AKADÉMIAI KIADÓ

UNIVERSITY of DEBRECEN

International Review of Applied Sciences and Engineering

14 (2023) 3, 402–412

DOI:
10.1556/1848.2023.00615

ORIGINAL RESEARCH PAPER

Packaging waste and recycle in EU

Aliz Vuk, István Szűcs and Andrea Bauerné Gáthy*

Faculty of Economics and Business, University of Debrecen, Hungary

Received: December 6, 2022 • Accepted: February 1, 2023
Published online: March 13, 2023

ABSTRACT

Nowadays, the use of plastic is very widespread, especially in packaging materials. Most packaging materials are made from fossil-based polymers, which contribute significantly to greenhouse gas emissions. The unprecedented leakage of single-use plastic waste into the environment is a major problem, with negative impacts on both ecosystems and human health. In this study we examine the development of packaging waste and recycled packaging in the European Union over a period of more than 20 years, highlighting changes in the regulatory context; assess the achievements of Hungary so far and forecast the expected developing of packaging volumes and recycling rates; and consider recycling and waste reduction options, including alternative sustainable packaging options. Our forecast based on the evidence shows that Hungary (47.62%), Germany (61.46%), Malta (26.27%), Romania (58.64%) and Croatia (49.41%) are not expected to reach the target set (65% by 2025) in EU legislation. Out of the 27 countries surveyed, 6 (Belgium 88.2%, the Netherlands 87.81%, Luxembourg 76.96%, the Czech Republic 77.79%, Finland 78.75% and Denmark 83.7%) exceeded the expectations, so we show their waste management and waste recycling good practice, as they can serve as good examples for Hungary and other countries.

KEYWORDS

overpackaging, packaging materials, economic, environment, packaging waste

1. INTRODUCTION

Nowadays, it is quite common to buy everything in packaging, even in our households we pile up these packaging materials. When the word packaging is used, many people mistakenly think only of the wrapping of the finished product, but the term goes far beyond that. According to its definition, which has been expressed by many, it means "the totality of operations whose basic purpose is to protect the product and to make it fit for transport or storage, or to contain it. According to another interpretation, packaging is the complex unit of the product and the group of elements or temporary protective covering that contains it" [1]. "Packaging is a multidisciplinary field, it is both a process and an outcome and can only be developed through the combined efforts of several business areas. There are three main types: consumer, bulk and carrier packaging" [2]. We can also talk about packaging as a logistical function; "The basic purpose of packaging is to preserve the utility value of the product from the end of production to the next user or consumer. Functions: protection; transport facilitating; loading, storage facilitating; information; sales facilitating" [3]. So packaging is not just about the packaging material, not just for one product, it is a whole life cycle process. The aim of our research is to explore how the recycling of packaging materials in the European Union and in Hungary is evolving in terms of regulations.

1.1. Short historical view of packaging

The history of packaging is almost as old as mankind. Protecting, storing and transporting food and other utility items has been with us since the beginning. In terms of raw materials, natural materials, paper and glass have the longest history. In the beginning, Neolithic humans used large leaves to store food. Then came basket weaving, followed by pottery. Then

*Corresponding author.
E-mail: bauerne.gathy.andrea@econ.unideb.hu

people started using paper. The industrial revolution brought progress in the use of paper-based packaging, when many patents have been granted. The use of glass also goes back a long way, with the perfect convenience of glass packaging brought about by the invention of the metal closure in the mid-1800s. Here is where we arrived to the period of the use of metal, plastic and associated materials. The rise of metal began in the 1800s. It was used to package canned food and later soft drinks. Today, metal packaging can be made of two different materials: steel or aluminium [2]. For thousands of years, ceramics, glass, wood, wicker baskets and textiles were the main materials used to store and trade organic products and materials, until the recent invention of plastics, which marked the beginning of a new era [4]. The latest widely used packaging material is plastic. The image of this youngest packaging material is not so positive. It can also be criticised from an environmental and health point of view. Associated materials are common these days, and it is rare for a package to be made from only one type of material. Currently the latest trend to reduce packaging and reducing environmental impact is to use natural and more environmentally friendly materials. Within this trend, a distinction is made between degradable materials and packaging that adapts to lifestyle (edible, disappearing). The biodegradable, plant-based packaging is being developed with recyclability taken into account. Lifestyle-friendly packaging that serves until the food is eaten or "disappears" during preparation [2]. Edible packaging is a type of active food packaging, which is a sustainable and biodegradable alternative and optimises food quality compared to traditional packaging. The benefits of edible packaging are seen in its ability to maintain food quality, extend shelf-life, reduce waste and contribute to the economy of packaging materials [5]. But there is still strong consumer resistance to these efforts [2].

1.2. Purpose and task of packaging

Packaging is important from both a business and macroeconomic perspective. The costs must always be in reasonable proportion to the value of the product to be packaged. The task of packaging usually starts at the end of the production process. From production through transport through wholesale and retail, it serves its purpose until it reaches the consumer. The task of the packaging at the consumer ends at the moment the product is removed from its packaging or thrown away. Taking packaging waste into account, the tasks of packaging material end with its destruction. From this perspective, two principles apply: packaging can never be an end in itself; the packaging expenditure must be recouped somewhere in the form of a profit. The functions of packaging in terms of inputs and economic benefits: protection of goods; protection of the environment from goods; rational design of handling and transport units; rational design of storage units; rational design of sales (consumer) units [6].

The primary and most ancient function of packaging is logistical, involving and enabling the safe storage of goods, providing protection and facilitating transport. It can also be part of a company's strategy, a cost-cutting factor or a source of competitive advantage. It is of paramount importance for marketing, as it reaches every consumer and is present at the critical moment in the point of purchase. Whereas the benefits of using can be interpreted at the social level, social functions can be identified. Environmentally, it is a device that protects the environment from the goods and the goods from the environment [2]. In addition, it should help to adapt to the speed of the production line; increase product density; facilitate product use; and have a reuse value for the user [7].

1.3. Types and function of packaging materials

Basically, packaging materials according to their function are distinguished into three types: primary; secondary and tertiary. The primary packaging is the one that is in direct contact with the product and provides the main protection. This is the smallest packaging unit, distinguishing between unit and group packaging. Secondary packaging is also known as commercial/collective packaging. Its task is to assemble, collect and make a certain quantity of goods ready for transport. A special type is shelf-ready packaging, which helps retailers. Tertiary packaging is required when the primary and secondary packaging need to form a movable unit. Its main function is to ensure the mobility of the goods and to protect them from the environmental impact of the change of location. These are often returnable (reusable) packaging for economic and environmental reasons, and are indeed designed for reuse. In international trade, there is often a fourth packaging, based on the means of transport. Such as the truck itself or a container [2].

