Jerzy KOZŁOWSKI, Dr, Eng.[1)], Marta LEWANDOWSKA, MSc. Eng.[1)], Dawid SOJKA MSc., Eng.[1)]

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[1)] The Łukasiewicz Research Network – Institute of Non-Ferrous Metals in Gliwice
5, General Józef Sowiński str., 44-121 Gliwice
e-mail: jerzyk@imn.gliwice.pl

WASTE MANAGEMENT IN POLAND AND IN OTHER EU COUNTRIES

GOSPODARKA ODPADAMI W POLSCE I INNYCH KRAJACH UNII EUROPEJSKIEJ

***Summary**: The subject of publication includes basic information on the waste management in Poland as compared to other EU countries and on the selected post-consumer waste, occurring in Poland. In the paper, the problems of the waste accumulation on the landfills in Poland and in the EU and the threats, connected with this problem, have been presented. The factors, enabling the effective recycling process have been indicated. Frequent technological changes of the manufactured products and the increasing demand on the mentioned products requires a special approach to the process of their recycling in accordance with the requirement of the natural environment.*

***Keywords**: waste management, recycling, WEEE, waste import, post-consumer waste, batteries, cells, packages, recycling of vehicles*

***Streszczenie**: Tematyka publikacji obejmuje podstawowe informacje o gospodarce odpadami w Polsce w porównaniu z krajami UE oraz wybranych odpadach pouzytkowych występujące w Polsce. W artykule przedstawiono problem gromadzenia odpadów na składowiskach w Polsce i UE oraz niebezpieczeństwa z tym związane. Wskazano czynniki umożliwiające prowadzenie efektywnego procesu recyklingu. Częste zmiany technologiczne wytwarzanych produktów oraz zwiększający się na nie popyt wymaga szczególnego podejścia do procesu ich recyklingu, zgodnie z wymogami środowiska naturalnego.*

***Słowa kluczowe**: gospodarka odpadami, recykling, WSEE, import odpadów, odpady pouzytkowe, akumulatory, baterie, opakowania, recykling pojazdów*

Introduction

Protection of natural environment is a priority target of Circular Economy (in Polish: GOZ). The mentioned aim may be reached by maximum limitation of harmful effect of dangerous materials and substances in the soil, air and human body. The success of the mentioned target is determined by development of waste-free production technologies of goods which limit generation of after-production waste and decrease the effect of harmful substances on natural environment. In the nineties of the 20th century, a sudden economic growth was recorded what was reflected in the increase of the mass of the generated waste. Frequent technological changes of the manufactured products and the increasing demand on these products requires a special approach to their recycling process, in accordance with the requirement of natural environment. Ensuring the appropriate organisation of the waste collection and their processing at the territory of the country is a factor which enables running the effective recycling process. Separation and sale of semi-products, coming from recycling is presently a dominating model of recycling in Poland. Currently, the repeated use of the equipment with the profits to the natural environment is the preferred direction of the waste management in the European Union. The subject of the publication includes information on the selected post-consumer waste such as:

- waste electric and electronic equipment
- waste of car wrecks
- multi-material waste
- waste cells and batteries

In the present publication, the problems of accumulation of the waste at the landfills and the related threats have been also discussed. In order to improve the effectiveness of waste collection and processing in the country, we should invest in educational activity, showing the ecological consequences of waste collection or their processing with the harm to natural environment. A lack of waste segregation is often justified by a lack of appropriate technologies for their processing. Such opinions are harmful for the natural environment as within the frames of many research studies, conducted in Poland, there were developed many technologies which could be applied in the process of waste management. The problems of the publication include basic information on the selected waste, containing metals which occur in Poland, their characteristics and their processing technologies. The mean annual world production is equal to

more than 20 billion Mg of industrial waste and ca. 1.5 billion Mg of post-consumer (municipal) waste coming from households. In Poland, more than 12 million Mg of waste, including ca. 10 million Mg of post-consumer waste are produced. The remaining quantity is constituted by industrial waste. The highest mass of waste is generated by mining and extractive industry (53% of the produced waste), processing sector – almost 23% of the waste and energetic industry generates 16% of the produced waste. If we add the post-consumer waste in the quantity of 8%, we may state that in 2019 we generated 12.754 million Mg of the waste in total; it is equal to 336 kg per one inhabitant. The greatest producer of the waste in Poland is mining and extractive industry which generated ca 6.7 million Mg of the waste in 2019. The second producer of the waste in respect of mass is processing sector which generated more than 2.8 million Mg of the waste in the mentioned above years. At the same time, energetic industry produced almost 1.5 million Mg of the waste. The mentioned three industrial sectors in Poland produced more than 11 million Mg of the waste in 2019. Diagram in Fig. 1 illustrates the producers of the waste in Poland who generated more than 12 million Mg waste in 2019.

