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Fulfillment of EU Goals in the Field of Waste Management through Energy Recovery from Waste

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Abstract: Is it really necessary for the more than 200 million tons of municipal waste produced by the EU to end up in landfills? Nowadays, there are many methods for using the raw materials and energy potential of waste in ways that are economical and environmentally acceptable. But first it is necessary to understand what waste is being produced, the possibilities for recycling, and the amount of waste deposited in landfills. Many studies show that, with the ever-increasing standard of living, which is accompanied by increasing consumption as well as increasing waste production, increasing separation of waste is a positive trend. However, it is essential to realize that many materials cannot be recycled indefinitely. Therefore, in our research, we focused on reducing the share of waste that goes into landfill with the goal of zero waste to landfill, so as to increase recycling and the amount of energy obtained from waste. We focused on the analysis of waste production in individual EU states, using the available data for the years 1995–2019. For a more detailed analysis, EU countries were evaluated in terms of individual waste management processes, according to available statistical data. We found that Switzerland, Germany, Sweden, Belgium, the Netherlands, Norway, Denmark, and Austria put the least amount of waste into landfills, which means that they obtain the most energy and raw materials from waste.

Keywords: municipal waste; waste management; European Union; energy recovery; circular economy

Citation: Tauš, P.; Šimková, Z.; Cehlár, M.; Krajňáková, I.; Drozda, J. Fulfillment of EU Goals in the Field of Waste Management through Energy Recovery from Waste. *Energies* **2023**, *16*, 1913. https://doi.org/10.3390/en16041913

Academic Editors: Abdul-Ghani Olabi and Lorenzo Ferrari

Received: 7 December 2022
Revised: 5 January 2023
Accepted: 12 February 2023
Published: 15 February 2023

1. Introduction

Waste is an integral part of human life [1]. Its ever-increasing production is closely linked to the economic strength and rate of development of individual countries [2]. However, in the context of sustainable development, more and more studies report that our waste is not only a problem for humans but is closely linked with the lives of nonhuman creatures and the future of the Earth we share [3,4]. The move to a more sustainable society requires greater sophistication in managing waste. A traditional linear reductionist approach is unsustainable because of its lack of flexibility and long-term thinking [5]. Rather, current trends in developed countries require a more holistic management of resources, in which the loop is closed and the concept of "end-of-pipe" waste management is replaced with integrated management of resources [6]. Waste management is considered as a part of a system covering the generation, collection, and disposal of waste. This systems approach, showing its relationship to other parts of the system, is examined in the light of developing more sustainable practices. A sustainable waste management system incorporates feedback loops, is focused on processes, embodies adaptability and diverts waste from disposal [5]. Many studies dealing with waste management focus on circularity as a primary approach [7–10]. Other studies describe waste management as the collection, transport, processing, recycling or disposal, and monitoring of waste materials. A typical waste management system consists of collection, transportation, pre-treatment, processing, and final abatement of residues. The purpose of waste management is to provide sanitary living conditions, to reduce the amount of matter that enters or leaves the society, and to encourage the reuse of matter within the society [11]. Transitioning to a sustainable waste management system requires the identification and application of leverage points for effecting change. The EU has set its own objectives as part of the Europe 2020 strategy [12]. The EU aims to be a climate-neutral and resource-efficient economy by 2050, which means an economy with net zero greenhouse gas emissions [13,14]. This objective is the heart of the European Green Deal, and is aligned with the EU's commitment to global climate action under the Paris Agreement. These overall goals have been further detailed in the Circular Economy Action Plan 2.0 [15]. According to this plan, it is necessary to halve the amount of residual (non-recycled) municipal waste by 2030 [16]. In 2008, the European Parliament approved Waste Directive 2008/98/EC, which is binding on all EU countries, and the revised 2018 version needs to be implemented in waste legislation. The framework directive also introduces changes in the area of separate waste collection. Its main objective is recycling and preparing for the re-use of waste. Under the directive, by 2035, countries were to take measures that would lead to an increase in the recycling of municipal waste from households to at least 65%, and 70% for packaging waste, by 2030 [17]. Currently, several countries are approaching these European standards and requirements, not only in the area of industry, but also in the area of pricing of waste services for citizens. For years, the cost of waste management services for citizens in Western Europe has been more than three times the cost for the average Slovak. The citizens of many EU countries therefore urgently need a suitable and proven waste management system for the coming years, avoiding the unnecessary attempts that have frequently been made in the West. These countries have tended to end up with the same model—separation, recycling, energy recovery, and eco-design [18]. In addition to positive environmental consequences, the introduction of effective waste management can also bring many socioeconomic impacts, such as estimated annual savings of €72 billion, an increase in the EU waste management and recycling sector of €42 billion and the creation of 400,000 jobs by 2020, as reported by a study by the European Commission [19]. The obstacle is our consumer society, which produces more and more waste [20]. The amount of municipal solid waste is increasing faster than the rate of urbanization, and waste is the signature product of an urban lifestyle. Ten years ago, 2.9 billion urban residents each generated about 0.64 kg of municipal solid waste per capita per day, amounting to 0.68 billion tons per year. We estimate that these amounts have increased to about 3 billion residents, each generating 1.2 kg per capita per day, for a total of 1.3 billion tons per year. By 2025 this will probably increase to 4.3 billion urban residents generating about 1.42 kg per capita per day of municipal solid waste, or 2.2 billion tons per year [21]. On average, Europeans produce 481 kg of municipal waste per year [22]. Other studies show that according to statistical trends, waste generation is increasing exponentially, and by 2050 will reach a level 1.7 times that of 2017 [23].

For comparison, at present in Slovakia a huge amount of waste is not used, but rather, ends up in landfills and, in addition to the environmental burden on future generations, generates greenhouse gases with a far-reaching impact on the atmosphere. In 2020, 48% of waste in the Slovak Republic went into landfills, the share of recycling was 44%, and 8% of waste was converted energy. European legislation requires reversal of this trend by 2035, with landfill at a maximum of 10% and recycling of at least 65%, and an intermediate recycling target of 55% by 2025 accompanied by a gradual reduction in landfill use [24,25]. The rest is to be recovered as energy. This composition fulfills not only the principles of the waste hierarchy, but also the principles of the circular economy. The application of material and the recovery of energy from waste is based on the absolute minimization of waste generation. This results in the production of electricity and heat, and also the return of materials back to industry in the form of secondary raw materials. This reduces use of primary raw materials and energy, especially in the context of the fourth industrial revolution, currently under way, which is fundamentally dependent on the importation of nonrenewable and exhaustible raw material resources [26,27]. Progressive waste recovery methods include incineration/waste-to-energy, gasification, and pyrolysis, which differ in processing temperature for specific types of waste [28,29].

Although the production of waste is a negative phenomenon in society, it is a phenomenon that is associated with advanced and wealthy societies [30]. Waste can be considered the raw material of the future, and since the current level of consumption of society is a long-term growing trend, the transformation of waste management is only the beginning of an important overall transition to a circular economy [31].

In view of these facts, the effective use of waste can be seen as a new opportunity for the search for new possibilities and raw materials. One major obstacle is waste that cannot be reused, put back into circulation or otherwise prepared for reuse [32]. The interim report of the European Environment Agency assumes that the EU will not meet its target for reducing residual (non-recycled) municipal waste, which would require either a significant reduction in waste production or a sharp increase in recycling rates [33]. Therefore, in the context of the Enviro strategy and the EU's strict objectives, a move to a lower level in the waste hierarchy is necessary. In order to do so, it is necessary to understand in detail the production of waste in each country to determine its effective use. From the point of view of the circular economy, a recent interdisciplinary approach, this effective use of waste has become increasingly important in recent years [34–36], not only from an economic or ecological point of view, since recycling materials is many times cheaper than extracting them from the depths of the Earth, but also in terms of the availability of raw materials and the security of their supply [37]. We now perceive waste as a raw material, as a renewable and sustainable energy source, or even a treasure in the form of materials, energy, or other reusable raw materials. In fact, most of the waste we generate can be used again [38,39].

In the context of the downward shift in the waste hierarchy, an important indicator is the circular material use rate, which is currently at 12.8% (data from 2020) [40]. This area is equally weak on a global scale, at only about 6% [41]. At the same time, significant differences exist between individual EU member states. While some are leaders, others are near the very beginning in areas such as material and energy recovery, as well as waste recycling [42]. We evaluated the current state and trends in waste management in EU countries based on up-to-date accessible information, knowledge of technologies stemming from experience with the application of circular economy principles, an appropriate number of examples from practice, legislation, and existing analyses, and data evaluations [43,44].