The packages in terms of their material are generally classified into 5 types:

- metal packaging;
- glass packaging;
- paper;
- plastic packaging;
- composite packaging: cardboard-plastic film; paper-plastic film; cardboard-plastic-aluminium film; plastic film-aluminium film; plastic film-plastic film [8].

Most packaging systems are designed to protect products from the hazards of the distribution environment. To properly design a packaging system, the packaging engineer needs to define design parameters in three areas: the distribution environment, the product and the packaging material. Among the many hazards in the distribution environment that can cause damage to the product, hit, vibration and compressive forces are of great importance and must be taken into account in the design [9].

1.4. Circular economy and the packaging

A linear economy is characterised by the use of natural resources to produce new products. In this case, consumers buy the products, use them for a certain period and then they become waste. By contrast, the circular economy does

not end with waste. Various definition exist, but all agree that smaller quantities should be used – specially from virgin raw materials (Reduce), such products and/or materials should be used which were wasted (Reuse) and waste materials have to be processed (Recycle). This 3Rs is nowadays extended with more Rs, such as energy recovery, remanufacturing, refusal to buy new products [10]. One of the points of the EU's Green Deal is "Mobilising industry for a green and circular economy". The introduction of the circular economy paradigm has changed the approach of the European Commission (EC) and encouraged the development of strategic measures to reduce packaging waste. With the adoption of the so-called "single-use plastics directive" in 2019 and its circular principles, the EC has for the first time introduced a systematic sectoral approach to packaging. The new circular economy action plan adopted in 2020 aims to reduce (over)packaging and packaging waste by promoting new designs that can be reused and recycled; reducing the complexity of packaging materials; introducing labelling to help sorting; and reviewing waste shipment regulations [11]. This approach changes the marketing over-packaging of B-to-C (business-to-consumer) and encourages companies to use recyclable packaging that promotes good waste management.

In this paper, we seek to answer the following main research questions:

Q1: Will the European Union Member States comply with meeting the targets set for packaging waste recycling by the set deadline?

H1: Based on the data for 2001–2019, we hypothesise that countries that have successfully met the targets set so far will continue to meet them in the future.

Q2: Based on the objectives of EU legislation, will Hungary meet the targets set for the recovery of packaging waste?

H2: Based on the 2001–2019 data, we expect that Hungary will not meet the target set by EU legislation.

2. METHODS

In our study, we examined and analysed the amount of packaging waste and the proportion of packaging waste recycled. Data on per capita packaging waste generation per EU country were taken from the Eurostat database. "'Packaging' in this context means all products made of any materials of any nature to be used for the containment, protection, handling, delivery and presentation of goods, from raw materials to processed goods, from the producer to the user or the consumer. 'Non-returnable' items used for the same purposes shall also be considered to constitute packaging. 'Packaging waste' means any packaging or packaging material covered by the definition of waste in the Waste Framework Directive 2008/98/EC, excluding production residues (Art.3 (1): 'waste' means any substance or object which the holder discards or intends or is required to discard) [12]." The recycling rate of packaging waste per EU country over 20 years was also obtained from the Eurostat database. "The indicator is defined as the share of recycled packaging waste in all generated packaging waste. Packaging waste covers wasted material that was used for the containment, protection, handling, delivery and presentation of goods, from raw materials to processed goods, from the producer to the user or the consumer, excluding production residues. Packaging waste is broken down into 'paper and cardboard packaging', 'plastic packaging', 'wooden packaging', 'metallic packaging' and 'glass packaging'. The ratio is expressed in percent (%) as both terms are measured in the same unit, namely tonnes. The source data set 'Recycling rates of packaging waste for monitoring compliance with policy targets, by type of packaging (env_waspacr)' includes two types of waste material (plastic and wood) an 'adjusted recycling rate'. That means the recycling rates adjusted for monitoring compliance with policy targets in accordance with Article 6 of Directive 94/62/EC and Article 6b (1) of Decision 2005/270. The relevant rates for those materials are:

- Recycling rate of plastic packaging waste counts exclusively material that is recycled back into plastic (material recycling/generation).
- Recycling rate of wooden packaging waste is calculated including repair (recycling + repair of wooden packaging waste/generation + repair of wooden packaging waste) [13]."

The data were compared with EU legislation on packaging waste management to see whether countries have met the targets set by the directives. In order to assess the expected delivery of the commitments for the next period, which have been set in line with EU regulations, we have prepared a forecast. This provided an opportunity to identify which Member States will be successful in achieving the targets set.

After testing several methods, the exponential function of Microsoft Excel forecast.esim was used to generate the forecasts. The advantage of this method is that it gives greater weight to data that are closer to the present, i.e. they have a greater impact on the predicted value, which is also assumed for the topic under consideration. We obtained a much better fit than if we had used linear functions, so the value obtained with the prediction equation can be considered more accurate. The R^2 values are also shown separately in the forecast plots, and in all cases they were above 0.8 ($R^2 > 0.8$), providing a reliable basis for the forecast.

The evaluations have been carried out for Hungary, first in relation to national legislation and then in relation to EU legislation. For those Member States that performed above the target in 2019, we conducted a literature search to see what measures they are using to achieve such good results. The trend in packaging waste and recycled packaging waste of these Member States is also plotted on a line graph. This was compared with the Hungary trend chart and the good practices collected. In our conclusions, we have made recommendations on what our country can do to increase the share of recycled packaging waste.

3. RESULT

3.1. Packaging and environment

At the end of the 20th century, the concept of environmental packaging design was born. This is a way of thinking where packaging is seen as a necessary element between the product and the environment, helping to prevent their interaction. So it protects the product from environmental stresses and at the same time protects the environment from the harmful effects of the product. But this positive effect is only present when the product is in the packaging. The production of packaging material and becoming waste after use is already environmentally damaging. The aim of environmental packaging design is to ensure that the packaging material performs its function with the least possible environmental impact throughout its life cycle [8]. The environmental regulation of packaging sets out as a general requirement the principles of reducing environmental impacts (prevention, reuse, recycling) [14].

Key aspects of prevention:

- weight reduction;
- avoiding multiple packaging;
- introduction of refill systems;
- optimising the quantity and characteristics of the packaged product;
- avoiding hazardous or harmful substances;
- research into alternative packaging materials [8].