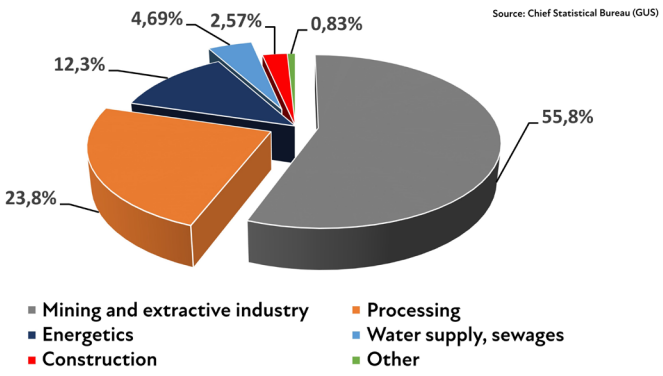

Fig. 1. Producers of the waste in Poland in 2019 (different classification)

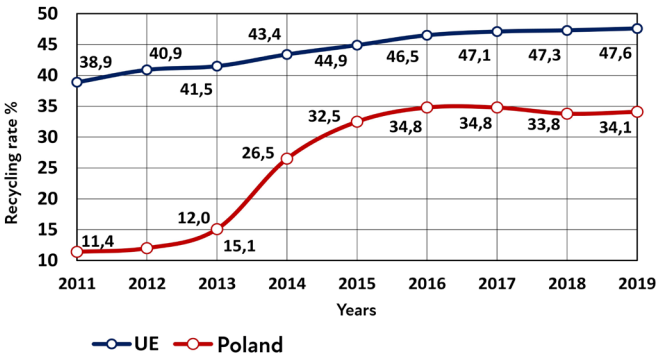

Fig. 2. Indices of waste recycling in the EU and in Poland in 2011–2019

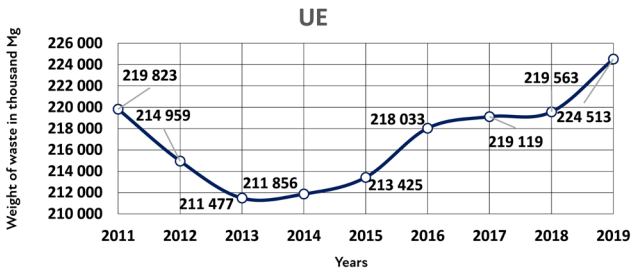

Fig. 3. Weight of the waste generated in the EU in the period of 2011–2019

Fig. 4. Weight of the waste produced in Poland in 2011–2019

POST-CONSUMER WASTE

The situation in respect of waste management in the European Union and in Poland

According to Eurostat data [1], the mean index of waste recycling in the European Union in 2019 amounted to 47.6% whereas in Poland – 34.1%. The comparison of recycling index in the EU and in Poland in 2019 is illustrated in Diagram in Fig. 2.

As it can be seen from the above diagram, since 2013, the 75-% increase in the waste recycling index in Poland has been observed; it increased successively in the next years. A small slowing down of the mentioned tendency was recorded in 2018 but since 2019, the rise in the recycling index has been stated. We are still behind the European Union which showed index of recycling at the level of 47.6% in 2019 what was by 13.5% more as and calculated into waste weight, was equal to 1721.6 thousand Mg of the waste. In Poland, the collection of municipal (post-consumer) waste shows the increasing tendency and in 2019, it amounted to more than 12.75 million Mg what is the participation of 5.68 % in the whole European Union (27 countries).

Fig. 3 and Fig. 4 illustrate the curves of the way of the generated municipal waste in the period of 2011–2019 in the European Union and in Poland. As it can be seen in the diagrams, the run of the lines in the diagram is similar, what is an evidence of rapid development of the economy, resulting in the generation of the waste. The examples of it include change of electronic equipment into a better-quality one, increase of the population incomes etc. The tendency of producing the waste by the society is demonstrated by the coefficient of waste weight, as calculated into 1 inhabitant of the country. In 2019, in the EU, the mentioned index was equal to 502 kg whereas in Poland it was 336 kg. Fig. 5 illustrates the discussed coefficient in the EU and Poland in 2011–2019.

When analysing the above diagram (Fig. 5) we may state that a citizen of our country in 2019 produced by 166 kg less (by 33%) waste than the mean in the European Union. Do we really produ-

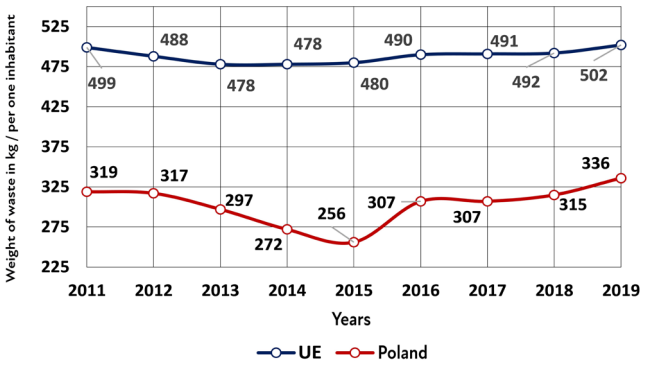

Fig. 5. Weight of municipal waste in the EU and in Poland per one inhabitant in the period of 2011–2019

ce less waste? That's one way of concluding but perhaps there is another reason; we are simply less rich country than a part of the EU countries and we consume less fixed assets. It is not food because we may assume that every person in each of the EU countries consumes in the same way. The mentioned problem requires deeper research analysis. The author encourages the respective competent institutions to perform such activity.

