Ginevičius, R. (2022). The efficiency of municipal waste management systems in the environmental context in the countries of the European Union. *Journal of International Studies, 15*(4), 63-79. doi:10.14254/2071-8330.2022/15-4/4

Journal of International Studies



*Scientific Papers*

# The efficiency of municipal waste management systems in the environmental context in the European Union

**Romualdas Ginevičius**
*Faculty of Public Management and Business, Mykolas Romeris University, Vilnius, Lithuania*
*romualdas.ginevicius@mruni.eu*
*ORCID 0000-0003-0268-009X*

**Abstract**. Performance criteria of non-energy materials hold an important place in the system of indicators of the green growth strategy. Management of generated municipal waste and its effectiveness depend to a large extent on the ratio of the amount of incinerated, recycled or composted waste to the amount taken to landfills. This ratio is tied to the level of economic development of the country. The conducted research revealed several regularities in the management of generated municipal waste. As the country's economic conditions improve the amount of generated municipal waste increases while the share sent to landfills decreases, and vice versa – less economically developed European Union countries are characterized by a lower amount of generated waste, but a larger amount of it sent to landfills. Multi-criteria methods were used in order to compare countries according to the efficiency of their municipal waste management system in an environmental context. Such assessment entails combining the components into one summarizing measure and taking into account the impact of these components on the environment at the same time. The ranking of the countries revealed that higher efficiency is found in the more economically developed countries of the European Union even though the amount of municipal waste generated in them is higher too. It also became apparent that as it grew, the efficiency gradually decreased.

**Received:** January, 2022
**1st Revision:** September, 2022
**Accepted:** December, 2022

DOI: 10.14254/2071-8330.2022/15-4/4

**Keywords:** generated municipal waste, efficiency of their management systems, environmental protection, multi-criteria methods.

**JEL Classification:** Q53, Q56, Q57.

## 1. INTRODUCTION

Europe, like other continents of the world, has been facing increasingly acute environmental problems in recent decades (Csikosova et al., 2022). The strategy of the European Green Deal was formed in the context of these challenges (Implementation of the European Green Deal, 2020). This is a timely and necessary response to further sustainable economic growth.

The OECD Green Growth the database includes member states and acceding countries, key partners (Brazil, China, India, Indonesia, South Africa), and other select non-OECD countries. It provides green growth monitoring indicators, thus helping to shape policies for further development and informing the general public about ongoing changes. This database devotes significant attention to performance evaluation indicators of non-energy materials, many of which reflect the situation related to the generated municipal waste (GMW). This is not by chance. Economic development of countries is impossible without an increase in the scale of production, turnover of goods and services provided, etc. However, this causes unwanted consequences like the increase in the amount of both industrial and municipal waste (Budică et al., 2015; Slusarczyk and Kot, 2018). Their scale largely depends on the country's situation and, above all, on the achieved level of economic development. The European Union (EU) consists of countries with significant differences in their development (Halaskova et al., 2022). For example, Ireland's Gross Domestic Product per capita (GDP) in 2019 was 8.2 times higher than Bulgaria's, 5.4 times higher than Croatia's, and Denmark – 6.1 and 4.0 times, respectively (Eurostat, 2020).

Although being part of the EU opened up faster development opportunities for less economically developed countries, the unequal level of economic development "gave birth" to contradictory trends in the management of generated municipal waste. 2009–2018 during the period in the ten most economically developed countries, the amount of GMW, measured in kilograms per inhabitant, increased by an average of 14 percent, while in the rest, i.e. in less developed countries, this indicator increased by half – 7.6 percent. (Implementation of the European Green Deal, 2020). On the other hand, thanks to greater opportunities, developed countries throw significantly less waste into landfills. Faster economic development of the less developed EU countries was accompanied by growing amounts of generated municipal waste. The existing systems for their management (MSGMW) could not ensure their efficient management, so most of them were sent to landfills – seven times more compared to developed EU countries.

The damage caused by municipal waste is primarily manifested in the impact on nature. Its scale depends exclusively on the structural capabilities of MSGMW, since the impact of individual waste management methods on nature is not the same. In this sense, two ways can be distinguished – GMW recycling and secondary use, which consolidate the strategy of green growth, as well as disposal to landfills. From their ratio, it is possible to judge the efficiency of MSGMW functioning. Looking to the future, there should be no landfilling of GMW at all. On the other hand, from an environmental point of view, the first way is also not ideal, because even in this case part of the pollution enters the atmosphere in the form of gases.

The purpose of the article is to evaluate the functioning efficiency of the municipal waste management system in the EU countries in the context of green growth. In order to achieve it, the following tasks will be solved: first, the impact of the countries' economic development on the structure of MSGMW is determined; secondly, the effectiveness of MSGMW functioning is evaluated.

The first part of the article reviews the scientific articles on the management of GMW; in the second part – the methodology of quantitative assessment of the efficiency of MSGMW functioning in the context of green growth is presented; in the third part – the results of the calculations made according to this methodology for the EU countries. The discussion discusses the possibilities of further increasing the efficiency of MSGMW functioning.

## 2. LITERATURE REVIEW

The problem of municipal waste management has been studied in many literature sources for a number of years, so it is appropriate to carry out their analysis based on the latest publications, since they integrate the results of previously conducted research. In order for it to be purposeful, it is appropriate to highlight its characteristic aspects. The first could be the stages of formation of GMW. Based on this, it is possible to distinguish studies that examine the factors of municipal waste generation and those that analyze waste management issues. The second aspect of the analysis is the system of indicators reflecting the management of GMW and the possibilities of increasing their efficiency. The third aspect is the methods of analysis of municipal waste management.

A study for Italy examines the factors influencing GMW collection (Romano et al., 2022). These factors are important environmental performance indicators that largely reflect the efficiency of the waste management system. The analysis is based on data from 103 regions of the country for the years 2007–2016. Applying correlation-regression analysis, important social and economic factors that characterize the quality of life are distinguished. It was found that the higher the average income of people, the longer life expectancy, the higher the number of educated people and the percentage of women working in municipalities, the better the rate of collection of sorted municipal waste. As the number of household members increases; for the youth employment rate; for the total amount of waste per capita; for the amount of GMW taken to the landfill, the amount of sorted waste collection decreases. It is concluded that municipal waste service managers and policy makers need to implement different strategies to achieve more effective environmental goals while improving people's quality of life. These measures are important due to the high significance of the ecological factors of well-being in quality of life perception (Tvaronavičienė et al., 2021) which steadily increase due to customers' responsibility growth and development of the environmental protection practices of enterprises consequently (Piwowar, 2020; Zielińska, 2020).