In addition to the potential benefits of reuse, there are also a number of disadvantages, which are shown in Table 1.

Recovery is a process by which the material, a component and/or the energy content of packaging waste can be recovered in whole or in part and reintroduced into the production process. In practice, this can be achieved by recovery of the waste material; incineration for energy recovery; aerobic or anaerobic biodegradation [8].

Recyclable packaging includes:

- glass (all colours);
- paper;
- aluminium foil;
- take-away containers;
- aluminium cans;
- tin and steel cans;
- PET;
- and HDPE [14].

Table 1. Advantages and disadvantages of reuse

Reuse	
Advantages	Disadvantages
lower material and energy consumption due to less packaging produced	the use of materials increases: in case of refillable packaging, as it is used more often and therefore has to withstand significantly higher loads
the returned discarded bottles leave the filling plant as easily treatable industrial waste	cost increaser: because of significant transport and handling losses, which increase costs
less waste can be expected to be generated	reusable, worn-out packaging must also be managed
	the transport and storage of empty packaging is environmentally damaging and costly
	deformation: damage occur on the filling line and during cleaning, leading to aesthetic and quality defects
	appropriate treatment of the waste water from the treatment process must also be ensured
	hygiene: the onus is on the trade to store returned packaging in a hygienic manner; and
	consumers prefer simpler, single-use, disposable packaging

Source: own editing based on [8].

3.2. Packaging waste and recycling in European Union

On 28 September 1976, for the first time since the creation of the European Union, the Organisation for Economic Co-operation and Development (OECD) published a recommendation for the development of a comprehensive waste management policy for Member States. The first legislation dealing specifically with packaging waste was introduced in Germany in 1991, based on the following principles:

- packaging does not constitute waste in the future;
- packaging should be made from environmentally friendly materials;
- the weight and volume of packaging should be kept to a minimum.

Directive 94/62/EC on packaging and packaging waste, adopted on 20 December 1994 and in force in the Member States of the European Union until 30 June 1996 [26]. Directive 94/62/EC sets EU rules for the management of packaging and packaging waste.

Directive 94/62/EC aims to:

- harmonise national measures on packaging and packaging waste management; and
- improve the quality of the environment by preventing and reducing the impact of packaging and packaging waste on the environment.

Directive (EU) 2018/852 is the latest amendment to Directive 94/62/EC and contains updated measures designed to:

- prevent the production of packaging waste, and
- to promote the reuse, recycling and other forms of recovery of packaging waste, rather than its final disposal, thus contributing to the circular economy.

The Directive covers all packaging placed on the European market and packaging waste, whether industrial,

commercial, office, business, service, household or any other level, irrespective of its material [15].

Directive 75/442/EEC summarises the unit of waste management and treatment, for all types of waste general regulatory aspects. Member States' measures should give priority to the prevention or reduction of waste generation and its hazardousness, and secondly to the recovery of waste. At the core of the Packaging Directive are the recycling quotas that all Member States have to reach within a certain deadline. Accordingly, after 5 years from the introduction of Directive 94/62/EC, i.e. until 30 June 2001, Member States:

- at least 50% and up to 65% of the packaging waste by weight must be recovered;
- at least 25% and up to 45% by weight of all packaging material had to be recycled, with a minimum of 15% per type of packaging material [8].

Data on the amount of packaging waste in 2001 (kg) and the % recycled can be found in the Eurostat database. On this basis, Fig. 1 shows the percentage distribution by Member State. This graph was used to test the target set.

The graph shows that all but 4 Member States have met the target. France, Italy, Finland and Spain are all less than 10% behind. Belgium and Germany also exceeded the maximum of 65%. The original German Packaging Directive occupies a fundamental place in the development of European packaging legislation, not least because it was Germany's internal policy that led to the Packaging Directive in the first place in the EU. France, Spain and Austria have copied the German packaging waste management model to a large extent. The results show that only Austria was able to perform above the threshold with this model [16]. In the case of Portugal, Greece and Ireland, the legislators took local conditions and technical and economic potential into account, so these countries only had to meet the recovery and recycling rates by 31 December 2005. Eurostat data show that despite the extended deadline, only Ireland has managed to reach the minimum target. Greece and Portugal did not fall far short of the target, missing the target by 8 and 6.5% respectively (Fig. 2).

The recycling quotas were further tightened for the period after 30 June 2001, with the amendment of the Directive, and accordingly until 2006:

- a minimum of 60% and a maximum of 75% by weight of packaging waste must be recovered;
- a minimum of 55% and a maximum of 70% by weight of all packaging materials shall be recycled [8].

In 2004, the 14 Member States were joined by 10 more countries, which were also covered by the amended Directive (Fig. 3).

The increased minimum target was 60%, which was reached by Belgium, Germany, Luxembourg, Austria and the Czech Republic, which joined in 2004. Among the new Member States, Cyprus and Malta were the worst performers. Cyprus has a problem not only with packaging recycling, but also with the destruction and proper use of its natural treasures [17]. The other newly acceded countries recycled between 37% and 48% of their packaging waste. Belgium has also exceeded the set maximum.

Directive 94/62/EC set the following targets:

- By 31 December 2025, at least 65% by weight of all packaging must be recycled. The recycling targets by material are:
  50% in plastic;
  25% wood;
  70% ferrous metals;
  50% aluminium;
  70% glass, and
  75% for paper and cardboard.
- By 31 December 2030, at least 70% by weight of all packaging must be recycled. Includes:
  55% of plastic;
  30% wood;
  80% ferrous metals;
  60% aluminium;
  75% glass, and
  85% for paper and cardboard [15].