The management of waste may be carried out by 4 following methods:

- accumulation (storage)
- recycling
- thermal processing
- composting

The quantity of the waste gathered or collected selectively for Poland in 2019 amounted to almost 104 kg per one inhabitant, including:

- biodegradable waste – 31 kg per 1 inhabitant (26kg in 2018
- large size waste – 16 kg per 1 inhabitant (14 kg in 2018)
- glass – 15 kg per 1 inhabitant (13 kg in 2018)
- mixed packaging waste – 13 kg per 1 inhabitant (15 kg in 2018)
- plastics – 10 kg per 1 inhabitant (9kg in 2018)
- paper and cardboard – 9 kg per 1 inhabitant (7 kg in 2018).

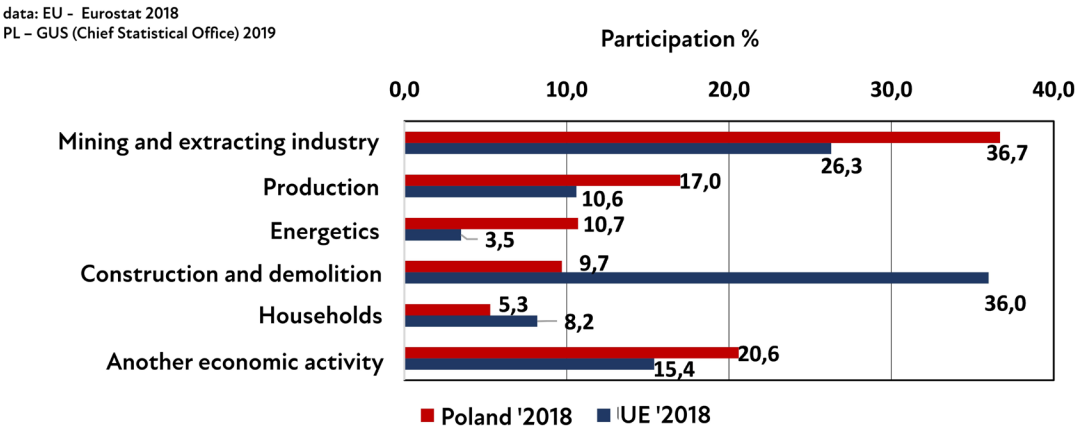

Fig. 6. Waste producers in Poland in 2019 and in the European Union in 2018

Import of waste

Many economic entities, dealing with the waste management are the importers of the waste. It is a profitable business for the entrepreneurs but harmful for the natural environment. Some foreign businessmen are happy to get rid of their waste, especially those poor in metal content or the dangerous ones. It happens especially in the case when the charges for their storage or disposal are high.

In 2019, 405 thousand Mg of waste were imported to Poland; they came mainly from Germany (ca. 68%). The remaining countries include: Great Britain, Sweden, Italy, Austria and Denmark. Due to such high index of waste import, certain media call our country as "garbage dump of Europe". Fig. 7 and Fig. 8 illustrate import of waste from 2015 to 2019. As it is stressed by the Ministry of Climate, Poland cannot forbid import of waste destined for recycling and those ones, present in the so-called green list (e.g. scrap-metal, waste paper) to Poland. Import/export of the mentioned waste is conducted within the frames of the EU on

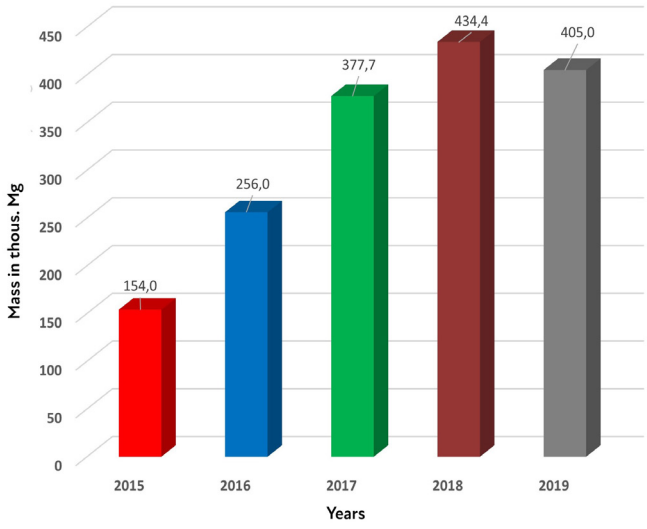

Fig. 7. Waste import to Poland in 2010

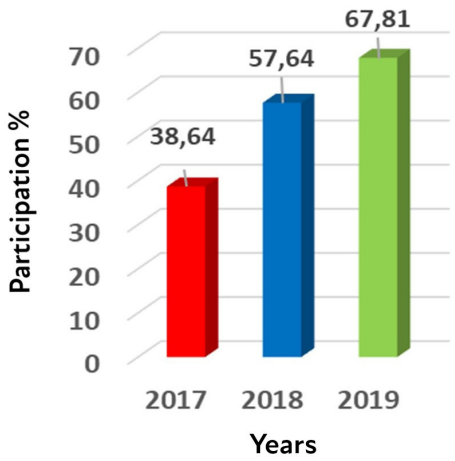

Fig. 8. Waste import to Poland from Germany in 2017–2019

the principles of free flow of goods and the eventual ban would have to refer to the whole European Union.