A separate direction of research is the analysis of articles devoted to the indicators of the municipal waste management system. They are examined in relation to sustainable growth, circular economy, investment decisions, public participation, etc. When linking the set of indicators to sustainable growth, three groups of indicators are distinguished, reflecting economic, social and environmental aspects (Deus et al., 2019; Waste-related indicators, 2020; Bastos et al., 2019; Stasiukynas et al., 2020). Particular attention is paid to the latter dimension. Indicators reflecting economic growth are designed to estimate the costs of development, maintenance and operation of municipal solid waste management systems. The environmental dimension is reflected by the following indicators: energy, the total amount of generated waste, the share of incinerated, recycled or composted and landfilled waste in their total volume. Basically, these are the OECD Green Growth Indicators. It is noted that the indicators reflecting the social dimension of sustainable growth have only just begun to be developed and therefore there are still few studies dedicated to this.

GMW management and energy consumption are emphasized, i.e. their combined impact on environmental performance and economic well-being. Such analysis was conducted in the United States (Guoyan et al., 2022). 1990–2018 on analyzed period. 2005-2020 period was analyzed by Moore et al. (2022).

Another study reviews articles dealing with GMW management systems (Sanjeevi, Shahabudeen, 2015). Indicators reflecting them are again distinguished and practical management methods based on them are proposed. This study is relevant due to the fact that waste management both in the country as a whole and in its cities is becoming more and more complicated, while the funds allocated for it are decreasing. In the study, the management areas of GMW are divided into 18 groups. One of them is performance indicators. Historically, the analysis of such indicators began in 1969. Later, several comparative studies were conducted. Starting in 1990 definitions of these indicators have been analyzed. In almost all cases, they are evaluated on the basis of investment decisions, the level of public acceptance, social participation and satisfaction of environmental needs. The offered indicators differ in their complexity, while simple ones are needed for practical use, i.e. understandable and easy to apply. Based on this, the authors of the study, taking into account the requirements of simplicity and complexity of the indicators, distinguish five performance indicators of the factors. It is indicated in which directions further research should take place in order to reduce the costs of managing GMW, better meet the needs of citizens, and involve people's communities wider. All this should reduce the impact of GMW management on the environment.

Evaluating municipal waste management as an important service, in order to connect it more and more with the circular economy, attempts are being made to offer new, more perfect methodologies for solving this problem, which foresee a new approach to waste, its management and related economic development (Whiteman et al., 2021; Zhidebekkyzy et al., 2022). The study presents a new conceptual framework based on global waste management theory. A roadmap is provided to allow a country or city to determine its current position and plan for further development. The nine stages are described, taking into account today's challenges and opportunities. The first four reflect incremental improvement towards the Sustainable Development Goals. Based on them, countries can choose ways to move to environmentally friendly waste management and handling in accordance to the 3R principle (reduce, reuse, recycle). The goal is to reach "Zero Waste" level. For this purpose, targeted management technologies are proposed, which include institutional reform, suitable and practically implemented GMW management systems, as well as adaptation of the decisions adopted for this purpose to different local needs and real conditions.

Another direction of research is the analysis of possibilities to increase the efficiency of GMW management systems (Freire-González et al., 2022). It is based on the premise that waste incineration and landfill taxation can significantly reduce pollution and the environmental impact of resource use. This is due to the fact that in this case, on the one hand, the amount of pollutants decreases, and on the other hand, the reuse and recycling of materials increases. At the same time, the scale of the circular economy is growing. A study carried out in Spain aims to assess the impact of GMW burning and landfill taxation on the country's economy and ecology. The impact is analyzed under different scenarios. The greatest attention is paid to the impact on the Gross Domestic Product per inhabitant; production sectors and the environment. The impact on the environment is analyzed differentiated – global warming, marine eutrophication potential, photochemical ozone formation potential, particulate matter formation, ecotoxicity and fossil resource use. All scenarios produced the same results – the mentioned taxes have only a limited economic impact. On the other hand, they reduce the environmental impact of all analyzed categories. This study supported the theory that incineration and landfilling of GMW should be taxed in order to enhance their effect on economic turnover while reducing the burden on the environment.

Two methods are usually used to analyze the problem of municipal waste management - content analysis (Waste-related indicators, 2020; Sanjeevi, Shahabudeen, 2015; Whiteman et al., 2021; Činčalová, S., 2021; Teo et al., 2022) and correlation-regression analysis (Deus et al., 2019; Prymak et al., 2020; Romano et al., 2022). Other methods are used less often – the quantum method of non-parametric causality estimation (Guoyan et al., 2022), the financial balance model (Freire-González et al., 2022), etc.

The following conclusions can be made summarizing the researches devoted to the management of generated municipal waste. First, many of them examine the impact of GMW management on various aspects of countries' development. This analysis is based on indicator systems. On the other hand, it remains unclear how to combine these partial indicators into an index reflecting the overall state of GMW management in the country. Therefore, the analysis of the impact of individual indicators is limited. Without assessing the GMW management system as a whole, it is impossible to compare individual countries. Second, there are practically no studies aimed at evaluating the effectiveness of GMW management systems, especially considering the environmental context. Therefore, there are again no possibilities for comparison between countries. The aim of the article is to comprehensively assess the state of municipal waste management systems from an environmental point of view and compare the countries of the European Union with each other.

## 3. METHODOLOGY

The "consequences" of scientific and technical progress are twofold. On the one hand, it is an essential condition for the economic development of countries, on the other hand, it causes negative changes in the environment. Among others, these changes manifest themselves in the increase of both industrial and municipal waste generated. The latter are predominant. In order to analyze the impact of countries' economic development on GMW, it is necessary to determine what their management system is. Life dictated its uniform, principled structure in all countries (Figure 1).