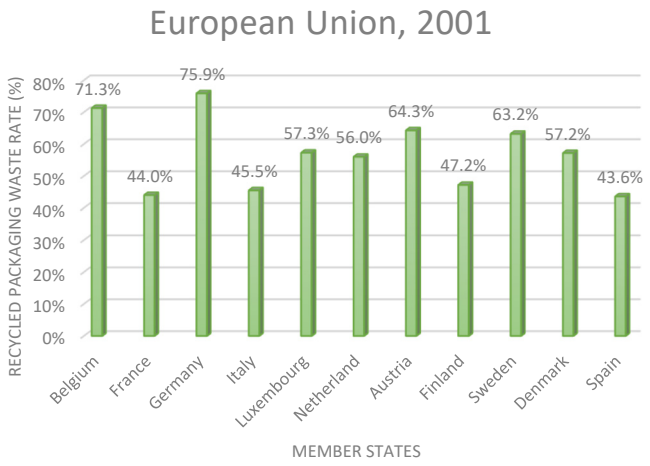

Fig. 1. Proportion of recycled packaging waste in EU, 2001
Source: own editing based on Eurostat database [12, 13]

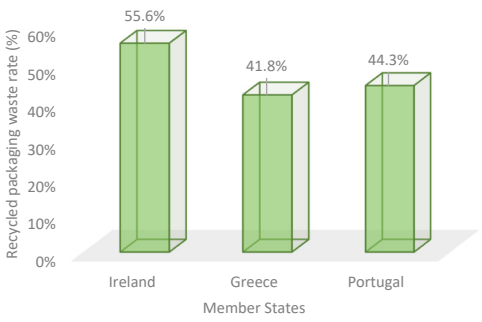

Fig. 2. Proportion of recycled packaging waste in EU, 2005
Source: own editing based on Eurostat database [12, 13]

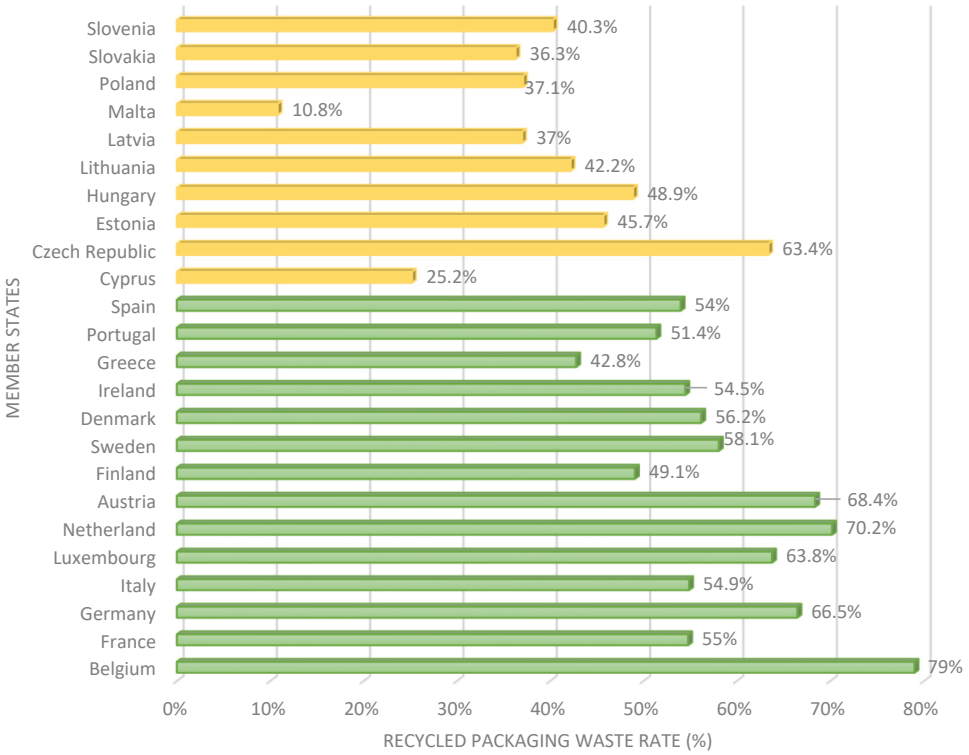

Fig. 3. Proportion of recycled packaging waste in EU, 2006
Source: own editing based on Eurostat database [12, 13]

The projection is based on data for the years 2000–2019 and plotted as a percentage (Fig. 4) for the years indicated above (2025, 2030), and will be discussed in more detail in later chapters.

According to the projections based on the data so far, 5 Member States - Germany, Hungary, Malta, Romania and Croatia - are expected to miss the 65% target by 2025. But only 4 countries are projected to miss the 70% target by

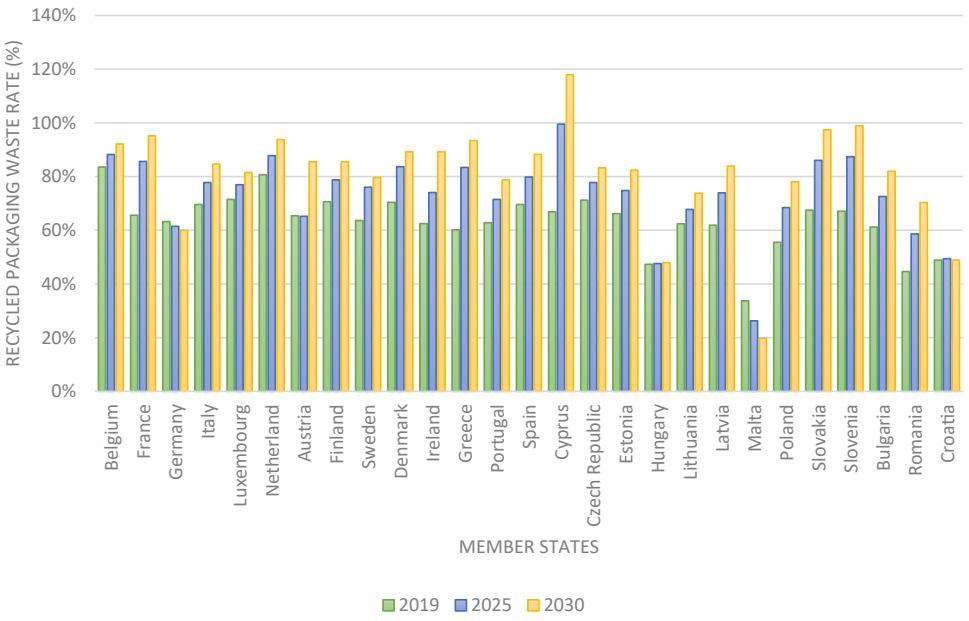

Fig. 4. Proportion of recycled packaging waste in EU, forecast
Source: own editing based on Eurostat database [12, 13]

2030. Compared to the previous list, Romania is expected to reach the minimum with 70.34%. Malta will achieve the lowest rate (19.8%), followed by Hungary (47.96%), Croatia (48.87%) and Germany (10% behind). Based on the result, countries can be grouped according to whether they show an improving, stagnating or deteriorating trend. Belgium, France, Italy, Luxembourg, the Netherlands, Austria, Finland, Sweden, Denmark, Ireland, Greece, Portugal, Spain, Cyprus, the Czech Republic, Estonia, Lithuania, Latvia, Poland, Slovakia, Slovenia, Bulgaria, Romania and Slovenia show a positive and improving trend. Hungary and Croatia are stagnant, i.e. close to the same values. Germany and Malta show a decline.