As the Ministry of Climate informs, Poland cannot forbid import of waste from the so-called green list of waste; the municipal waste – according to the Ministry – is not imported to Poland. As it can be concluded from the above data, presented in the diagram (Fig. 7) import of waste to Poland in the period of 2015–2019 was systematically increasing: from 154 thousand Mg in 2015 to 434 thousand Mg in 2018 and 405 thousand Mg in 2019. In this respect, Germany is dominating as 67.81% of the total weight of the imported waste was imported in 2019 from the mentioned country (Fig. 8).

According to information of the Ministry of Climate [27], "*cross-border movement of waste is a common phenomenon in the whole Europe and Poland participates in it to a small degree. The mass of the imported waste is a marginal quantity in the scale of the whole country, for example: weight of the imported waste in 2017 constitutes 0.33% of the total mass of the waste, generated in Poland in the mentioned year.*

In 2016 (EUROSTAT data), on the grounds of the authorizations of their official authorities, Germany imported almost 6.5 million tonnes of waste from other countries, including Poland (more than 2 million tonnes). The waste intended to be recycled and mentioned in the so-called green list of waste (e.g. scrap-metal, wasted paper) are not "the rubbish"; the raw materials are processed in modern installations which meet the environmental requirements".

The Ministry of Climate informs also that in 2018, there was introduced "*the complete ban on importing – to Poland – all types of waste, destined for disposal and of municipal waste and the waste, resulting from processing of municipal waste, excluding the selectively collected waste, intended for recycling*". The Ministry of Climate informs also that the use of wording "garbage dump of Europe" by certain media in relation to Poland "*is completely untrue, is not reflected by the real state, is a result of failure to know or understand the rules of Polish and EU law, or is simply a pure lie and manipulation*".

Hazards of landfills

Inappropriate storage of waste causes a danger if fire, especially when it is the so-called "wild" landfill, i.e. without the owner. Such landfills may be found on the wastelands or in the forests. At present, the mentioned territories are often monitored, protecting the unlawful waste storage. Fig. 9 illustrates the relationship between the mass of the imported waste and the number of fires in the period of 2015–2018.

We may observe here a certain relationship after 2017. Since 2017, the troubles with the export of the secondary raw materials to China have been commenced. In 2019, there were fires of 243 landfills (Fig. 10) and, as it was given by media, it could be connected with the import of waste to Poland in the discussed period. To confirm the mentioned relationship, we should conduct the appropriate expertises and analyses by the competent institutions.

The mentioned above thesis may be confirmed by the fact that the number of landfill fires in Poland in the period of 2012–2018 increased by ca. 70%. Extinction of the burning landfill is very difficult to be overcome and often impossible in the sites where the combustion gases are harmful to human health and natural environment and increase the so-called "carbon footprint".

Fig. 9. Comparative diagram of the relationship between the amount of landfill fires and the amount of the imported waste in 2015–2018

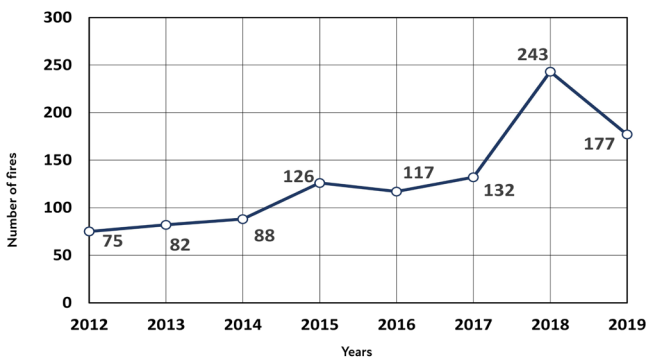

Fig. 10. Landfill fires in Poland in 2012–2018

WASTE ELECTRIC AND ELECTRONIC EQUIPMENT (WEEE)

WEEE waste, being also called "electro-waste" are used, broken-down, defective, inefficient, destroyed, out-of-use or simply unnecessary equipment, the operation of which is dependent on the supply of electric current of electromagnetic fields. There-

fore, all types of the used equipment, operated by power or batteries are "electro-waste".