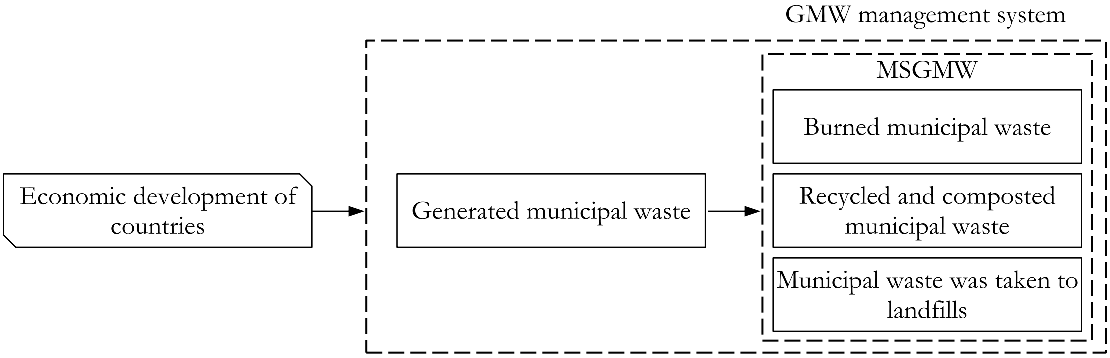


**Figure 1. The impact of countries' economic development on the municipal waste management system (MSGMW)**
*Source*: compiled by the author

From Figure 1 it can be seen that it is appropriate to perform the analysis of MSGMW functioning in two stages. First of all, it is necessary to determine the effect of the country's economic condition on the elements of GMW and MSGMW (Figure 2).

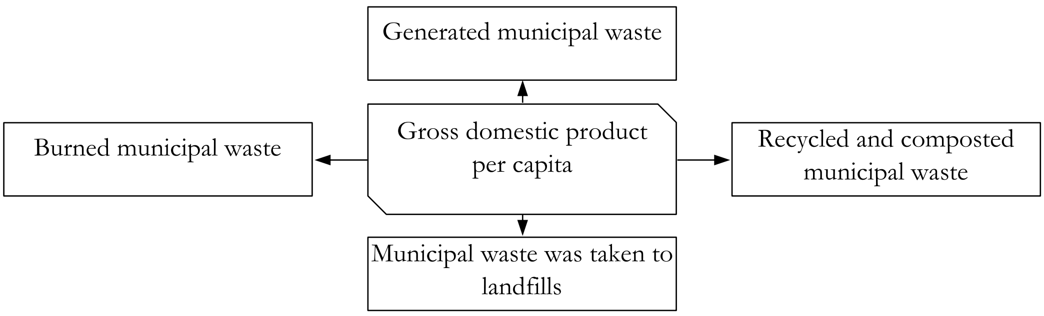


**Figure 2. Analysis model of the impact of the country's economic development on the generated municipal waste and MSGMW elements**
*Source*: compiled by the author

The next stage of the analysis is the analysis of the interaction between MSGMW elements (Figure 3).

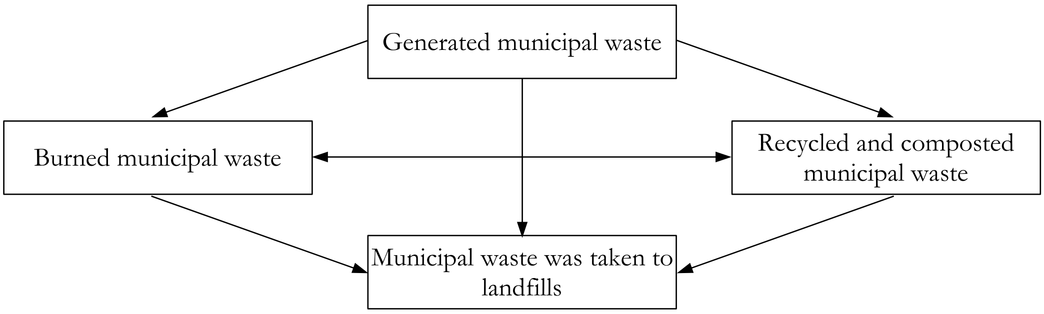


**Figure 3. Analysis model of mutual interaction between the elements of the municipal waste management system**

*Source*: compiled by the author

The first and second stages reflect the more quantitative side of the problem under consideration. The analysis will be incomplete if the functioning efficiency of the resulting municipal waste utilization system is not evaluated. It can be seen as the third final stage of the complex analysis of the problem.

In order to perform Figure 1 and 2 interactions shown, the quantities in question should be given the appropriate symbols (Table 1).

Table 1

Symbols of the resulting elements of the municipal waste management system

| Indicator | Unit of measurement | Symbol |
|---|---|---|
| Gross domestic product per capita | thousand EUR/living | GDP |
| Generated municipal waste | kg/capita | $X$ |
| Burned municipal waste | percent treated waste | $Y_1$ |
| Recycled or composted municipal waste | percent treated waste | $Y_2$ |
| Municipal waste dumped in landfills | percent treated waste | $Y_3$ |
| The efficiency of the generated municipal waste utilization system | – | $E$ |

*Source*: compiled by the author.

Both the analysis of the impact of the countries' economic development on the generated municipal waste and MSGMW elements, as well as their mutual interaction, can be performed based on the following correlation-regression analysis models:

a) the impact of the country's economic development on the generated municipal waste and MSGMW elements:

$$X_{ji} = f(BVP_j); \quad (1)$$

b) interactions between the generated municipal waste and the elements of Municipal waste utilization system (MWUS):

$$Y_{ji} = f(X_{ji}); \quad (2)$$

c) the impact of the economic development of the country and the generated municipal waste on the efficiency of MSGMW functioning:

$$E_j = f(BVP_j); \qquad (3)$$

$$E_j = f(X_{j1}); \qquad (4)$$

here, GDP is an indicator of the state of economic development of the j-th country in the considered year; $X$ – the i-th indicator of municipal waste generated by the j-th country in the considered year; $Y_{ji}$ – value of the i-th element of MSGMW of the j-th country in the considered year.

Based on Table 1, the structure of the correlation-regression analysis of the impact of the country's economic development on the generated municipal waste and MSGMW elements, as well as the interaction between these elements, will look like this (Table 2).

Table 2

The structure of the correlation-regression analysis of the impact of the state of economic development of the country on the generated municipal waste, MSGMW components, as well as their mutual interaction

| | | Function | | | |
|---|---|---|---|---|---|
| | **Indicators** | $\boldsymbol{X}$ | $\boldsymbol{Y_1}$ | $\boldsymbol{Y_2}$ | $\boldsymbol{Y_3}$ |
| Argument | GDP | ∨ | ∨ | ∨ | ∨ |
| | $X$ | | ∨ | ∨ | ∨ |
| | $Y_1$ | – | | ∨ | ∨ |
| | $Y_2$ | – | – | | ∨ |
| | $Y_3$ | – | – | – | |

*Source*: compiled by the author.