We consider our first hypothesis (H1) to be partially accepted, as it is only Germany's forecast performance that is not confirmed, which underperforms the targets. Of the countries that have met and are expected to meet the various benchmarks year after year, Germany stands out. Our assumption is confirmed for the other well performing countries (Belgium, Luxembourg, the Netherlands and Austria).

3.3. Packaging waste and recycling in Hungary

In Hungary, Act XLIII of 2000 on Waste Management (Hgt.) was entered into force on 1 January 2001. It gives special attention to packaging waste, as 56 § (8) states that base on the take-back obligation requires that by 1 July 2005 packaging materials that have become waste

- at least 50% of the land must be used,
- of which at least 25% is recovered in material, with a minimum of 15% for each type of material [8].

In 2005, this was as follows, based on Eurostat data (Fig. 5). Based on the nomenclature of the European Union, the data are per capita.

In Hungary, the weight of packaging waste and the weight of the recycled fraction shown in Fig. 5 was 45.9% by weight, which means that the recovery rate required by law was not met. After Hungary joined European Union, those directives will apply to Hungary as an EU Member State. Figure 6 shows the evolution of packaging waste and recycling rates after accession.

Fig. 5. Packaging waste and recycling in Hungary, 2005
Source: own editing based on Eurostat database [12, 13]

The lowest value of packaging waste in kg (80.64 kg) was in the year of accession to the EU (2004). Between 2009 and 2011, the amount of packaging waste decreased significantly, which may be explained by the fact that the economic crisis has reduced consumption. The second lowest weight was in 2011 (84.08 kg), after which the amount of waste has been steadily increasing each year, including a significant increase in the amount of packaging paper waste. The lowest recycling rate was in 2004 (34.91 kg), when the rate was 43.3%, which was not in line with the current EU directive. The highest recycling was 67.08 kg in 2019, which meant 47.3%. This is still below EU standards. Figure 6 shows the gap between the two values. It paints a negative picture as the amount of packaging waste increases, and this effect is underlined by the fact that recycling rates do not follow suit. To get an idea of the trend Hungary is likely to follow, using Microsoft excel forecast.esim statistics, a trend analysis based on data from previous years [12, 13] was used, as the trend for both packaging waste ($R^2 = 0.8253$) and recycling rate ($R^2 = 0.9154$) was suitable for forecasting (Fig. 7).

The volume of packaging waste in Hungary is forecast to increase over the period under review, but recycling rates are not expected to follow this trend. Our country will not comply with the EU directive and will fall 20–30% short of the minimum set.

Our second hypothesis (H2) is confirmed by the forecast for Hungary. Our assumption that our country will not meet the target is confirmed by our results.

4. DISCUSSION

Comparing the recycling data for 2019, 22 Member States met the minimum level set by the Directive (60%). The 2019 data is summarised in Table 2.

Out of 22 countries, 6 were the top performers, with over 70%. The best result was achieved by Belgium with 83.5%. If we look at Belgian waste management policy, we find several examples of good practice. For example, canteen and lunch box use by children in schools has been initiated; shops have been urged to use paper bags instead of plastic bags, and reusable bottles instead of plastic bottles and returnable packs for drinks. In addition, forums were held in municipalities with experts to reduce packaging waste and encourage residents to choose less-wrapped products instead of those with combined packaging. Comprehensive provisions include an integrated product policy (eco-tax); use and enforcement of the "polluter pays" principle [18]. This means that the company that causes environmental damage is liable for the damage caused, must take the necessary preventive or remedial measures and must bear the costs of the damage [19]. Active municipalities receive support for awareness-raising from regional governments; a system for waste prevention, recycling and incineration is in place at municipal level. The Flemish waste management administration provides financial support for home composting schemes and eco-advisors to help people [18]. In 2010 there was a grant from a Green Point organisation to Belgian

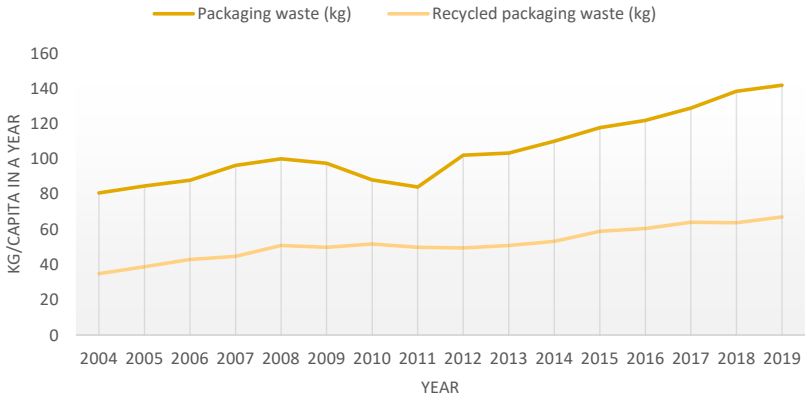

Fig. 6. Packaging waste management in Hungary
Source: own editing based on Eurostat database [12, 13]

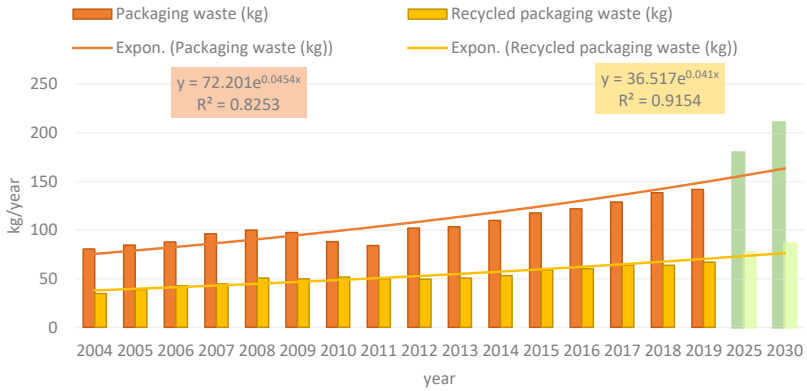

Fig. 7. Packaging waste management in Hungary, with forecast
Source: own editing based on Eurostat database [12, 13]

