FORECASTS OF WASTE DYNAMICS IN LATVIA IN THE CONTEXT OF EU WASTE MANAGEMENT POLICY

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Abstract
Latvia faces growing waste challenges due to urbanization and consumption. Aligned with EU goals, it aims to cut landfill waste to 10% by 2035 through prevention, reuse, and recycling. This study assesses the dynamics of waste volume and flow in Latvia from 2018 to 2023, evaluating current waste management performance and forecasting future trends. The research is based on historical data from public databases and the regional waste management company SIA 'AAS Piejūra', analyzing various waste fractions. Results reveal a consistent increase in total waste volumes, rising from 3,439 tons in 2018 to 11,877 tons in 2023, with a notable spike in 2020 (10,220 tons). Key recyclable waste categories demonstrated significant growth: glass recycling increased from 277 tons in 2018 to 2,399 tons in 2023, and cardboard and paper from 264 tons to 1,739 tons in 2020. Mechanical waste processing remained the dominant category, peaking at 7,223 tons in 2023, indicating robust material recovery performance. Results reveal a consistent increase in total waste volumes, rising from 3,439 tons in 2018 to 11,877 tons in 2023, with a notable spike in 2020. Glass and cardboard recycling improved, while mechanical processing had the highest volumes. Fluctuations in tires and PET reflect changing infrastructure. Results show progress in recycling and waste processing efficiency. Advancements highlight the need for continued investment in infrastructure and awareness to support Latvia's circular economy. The study aids planning for better recycling, future needs, and EU compliance.
Keywords: waste volume trends, urbanization and waste, public awareness in waste management.

Introduction

The increasing production of waste globally, including in Latvia, is regarded as a pressing environmental and social challenge. This phenomenon is primarily attributed to rapid urbanization, rising consumption, and technological advancements, which collectively exert significant pressure on waste management systems to adapt and evolve. Urbanization, in particular, has been associated with heightened waste generation, as increased population density and consumption patterns in cities result in larger volumes of waste (Ciuta et al., 2015; Burlakovs et al., 2020). The waste generated in urban areas is typically characterized by a significant proportion of organic materials, which are recognized as complicating waste management efforts (Romero-Hernández & Romero, 2018).

In response to these challenges, ambitious waste management policies have been established by the European Union (EU) to reduce landfill dependency, prioritize recycling and reuse, and facilitate the transition toward circular economies. These policies are designed to ensure compliance with international standards for environmental sustainability by member states, including Latvia (Avarand et al., 2023). Emphasis is placed by the EU's Waste Framework Directive on waste prevention and resource recovery, encouraging the implementation of strategies that align with circular economy principles (Avarand et al., 2023).

In Latvia, an ambitious target has been set to reduce landfill waste to 10% of total waste by 2035, demonstrating a strong commitment to sustainable waste management practices (European Commission, 2020). The importance of prevention, reuse, and recycling over traditional waste disposal methods is highlighted by this goal. The transition to a circular economy is aimed not only at minimizing waste generation but also at maximizing the value derived from waste materials, thereby contributing to environmental sustainability and economic resilience (Mihajlov et al., 2021).

The dynamics of waste generation and its composition in Latvia are influenced by multiple factors, including seasonal variations, urbanization, and industrial activities. These elements are recognized as creating a complex landscape for waste management, particularly in coastal regions where seasonal population surges exacerbate existing challenges. An understanding of these dynamics is regarded as essential for the development of effective waste management strategies that align with both local needs and European Union (EU) directives.

Significant fluctuations in waste generation are experienced in coastal regions of Latvia due to seasonal population increases, particularly during the summer months when tourism peaks. This influx of visitors is observed to generate more waste, which can overwhelm existing waste management systems (Burlakovs et al., 2020; Gbolahan, 2023). The composition of waste during these periods is characterized by a notable increase in organic waste from food services and recreational activities (Kubule et al., 2019). Such dynamics are recognized as necessitating adaptive waste management strategies to accommodate varying waste streams throughout the year.