It can be seen from Table 2 that for the analysis it is necessary to know the state of economic development of the countries, as well as the values of the indicators reflecting the elements of municipal waste and MSGMW. The analysis will be performed for the year 2018 (the last year before the COVID-19 pandemic). The necessary data for it are given in Table 3.

The country's economic development indicator must meet the following requirements: reflect the essence of economic growth, people's living standards, be suitable for evaluating the structure of the economy, provide an opportunity to compare countries with each other, be adequate to the current situation, and information about it must be easily accessible.

The adequacy of this indicator largely depends on whether its complexity corresponds to the complexity of the phenomenon under consideration. There are two main ways to solve this problem. In one case, such an indicator can be taken as one of the existing indexes, which possibly better meets the mentioned requirements (Moldan et al., 2012; Brizga et al., 2014; Kozyreva et al., 2017). In the second case, it should be formed from many partial indicators that reflect the phenomenon under consideration in various aspects, after combining them in an appropriate way into a summarizing measure (Oželienė, 2019; Volkov, 2018; Gedvilaitė, 2019; McLaren et al., 1998; Molly, 2018; Strezov et al., 2017; Radovanović, Lior, 2017; Jia et al., 2017). This approach opens up wide possibilities for forming the desired complexity index. On the other hand, in such a case, one would have to face today insurmountable difficulties, which make this path only a theoretical possibility. They manifest themselves primarily in the fact that the number and structure of indicators reflecting the state of economic development of countries differ (Bolcarova, Kološta, 2015; Jia et al., 2017; Radovanović, Lior, 2017; Chursan, 2013; Babu, Datta, 2015). It is practically impossible to get information about the values of primary indicators; complex and demanding ways of combining them into a summarizing quantity, etc. (Jacquet-Lagreze, Siskos, 1982; Liu, 2009; Wu et al., 2009; Roubens, 1982).

The indicator that comes closest to the index reflecting the country's economic development is the gross domestic product per capita (GDP). Its structure is the same in all countries, so they can be compared with each other according to this feature. Information about it is regularly provided by global statistical publications such as Eurostat, etc. It is no accident that GDP is today unanimously established and used as an indicator reflecting the state of economic development of countries (Jurevičienė et al., 2020; Lisiński et al., 2020; Jędrzejczak-Gas, Barska, 2019; Kozyreva et al., 2017; Shkolnyk et al., 2021; Prokopchuk et al., 2022). It is also used in this study.

Solving the problem of municipal waste depends both on how much it is generated and on how efficiently the waste management system functions. In order to determine this, first of all, it is necessary to define the meaning of the efficiency of its functioning. Various types of efficiency are mentioned in scientific sources, but the following are usually distinguished: allocative, dynamic and technological (Kukhta, Dorogan, 2015; Zofio et al., 2013; Suseata et al., 2016; Masunda et al., 2021). Allocative efficiency is the maximum return obtained with available limited resources; dynamic is achieved when changes occur quickly and at the right time; technological or technical means the complete absence of loss in the appropriate use of available resources. In recent years, there has been talk about another type of efficiency – ecological efficiency (Lukaševičius et al., 2005). It could be understood as the functioning of MSGMW that pollutes the environment the least.

The efficiency of the resulting municipal waste management system, which does not meet environmental requirements, can be determined by comparing the amount of waste sent to the landfill with the amount burned, recycled or composted. In order to assess the above-mentioned requirements, the indicators reflecting the existing MSGMW structure need to be transformed in such a way that the damage caused to the environment is assessed. If we conditionally equate it to a unit, then it can be distributed among all three components of the system in an appropriate way:

$$P = \omega_d + \omega_p + \omega_s = \sum_{i=1}^{n} \omega_i = 1.0, \quad (5)$$

here $P$ is the total environmental damage of MSGMW components; $\omega_i$ – environmental impact of the $i$-th MSGMW component ($i = \overline{1,n}$, $n$= 3); $\omega_d$– environmental impact of incinerated municipal waste; $\omega_p$ – the same, recycled or composted; $\omega_s$ – the same, taken to the landfill.

Size $\omega_i$ values can be determined by experts. Knowing them, the efficiency of MSGMW functioning, which evaluates the environmental context, can be calculated in the following way:

a) if $W_{jd} + W_{jp} > W_{js}$: (6)

$$E_j = 1 - \frac{\omega_s W_{js}}{\omega_d W_{jd} + \omega_p W_{jp}}; \quad (7)$$

b) if $W_{jd} + W_{jp} < W_{js}$: (8)

$$E_j = 1 - \frac{\omega_d W_{jd} + \omega_p W_{jp}}{\omega_s W_{js}}, \quad (9)$$

here $E_j$ – the functioning efficiency indicator of the MSGMW of the $j$-th country; $W_{jd}$ – indicator of the amount of incinerated waste of the $j$-th country; $W_{jp}$ – the same, recycled or composted; $W_{js}$ – the same, taken to the landfill.

If $E_j > 0$, it means that MSGMW functions efficiently, since less municipal waste is taken to the landfill than is burned, processed or composted; if $E_j < 0$, it means that MSGMW functions inefficiently, more municipal waste is taken to the landfill than is burned, processed or composted.

Calculating the indicator $E$, the countries under consideration can be grouped according to the efficiency of their MSGMW functioning.

## 4. EMPIRICAL RESULTS AND DISCUSSION

The empirical study was based on data on the gross domestic product per capita of the countries of the European Union, data on the performance of non-energy materials for green growth (Table 3), as well as an expert assessment of the environmental impact of MSGMW components (Table 4).

