Waste production and waste management in the EU

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Abstract. The constant growth of the population increases the demands on raw material resources, which is reflected in increasing pressure on the environment. The impact of mankind on the environment is nowadays an increasingly acute problem, which is being addressed by the governments of individual countries, not only the EU, through legislative interventions. The most addressed areas are the issue of production and subsequent waste management. Waste production in the world has been growing for a long time, which causes considerable problems for individual countries. Each country is currently looking for the optimal way of waste management to reuse it as secondary raw material. In this paper, we analysed twenty-eight EU countries in terms of production and waste management and found significant differences between countries. We looked for factors that lead to different results between countries in the production and management of waste, based on the population, the size of the country to the indicators of living standards, and legislation applicable to those countries.

1. Introduction
Waste is considered to be a movable thing or a substance that its user wants to dispose of or is obliged to dispose of by the law. So waste is something that is no longer important to us and we want to get rid of it. According to this Act, basic terms are defined as a waste stream, which means a group of types of waste with similar properties that allow their further joint management. [2],[3].

Following the Waste Act, waste management means waste collection, waste transport, waste recovery, and waste disposal, including subsequent care of the disposal site. Waste management leads to its disposal. Waste disposal is the treatment of waste that does not cause harm to the environment or endanger human health. There are several options for waste disposal. Among the most commonly used are landfilling, energy recovery, storage (primarily hazardous waste), and waste recycling. Recycling involves the greatest recovery of waste - activities leading to the use of physical, chemical, or biological properties of waste. In energy recovery, heat and electricity are produced from waste in the combustion process. Another product of energy recovery in specialized facilities can be an alternative fuel for the production of cement products. [3],[4].

Waste Framework Directive DIRECTIVE 2008/98 / EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 November 2008 on waste and repealing certain Directives defines recycling as: "The term" recycling "means any recovery operation by which waste materials are reprocessed into products, materials or substances intended for the original purpose or other purposes. It includes the reprocessing of organic material, but does not include energy recovery and reprocessing into materials to be used as fuel or backfilling activities. The materials thus obtained are used either alone or mostly as an impurity in the manufacture of products from primary raw materials, to reduce production costs and in some cases also to improve the properties of the product itself [4].
The EU Circular Economy Action Plan sets out concrete and ambitious action program with measures covering the whole cycle: from production and consumption to waste management and the secondary raw materials market, and a revised legislative proposal on waste. At the same time, the Annex to the Action Plan sets out a timetable in which the individual actions will be completed. [10,11,12]. The proposed measures are intended to contribute to the "closing of the cycle" of the product life cycle through greater recycling and re-use and will benefit not only the environment but also the economy.[5],[6] The revised legislative framework on waste entered into force in July 2018. It sets clear waste reduction targets and an ambitious and credible long-term path in waste management and recycling [7], [8].

2. Methodology
We collected data by recording the continuously published values of selected indicators from the portal https://ec.europa.eu/eurostat/data/database [9] for all available years and all available Member States. We recorded, sorted, and edited the collected data in a database created in the MS Excel spreadsheet editor according to the requirements of the statistical software JMP 15 from the company © SAS Institute Inc., to which the modified data were transferred and subsequently analysed. The collected data present the results of six indicators for the period 2004 - 2018 (Table 1). The database created consists of 2,129 data and each indicator is defined for a specific EU Member State and a specific year. The scope of published data varies considerably from one indicator to another, with the volume of data being related to incomplete input by countries or the publication of data for some indicators every other year, such as recycling rates, landfilling, and circular material recovery. We adapted the choice of analyses and the formulation of conclusions to the scope and structure of the obtained data.

| Table 1. Structure of collected data (source: own processing in Excel environment). |
|-----------------------------------------------|
| Name of the indicator | Registered period |
|-----------------------------------------------|
| Production of the waste in the EU | 2008-2018 |
| EU waste / per capita production | 2004-2018 |
| Waste production / GDP in the EU | 2008-2018 |
| Landfill rate in the EU | 2010-2012-2014-2016-2018 |
| EU waste recycling rate | 2010-2012-2014-2016-2018 |
| Circular material utilization rate in the EU | 2010-2012-2014-2016-2018 |

We performed the data analysis in the following points:
- a) Defining the development trend of waste products for the EU as a whole using regression analysis
- b) Comparison of countries using cartographers - waste production
- c) Defining waste production per capita average and Std. Dev for the EU using descriptive statistics
- d) Comparison of countries using graphical analysis - waste production per capita
- e) Defining the trend of waste production in summary for EU / GDP using regression analysis
- f) Comparison of countries using graphical analysis - waste production / GDP
- g) Comparison of countries using graphical analysis - recycling rate, landfill rate, circular material utilization rate.

Each indicator was analysed separately from several perspectives, and our effort was to define the development of the average values of the indicator for the European Union as a whole and compare it with the development of individual countries. The development trend of the indicator for the whole European Union was analysed using regression analysis and expressed mathematically. In the second part, the countries were compared with each other, looking for differences between countries in the years under review (we identified countries with above-average and below-average values of the indicator compared to the European average), as well as the overall direction of individual countries. [11]. The graphical analysis was performed using cartographers in which we compared the results of individual EU member states in 2008 and repeatedly in 2018 while examining whether there is a change in the structure of countries with a 10-year time lag. Using the scatter plot, the results of the indicator
for individual countries were compared, color-coded according to years. Recent periods are highlighted by the brand; thanks to which it was possible to assess the direction of individual countries.