In 2019, about 53.6 million Mg of WEEE waste were generated all over the world what calculated into 1 person gives 6.9 kg (EU – 16.2 kg/person; Poland – 11.7%) [7]. 82.6% of the above value is processed without documents what gives weight of 44.3 million kg. During the mentioned period, in Europe, there was processed 12 million Mg of WEEE waste, including legally processed 5.1 million Mg, i.e. 42.5%. The participation of Poland in the mentioned weight is 443 thousand Mg i.e. almost 8.7%. The classification of the world collection of waste in 2019 according to the types of the waste is presented in Tab. 1.

During the period of 2009–2019, i.e. 9 years, the weight of the electric and electronic equipment, imported to Poland was increased by ca. 80% whereas the collection of the used equipment during the discussed period was increased by more than 307%.The run of the indicators of the weight of the imported equipment and the collected WEEE waste is shown in diagram (Fig. 11).

Table 1. Weight of WEEE waste collected all over the world in 2019 according to the types of waste

No.	Type of equipment	Million Mg
1	Small household appliance	17.4
2	Big household equipment	13.1
3	Replacement of temperature sensors	10.8
4	IT and internet	6.7
5	Telecommunication	4.7
6	Lamps	0.9
7	**Total**	**53.6**

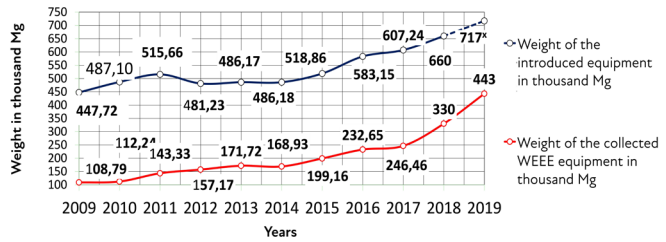

Fig. 11. Weight of WEEE equipment introduced to and collected in Poland in 2009–2018 Remark: x) Due to the lack of the data, the weight of the equipment imported in 2019 was calculated on the grounds of the growth index of 2017/2018

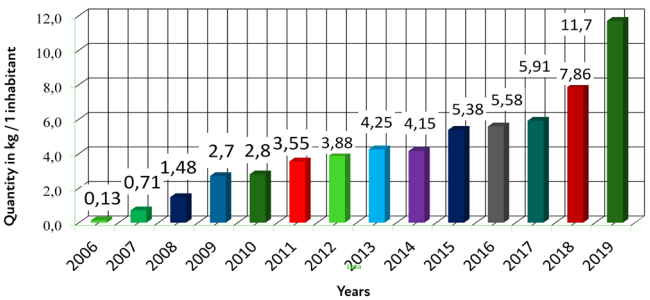

Fig. 12. WEEE equipment collection in Poland in 2019, as calculated into 1 person

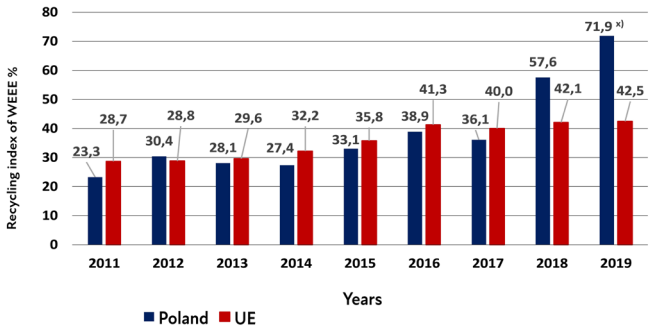

Fig. 13.Index of WEEE equipment recycling in Poland and in EU since 2011

Remark to Fig. 13: x) Index of recycling was calculated from the mean weight of the introduced WEEE equipment from 3 years: 2016-2018 which amounted to 616 thousand Mg and from the weight of the collected WEEE equipment in 2019 what was equal to 443 thousand Mg [7]. As it can be seen from the diagram (Fig. 14), since 2019 WEEE equipment recycling index in Poland was increasing (with certain fluctuations) and in 2018 it reached 57,65% as compared to the European Union (42.1%).

During the period of 2019–2018, the collection of WEEE equipment in Poland increased by more than 34%. The run of the WEEE equipment collection coefficient in Poland in 2006–2018, as calculated into 1 inhabitant is shown in diagram (Fig. 12). On the other hand, Fig. 13 illustrates a recycling index of WEEE since 2011.

Since 2018, GIOŚ (Chief Inspectorate for Environmental Protection) has stopped publishing the report on WEEE equipment management in the country what makes analysis of the state of WEEE equipment management in Poland difficult. All data were collected from Internet pages (publications etc) and from EUROSTAT information. The level of the WEEE equipment recycling index as being calculated above (71.9%) is surprising as during the previous years it varied within the limits of 40–42%. The mentioned value resulted from Eurostat information on the level of WEEE recycling index in Poland at the level of 443 thousand Mg, and GIOŚ information from reports concerning the earlier years. Due to these reasons, it is not possible to verify the calculated recycling index with the real value. The remarks concerning the discussed situation are considered in the final part of the present publication.