Table 3

Gross domestic product per capita of European Union countries, green growth performance of non-energy materials in 2018 and calculation results

| Row No. | Country | Indicators | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | GDP, thousand euros | Generated municipal waste, kg/inhabitant ($X$) | Incinerated municipal waste, % of treated waste ($Y_1$) | Processed, composted GMW, % of treated waste ($Y_2$) | GMW thrown into the landfill, % of treated waste ($Y_3$) | MSGMW functioning efficiency ($E$) | Ranks | |
| | | | | | | | | Forming GMW | MSGMW functioning efficiency |
| 1. | Austria | 43.6 | 576 | 39 | 59 | 2.0 | 0.95 | 18 | 7 |
| 2. | Belgium | 40.2 | 409 | 43 | 55 | 1.0 | 0.98 | 6 | 5.5 |
| 3. | Czech Republic | 19.5 | 350 | 17 | 34 | 49.0 | -0.40 | 2 | 15 |
| 4. | Denmark | 52.0 | 771 | 51 | 48 | 0.9 | 0.98 | 22 | 4 |
| 5. | Estonia | 19.7 | 405 | 44 | 30 | 23.0 | 0.38 | 4 | 12 |
| 6. | Finland | 42.5 | 551 | 57 | 42 | 0.7 | 0.98 | 17 | 1.5 |
| 7. | France | 35.0 | 527 | 35 | 44 | 21.0 | 0.38 | 16 | 11 |
| 8. | Germany | 40.3 | 614 | 31 | 67 | 0.2 | 0.99 | 20 | 1 |
| 9. | Greece | 17.2 | 525 | 1 | 21 | 78.0 | -0.89 | 15 | 22 |
| 10. | Hungary | 13.7 | 384 | 13 | 37 | 49.0 | -0.65 | 3 | 18 |
| 11. | Ireland | 66.7 | 604 | 43 | 38 | 15.0 | 0.60 | 19 | 9 |
| 12. | Italy | 29.2 | 498 | 21 | 55 | 24.0 | 0.10 | 12 | 13 |
| 13. | Latvia | 13.0 | 407 | 2 | 29 | 68.0 | -0.88 | 5 | 21 |
| 14. | Lithuania | 15.1 | 464 | 14 | 59 | 27.0 | -0.15 | 9 | 14 |
| 15. | Luxembourg | 98.6 | 614 | 44 | 50 | 6.0 | 0.86 | 21 | 8 |
| 16. | Holland | 44.9 | 516 | 43 | 56 | 1.0 | 0.98 | 14 | 5.5 |
| 17. | Poland | 16.2 | 329 | 24 | 34 | 42.0 | -0.43 | 1 | 16 |
| 18. | Portugal | 19.8 | 511 | 19 | 30 | 51.0 | -0.61 | 13 | 17 |
| 19. | Slovakia | 16.5 | 413 | 8 | 36 | 55.0 | -0.75 | 7 | 20 |
| 20. | Slovenia | 22.1 | 485 | 13 | 75 | 12.0 | 0.54 | 11 | 10 |
| 21. | Spain | 25.7 | 476 | 13 | 36 | 51.0 | -0.66 | 10 | 19 |
| 22. | Sweden | 47.3 | 440 | 54 | 46 | 0.7 | 0.99 | 8 | 1.5 |

*Source*: compiled by the author based on Eurostat, 2020; European Green Course, 2020.

Table 4

Results of the expert assessment of the environmental impact of MSGMW components

| MSGMW components | The generated municipal waste is burned | Recycled or composted generated municipal waste | The generated municipal waste was taken to landfills | Total |
|---|---|---|---|---|
| Environmental impact assessment of MSGMW components | 0.325 | 0.125 | 0.550 | 1.0 |

*Source*: compiled by the author

Based on Figures 2 and 3, as well as Tables 2, 3 and 4, in the first stage, a complex correlation-regression analysis of the functioning of the municipal waste management system of the European Union countries was performed. Its results are given in Table 5.

Table 5

Results of the correlation-regression analysis of the functioning of the municipal waste management system of the European Union countries

| Research block | Model | The equation | value of the correlation coefficient *r* | Student's criterion *t* value | |
|---|---|---|---|---|---|
| | | | | actual | critical |
| I | $Y_1 = f(BVP)$ | $Y_1 = 351.493 - 4590BVP$ | 0.702 | 4.299 | 2.080 |
| | $Y_2 = f(BVP)$ | $Y_2 = 0.702 + 0.765BVP$ | 0.799 | 5.143 | 2.110 |
| | $Y_3 = f(BVP)$ | $Y_3 = 22.043 + 0.642BVP$ | 0.675 | 3.545 | 2.110 |
| | $Y_4 = f(BVP)$ | $Y_4 = 46.573 - 0.666BVP$ | –0.574 | 3.057 | 2.080 |
| II | $Y_4 = f(Y_1)$ | $Y_4 = 86.770 - 0.128Y_1$ | –0.597 | 3.245 | 2.080 |
| | $Y_4 = f(Y_2)$ | $Y_4 = 61.202 - 1.222Y_2$ | –0.853 | 7.314 | 2.074 |
| | $Y_4 = f(Y_3)$ | $Y_4 = 82.492 - 1.276Y_3$ | –0.713 | 4.546 | 2.074 |
| III | $Y_2 = f(Y_1)$ | $Y_2 = -9.394 + 0.080Y_1$ | 0.506 | 2.557 | 2.080 |
| | $Y_3 = f(Y_1)$ | $Y_3 = 12.400 + 0.065Y_1$ | 0.484 | 2.280 | 2.093 |
| IV | $Y_3 = f(Y_2)$ | $Y_3 = 38.286 + 0.203Y_2$ | 0.254 | 1.174 | 2.074 |
| V | $E = f(BVP)$ | $E = 4.602 + 0.118BVP$ | 0.449 | 2.132 | 2.086 |

*Source*: compiled by the author

As can be seen from Table 4, the correlation-regression analysis consists of five blocks: the impact of countries' economic development on GMW, as well as on the components of their management system; the dependence of the amount of waste transported to the landfill on GMW and the components of their management system; dependence of the amount of incinerated and recycled GMW on their total amount; the interdependence of incinerated and recycled or composted GMW, as well as the dependence of the functioning efficiency of GMW on the country's economic development.

The results of the calculations show that the dimensions of both the GMW and the components of their management system largely depend on the level of economic development achieved by the country (research block I) – these dimensions are larger, the higher this level is. On the other hand, as the amount of GMW increases, less of it is taken to landfills.

From the results of the second block of research, it can be seen that as the scale of both GMW and their management system components increases, the amount of waste transported to landfills decreases.

A rather strong dependence of the amount of incinerated and recycled or composted GMW on their total amount has been established – as it grows, the scale of the above-mentioned components increases.

