102(2):153–164. <https://doi.org/10.1177/0036850419854252>

Ministarstvo zaštite okoliša i zelene tranzicije (2024) Izvješće o komunalnom otpadu za 2023. godinu. Zagreb: Ministarstvo zaštite okoliša i zelene tranzicije.

Nejašmić I, Toskić A (2013). Starenje stanovništva u Hrvatskoj - sadašnje stanje i perspektive. *Hrvatski geografski glasnik* 75(1):89–110.

Narodne novine (2020). Pravilnik o gospodarenju otpadom. *Narodne novine*, br. 81/2020.

Narodne novine (2005). Strategija gospodarenja otpadom Republike Hrvatske. *Narodne novine*, br. 130/2005.

Narodne novine (2021/2023). Zakon o gospodarenju otpadom. *Narodne novine*, br. 84/2021 i 142/2023.

Szpilko D, de-la-Torre-Gallegos A, Jiménez Naharro F, Rzepka A (2023) Waste management in the smart city: Current practices and future directions. *Resources*, 12(10), p.115. <https://doi.org/10.3390/resources12100115>

Simončić V (2001) Zbrinjavanje otpada. In: D. Đikić, H. Glavač, V. Glavač, V. Hršak, V. Jelavić, D. Njegač, V. Simončić, O.P. Springer, I. Tomašković i V. Vojvodić, eds. *Ekološki leksikon*. Zagreb: Barbat; Ministarstvo zaštite okoliša i prostornog uređenja Republike Hrvatske, pp. 143–161.

Sofilić T (2015) Zdravlje i okoliš. Sisak: Sveučilište u Zagrebu, Metalurški fakultet

Srpak M (2017) Ekološka održivost. Međimursko veleučilište u Čakovcu. <https://www.mev.hr/wp-content/uploads/2018/02/Ekoloska-odrzivost.pdf>

Srpak M, Pavlović D, Klopota I (2022) Perception, attitudes and knowledge of students of the Polytechnic of Međimurje about the system of sustainable waste management. *Interdisziplinäre Managementforschung*, pp 707–723.

Srpak M, Zeman S (2017) Zbrinjavanje azbestnog otpada. *Zbornik radova Međimorskog veleučilišta u Čakovcu* 8(2):95–106

Srpak M, Zeman S, Križaić V, Pavlović D (2024). Spatial-planning aspect of waste management in Varaždin county. In: *Book of Abstracts - Eighth International Scientific Conference "June 5th - World Environment Day"*. University of Bihać, Biotechnical Faculty, pp 104–105.

Salau O, Osho S, Sen L, Osho G S (2017) Urban sustainability and the economic impact of implementing a structured waste management system: A comparative analysis of municipal waste management practices in developing countries. *International Journal of Regional Development*, 4(1), pp.1–??.
<https://doi.org/10.5296/ijrd.v4i1.10005>

Ujedinjeni narodi (2019) Izvješće o svjetskom razvoju 2019.: Promjenjiva priroda posla. Washington, DC: Svjetska banka. ISBN 9781464814570

Vieira V H A de M (2018) The impact of socioeconomic factors on municipal solid waste generation in São Paulo, Brazil. *Waste Management & Research*, 36(1), pp.79–85. <https://doi.org/10.1177/0734242X17744039>

Wegmann V (2017) Waste Management in Europe. Good Jobs in the Circular Economy? EPSU. https://circulareconomy.europa.eu/platform/sites/default/files/waste_management_in_europe._good_jobs_in_the_circular_economy_for_web.pdf

Wegmann V (2023) Waste management in Europe. EPSU. https://www.epsu.org/sites/default/files/article/files/Waste%20Management%20in%20Europe_EN.pdf

Zhou J, Li L, Wang Q, Fan Y V, Liu X, Klemeš J J, Wang X, Tong Y W, Jiang P (2022). Household waste management in Singapore and Shanghai: Experiences, challenges and opportunities from the perspective of emerging megacities. *Waste Management*. <https://pubmed.ncbi.nlm.nih.gov/35397419/>