In the world and in Europe, the availability of equipment for energy recovery from waste as part of the waste hierarchy preceding landfill is growing. While 455 waste-to-energy plants were operational in Europe in 2010, led by France, with 129 sites, in 2016 energy was recovered from almost 94 million tons of municipal waste at a total of 488 waste-to-energy plants [45]. Based on European as well as Slovak data, energy recovery can be considered one of the most important pillars of waste management in many individual countries. We find a direct correlation between waste generation, an increase in recycling and energy recovery, and a reduction in the share of waste going to landfill. It is appropriate to assess the environmental impacts of this method of waste management as responsibly as possible, in order to avoid any doubts about the safety, impacts and benefits of energy recovery. However, a necessary condition for the efficient use of energy obtained from waste is the combined production of electricity and heat in parallel with the use of these types of energy at the place of production. Especially in the case of heat, this tends to be the most important obstacle to the economic justification for the need to build a plant for energy recovery from waste. At a construction site, continuous heat abstraction is required, whether for technological uses (industrial enterprises, chemical plants), the site's own technological consumption, or municipal use for domestic heating. Waste-to-energy plants are a common part of urban agglomerations without increased negative impacts on the air, as this controlled energy source normally replaces the need for production of energy from fossil fuels. According to data from CEWEP (Confederation of European Waste-to-Energy Plants), 492 energy recovery plants are operated in Europe (2018 data), converting almost 96 million tons of waste into heat and electricity annually. The largest increases in the number of facilities have been in Germany (by 26) and the United Kingdom (by 17) (Figure 1).

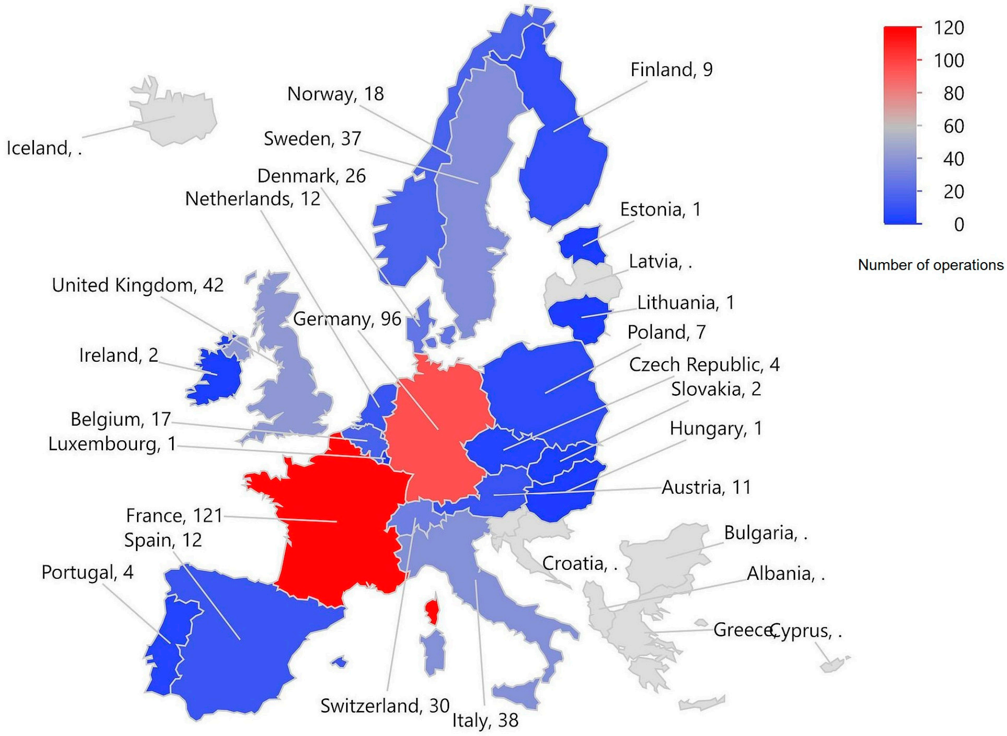


Figure 1. Waste-to-energy operations in the EU in 2018.

The Netherlands is the unequivocal leader in this area, with one facility on average processing more than 600 thousand tons of waste. The current "cleanest" waste-to-energy plant in the world is Amager Bakke, also known as Copenhill, in Denmark. The plant can process 400 thousand tons of municipal waste per year, with an electrical capacity of 0–63 MW and a heat output of 157–247 MW depending on the need for the relevant energy consumption. In 2020, due to demand, the plant processed as much as 599 thousand tons of municipal waste and supplied electricity to 80 thousand households and heat to 90 thousand apartments. Its flue gas cleaning technology captures almost 100% of NOx emissions and about 95% of dioxin and HCl emissions [46].

2. Materials and Methods

The aim of the present article was to analyze the production and management of municipal waste in EU countries, focusing on the following representative targets: the current state of waste management in the field of municipal waste; waste management; the dominant terminal equipment for waste management; and current and future capacities.

2.1. Methodology and Data Collection

We collected data at the EU level by using the selected indicators from the database at https://ec.europa.eu/eurostat/data/database (accessed on 2 December 2022), which is the portal for all available years and all available EU Member States [47]. As a first step, we recorded, sorted, and edited the collected data in a database created in MS Excel. The data were processed in a spreadsheet editor according to the requirements of the JMP 15 statistical software from © SAS Institute Inc. (Cary, NC, USA), which we also used to prepare most of our figures (Figures 3 and 7–13). The data were then modified, transferred and analyzed. The collected data present the results of eleven indicators for the period 1995–2019 (Table 1). The created database consists of 21,375 data items; each indicator is defined for a specific EU Member State and a specific year. The range of data disclosed varied significantly from one indicator to another, the volume of data depending on the completeness of country input. Data for some indicators was only published every other year. We have adapted our analysis and the formulation of our conclusions to the scope and structure of the data obtained during our research.

Table 1. Structure of data collected.

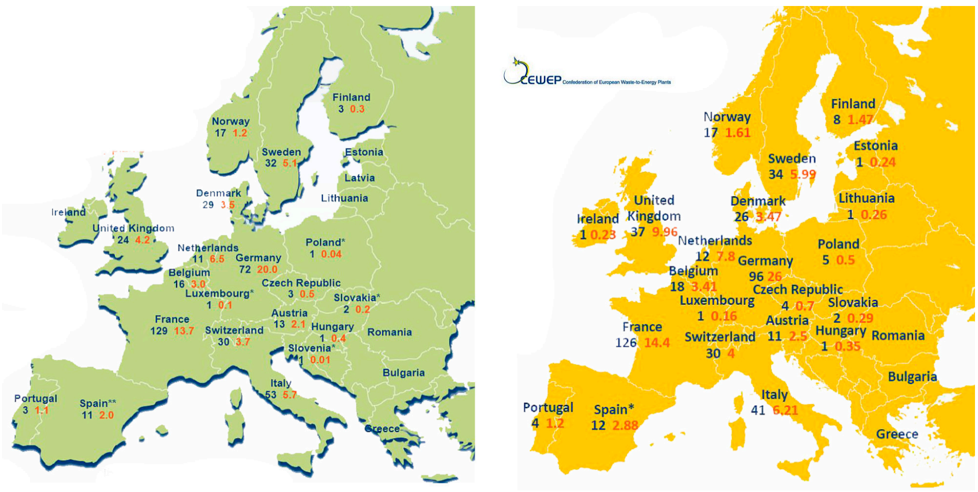
Indicator	Period
Production of municipal waste in the EU	1995–2019
Trend of municipal waste in the EU	1995–2019
Municipal waste recycling in the EU	1995–2019
Energy recovery from municipal waste in the EU	1995–2019

2.2. Data Analysis

As part of the data analysis, we focused on analyzing each indicator at the EU level. We have preserved the analytical procedure for the evaluation of each indicator under consideration. Following is a brief description of the individual steps, sub-procedures and graphical comparative outputs used. Each indicator was analyzed separately from several points of view.

Our goal was to define the evolution of the average values of the indicator for the European Union as a whole, and then to compare it with the development of individual EU countries. The trend in the development of the indicator for the whole of the European Union was analyzed using time series and mathematically expressed using a regression model.