Table 2. The states proportion of recycled packaging waste in 2019

State	Proportion of recycled packaging waste	State	Proportion of recycled packaging waste
Belgium	83.5%	Sweden	63.6%
Netherland	80.7%	Germany	63.2%
Luxembourg	71.5%	Portugal	62.8%
Czech Republic	71.2%	Ireland	62.5%
Finland	70.6%	Latvia	62.4%
Denmark	70.4%	Lithuania	61.9%
Italy	69.6%	Bulgaria	61.2%
Spain	69.6%	Greece	60.1%
Slovakia	67.5%	Poland	55.5%
Slovenia	67.1%	Croatia	48.9%
Cyprus	66.8%	Hungary	47.3%
Estonia	66.2%	Romania	44.6%
France	65.6%	Malta	33.7%
Austria	65.4%		

Source: own editing based on Eurostat database [13].

municipal waste companies to finance their household waste activities [20]. Dutch packaging policy has been more progressive than European policies, but since 2000 it has failed to achieve its policy goals. Companies are individually responsible for prevention, collection and recycling of the packaging they place on the market. The "polluter pays" principle applies. From 2008, companies will have to pay a tax on packaging materials. Following the implementation of the Packaging Regulation, it has become clear that the packaging industry is not able to implement the measures established for the collection and processing of packaging waste on its own, and cooperation with municipal authorities is necessary [21]. This promoted joint work between businesses and municipalities to tackle packaging waste. Luxembourg plans to ban plastic packaging for fruit and vegetables in addition to single-use plastics from 2023. It is up to retailers to develop a plan to reduce unnecessary packaging of food. Luxembourg aims to reduce packaging waste by 70% by 2030 [22]. In the Czech Republic, Rossmann and DM stores are introducing a detergent and shampoo refill system to reduce packaging waste. This practice has already been successfully adopted in Romania, Slovakia and Austria [23]. In Finland, there are two pressures that encourage people to recycle packaging waste: environmental values and social pressure and expectation. There is also an environmental tax to motivate companies and private individuals. It has been observed that having the

collection point at a shorter distance from the household increases the propensity to recycle [24]. Denmark has two practices in the prevention phase of packaging waste management: clean technology and green accounting. There is also a waste tax, which could be a model for other environmental taxes, and a "green tax" on packaging. The latter helps to promote products that are more environmentally friendly and use less packaging. Local and regional authorities are responsible for the collection and disposal of waste. And recycling is mandatory throughout the country [25]. If we look at the packaging waste management curves of these 6 countries (Fig. 8), we can conclude that their waste recycling policies are forward-looking. In general, the trend in recycling follows the trend in waste generated, in contrast to the trend graph for Hungary analysed above.

The projections for the recycling rates of packaging waste in the 6 countries (Fig. 9) assume a continuing forward trend. The R^2 value is below 0.8 for Denmark alone of the 6 countries, so the trend function is suitable for forecasting for the remaining countries.

For Hungary to catch up in packaging waste recycling and not only reach the projected 47%, it can look to these

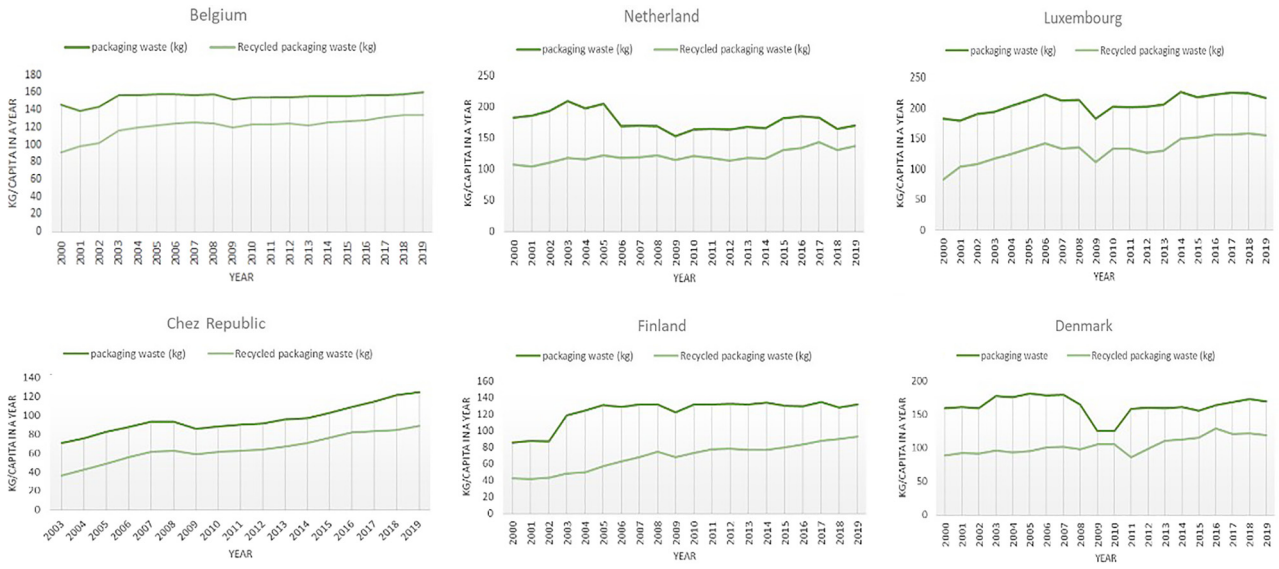

Fig. 8. Packaging waste management in the 6 best-performing countries
Source: own editing based on Eurostat database [12, 13]