Urban centers in Latvia, marked by dense populations and concentrated industrial activities, are acknowledged as presenting further challenges to waste management efforts. High volumes of waste are generated in these areas, consisting of municipal solid waste (MSW), industrial by-products, and construction debris (Barisa et al., 2015). The diverse

composition of waste in urban settings is understood to require innovative approaches to sorting and processing, as traditional methods are often inadequate for handling the variety of materials present (Grainger et al., 2018). For example, the integration of waste-to-energy technologies has been proposed as a viable solution for converting non-recyclable waste into energy, thereby reducing landfill dependency (Gbolahan, 2023).

Innovative approaches are recognized as essential for addressing the complexities of waste generation in Latvia. Enhanced waste sorting systems, supported by public awareness initiatives, have been shown to improve recycling rates and reduce contamination in recyclable materials. The implementation of deposit-refund systems for beverage containers has been demonstrated as an effective method for increasing recycling participation among residents (Dāce et al., 2013). Additionally, the application of life cycle assessment (LCA) methodologies is acknowledged as providing valuable insights into the environmental impacts of various waste management strategies, guiding policymakers toward sustainable practices (Yay, 2015).

The improvement of waste management infrastructure is identified as critical for effectively managing the dynamics of waste generation in Latvia. Investments in modern recycling facilities and composting systems are considered essential for better processing of organic waste and recyclables (Kubule et al., 2019). Furthermore, public engagement campaigns aimed at educating citizens about waste sorting and recycling are recognized as fostering a culture of sustainability and encouraging responsible waste disposal behaviours (Cantillo & Quesada, 2022).

The dynamics of waste generation and its composition in Latvia are shaped by seasonal variations, urbanization, and industrial activities, presenting unique challenges for waste management systems. Addressing these challenges is understood to require innovative approaches, improved infrastructure, and active public engagement. By adopting comprehensive waste management strategies that consider the complexities of waste generation, Latvia can work toward achieving its sustainability goals and complying with EU directives.

Despite the growing importance of sustainable waste management, there is a lack of comprehensive, data-driven analyses that track long-term waste volume and flow dynamics in Latvia, especially in relation to specific waste fractions and seasonal fluctuations. Existing studies tend to focus on isolated aspects, such as waste composition or public attitudes, without providing integrated assessments over time. Therefore, this research aims to fill this gap by offering a systematic overview of waste generation trends, their alignment with EU policy goals, and implications for future planning.

This study is focused on the analysis of waste volume and flow dynamics in Latvia between 2018 and 2023. Historical data from publicly available databases and SIA ʻAAS Piejūraʼ have been examined to provide a comprehensive evaluation of trends in waste management efficiency and infrastructure development. Special attention has been directed toward the success of recycling programs, fluctuations in specific waste categories, and the factors driving these changes.

The goal of this research is defined as the identification of key trends and challenges in waste management, the assessment of progress toward EU compliance, and the proposal of strategic recommendations for improving recycling efficiency and reducing landfill dependency. By fostering sustainable waste practices, it is intended that a green economy will be supported, environmental impacts will be reduced, and long-term solutions benefiting both society and the environment will be created.

This paper is aimed at providing valuable insights into the evolution of waste management systems in Latvia and offering a framework for addressing future waste challenges. The findings are designed to guide policymakers, researchers, and waste management practitioners in the development of robust strategies that align with EU directives and contribute to a more sustainable future.

Materials and Methods

The research area

The study was conducted in the Piejūra region, located along the western coast of Latvia and managed by the Piejūra Waste Management Association (SIA ʻAAS Piejūraʼ). This region, encompassing municipalities such as Talsi, Tukums, Ventspils, and parts of Jūrmala, is characterized by a diverse mix of urban centers, rural areas, and coastal zones ʻFigure 1ʼ.

A combination of geographic, demographic, and economic factors was observed to shape the waste generation dynamics in the region. Urban centers, including cities like Ventspils and Tukums, were identified as significant contributors to municipal solid waste due to higher population densities and concentrated industrial activities. Surrounding rural areas were noted to produce biodegradable agricultural waste, reflecting the agrarian economy of the region. The Baltic Sea coastline was recognized as an influential factor, with seasonal surges in population during peak tourism periods significantly increasing the volume of waste generated, particularly organic waste from recreational activities and food services. The waste management system in the Piejūra region was observed to operate under an integrated framework, including collection, sorting, and recycling services overseen by SIA ʻAAS Piejūraʼ.