At the same time, as part of the analysis, we compared individual states with each other, looking for differences between states in the years considered (we identified states with above-average and below-average values for the indicator compared to the European average), as well as the overall trends of individual states. The graphical analysis was carried out using cartographs (Figure 2), in which we compared the results of individual EU Member States in 2011 and again in 2016. We studied whether there was a change in the structure of countries over this 7-year timespan (Figure 2). On the cartographs (Figure 2), the number of waste-to-energy plants is marked in blue, with the quantity (in millions of tons) of waste thermally treated in waste-to-energy plants marked in red.



(**a**) Year 2011
** Includes plant in Andorra

(**b**) Year 2016
* Includes plant in Andorra and SAICA plant

Figure 2. Cartograph demonstration—energy recovery operations in the EU in 2011 and 2016.

Using a scatter chart, the indicator results were compared across countries by year. Recent periods are highlighted with black dots, making it possible to assess the trends of individual countries, as shown in the graph below (Figure 3).

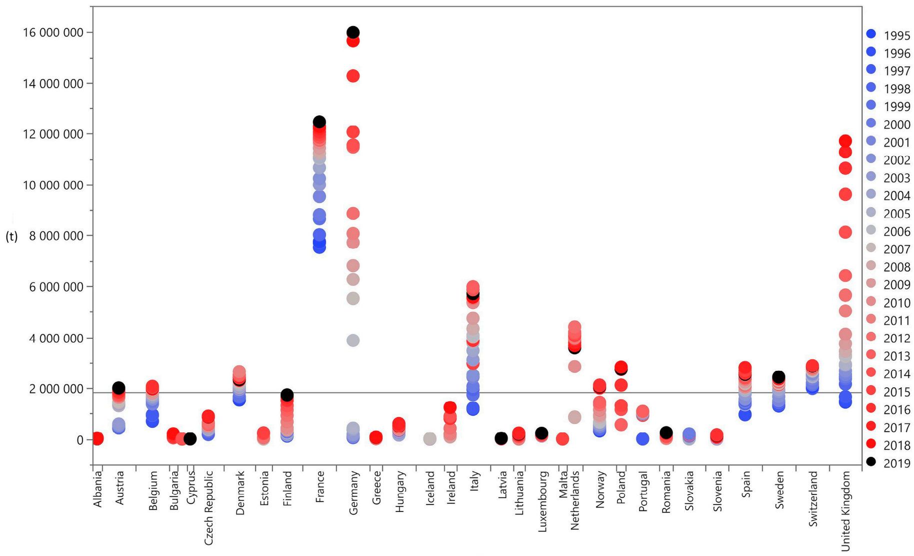


Figure 3. Sample point graph—energy recovery from municipal waste in the EU 1995–2019.

3. Results and Discussion

The unevenness of waste management in EU countries is illustrated by the following graphs, which show the proportion of waste treatment processes according to Eurostat data in 2011 and 2018 (Figure 4). Countries that reported complete data on individual processes were selected for the graphical view.

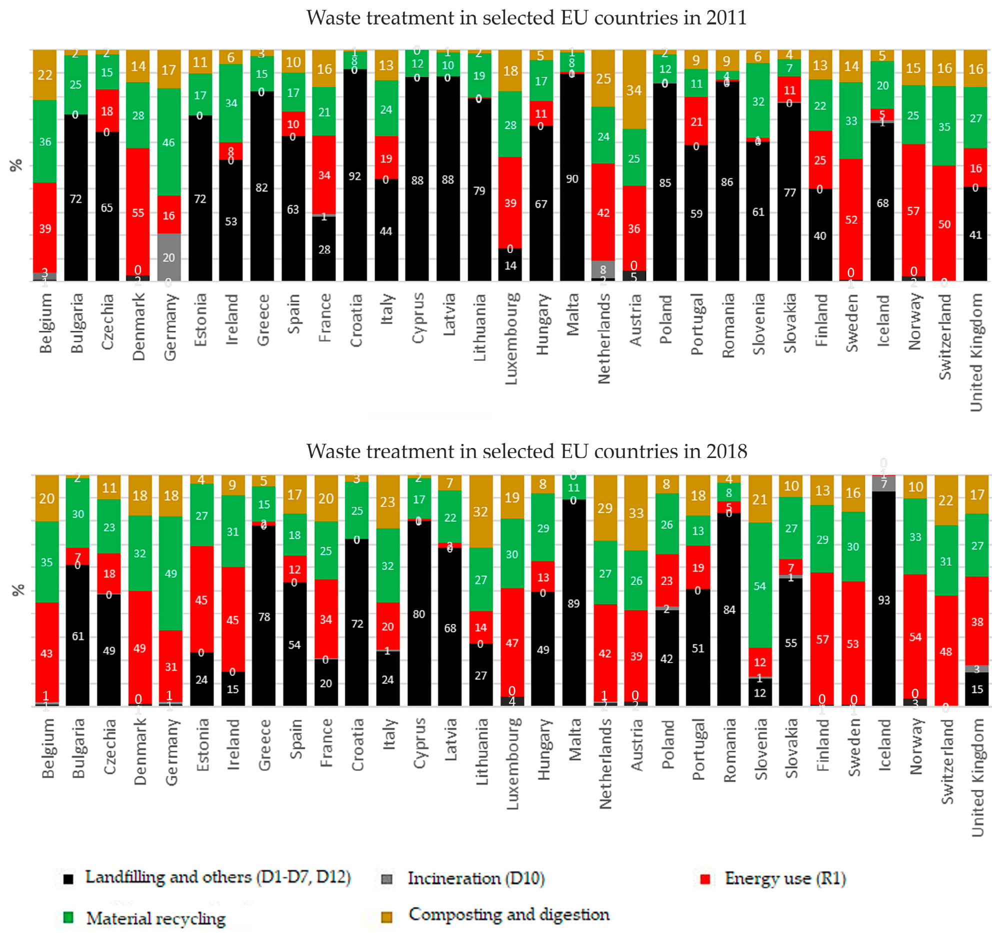


Figure 4. Comparison of municipal waste management in the EU in 2011 and 2018.

As can be seen from the figures, one positive finding is that the share of waste incineration without energy use and the share of waste sent to landfill has fallen significantly in most countries. The increase in waste recycling, composting and use in digestion processes, as well as the increase in the use of energy from waste, is also positive in terms of environmental impact. In the graph below, the same values are sorted for a clearer visualization according to the above waste management methods—landfill use, recycling, and energy recovery—in 2011 and 2018 (Figures 5 and 6), using the same legend as in Figure 4.