In respect of the quantity of the collected WEEE equipment, Poland occupies the seventh place from among the EU countries; the Scandinavian countries are unquestionable leaders. In Sweden, more than 80% of the weight of introduced electronic equipment is collected and subjected to recycling or prepared to the repeated use. High levels of the collection are also recorded in Norway (75 % of the weight of the introduced equipment) and in Switzerland (65%) although the EU regulations are not applied to these countries. The worst situation in respect of electro-waste collection is recorded in such countries as Greece (25%), Rumania (15%) and Cyprus (20%).

The occurrence of multi-componential different types of materials in electric and electronic equipment causes that they are the waste difficult to be processed. WEEE equipment contains metals as well as non-metals being connected in a solid or non-solid way. Metals include steel and non-ferrous metals and non-metals consist mainly of plastics and ceramics. A part

of WEEE equipment contains additionally printed circuit boards (PCBs). The PCB plate wastes are conglomerate of many materials, including precious metals. In manufacture of PCBs, different types of medium are employed, e.g. epoxy resins, reinforced with glass fibre with admixture of the compounds, limiting flammability; they are most frequently bromine derivates. Paper saturated with phenol resins with the admixture of flammability-limiting organic compounds is another universally used laminate. The conducting paths, put on the plates are mainly made of copper but we can meet also conducting elements made of nickel, silver, gold or alloy of tin and lead, or silver solder. The electronic elements, as being assembled on the plates contain a whole series of metals, including non-ferrous metals and their alloys and also, precious metals and REE (Rare Earth Elements). Apart from the metals, there are also ceramic compounds from silicone and aluminium. We may meet also alkaline earth oxides, and mica. However, the basic group of metals which can be found in the PCB plates include non-ferrous metals such as copper, nickel, aluminium and their alloys, iron and tin-lead solder. Depending on the period of time in which the discussed plates were produced, their content of metals is differentiated; for example, copper content may vary from 10-15%, that of aluminium – 5-8%, nickel 1-2%, lead – 1-2% and iron – 5-10% whereas that of precious metals such as silver – up to 1% and gold - several hundred grams per 1 tonne of waste. Besides it, the waste of this type contains also certain amounts of palladium and platinum. The knowledge of the scraped electronic equipment, especially of PCB plates with electronic elements allows choosing the optimum method for processing, enabling maximum utilization of materials (especially non-ferrous metals and precious metals) and on the other side, minimizing the detrimental effect on the environment.

In order to meet the requirements of the Circular Economy, it is necessary to ensure that the electric and electronic equipment (mainly household devices and Radio and TV equipment; in Polish AGD, RTV) is correctly designed and does not cause any problems during the process of its recycling. The Law on the waste electric and electronic equipment, which is obligatory in our country, does not ensure the following requirement; there is a lack of specified safety standards in respect of the re-use of the equipment, there is no list of the types of such equipment and determining which organ would be a supervisor. The producers of the discussed equipment have also doubts concerning the service of such equipment – who would give guaranties?

During the annual conference: "*Recycling of waste electric and electronic equipment*", being held on-line in April, 14, 2021, the perspectives for the duty of collecting WEEE (being introduced into use in 2011–2018) for the years 2021–2023 were presented. It results from the above mentioned prognosis that – for example – in 2021, we should collect 93% of waste from the equipment introduced in 2011, then, in 2022 – 109% and in 2023 – 126% more than it was introduced if we adopt the requirements of the EU '{28]. It is practically impossible if we adopt the s-far existing coefficients, reached during the recent years. It is a great problem if Poland wants to avoid high penalties for failure to fulfil the duties.

WASTE OF PASSENGER CARS

Status of vehicle fleet in Poland

According to the data of IBRM Sambor, in 1928, there were more than 30.7 million pcs of car vehicles registered in Poland. It includes above 23 million pcs of passenger cars. The mean age of car in Poland is 13 years what gives us the 17th place from among 25 European countries (Fig. 14).

As it can be seen from the above diagram (Fig. 15), in 2018 the passenger cars at the age of 10-15 years constituted the highest number of cars moving on domestic roads. The cars below 10 years of age contributed to 28.7% of the whole number of cars, moving on Polish roads.

In 2019, there were 31500 thousand pcs of vehicles, including 24610 thousand pcs (78.1%) of passenger cars. During the coming years, the multi-age vehicles, bought in the country as well as the imported used cars will be subjected to scraping. The age structure of cars in Poland changes from year to year.