Facilities for sorting and processing recyclable materials, such as glass, paper, and plastics, were reported to align with European Union (EU) waste management directives.

Figure 1
The area of AAS 'Piejūra' waste management services

Seasonal waste management strategies were implemented to address fluctuations in waste volume during tourism peaks, and innovative programs, such as deposit-refund systems for beverage containers and waste-to-energy initiatives, were highlighted as key components of the system. These characteristics were considered essential in contextualizing the waste management challenges and opportunities within the Piejūra region, providing a relevant framework for assessing the effectiveness of sustainable waste practices.

Data collection

The information required for the study was obtained from publicly available databases, including the Central Statistical Bureau of Latvia (CSP), the State Environmental Service (VVD), the Latvian Environment, Geology and Meteorology Centre (LEGMC; in Latvian: LVĢMC), and historical data from the waste management company ʻAAS Piejūraʼ (Limited Liability Company ʻAAS Piejūraʼ, or SIA ʻAAS Piejūraʼ) on waste volumes and flows by fractions from previous years. Regional and national statistical data sources were utilized to analyze changes in waste volumes and composition. Demographic data regarding population changes and lifestyle shifts in the region were also collected and analyzed.

The dataset included specific waste fractions such as cardboard and paper (150101), glass (150107), PET plastic (150102), used tires (160103), household electrical equipment (200136), biodegradable waste (200201), and waste from mechanical processing (191212), among others. Data were collected annually for the period from 2018 to 2023. Descriptive statistical methods were used to evaluate annual changes in total and category-specific waste volumes. These results were interpreted in the context of the European Union's Waste Framework Directive, particularly focusing on the target to reduce landfill waste to 10% of total waste by 2035. The analysis emphasized trends in recycling efficiency, fluctuations in specific waste types, and the capacity of existing waste infrastructure.

Results and Discussion

The table (Table 1) provides a comprehensive overview of annual waste quantities realized from 2018 to 2023, with total, average, maximum, and minimum values presented across various waste categories. Trends, fluctuations, and overall changes in waste management efficiency and practices are reflected over this period. Total waste volumes were observed to increase consistently, rising from 3,439.260 tons in 2018 to 11,877.354 tons in 2023. A significant spike was identified in 2020, during which waste volumes more than tripled compared to 2019, indicating substantial growth in waste collection or processing. Similarly, average annual waste volumes followed an upward trajectory, demonstrating improvements in waste management systems.

Certain waste categories, including cardboard and paper waste (150101) and glass (150107), were found to exhibit significant maximum realized quantities in 2020 and 2023, respectively, indicating the success of recycling programs. Mechanical waste processing (191212) remained the largest category throughout the study period, peaking at 7,223.440 tons in 2023, which reflects the robustness of recycling and material processing activities. In contrast, fluctuations were observed in categories like used tires (160103) and PET (150102), potentially influenced by variations in demand, collection rates, or the availability of infrastructure.

The analysis emphasizes overall improvements in waste management practices, with particular progress noted in the expansion of recycling efforts and processing capacities. These findings underscore the critical importance of maintaining steady investment in waste infrastructure and programs to ensure long-term sustainability and compliance with environmental policies. This evaluation serves as a solid foundation for future strategic planning in waste management, with a focus on improving recycling efficiency and adapting infrastructure to meet evolving demands and environmental targets. The analysis of waste volume and flow dynamics in Latvia from 2018 to 2023 provides critical insights into the evolution of waste management practices and their alignment with European Union (EU) directives. The observed increase in total waste volumes, from 3439260 tons in 2018 to 11877354 tons in 2023, highlights the growing challenges of waste generation driven by urbanization, rising consumption, and technological advancements. This trend reflects a broader pattern seen across many EU member states, where waste generation has been closely linked to economic activity and population growth (Valenćiková & Fandel, 2023). The significant spike in waste volumes in 2020, when waste generation more than tripled compared to 2019, may be attributed to changes in collection or processing

systems, suggesting that waste management practices are becoming increasingly responsive to emerging demands and fluctuations in consumer behavior.