3. Results

3.1. Waste production

3.1.1. Total waste production in the EU - trend for the years 2008 - 2018. The analysis shows a long-term growth trend of waste produced in total for the EU in the observed period 2008-2018 with a linear trend and a year-on-year average increase of 0.6%, which represents about 16,749 thousands ton (Figure 1).

Figure 1. Total waste production in tonnes for the EU in 2008-2018 - a linear trend.

3.1.2. Comparison of countries - total waste production for the EU. By comparing individual countries in waste production over the last 10 years, it can be stated that the most significant producers of waste are Germany and France, they are also countries with a strong economic background. Looking at the cartographer for 2008 and 2018, there is no significant structural change in the countries (Figure 2).

Figure 2. Cartographer - comparison of waste production in tons at the level of countries in 2008 and 2018.
3.1.3. Waste production per capita. In addition to the total waste production per country and its impact on the environment, waste production per capita and GDP must be taken into account, making the comparison more objective and taking into account the country's population density and production capacity. At the same time, it will be possible to assess the purity of production of individual countries to achieve one of the EU's environmental goals - reducing waste per unit of production. It is clear that per capita waste production across the EU showed a declining trend until 2014, unfortunately, since 2014, we have seen a gradual increase in per capita waste production (Figure 3).

**Figure 3.** Waste production per capita kg / capita - development in 2004 – 2018.

Within the indicator under consideration, Estonia stands out very significantly, having seen an increase in waste production per capita of almost 2,000 kg since 2006 over the last 12 years. Bulgaria, Belgium, and Serbia saw a half increase over the period. Most EU countries show more or less stagnant waste production per capita. Finland is a leader in reducing the target, but despite a reduction in waste production per capita of more than 2,000 tonnes in 12 years, it is still above the EU average, along with Estonia and Belgium. The leaders are Croatia, Lithuania, and Turkey, which produce below-average waste per capita, although they do not reduce this indicator, even increasing Turkey (Figure 4).
3.1.4. Waste production per GDP. The analysis shows a long-term declining trend of waste production / GDP in total for the EU in the observed period 2008-2018 with a linear trend and a year-on-year average decrease of 0.6%, which represents about 0.455 kg / 1 GDP (Figure 5.)

![Figure 5. Trend of waste production / GDP summary for the EU in the years 2008 – 2018.](image)

As part of the monitoring of waste production per GDP, only Serbia shows an increase over the period under review; other countries are either stagnating or reducing waste production per unit of GDP. In contrast, Estonia is the leader in this indicator. This indicates the dependence of waste produced on the rate of GDP growth and thus that waste production increases with the subsistence level in this country. The second "jumper" in this category are Romania, Lithuania, and Hungary (Figure 6).

![Figure 6. Comparison of EU countries within the indicator of waste production / GDP for the years 2004-2018.](image)

3.2. Waste management method

3.2.1. Landfill percentage rate. A positive finding is a decline in landfill rates in most EU countries and, overall, across the EU. A negative example, in this case, is again Estonia, which increased the landfill rate by almost 20% over the period under review (Figure 7).
Figure 7. Landfill rate in% for individual EU countries in the years 2010 – 2018.

3.2.2. Waste recycling percentage rate. A very important and preferred way of waste management is waste recycling. The EU’s commitment in this indicator speaks of increasing the recycling rate to 55% in 2025, and in 2035 the EU aims to recycle up to 65% of waste.

Figure 8. Waste recycling rate in% for individual EU countries in 2010 – 2018.

As the analysis in figure 8 shows, most EU countries take this target seriously and are gradually increasing their recycling rates. The leader in this area is Croatia, which increased the recycling rate from about 30% in 2010 to almost 60% in 2018. We can also evaluate Hungary and Lithuania positively.

3.2.3. Circular material utilization percentage rate. In addition to recycling itself, great emphasis is also placed on the so-called circular rate of material utilization. One of the reasons is that recycled waste should serve as a substitute for the primary raw material as much as possible. In this indicator, most countries seek to increase the reuse of material as a substitute for the primary raw material, with Italy, Belgium, and Austria being the leaders, according to available data. On the contrary, Luxembourg is experiencing a significant decline in this indicator, although it is still above the EU average (Figure 9).
4. Conclusion
In this article, we focused on the production of waste in the countries of the European Union and the analysis of data on the production of waste in terms of several factors. They were mainly the production of waste in general, the production of waste per capita. We determined the dependence of waste production and GDP.

We assessed the landfilling and recycling of waste from the available data and also addressed the rate of circulating return within the circulating reuse of materials.

We have found that strong economies produce increasing amounts of waste. Also, the economies of states that have a growing tendency tend to grow in the production of waste per capita. See the example of Estonia.

Although several countries, such as Finland, are making significant progress in reducing waste, the levels set by the European Union are still not being reached.

Most EU countries take the goal of waste recycling very seriously. Croatia is doing its best, doubling its recycling rate in eight years. It is important that the findings are progressively incorporated into practice and legislation.

A solution to reducing the amount of waste per capita could be a form of incentivising the use of packaging-free products. For companies, encouraging the recycling of materials that are suitable for this purpose.

The circular use of materials remains a major challenge for EU countries.

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