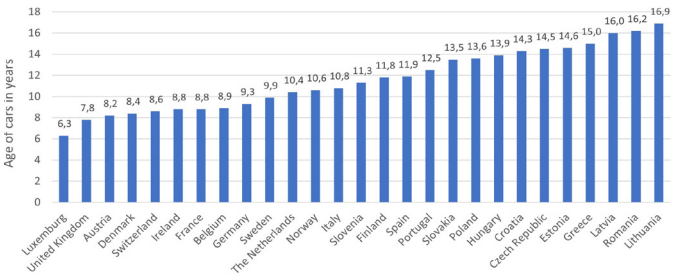

Fig. 14. The mean age of passenger cars in the European countries in 2018

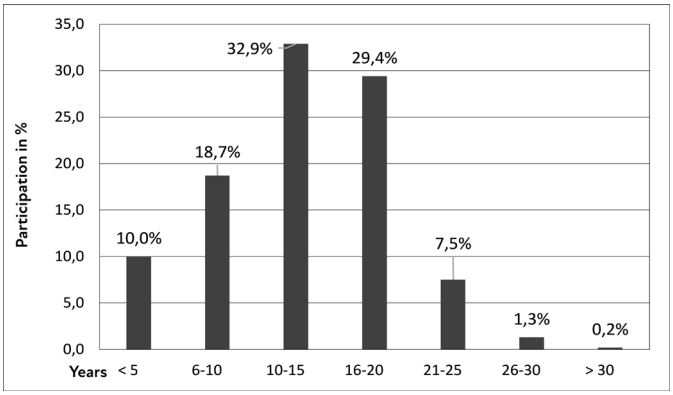

Fig. 15. The age structure of personal cars in Poland in 2018 (Source: The European Association of Car Producers, ACEA)

As it can be seen in Fig. 15 and Tab. 2–3, the number of the registered cars in Poland during the several years has been increasing and in 2019, it reached the level of 31.5 million pcs. Also, the participation of passenger cars was increased whereas the percentage of trucks and tractors decreased from 12.2% in 2018 to 8.9% in 2019. The increasing number of cars causes the generation of greater amount of the waste. Samar Institute, as developing the reports connected with car market in Poland, pays attention to the presence of the registered cars which do

Table 2. The number of registered vehicles in Poland in 2010–2019

Type of vehicle	Years									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	Number of registered vehicles in thousand pcs									
Passenger	17 240	18 125	18 744	19 389	20 004	20 723	21 675	22 504	23 429	24 610
Trucks and tractors	2 982	3 131	3 178	3 242	3 341	3 429	3 542	3 640	3 759	2 790
Buses	97	100	100	103	106	110	113	116	119	
Motorbikes	1 013	1 069	1 107	1 153	1 190	1 272	1 356	1 427	1 503	4 100
Other	1 706	1 764	1 746	1 796	1 832	1 875	1 915	1 948	1 890	
Total	23 037	4 189	24 876	25 684	26 472	27 409	28 601	29 635	30 701	31 500

Table 2. Percentage participation of the registered vehicles (acc. to the type) in Poland in 2010–2019

Type of vehicle	Years									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	Participation of registered vehicles according to type, in %									
Passenger	74,8%	74,9%	75,4%	75,5%	75,6%	75,6%	75,80%	75,90%	76,3%	78,1%
Trucks and tractors	12,9%	12,9%	12,8%	12,6%	12,6%	12,5%	12,40%	12,30%	12,2%	8,9%
Buses	0,4%	0,4%	0,4%	0,4%	0,4%	0,4%	0,40%	0,40%	0,4%	
Motorbikes	4,4%	4,4%	4,5%	4,5%	4,5%	4,6%	4,70%	4,80%	4,9%	13,0%
Other	7,4%	7,3%	7,0%	7,0%	6,9%	6,8%	6,70%	6,60%	6,2%	
Total	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0	100,0	100,0	100,0

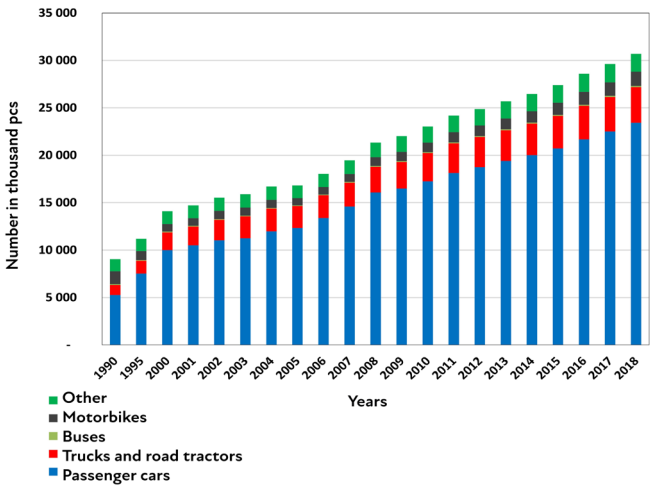

Fig. 16. The number of the registered vehicles in Poland in 1990–2016, with classification into passenger cars, trucks, agricultural tractors, buses and motorbikes

not participate in the movement, i.e. the so-called "dead souls" and which have not been deregistered. It is assumed that the "dead soul" is a vehicle which was registered in Poland 10 years ago and since at least 6 years its data in the car base have not been modified. It is the vehicle which has not been insured for 6 years in respect of third-party liability insurance (in Polish: OC), its owner has not been changed and it has not been subjected to obligatory technical review. According to Samar data, the mentioned difference may constitute even 25% i.e. almost 8 million cars.