The increase in waste volumes aligns with the EU's New Circular Action Plan, adopted in March 2020, which aims to reduce waste generation while promoting sustainable practices across various sectors, including packaging, batteries, and construction materials (Homenko et al., 2021). This plan emphasizes the importance of adhering to the Waste Framework Directive 2008/98/EC, which established the waste management hierarchy prioritizing prevention, reuse, and recycling over disposal. The implementation of such directives is crucial for countries like Latvia, which are striving to enhance their waste management systems in accordance with EU standards (Kubule et al., 2019).

Moreover, the growth in waste volumes raises questions about the effectiveness of current waste management strategies and the need for continuous improvement. As highlighted by Przydatek (2020), many new EU member states, including Latvia, still face challenges related to high volumes of non-selectively collected waste, which can hinder recycling efforts and increase landfill dependency. This underscores the necessity for Latvia to develop and implement more robust waste management policies that not only comply with EU regulations but also promote sustainable development and resource efficiency.

The findings also suggest that public awareness and engagement play a critical role in improving waste management practices. As noted by Melece et al. (2018), changing attitudes and behaviors among households is essential for achieving recycling targets set by the EU, such as the goal of recycling 60% of municipal waste by 2025 (Melece et al., 2018). Therefore, initiatives aimed at educating the public about waste sorting and recycling can significantly enhance the effectiveness of waste management systems.

Table 1

The realized material in tons from 2018 to 2023

Code	***Realized Material***	***Total (2018-2023)***	***Aver. (2018-2023)***	***(Year) Max.***	***(Year) Min.***
150101	Cardboard, paper waste	6,384.816	1,064.136	2020 (1739.112)	2018 (264.200)
150107	Glass	7,614.990	1,269.165	2023 (2399.460)	2018 (276.720)
150102	PET	435.736	72.623	2020 (146.636)	2023 (0.000)
150102	Film, Big Bag	1,139.042	189.840	2023 (292.760)	2019 (63.169)
150102	HDPE and PP materials	194.863	32.477	2020 (72.897)	2018 (8.520)
150104	Metal packaging	17.770	2.962	2021 (13.380)	2018 (0.000)
200136	Used household electrical equipment	491.155	81.859	2021 (137.240)	2018 (10.620)
200102	Glass (window)	151.740	25.290	2023 (68.980)	2018 (0.000)
200121	Fluorescent lamps	4.800	0.800	2020 (1.720)	2019 (0.000)
160103	Used tires	1,010.560	168.427	2022 (311.600)	2019 (0.000)
200140	Metals	148.751	24.792	2020 (39.973)	2018 (0.000)
191212	Waste from mechanical processing	29,212.020	4,868.670	2023 (7223.440)	2019 (1525.760)
191207	Wood	201.840	33.640	2019 (163.920)	Other years (0.000)
200201	Biodegradable waste (branches)	650.340	108.390	2023 (233.100)	2018 (0.000)

In conclusion, the analysis of waste volume and flow dynamics in Latvia from 2018 to 2023 reveals significant trends that reflect both challenges and opportunities in waste management. The increasing waste volumes highlight the need for adaptive strategies that align with EU directives while addressing local conditions. Continued investment in waste management infrastructure, coupled with public engagement and education, will be essential for Latvia to achieve its sustainability goals and effectively manage waste in the future.

The findings of this research provide a robust foundation for strategic planning in waste management in Latvia, emphasizing the need to improve recycling efficiency, adapt infrastructure to meet evolving demands, and align practices with European Union (EU) environmental compliance goals. As Latvia navigates the complexities of waste generation and

management, it is imperative to address current challenges while leveraging successful initiatives that have emerged over recent years. For instance, the implementation of extended producer responsibility (EPR) schemes has shown a promise in enhancing recycling rates and reducing landfill dependency, as highlighted by Kubule et al. (2019). Such initiatives not only contribute to waste reduction but also foster a culture of sustainability among producers and consumers alike.