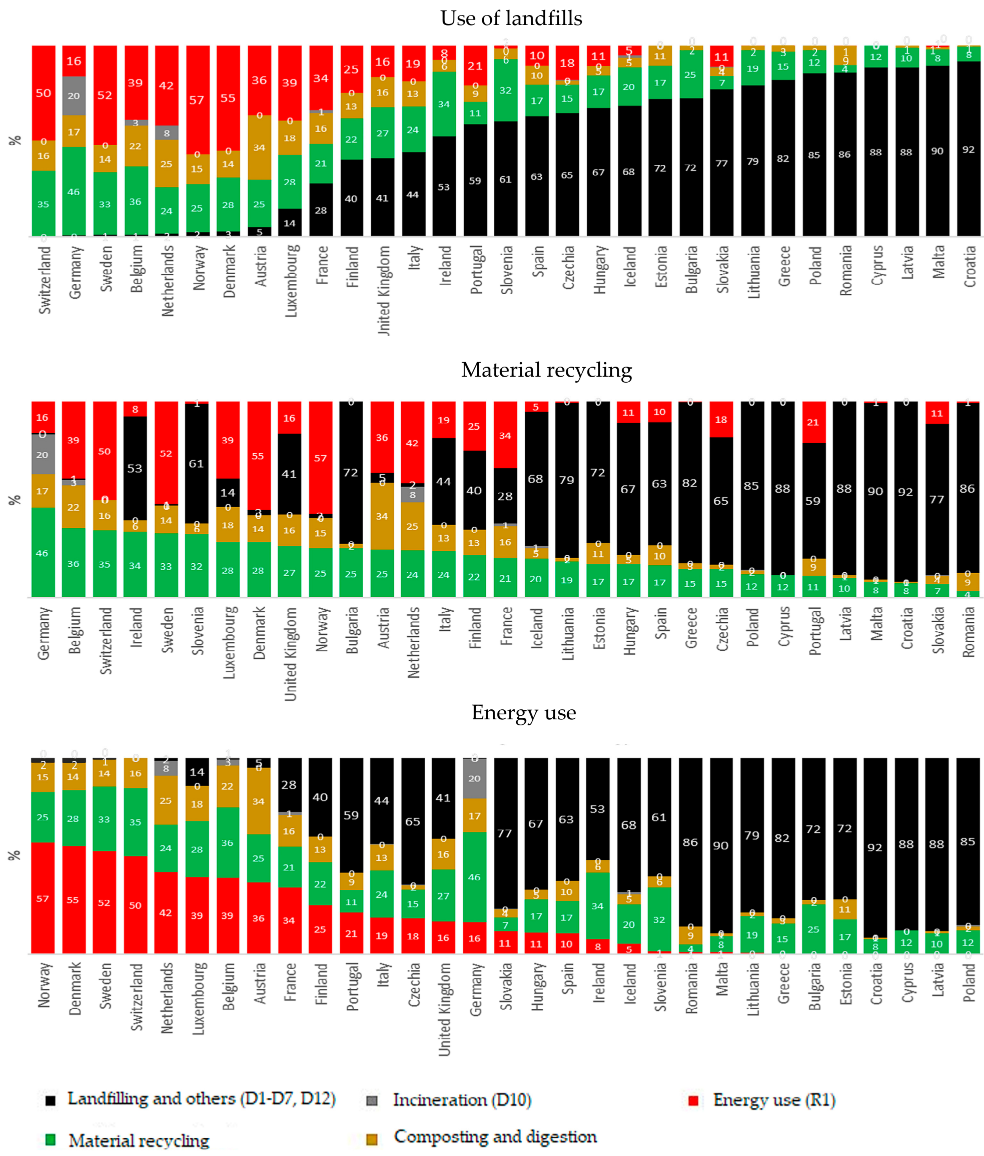


Figure 5. Ranking of countries by waste treatment process in 2011.

The visualized data show that EU countries are gradually trying to reduce the proportion of waste placed in landfills, eliminating the incineration of waste without energy use and increasing the share of energy recovery from waste (which is linked to an increase in the proportion of waste sorting), with an almost unchanged share of material recycling of waste. This indicates the dependence of reducing landfill on increasing the sorting of waste related to energy recovery. The steady share of recycling indicates that the increased amount of sorted waste does not result in an enormous increase in recycling.

The reason for this is probably that some waste is no longer technically or technologically feasible, or economically not profitable, to recycle. The final treatment for mixed municipal waste that is treated and no longer recyclable is energy recovery. As can be seen in the above graphs, the top ten countries where the least waste goes to landfills and where the most energy is recovered are almost identical in 2011 and in 2018 (see Tables 2 and 3).

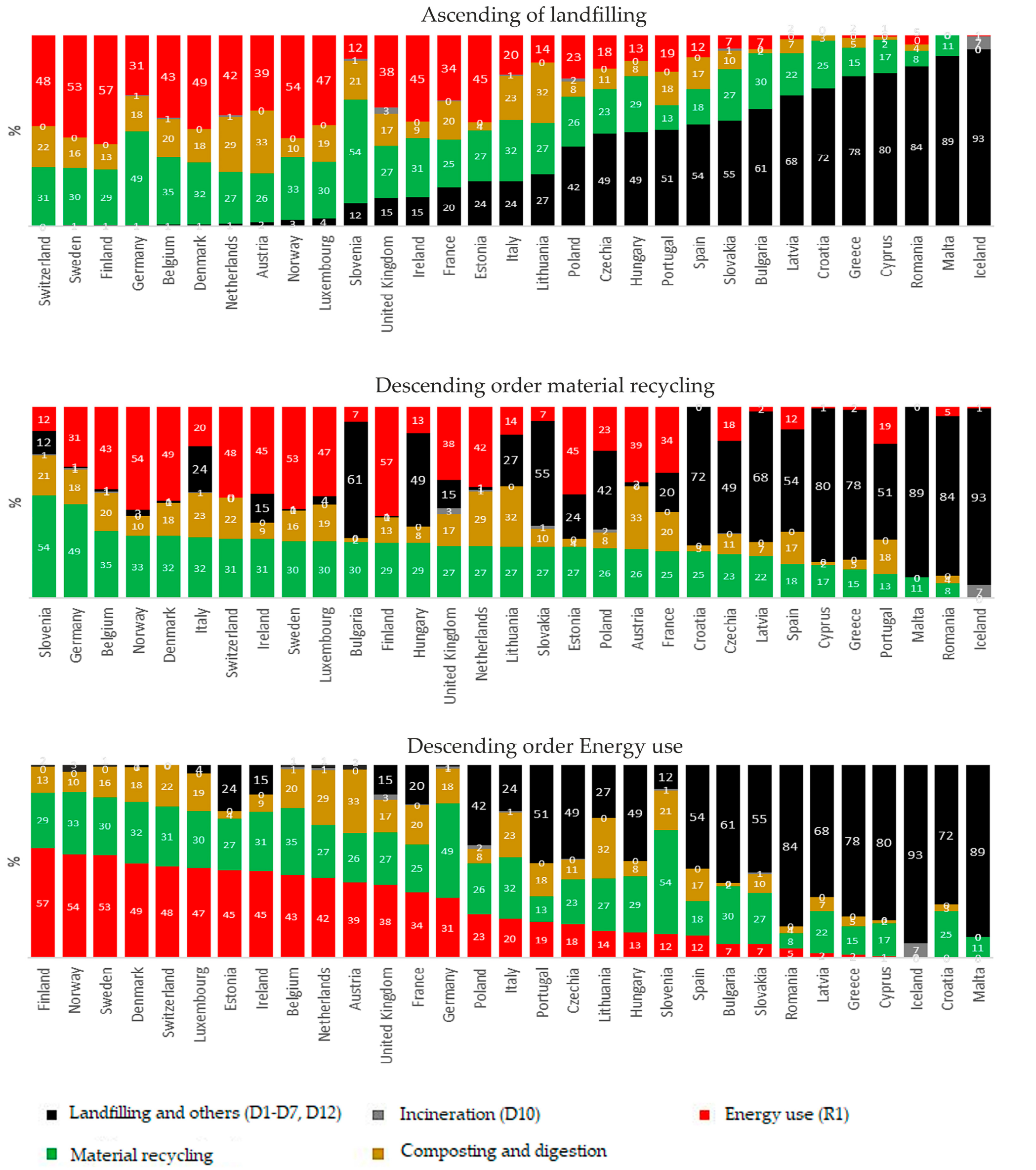


Figure 6. Ranking of countries by waste treatment process in 2018.

Table 2. Top 10 EU countries in 2011 by waste hierarchy.

2011					
Rank	**Waste-to-Energy Plants**	**Rank**	**Recycling**	**Rank**	**Landfill Use**
1.	Norway	1.	Germany	1.	Switzerland
2.	Denmark	2.	Belgium	2.	Germany
3.	Sweden	3.	Switzerland	3.	Sweden
4.	Switzerland	4.	Ireland	4.	Belgium
5.	Netherlands	5.	Sweden	5.	Netherlands
6.	Luxembourg	6.	Slovenia	6.	Norway
7.	Belgium	7.	Luxembourg	7.	Denmark
8.	Austria	8.	Denmark	8.	Austria
9.	France	9.	Great Britain	9.	Luxembourg
10.	Finland	10.	Norway	10.	France

Table 3. Top 10 EU countries in 2018 by waste hierarchy.

2018					
Rank	**Waste-to-Energy Plants**	**Rank**	**Recycling**	**Rank**	**Landfill Use**
1.	Finland	1.	Slovenia	1.	Switzerland
2.	Norway	2.	Germany	2.	Sweden
3.	Sweden	3.	Belgium	3.	Finland
4.	Denmark	4.	Norway	4.	Germany
5.	Switzerland	5.	Denmark	5.	Belgium
6.	Luxembourg	6.	Italy	6.	Denmark
7.	Estonia	7.	Switzerland	7.	Netherlands
8.	Ireland	8.	Ireland	8.	Austria
9.	Belgium	9.	Sweden	9.	Norway
10.	Netherlands	10.	Luxembourg	10.	Luxembourg

The Nordic countries are leaders not only in reducing the share of landfill use and increasing the share of recovery of energy from waste, but also in recycling—recovery of material from waste. In the context of reducing the share of landfill use to increase energy recovery capacity, it is interesting that the number of countries introducing this method of waste recovery is also increasing. While in 2011 eight countries had a zero share of energy recovery and three countries recovered only 1% of their waste energy, in 2018 only Malta and Croatia reported no energy recovery and only two countries, Iceland and Cyprus, recovered only 1% of waste as energy.