Amounts of incinerated and recycled or composted GMW. This means that the development of these MSGMW components is not taking place at the expense of each other, but at the expense of reducing the amount of GMW sent to landfills.

A sufficiently strong positive relationship between the state of economic development of the countries and the ecological efficiency of MSGMW functioning has been established.

Table 3 shows that in nine countries, the amount of waste disposed of in landfills exceeded the amount of waste incinerated and recycled or composted, so the sign of the efficiency indicator is negative. Table 3 also gives the rankings of the countries both according to the amount of GMWs formed and according to the efficiency of MSGMW functioning. Based on the model of correlation-regression analysis, $E_j = f(X_{j1})$ the relationship between these two quantities was established. It is not strong (r = –0.213), but it reveals a general trend that, as the amount of generated municipal waste increases, the efficiency of MSGMW functioning decreases. This means that the MSGMW of the countries are unable to efficiently manage the growing amount of municipal waste.

Based on Table 3, the countries under consideration can be grouped according to the amount of municipal waste generated in them and the efficiency of MSGMW functioning. The division of countries into two groups is chosen. In this case, the interval sizes can be set as follows:

$$h = \frac{R_{\max} - R_{\min}}{2}, \tag{11}$$

here h is the size of the interval; $R_{\max}$ and $R_{\min}$ are the highest and lowest country ranks, respectively.

Based on formula (11), the following ranges of country groups were obtained (Table 6).

Table 6

Intervals for the grouping of countries according to the functioning efficiency of GMW and MSGMW

| Interval number | Intervals | | | |
|---|---|---|---|---|
| | generated municipal waste | | MSGMW functioning efficiency | |
| | from | until | from | until |
| first | 329 | 550 | 1 | 11.5 |
| Second | 550 | 771 | 11.5 | 22.0 |

*Source*: compiled by the author

It is convenient to group countries in the form of a matrix. The results are given in Table 7.

From Table 7, it can be seen that large amounts of GMW, but high ecological efficiency of the functioning of their management system, are characteristic of highly economically developed countries. Meanwhile, the economically developing EU countries are characterized by a small amount of GMW, but also a small ecological efficiency of the functioning of their management system

Table 7

Grouping of the countries of the European Union according to the amount of generated municipal waste and the efficiency of its management in an environmental context

| | | Amount of generated municipal waste | |
|---|---|---|---|
| | | small | big |
| The efficiency of the functioning of the generated municipal waste management system | big | Belgium<br>Sweden | Austria<br>Denmark<br>Finland<br>Germany<br>Ireland<br>Luxembourg<br>Holland<br>France |
| | small | Czech Republic<br>Estonia<br>Hungary<br>Latvia<br>Lithuania<br>Poland<br>Slovakia<br>Spain | Greece<br>Italy<br>Slovenia |

*Source*: compiled by the author

The world's attention to waste management is constantly growing. The main debate that is taking place today is the method of their processing: whether to incinerate, or to recycle and reuse, or to dump in landfills. In most EU countries, incinerated and recycled or composted waste prevails. For example, in such a small country as Lithuania, as many as three powerful cogeneration power plants have been built. Opinions about this way of solving the waste problem differ. Despite the fact that it is unequivocally better than landfills, it is argued that power plants are not the best solution either. Their construction costs hundreds of millions of euros, so countries where this path prevails are not interested in developing other ways of waste management. Proponents of the power plants claim that heat and energy are produced here from the waste left after sorting, i.e. apart from those that can be recycled. In addition, they cover a large part of the heat and energy needs of cities.

The biggest disadvantage of cogeneration power plants, besides the high price, is the negative impact on the environment. It is argued that they do not contribute to solving the problems of climate change and non-recyclable waste. This is because burning them is a carbon-intensive process. It is argued that this way of recycling waste is more harmful than helpful in the transition to a circular economy. In order to implement the ambitious goal set by the EU – by 2050 Achieving CO2 neutrality requires rapid and decisive changes, which will be difficult to achieve with waste incineration. On the other hand, today there are no technologies without flaws, so CO2 emissions need to be looked at in a complex way, i.e. it needs to be seen in its full context. The engine of economic development of countries today is energy. In this sense, cogeneration plants are not much different from other fuel-burning devices. Meanwhile, the energy sector is one of the main sources influencing CO2 emissions in industry.

Two conflicting issues emerge from the situation discussed. On the one hand, burning waste, regardless of strict air pollution requirements, inevitably releases poisonous gases into the atmosphere – not only CO2, but also various dioxins, phorans, etc. The problem could be solved by reducing the scale of this waste processing method and developing more advanced ones – prevention of their formation, secondary processing and utilization. Opponents propose exactly these paths. On the other hand, without criticizing the recycling of waste by incineration, they do not provide any concrete proposals on how to reduce the problem of not only waste incineration, but also the problem of burial in landfills. Waste incinerators say the goal of cogeneration is to solve problems now, not to wait for new environmentally friendly technologies to be developed decades from now. Landfills are a much worse alternative to climate change because they emit methane, which is ten times more dangerous than CO2. Moreover, if it were decided to reduce or stop using waste incinerators, many countries would face two problems at once. First, where to get energy from and second, how to manage waste that cannot be recycled. Biofuels, renewable energy sources would not cover the energy shortage today. Thus, the strategic way of solving the problem of waste management is, first of all, its prevention and secondary use. To that end, waste sorting should be addressed in the first place. Industrial companies can solve this more simply, the biggest problem is with municipal waste.

## 5. CONCLUSION

The management of generated municipal waste occupies an important place in the Green Growth Strategy. This is because the economic development of countries is accompanied by an increasing number of them, so it depends on the achieved level of economic development of the country. This was confirmed by the conducted research – in the ten most economically developed countries of the European Union, 1.33 times more municipal waste is generated compared to ten developing countries. On the other hand, in the countries of the first group, 9.4 times less is taken to landfills than in the countries of the second group.

In order to increase the efficiency of emerging municipal waste management systems, the following tasks need to be solved: first, a comprehensive assessment of the current state; second, to relate this assessment to the environmental impact of their components. Such assessment can be done based on multi-criteria methods. The resulting index allows countries to compare with each other. The ranking of countries carried out in this way revealed a regularity: developed EU countries are characterized by a large amount of generated municipal waste, but on the other hand, by a high ecological efficiency of the functioning of their management systems. In less developed countries, the picture is reversed – smaller amounts of generated municipal waste, but also a low efficiency of the functioning of their management system. The study revealed another trend – as the amount of this waste grows, the efficiency of their management systems decreases. This means that due to various reasons (financial, administrative, managerial, etc.), their processing is lagging behind.