Moreover, the transition toward a circular economy is crucial for prioritizing sustainability, resource efficiency, and environmental protection. The EU's Circular Economy Action Plan provides a comprehensive framework that Latvia can adopt to promote sustainable practices across various sectors, including packaging, textiles, and electronics (Gbolahan, 2023). By aligning national policies with EU directives, Latvia can enhance its waste management systems and contribute to broader environmental goals, such as reducing greenhouse gas emissions and conserving natural resources.

To ensure the effectiveness of these strategies, further studies are recommended to explore the long-term impacts of current waste management practices and to refine policies for future optimization. Research focusing on the economic, social, and environmental implications of waste management initiatives will provide valuable insights for policymakers and stakeholders. Additionally, examining the role of public engagement and education in promoting responsible waste disposal behaviors can enhance community participation in recycling programs, as noted by Popova and Sproģe (Popova & Sproģe, 2021).

Furthermore, the integration of advanced technologies in waste processing and recycling, such as artificial intelligence and machine learning, could significantly improve operational efficiencies and sorting accuracy. Investigating the potential of these technologies in the Latvian context will be essential for modernizing waste management practices and achieving sustainability targets.

In conclusion, Latvia is well-positioned to transition toward a circular economy by addressing current challenges in waste management and leveraging successful initiatives. By focusing on improving recycling efficiency, adapting infrastructure, and aligning with EU environmental compliance goals, Latvia can pave the way for a more sustainable future. Continued research and collaboration among stakeholders will be vital for refining waste management strategies and ensuring their long-term success.

Conclusions

1. Total waste volumes increased steadily, from 3,439.260 tons in 2018 to 11,877.354 tons in 2023, with a notable spike in 2020. This trend reflects growing challenges associated with urbanization, rising consumption, and technological advancements. The increasing waste volumes underline the importance of adaptive and innovative waste management strategies to handle the escalating demands effectively.
2. Specific waste categories, such as cardboard and paper (150101) and glass (150107), exhibited significant growth in recycling, demonstrating the success of targeted initiatives. Mechanical waste processing (code 191212) remained the largest waste fraction throughout the study period, with volumes increasing from 1,526 tons in 2019 to 7,223 tons in 2023. This indicates improved material recovery and reflects greater capacity in sorting and recycling systems.
3. Categories like used tires (160103) and PET (150102) displayed notable fluctuations, indicating gaps in collection rates and infrastructure. Addressing these inconsistencies requires further investment in waste sorting systems and expanded recycling capacity to ensure stable and efficient resource recovery.
4. Latvia's progress in improving recycling rates and reducing landfill dependency aligns with the European Union's (EU) circular economy and waste management directives. However, sustained efforts are needed to achieve the ambitious target of reducing landfill waste to 10% of total waste by 2035. In 2023, approximately 49% of municipal waste was still landfilled in Latvia, indicating a significant gap between the current situation and the EU target. Bridging this gap will require accelerated investment in recycling infrastructure and waste diversion strategies.
5. Public awareness and participation were identified as critical drivers for achieving effective waste management. Initiatives like deposit-refund systems have proven successful in increasing recycling participation, but further public education campaigns are essential to foster responsible waste disposal behaviors.
6. Continued investment in modern waste management infrastructure, including advanced recycling facilities and composting systems, is crucial for addressing the growing waste volumes and achieving long-term sustainability. Integrating technologies such as waste-to-energy systems and artificial intelligence for sorting could enhance efficiency.
7. The seasonal surges in waste generation, particularly in coastal regions during peak tourism months, present unique challenges. Adaptive strategies, such as seasonal waste collection schedules and infrastructure expansion, are necessary to address these variations effectively.