Of course, these values represent the percentage of individual waste treatment processes as part of the total volume of waste produced, which, fortunately, is declining year-on-year in most EU countries, with the exception of a few countries, unfortunately including Slovakia. A comparison of countries in terms of the development of total municipal waste production in each of the years considered is shown in the graph below (Figure 7).

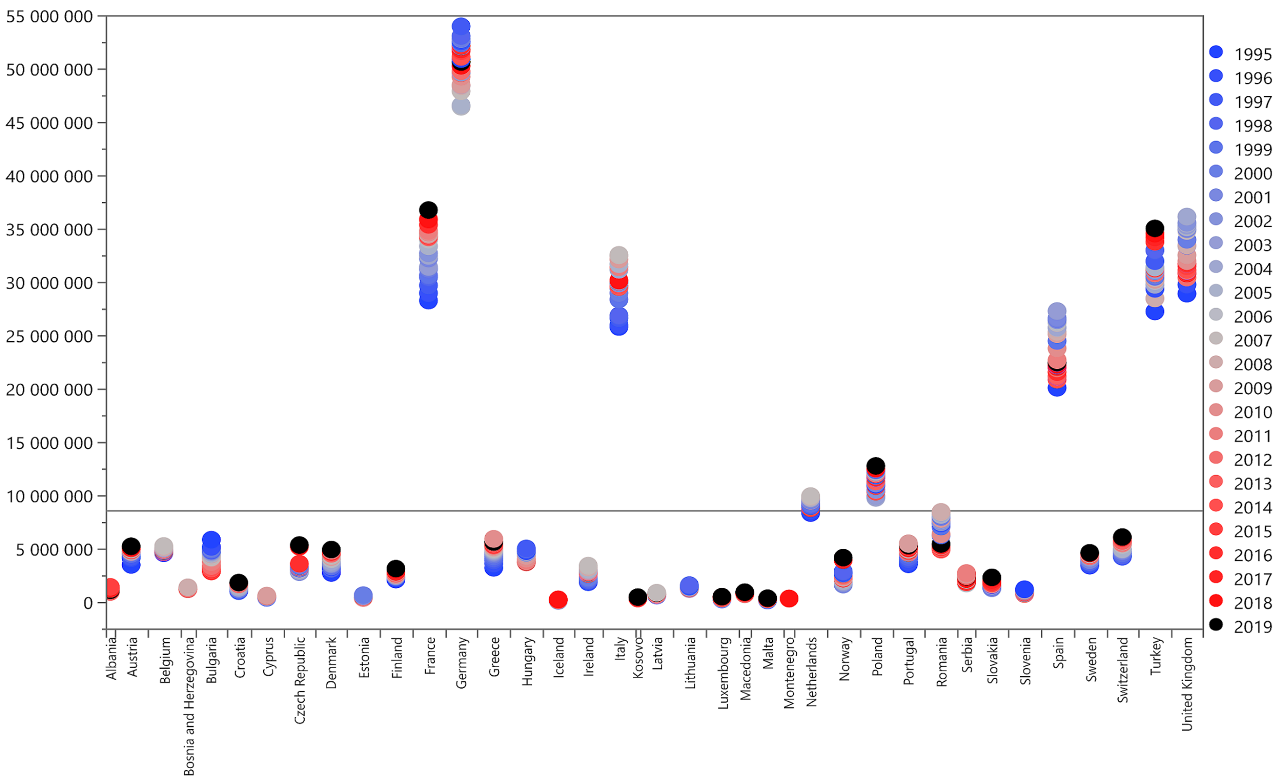


Figure 7. Municipal waste generation in the EU 1995–2019 in tons.

For a more detailed analysis, EU countries were evaluated from the point of view of individual waste management processes, according to the available statistical data. As already mentioned, in most countries the production of municipal waste has decreased. Countries that have failed to do so should take swift and workable measures to gradually reduce the generation of municipal waste. The following analysis shows the amount of waste per year measured in tons, making it possible to track changes in municipal waste management visually.

The production of municipal waste by year is shown in the following graph (Figure 8). The trend in production can be traced by year. The latest year under consideration (2019) is marked in black. The values of individual points are in tons of waste in a given year. A black point in the highest position means that a given country is increasing waste production, while a black point in the lowest location means a positive trend—reducing the production of municipal waste. The absence of a black dot means that the country in question did not provide complete data for 2019.

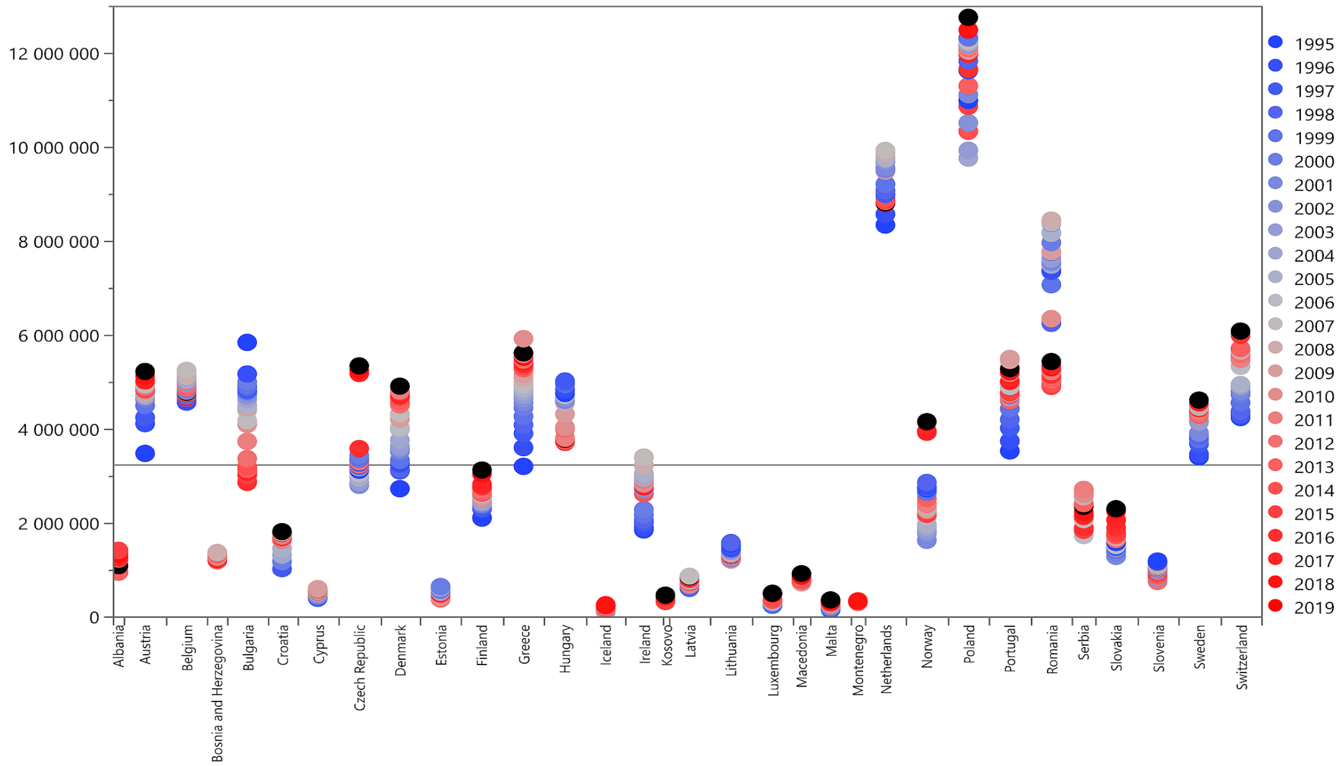


Figure 8. Municipal waste production in the EU with production of up to 13 million tons per year.