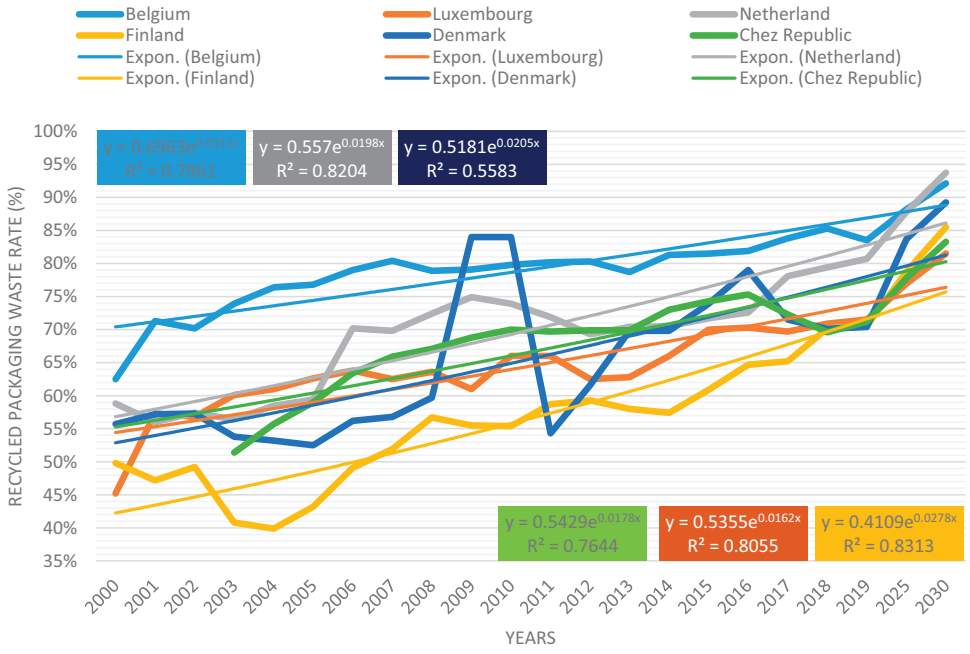

Fig. 9. Forecast of recycled packaging waste (%)
Source: own editing based on Eurostat database [12, 13]

countries as examples. It is important that separate waste collection is available in municipalities and that all residents are properly informed. A single regulation calling on retailers and manufacturers to reduce packaging and use more sustainable packaging materials would help. The development of refill systems and wider distribution of returnable bottles would be useful. Using sustainable packaging materials can also reduce packaging waste. Food packaging can be made using biopolymers, which are biodegradable. Their use contributes to reducing packaging waste by allowing such materials to be recycled back into the natural cycle under appropriate conditions (composting). A precondition for this is the establishment of selective waste collection and the creation of appropriate composting sites [26]. The amount of packaging required for a product can be reduced by making the product lighter. This requires companies to measure the ratio between the amount of packaging material used and the amount of product delivered. The reduction in the amount of materials used in packaging elements is the result of design or material innovation. For example, in 2006 Unilever introduced a detergent that was three times more concentrated than conventional detergents [27]. Polylactide (PLA), a biodegradable aliphatic polyester, has been widely studied for all its applications, from food packaging to car interiors. One of the advantages of PLA is that its raw material, lactic acid, can come from renewable sources, which makes PLA attractive for packaging and is considered green packaging [28]. Polylactic acid (PLA) is a compostable and natural plastic. Its mechanical properties are very similar to PET, this making PLA a good alternative for highly regulated food applications [29]. PLA (like PLLA and PDLLA) is more resistant to deformation forces, so the material's load-bearing capacity is better than that of PET, which is currently used. Strengths include specific load carrying capacity, lower moulding temperature [30]. Setting environmental requirements in product development is not only important for the environment, but also for business. The key objective is to reduce harmful environmental impacts while continuing to the increase consumption. Eco-design is the integration of an environmentally conscious approach into product development. The main goal of eco-design is to develop products and services so that they are sustainable, reducing the environmental impact of products throughout their life cycle. It pays attention to consumer requirements in terms of functionality, quality, safety, cost, manufacturing, ergonomics and aesthetics. Eco-design also involves optimising the packaging of the product, which further reduces the use of raw materials. These steps all contribute to lower CO_2 emissions. In the context of eco-design, several types of certificates aim to prevent environmental pollution and inform consumers about the environmentally friendly features of the product and the amount of energy that can be saved by buying it [31]. Using these and similar materials can reduce packaging waste and increase recycling. This study has highlighted the differences in the way Member States meet the requirements. Our results show that there are marked differences between Member States, with Hungary presenting stagnating results. A further research opportunity is to explore ways to improve domestic regulation, from the consumer side and from a legislative approach.

5. CONCLUSION

The main purpose of packaging is to protect the product from the harmful effects of the environment and to protect the environment from the goods. In terms of packaging materials, plastic is the biggest threat to both ecosystems and human health. Our objective was to show how the Member States of the European Union, and Hungary in particular, can meet the targets set by EU legislation. The European Union has already set several directives for the management and recovery of packaging waste. First, to 2001 the then Member States had to recycle 50% of their packaging waste. France, Italy, Finland and Spain were all less than 10% behind. They then had to achieve a 60% recovery rate by 2006. The increased minimum target was met by Belgium, Germany, Luxembourg, Austria and the Czech Republic, which joined in 2004. Currently, there are two targets, 65% of packaging waste to be recovered by member states by 2025 and 70% by 2030. The 2025 rate is projected by us to be missed by Germany, Hungary, Malta, Romania and Croatia. By 2030, only 4 countries are not expected to meet the target. Compared to the previous list, Romania is expected to meet the target. In 2005, Hungary failed to meet the 50% recovery rate required by national and EU legislation. According to the forecast, the annual volume of packaging waste in Hungary is expected to increase, but the recycling rate will not follow this trend. It is not in line with the EU directive and is expected to be 20–30% below the minimum set. For Hungary to catch up, it can look to other recycling leader countries as an example. Belgium, the Netherlands, Luxembourg, the Czech Republic, Finland and Denmark are the Member States that achieved over 70% packaging waste recycling in 2019. All 6 countries are recycling regulated, promoting packaging-free products or products with less packaging. The "polluter pays" principle applies, and various taxes are being used to fight plastic and combined packaging. In addition, the market for sustainable packaging is also gaining ground, as it is easier to decompose and has good properties. Such packaging materials include biopolymers, PLA, etc. It can also be used to lighten products and thus reduce the weight of packaging. And eco-design is an environmentally conscious approach that can be incorporated into product development. By using such methods, Hungary can catch up with the Member States and also reduce the country's environmental burden and improve people's health.

REFERENCES

[1] O. Rockstroh, *Csomagolástechnikai kézikönyv*. Műszaki Könyvkiadó, 1979, p. 603, ISBN 9631032795.