References

Avarand, N., Bora, K., & Tavakoli, B. (2023). Life cycle assessment of urban waste management in Rasht, Iran. *Integrated Environmental Assessment and Management, 19*(5), 1385-1393. https://doi.org/10.1002/ieam.4751

Barisa, A., Romagnoli, F., Blumberga, A., & Blumberga, D. (2015). Future biodiesel policy designs and consumption patterns in Latvia: A system dynamics model. *Journal of Cleaner Production*, 88, 71–82. https://doi.org/10.1016/j.jclepro.2014.05.067

Burlakovs, J., Jani, Y., Kriipsalu, M., Grinfelde, I., Pilecka, J., & Hogland, W. (2020). Implementation of new concepts in waste management in tourist metropolitan areas. *IOP Conference Series: Earth and Environmental Science*, 471, Article 012017. https://doi.org/10.1088/1755-1315/471/1/012017

Cantillo O. J. E. & Quesada, B. (2022). Solid Waste Characterization and Management in a Highly Vulnerable Tropical City. *Sustainability*, *14*(24), Article 16339. https://doi.org/10.3390/su142416339

Ciuta, S., Apostol, T., & Rusu, V. (2015). Urban and rural MSW stream characterization for separate collection improvement. *Sustainability*, *7*(1), 916-931. https://doi.org/10.3390/su7010916

Dāce, E., Pakere, I., & Blumberga, D. (2013). Analysis of sustainability aspects of the packaging deposit-refund system in Latvia. *WIT Transactions on Ecology and the Environment*, 173, 729-739. https://doi.org/10.2495/SDP130611

European Commission. (2020). *A new Circular Economy Action Plan: For a cleaner and more competitive Europe*. Brussels. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0098

Eurostat. (2024). *Municipal waste by waste operations*. Retrieved May 20, 2025, from https://ec.europa.eu/eurostat/databrowser/view/env_wasoper/default/table

Gbolahan, O. S. (2023). Interaction between waste management and energy generation systems in terms of material properties and environmental impact in the European Union. *International Journal of Progressive Research in Engineering Management and Science*, *02*(12), 30-40. https://doi.org/10.58257/ijprems30525

Grainger, M. J., Aramyan, L., Logatcheva, K., Piras, S., Righi, S., Setti, M., …, & Stewart, G. B. (2018, March 1). *The use of systems models to identify food waste drivers*. Global Food Security, Elsevier B. V. https://doi.org/10.1016/j.gfs.2017.12.005

Homenko, I., Vujčenko, M., Gomeniuk, M., Mazur, Y., & Haidai, O. (2021). Imperatives for the formation and development of the circular economy and global waste management. *E3s Web of Conferences*, 255, Article 01034. https://doi.org/10.1051/e3sconf/202125501034

Kubule, A., Kļavenieks, K., Vesere, R., & Blumberga, D. (2019). Towards efficient waste management in Latvia: an empirical assessment of waste composition. *Environmental and Climate Technologies*, *23*(2), 114-130. https://doi.org/10.2478/rtuect-2019-0059

Melece, L., Brizga, J., & Ernsteins, R. (2018). Municipal waste management issues. *Engineering for Rural Development*. https://doi.org/10.22616/erdev2018.17.n474

Mihajlov, A., Mladenović, A., & Jovanovic, F. (2021). Country in transition (Serbia) case: circular economy starts from waste management. *Environmental Research and Technology*, *4*(1), 83-88. https://doi.org/10.35208/ert.853792

Popova, Y. & Sproģe, I. (2021). Decision-making within smart city: waste sorting. *Sustainability*, *13*(19), Article 10586. https://doi.org/10.3390/su131910586

Przydatek, G. (2020). Assessment of changes in the municipal waste accumulation in Poland. *Environmental Science and Pollution Research*, *27*(20), 25766-25773. https://doi.org/10.1007/s11356-020-08943-6

Romero-Hernández, O. & Romero, S. (2018). Maximizing the value of waste: from waste management to the circular economy. *Thunderbird International Business Review*, *60*(5), 757-764. https://doi.org/10.1002/tie.21968

Valenćiková, M. & Fandel, P. (2023). Assessing waste management efficiency in the European Union: a focus on the Slovak Republic. *Ecocycles*, *9*(2), 7-25. https://doi.org/10.19040/ecocycles.v9i2.285

Yay, E. A. S. (2015). Application of life cycle assessment (LCA) for municipal solid waste management: A case study of Sakarya. *Journal of Cleaner Production*, 94, 284–293. https://doi.org/10.1016/j.jclepro.2015.01.089