The object of further research into the management of generated municipal waste should first of all be its prevention and secondary use based on advanced technologies. Waste sorting is closely related to this.

## REFERENCES

Babu, S., & Datta, S. (2015). Revisiting the link between socio-economic development and environmental status indicators focus on panel data. *Environmental Development and Sustainability, 17*(3), 567-586. doi:10.1007/s10668-014-9561-6

Bastos, J., Garcia, R., & Freire, F. (2019). Indicators for waste prevention and management Measuring circularity. University of Coimbra. https://www.urbanwins.eu/wp-content/uploads/2019/05/d2.3-Indicators-for-waste-prevention-and-management.pdf

Bolcarova, P., & Kološta, S. (2015). Assessment of sustainable development in the EU27 using aggregated SD index. *Ecological Indicators, 48*, 699-705. http://dx.doi.org/10.1016/j.ecolind.2014.09.001

Brizga, J., Mishchuk, Z., & Golubovska-Onisimova, A. (2014). Sustainable consumption and production governance in countries in transition. *Journal of Cleaner Production, 63*, 45-53. https://doi.org/10.1016/j.jclepro.2013.06.011

Budică, I., Busu, O. V., Dumitru, A., & Purcaru, M. -. (2015). Waste management as commitment and duty of citizens. *Polish Journal of Management Studies*, 11(1), 7-16

Csikosova, A., Culkova, K., Janoskova, M., Mokrisova, V. (2021). Evaluation of Environmental Taxes Influence to the Business Environment. *Montenegrin Journal of Economics*, 17(3), 31-40.

Chursan, S. (2013). Assessing the Sustainable Development in Thailand. Procedure. *Environmental Sciences, 17*, 611-619. https://doi.org/10.1016/j.proenv.2013.02.077

Činčalová, S. (2021). The impact of the level of corporate social responsibility on financial performance: Evidence from insurance firms in the Czech Republic. *Insurance Markets and Companies, 12*(1), 64-71. doi:10.21511/ins.12(1).2021.06

Deus, R.M., Bezerra, B.S., & Battistelle, R.A.G. (2019). Solid waste indicators and their implications for management practice. *International Journal of Environmental Science and Technology, 16*, 1129-1144. https://doi.org/10.1007/s13762-018-2163-3

Freire-González, J., Martinez-Sanchez, V., & Puig-Ventosa, I. (2022). Tools for a circular economy: Assessing waste taxation in a CGE multi-pollutant framework. *Waste Management, 139*, 50-59. https://doi.org/10.1016/j.wasman.2021.12.016

Gedvilaitė, D. (2019). The assessment of sustainable development of a country's regions. Doctoral dissertation. *Vilnius: Technika*. http://dspace.vgtu.lt/bitstream/1/3797/1/Gedvilaite%20 dissertation%2005%2016nn.pdf

Guoyan, S., Khaskheli, A., Raza, SA et al. (2022). Nonlinear impact of municipal solid waste recycling and energy efficiency on environmental performance and economic growth: evidence from non-parametric causality-in-quantiles. *Environmental Science and Pollution Research, 29*, 16066-16081. https://doi.org/10.1007/s11356-021-16721-1

Halaskova, R., Halaskova, M., Gavurova, B., Kocisova, K. (2022). The Local Governments Efficiency in the EU Countries: Evaluation by Using the Data Envelopment Analysis. *Montenegrin Journal of Economics*, *18*(1), 127-137. DOI: 10.14254/1800-5845/2022.18-1.10

Implementation of the European Green Deal. (September 17, 2020). www.europa.eu

Jacquet-Lagreze, E., & Siskos, J. (1982). Assessing a set of additive utility functions for multicriteria decision-making, the UTA method. *European Journal of Operational Research, 10*(2), 151-164. https://doi.org/10.1016/0377-2217(82)90155-2

Jędrzejczak-Gas, J., & Barska, A. (2019). Assessment of the Economic Development of Polish Regions in the Context of the Implementation of the Concept of Sustainable Development - Taxonomic Analysis. *European Journal of Sustainable Development, 8*(5), 222-233. https://doi.org/10.14207/ejsd.2019.v8n5p222

Jia, X., Foo, D.C.Y., Tan, R.R., & Li, Z. (2017). Sustainable development paths for resource-constrained process industries. Resources. *Conservation and Recycling, 119*, 1-13. https://doi.org/10.1016/j.resconrec.2016.11.004

Jurevičienė, D., Skvarciany, V., & Lagunavičiūtė, A. (2020). Factors influencing individuals' decision-making and causing financial crisis. *Journal of Business Economics and Management, 21*(4), 1149-1164. https://doi.org/10.3846/jbem.2020.12890

Kozyreva, O., Sagaidak-Nikituk, R., & Demchenko, N. (2017). Analysis of the Socio-Economic Development of Ukrainian Regions. *Baltic Journal of Economic Studies, 3*(2), 51–58. https://doi.org/10.30525/2256-0742/2017-3-2-51-58

Kukhta, K.O., & Dorogan, L.O. (2015). A DEA - analysis as method of estimation of efficiency of production is on agricultural enterprises. *Economy of AIC, 10*, 93-104.

Lisiński, M., Augustinaitis, A., Nazarko, L., & Ratajczak, S. (2020). Evaluation of dynamics of economic development in Polish and Lithuanian regions. *Journal of Business Economics and Management, 21*(4), 1093-1110. https://doi.org/10.3846/jbem.2020.12671

Liu, P. (2009). Multi-attribute decision-making method research based on interval vague set and TOPSIS method. Technological and economic development of economy. *Baltic Journal on Sustainability, 15*(3), 453-463. https://doi.org/10.3846/1392-8619.2009.15.453-463

Lukaševičius, K., Martinkus, B., & Piktys, R. (2005). Business economics. Kaunas: KTU publishing house Technology.

Masunda, S., & Choga, I. (2021). Impact of trade liberalization on technical efficiency of mining sector: A case of selected SADC countries. *Problems and Perspectives in Management, 19*(4), 362-374. https://doi.org/10.21511/ppm.19(4).2021.29

McLaren, D., Bullock, S., & Yousef, N. (1998). *Tomorrow's world: Britain's share in a sustainable future*. London.