[2] K. R. Dörnyei, *Csomagolásmenedzsment*. Kossuth Kiadó, 2019, p. 302, ISBN 978-963-099-307-4.
[3] E. Halmos, *Csomagolás és logisztika*. Papír-Press Egyesülés, 2002, p. 127.
[4] M. Kedzierski, D. Frère, G. Le Maguer, and S. Bruzaud, "Why is there plastic packaging in the natural environment? Understanding the roots of our individual plastic waste management behaviours," *Sci. Total Environ.*, vol. 740, p. 139985, 2020. https://doi.org/10.1016/j.scitotenv.2020.139985.
[5] A. Trajkovska Petkoska, D. Daniloski, N. M. D'Cunha, N. Naumovski, and A. T. Broach, "Edible packaging: sustainable solutions and novel trends in food packaging," *Food Res. Int.*, vol. 140, p. 109981, 2021. https://doi.org/10.1016/j.foodres.2020.109981.
[6] P. Földesi, "LOGISZTIKA I-II," p. 336, 2006. HEFOP 3.3.1-P-2004-09-0102/1.0 pályázat támogatásával.
[7] W. R. Mason, "A theory of packaging in the marketing mix," *Business Horizons*, vol. 1, no. 3, pp. 91–5, 1958. https://doi.org/10.1016/0007-6813(58)90082-X.
[8] A. Tiefbrunner, *Csomagolás és környezetvédelem*. Papír-Press Egyesülés, 2002, p. 199, ISBN 963 86223 2 6.
[9] J. Marcondes, "Packaging," in *Anonymous Encyclopedia of Vibration, Three-Volume Set*. Elsevier, 2001, pp. 983–9, ISBN 0080523625.
[10] H. Boonman, P. Verstraten, van der Weijde, and H. Adriaan, "Macroeconomic and environmental impacts of circular economy innovation policy," *Sustain. Prod. Consump.*, vol. 35, pp. 216–28, 2023. https://doi.org/10.1016/j.spc.2022.10.025.
[11] I. Sazdovski, D. Bojovic, L. Batlle-Bayer, R. Aldaco, M. Margallo, and P. Fullana-i-Palmer, "Circular economy of packaging and relativity of time in packaging life cycle," *Resour. Conserv. Recycl.*, vol. 184, p. 106393, 2022. https://doi.org/10.1016/j.resconrec.2022.106393.
[12] Eurostat, "Generation of packaging waste per capita," 2022a. Available at: https://ec.europa.eu/eurostat/databrowser/view/cei_pc040/default/table?lang=en.
[13] Eurostat, "Recycling rate of packaging waste by type of packaging," 2022b. Available at: https://ec.europa.eu/eurostat/databrowser/view/cei_wm020/default/table?lang=en.
[14] J. Marshall, "Packaging unwrapped," *NewScientist*, vol. 194, no. 2598, pp. 37–41, 2007. https://doi.org/10.1016/S0262-4079(07)60869-0.
[15] Eur-lex.europa, "Csomagolás és csomagolási hulladék," 2020a. Available at: https://eur-lex.europa.eu/legal-content/HU/ALL/?uri=LEGISSUM:l21207.
[16] I. Bailey, "Flexibility, harmonization and the single market in EU environmental policy: the packaging waste directive," *JCMS: J. Common Market Stud.*, vol. 37, no. 4, pp. 549–71, 1999. https://doi.org/10.1111/1468-5965.00196.
[17] M. T. García-Álvarez and B. Moreno, "Environmental performance assessment in the EU: a challenge for the sustainability," *J. Clean. Prod.*, vol. 205, pp. 266–80, 2018. https://10.1016/j.jclepro.2018.08.284.
[18] F. Vassne, "Belgium hulladékgazdálkodás a flamand régióban," 2006, p. 11.
[19] Eur-lex.europa, "A „szennyező fizet" elve és a környezeti felelősség," 2020b. Available at: https://eur-lex.europa.eu/HU/legal-content/summary/the-polluter-pays-principle-and-environmental-liability.html.
[20] S. De Jaeger and N. Rogge, "Cost-efficiency in packaging waste management: the case of Belgium," *Resour. Conserv. Recycl.*, vol. 85, pp. 106–15, 2014. https://doi.org/10.1016/j.resconrec.2013.08.006.
[21] M. Rouw and E. Worrell, "Evaluating the impacts of packaging policy in The Netherlands," *Resour. Conserv. Recycl.*, vol. 55, no. 4, pp. 483–92, 2011. https://doi.org/10.1016/j.resconrec.2010.12.013.
[22] Dontwasteit, "Luxemburg betiltja az egyszer használatos műanyagok használatát 2023-tól," 2022. Available at: https://dontwasteit.hu/2022/04/28/luxemburg-betiltja-az-egyszer-hasznalatos-muanyagok-hasznalatat-2023-tol/.
[23] Novinky, "Nový trend. Drogerie začínají prodávat zboží bez obalu," 2019. Available at: https://www.novinky.cz/clanek/ekonomika-novy-trend-drogerie-zacinaji-prodavat-zbozi-bez-obalu-40302741.
[24] H. Reijonen, S. Bellman, J. Murphy, and H. Kokkonen, "Factors related to recycling plastic packaging in Finland's new waste management scheme," *Waste Manage.*, vol. 131, pp. 88–97, 2021. https://doi.org/10.1016/j.wasman.2021.05.034.
[25] Zs. Farkas, "Dán törvényhozás az újrahasznosítást még a hulladékadó bevezetése előtt kötelezővé tette," p. 6, 2006.
[26] J. Beczner, J. Perédi, B. Haidekker, B. Kertész, J. Lajos, P. K. Vásárhelyiné, and Gy. Kardos, "A biológiai úton lebomló csomagolóanyagok előállítási és felhasználási lehetőségének vizsgálata itthon és külföldön," *IIC Int. Rev. Intellect. Prop. Compet. Law*, vol. 51, no. 9, pp. 0018–9855, 1997.
[27] S. Dharmadhikari, "Eco-friendly packaging in supply chain," *IUP J. Supply Chain Manage.*, vol. 9, no. 2, pp. 7–18, 2012.
[28] J. Ahmed and S. K. Varshney, "Polylactides—chemistry, properties and green packaging technology: a review," *Int. J. Food Prop.*, vol. 14, no. 1, pp. 37–58, 2011. https://10.1080/10942910903125284.
[29] T. Horváth, T. J. Szabó, and K. Marossy, "Synthesis of polylactic acid (PLA) by polycondensation method," *Int. J. Eng. Manage. Sci. (IJEMS)*, vol. 5, no. 2, 2020a. https://10.21791/IJEMS.2020.2.32.
[30] T. Horváth, T. J. Szabó, and K. Marossy, "Polylactic acid as a potential alternatives of traditional plastic packagings in food industry," *Int. J. Eng. Manage. Sci. (IJEMS)*, vol. 5, no. 2, 2020b. https://10.21791/IJEMS.2020.2.16.
[31] I. Gurauskienė and V. Varžinskas, "Eco-design methodology for electrical and electronic equipment industry," *Environ. Res. Eng. Manage.*, vol. 37, no. 3, 2006.