Differences in the proportions of municipal waste production are large and are related to the population of the countries. However, it is clear from the above that, of the countries with the highest total municipal waste generation, France and Turkey have the highest year-on-year increases in absolute terms, followed by Poland. Germany, Italy, and the United Kingdom report varying waste production values in the range of 10 million tons. For the sake of clarity of the results, the graph below shows countries with annual municipal waste production of less than 13 million tons in an increased scale (Figure 8).

Bulgaria and Hungary, in particular, show a clearly positive downward trend in municipal waste production, with a smooth transition from blue to red. Unfortunately, in addition to Slovakia, Austria, Croatia, Denmark, Finland, Portugal, Sweden, and Switzerland are also seeing the opposite trend.

As can be seen from the above, the direct objective and, in some countries, the achieved trend in the European Union is first to reduce the production of waste and to recover as much as possible of the waste already produced. Whether it by material recovery, composting and preparation for digestion, or energy recovery, the result should be to reduce the amount of waste deposited in landfills (Figure 9).

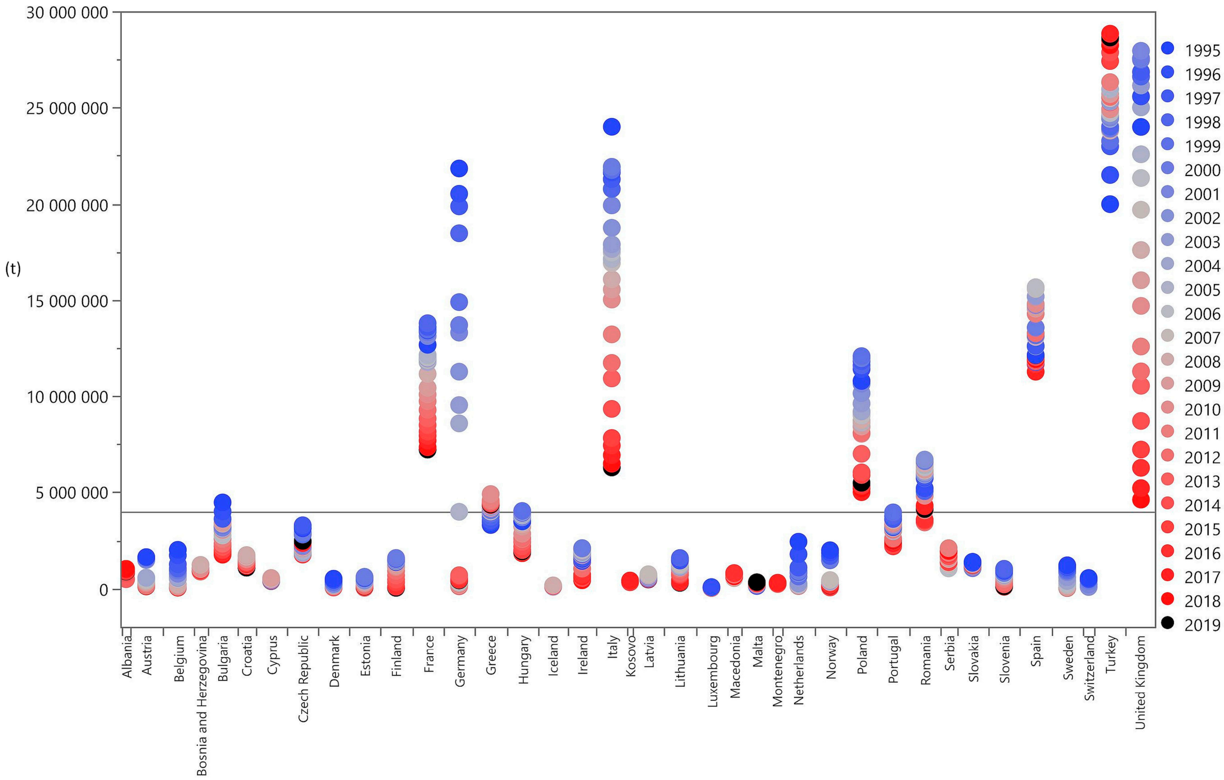


Figure 9. Landfill use in EU countries.

From a recycling perspective, it is a positive finding that all the countries examined show a year-on-year increase in municipal waste recovered by recycling, as shown in the graph below (Figure 10).

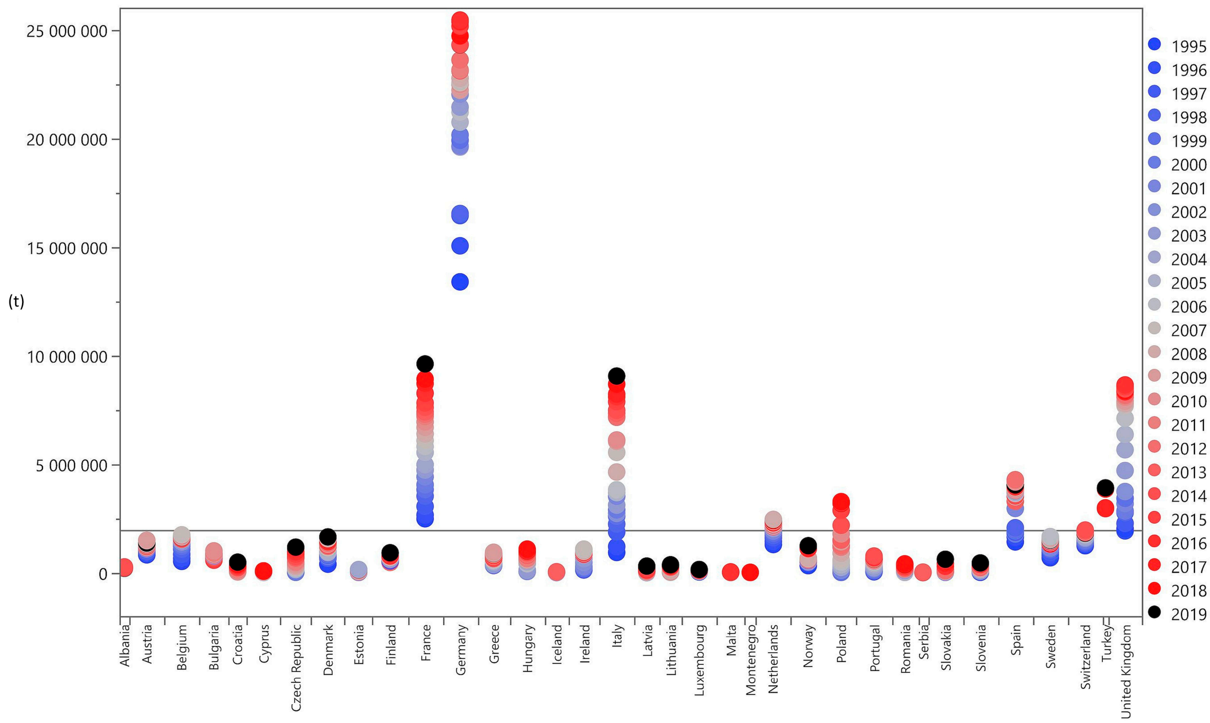


Figure 10. Recycling of municipal waste in the EU 1995–2019.

Although composting and digestion are among the most ecologically favorable ways of recovering municipal waste, analyses of compost from municipal waste have sparked extensive expert discussions on the appropriateness of this method of municipal waste management, since the presence of (primarily) microplastics in such compost makes it most suitable for use as a reclamation material in landfills. The problem with the presence of microplastics is not their presence as such, but the fact that, through natural processes, they enter the soils, then the waters, and then pass through the food chain to the animals that consume them. Nevertheless, all countries show an increase in the amount of municipal waste treated through composting, as shown in the graph below (Figure 11).