Moldan, B., Janousková, S., & Hák, T. (2012). How to understand and measure environmental sustainability: Indicators and targets. *Ecological Indicators, 17*, 4–13. https://doi.org/10.1016/j.ecolind.2011.04.033

Molly, K.M. (2018). Regional differences in Slovenia from the viewpoint of achieving Europe's sustainable development. *Acta Geographica Slovenia, 58*(2), 2–46.

Moore, J., Folkinshteyn, D., & Howell, J.P. (2022). The potential for exchange-traded futures on recycled materials to improve recycling efficiency. *Investment Management and Financial Innovations, 19*(3), 93-104. https://doi.org/10.21511/imfi.19(3).2022.09

Oželienė, D. (2019). Modeling the factors of a company's sustainable development. Doctoral dissertation. *Vilnius: Technika.*

Piwowar, A. (2020). Challenges associated with environmental protection in rural areas of Poland: Empirical studies' results. *Economics and Sociology, 13*(1), 217-229. https://doi.org/10.14254/2071-789X.2020/13-1/14

Prokopchuk, O., Nepochatenko, O., Malyovanyi, M., Ulyanych, Y., & Bilan, Y. (2022). Trends in the functioning of the Ukrainian insurance services market. *Insurance Markets and Companies, 13*(1), 47-65. https://doi.org/10.21511/ins.13(1).2022.05

Prymak, T., Ivchenko, L., Pohuda, N., Levchenko. V., & Trynchuk V. (2020). The peculiarities of establishing the charter air transportation: European experience in Ukraine. *Innovative Marketing, 16*(1), 43-56. doi:10.21511/im.16(1).2020.05

Radovanović, M., & Lior, N. (2017). Sustainable economic–environmental planning in Southeast Europe – beyond-GDP and climate change emphases. *Sustainable Development, 25*(6), 580–594. https://doi.org/10.1002/sd.1679

Romano, G., Lombardi, G.V., Rapposelli, A., & Gastaldi, M. (2022). The factors affecting Italian provinces' separate waste-collection rates: An empirical investigation. *Waste Management, 139*, 217-226. https://doi.org/10.1016/j.wasman.2021.12.037

Roubens, M. (1982). Preference relations on actions and criteria in multicriteria decision making. *European Journal of Operational Research, 10*(1), 51–55. https://doi.org/10.1016/0377-2217(82)90131-X

Sanjeevi, V., & Shahabudeen, P. (2015). Development of performance indicators for municipal solid waste management (PIMS): A review. Waste Management & Research: *The Journal for a Sustainable Circular Economy, 33*(12), 1052-1065. https://doi.org/10.1177/0734242X15607428

Shkolnyk, I., Ladyka, Y., Orlov, V., Aldiwani, K., & Kozmenko, Y. (2021). Balancing state budget expenditures: A case of Ukraine using the simplex method. *Public and Municipal Finance, 10*(1), 34-46. https://doi.org/10.21511/pmf.10(1).2021.04

Slusarczyk, B., Kot, S. (2018). Solution for sustainable development: Provisions limiting the consumption of disposable plastic carrier bags in Poland. *Journal of Security and Sustainability Issues*, 7(3), 449-458. doi:10.9770/jssi.2018.7.3(7)

Stasiukynas, A., Smalskys, V., Survila, A., Yermachenko, V., & Gavkalova, N. (2020). Civil participation in decision-making on waste management at the local authorities level. *Problems and Perspectives in Management, 18*(1), 438-448. https://doi.org/10.21511/ppm.18(1).2020.38

Strezov, V., Evens, A., & Evans, T.J. (2017). Assessment of the economic, social and environmental dimensions of the indicators for sustainable development. *Sustainable Development, 25*(3), 242–253. https://doi.org/10.1002/sd.1649

Suseata, A., Adams, D.C., Carter, D.R., Gonzalez-Benecke, C., & Dwivedi, P. (2016). Technical, allocative, and total profit efficiency of loblolly pine forests under changing climatic conditions. *Forest Policy & Economics, 72*, 106-114. https://doi.org/10.1016/j.forpol.2016.06.021

Teo, T. C., & Divakar, A. (2022). Voluntourism inspiring change in service of the common good: The mediating role of volunteer travelers. *Tourism and Travelling, 4*(1), 16-29. https://doi.org/10.21511/tt.4(1).2022.02

Tvaronavičienė, M., Mazur, N., Mishchuk, H., & Bilan, Y. (2021). Quality of life of the youth: assessment methodology development and empirical study in human capital management. *Economic Research-Ekonomska Istraživanja*, 1-18. DOI:10.1080/1331677X.2021.1956361

Volkov, A. (2018). Assessment of the impact of the common agricultural policy direct payments system on agricultural sustainability. Doctoral dissertation. *Vilnius: Technika.*

Waste-related indicators. (2020). Eurostat. Your key to European statistics: https://ec.europa.eu/eurostat/web/waste/data/indicators

Whiteman, A., Webster, M., & Wilson, D.C. (2021). The nine development bands: A conceptual framework and global theory for waste and development. *Waste Management & Research, 39*(10), 1218-1236. doi:10.1177/0734242X211035926

Wu, H.-Y., Tzeng, G.-H., & Chen, Y.-H. (2009). A fuzzy MCDM approach for evaluating banking performance based on Balanced Scorecard. *Expert Systems with Applications, 36*, 10135–10147. https://doi.org/10.1016/j.eswa.2009.01.005

Zielińska, A. (2020). A comparative analysis of reverse logistics implementation for waste management in Poland and other European Union countries. J*ournal of International Studies, 13*(4), 171-183. https://doi.org/10.14254/2071-8330.2020/13-4/12

Zhidebekkyzy, A., Temerbulatova, Z., & Bilan, Y. (2022). The improvement of the waste management system in kazakhstan: impact evaluation. *Polish Journal of Management Studies*, 25(2), 423-439. https://doi.org/10.17512/pjms.2022.25.2.27

Zofio, J.L., Pastor, J.T., & Aparicio, J. (2013). The directional profit efficiency measure: on why profit inefficiency is either technical or allocative. *Journal of Productivity Analysis, 40*(3), 257-266. https://doi.org/10.1007/s11123-012-0292-0