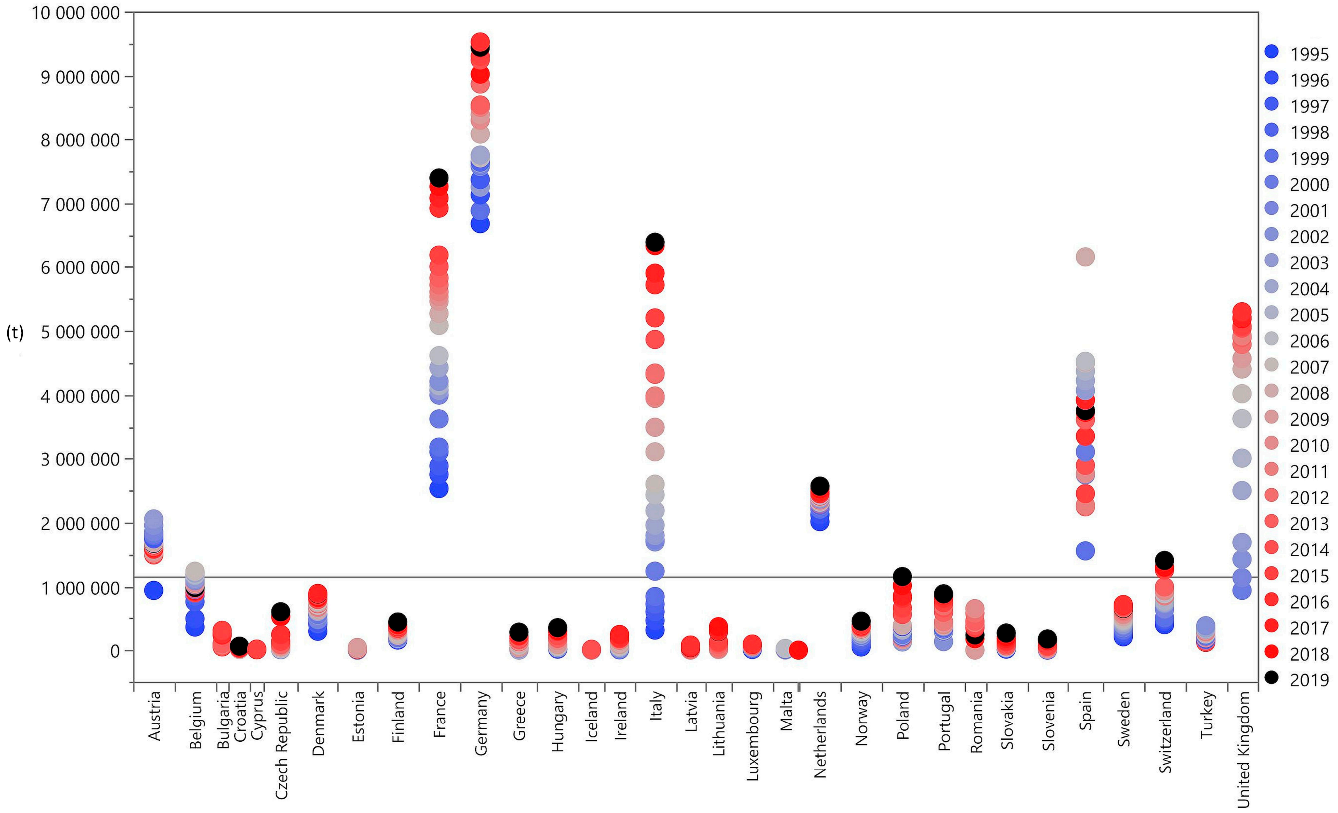


Figure 11. Composting and digestion of municipal waste in the EU for the years 1995–2019.

If the origin of this waste is from mechanical-biological treatment, the largest fraction of the process, the risk exists of the presence of microplastics and other undesirable substances that may be introduced into the natural environment. Through biological treatment, the stabilization of the biochemical processes of the biological component of municipal waste certainly has an impact on reducing the generation of methane and other greenhouse and landfill gases that would otherwise be generated in piles of rotting mixed waste. Unfortunately, this may not bring real benefits to landfill use as such, precisely because of the pollution of municipal waste and, consequently, of compost, which environmentalists and environmental authorities may have reservations about being used in nature or fields [48,49].

The undesirable impurities contained in municipal waste (a major fraction after mechanical-biological treatment) sent to composting plants, or the biocomponents sent to biogas plants, present a similar problem. The issue of energy recovery from municipal waste is also subject to heated debates between its proponents and opponents. Individual EU countries approach the issue of the energy recovery from waste (Figure 8) as shown in the following graphs. The second graph uses an increased scale to show the countries in which the amount of waste treated to extract energy was below 5 million tons per year (Figure 12).

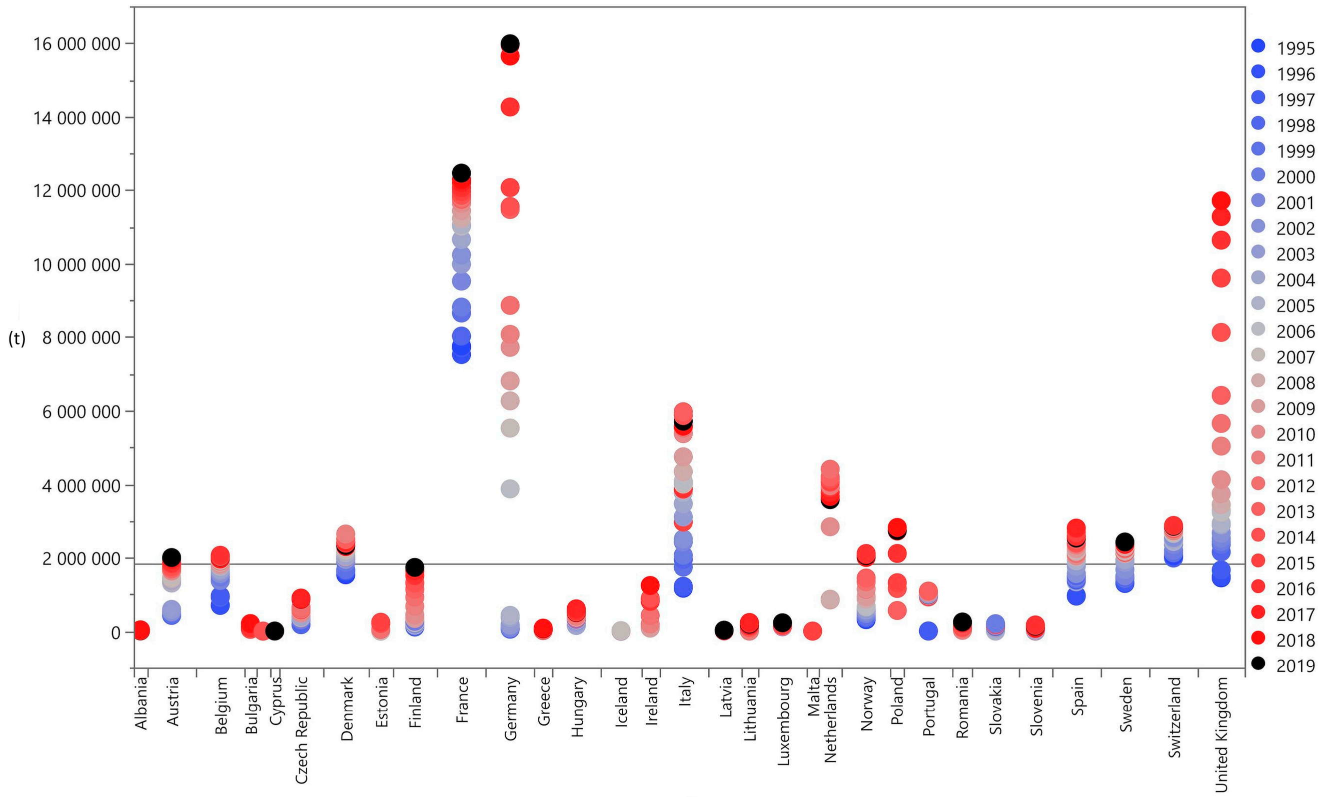


Figure 12. Energy recovery from municipal waste in the EU for the years 1995–2019.

The results of this analysis are also influenced by the fact that energy recovery from municipal waste was not introduced and conducted in all EU countries at the same time.

From the above analyses, we can deduce that increasing the share of energy recovery has a clear impact on the increased rate of waste sorting and subsequent recycling. This is not directly due to the energy recovery, but probably to the culture that a waste-to-energy plant brings to the region.

The set of waste management measures used in a given country over time, which we may call the evolution of waste management, has a natural tendency to focus first on the separation of waste at the source, followed by more successful recycling of materials (accompanied by the expansion of capacity for material recovery of municipal waste) and education of society on this topic, as another environmental step towards achievement of the popular "zero waste" principle. Thus, the synergistic effects of moving away from landfill use by building capacity for energy recovery have been proven to lead to the building of recycling capacity and to the establishment of the principles of the circular economy in the waste management of individual EU countries.

The following graph (Figure 13) illustrates this process using the examples of the United Kingdom, Germany, Italy, and France, where an increasing share of energy recovery has led to an increasing share of recycling and a decreasing share of landfill use. These patterns and characteristics are visible in the development of waste management from 1995 to the present day. Similar characteristics can be seen in graphs and data for Nordic countries such as Finland, Sweden, and Denmark, which are among the leaders in waste management and the circular economy in the EU.

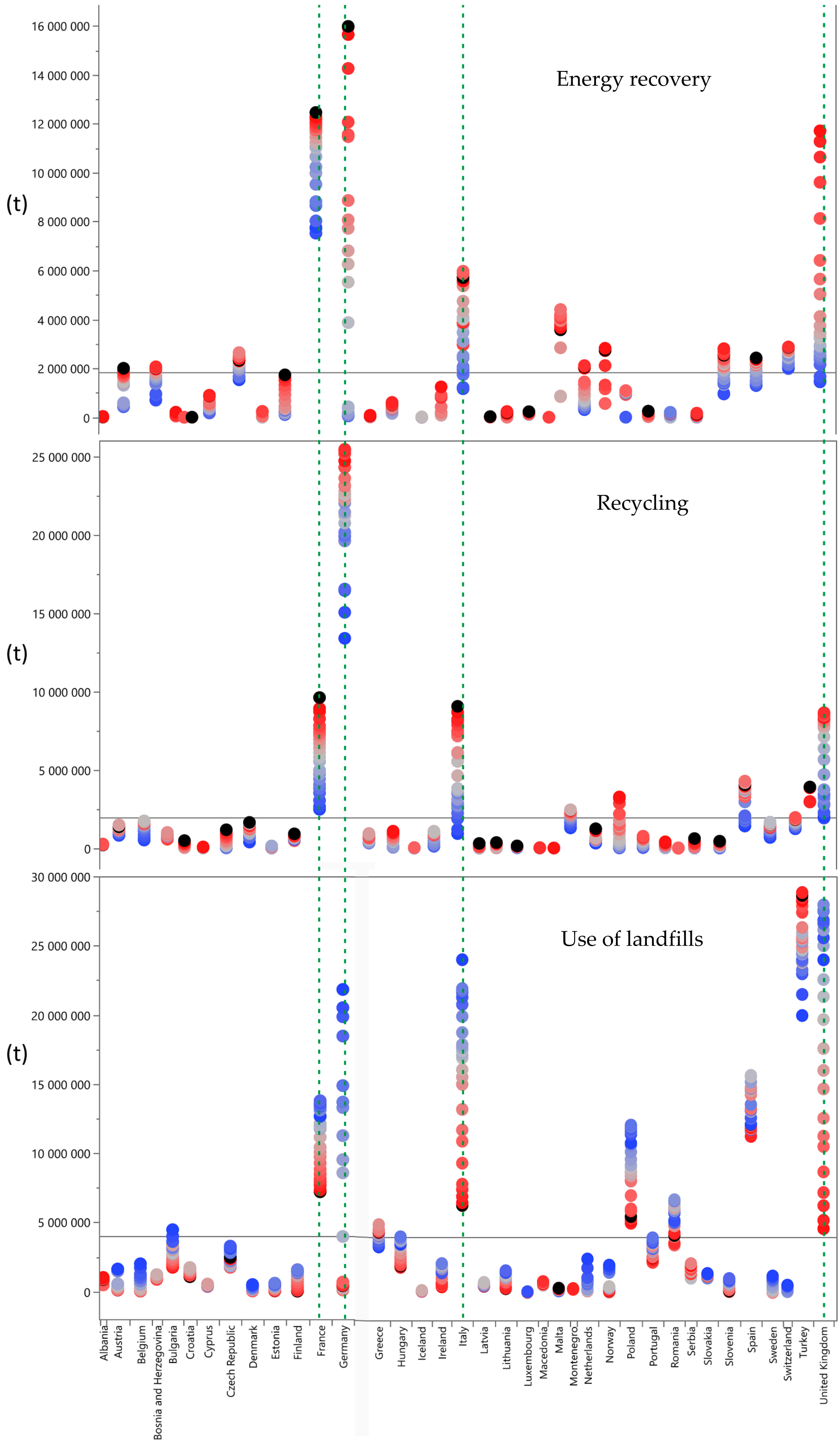


Figure 13. Methods of municipal waste management methods, in tons.

4. Conclusions

The permitting process for any waste management activity takes years, so it is necessary to act quickly to define targets and cost-effective and socially acceptable solutions, as well as to identify existing technologies that will guarantee the most environmentally beneficial methods for the management of municipal waste now and in the future. As we have mentioned, waste is a natural part of human life, so it is worth considering waste as a raw material or a renewable source of energy and materials that can be used or extracted in the most economical and ecological way, which in turn fulfills the goal of sustainability and preserves nonrenewable and exhaustible resources. It should also be noted that, given the calorific value of waste used for energy production compared to the calorific value of natural gas (approx. 44 MJ/Kg) and hard coal (24–28 MJ/Kg), the production of energy from waste may, to some extent, gradually replace part of the energy production from exhaustible and nonrenewable fossil fuels in each EU region [50].

Air pollution from emissions due to the heat treatment of waste is often considered to be the biggest negative of energy recovery from waste from the point of view of public opinion, and current technologies for energy recovery from waste fall under the strictest emission controls. At the level of the European Commission, the best available techniques are continually improving the management of waste and its energy recovery, and provide a combination of techniques that mitigate the effects of this activity on environmental components.

This approach can also be considered as an opportunity to enhance the return of raw materials and energy into circulation. Detailed knowledge of the waste management of each country helps to determine its effective use, which is important from the point of view of the circular economy. It can even be argued that waste could be considered a raw material, a renewable source of energy or a source of other reusable raw materials.

The application of the zero waste concept to landfill use would significantly reduce the raw material and energy dependence of the EU and the Slovak Republic, as up to 90% of municipal solid waste can be recovered as material or energy. The application of this approach should be addressed by every national government and sensitively implemented in raw material and energy policies. Not only from the point of view of materials and energy, but also in terms of supply security, municipal solid waste is a renewable resource. The approach of the circular economy also points to this fact as a key tool for preventing the flood of waste we experience, since many studies show that recycling is insufficient.

Our research has confirmed that some EU countries are examples of good practice in which increasing the share of energy recovery has an impact on the increased rate of waste sorting and subsequent recycling. This naturally results in reducing landfill use. The data from the Eurostat database also clearly confirmed that countries that recover energy from a high proportion of waste reduce the use of landfills and increase recycling. Therefore, in countries that do not yet have an energy recovery infrastructure in place, it is important to ensure this stable and affordable source of energy and method for recovering waste as an essential need for the next decade.

As an excellent example, we can cite Germany, where waste production was 628 kg per capita in 2020. Although this was an increase over previous years, our research shows that recycling, which goes hand in hand with waste-to-energy recovery, is growing in Germany.

The year 2022 has been marked across Europe by volatile geopolitical relations, the impact of which can be seen across the world and whose economic consequences have escalated into an energy crisis. Shortages of energy, fossil resources, price caps, and quantitative restrictions have helped to accelerate efforts to obtain all available energy alternatives in the EU. The recovery of energy from waste is entering the energy mix for developed European countries, clearly confirming its importance. At the same time, in this turbulent and unstable external environment, this can also be seen as a huge opportunity for strategic management.

Author Contributions: Conceptualization, Z.Š. and I.K.; methodology, P.T.; software, P.T.; validation, M.C. and J.D.; formal analysis, J.D. and I.K.; investigation, P.T. and Z.Š.; resources, J.D. and I.K.; data curation, P.T.; writing—original draft preparation, M.C. and Z.Š.; writing—review and editing, Z.Š.; visualization, I.K.; supervision, P.T.; project administration, J.D.; funding acquisition, Z.Š. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the Slovak Research and Development Agency under the Contract No. APVV-21-0188 and under the Contract No. APVV-20-0076" entitled "Waste and Construction—Modelling the Effectiveness of Alternative Options for Cooperation between Administrative Authorities". This research was supported by the Scientific Grant Agency of the Ministry of Education, Science, Research, and Sport of the Slovak Republic and the Slovak Academy Sciences as part of the research project VEGA No. 1/0590/22: "Exploration of natural, social and economic potential of areas with environmental burdens in the Slovak Republic for the development of specific forms of domestic tourism and quantification of environmental risks".

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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