Car import

In February 2021, there were 71275 imported passenger cars and delivery (up to 3.5 tonnes) cars in Poland; it is a decline by 13% during the year. In total, during 2 months of the present year, the number of registrations of the imported vehicles was equal to 136817 pcs; it makes by 16.5 % less than in the analogical period of 2020. In January, the mentioned decrease amounted, however, to almost 20%. The anticipated level of import by the end of the years is ca. 850 thousand pcs [11]. The mean age of the cars imported to Poland in 2021 is 12 years. In case of the cars with petrol engines, the mean age of the cars is higher and is equal to more than 13 years. From the mentioned number, one third of the discussed cars are cars dating back to 2006 – 2009. We may observe a systematic decrease of interest in diesel cars. Import of the diesel-driven cars in February of 2021 constituted 41.4% of all imported passenger cars, i.e. by 42.4% less as

compared to 2018. The greatest number of the cars imported in 2021 came from Germany (almost 60% i.e. 80182 pcs) and from France (14155 pcs).

Recycling of road vehicles

According to the announcement of the Marshall of Polish Parliament (the Seym) dated 16 January 2015 on the publication of consolidated text of the Law on "recycling of vehicles, withdrawn from operation" and the Annex to the mentioned Law dated 20 January 2005 on "recycling of vehicles withdrawn from operation", it is considered that a complete vehicle destined for scraping means the vehicle which contains all significant elements and its weight is not lower than 90% of the car weight. Since January, 1, 2015, there have been introduced new, higher levels of recovery and recycling which are equal, respectively, to 95% and 85% of the weight of the cars, accepted to disassembly during the year. Until the end of 2014, the discussed level amounted to 85% and 80%, respectively. In Poland, in 2020, 405204 cars were deregistered on the grounds of certificate from the disassembly station. It is by 13.6% lower number as compared to the previous year, and by 19.6% less than in 2018. The decreasing quantity of the deregistered cars is probably caused by lasting pandemic but also by the existing illegal points of disposal, being called "a grey zone". The cars produced during 1998–2000 were most often directed to disposal (more than 40% of the scraped cars). But as early as in 1999, 15% of all registered cars were subjected to disposal. The cars with petrol engine constituted the highest percentage (71.4%). In 2019, almost 540 thousand cars were deregistered in Poland; 90% of them were found in scrap yard.

The composition of materials used in production of the cars is different, depending on the type of a car. It has an influence on the products, obtained in the recycling process. Tab.5 shows the mean content of materials in passenger car.

From the mean weight subjected to scraping in 2020, it is possible to recover more than 442 thousand Mg of metals including:

— 319.3 thousand Mg of iron;
— 74.2 thousand Mg of cast iron;
— 33.4 thousand Mg of aluminium;

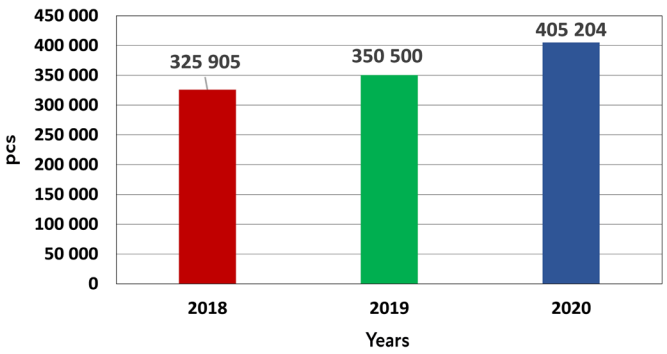

Fig. 17. Number of scraped cars in Poland in 2018–2020

Table 4. The mean content of materials in passenger car

Material	Weight, kg	Participation, %
Metals		
Steel	788,7	60,00
Cast iron	183,1	13,9
Aluminium	82,6	6,3
Copper	19,1	1,5
Zinc	7,3	0,6
Lead	11,3	0,9
Metals in total	**1092,10**	**83,1**
Non-metals		
Tyre	27,3	2,1
Oils	3,6	0,3
Cooling liquids	3,2	0,2
Braking liquids	2,6	0,2
Glass	25,4	1,9
Plastics	7,6	0,6
PU foam	6,3	0,5
Rubber	8,0	0,6
Other	138,7	10,5
Non-metals in total	**222,70**	**16,9**
The whole content in total *)	**1314,8**	**100,0**

*Remark: *) in total weight of the car, we should consider also the content of precious metals, in the weight of ca. 0.0027–0.0050 kg*

— 7.7 thousand Mg of copper;
— 2.9 thousand Mg of zinc;
— 4.6 thousand Mg of lead.

The number of the cars, being directed annually to scraping in Poland is difficult to be specified because in all available information sources, the different data are given. one of them inform that there is 1 million of scraped cars per years and a half of them is done illegally; the other sources inform that about 500 thousand cars are scraped annually in the official way and the doubled quantity is scraped illegally. When taking into account the age structure of the cars, moving on the roads in Poland in 2018, we may adopt that 71.3% are the cars, being more than 10 years old what gives more than 22 million pcs. We may assume that at least 50% of them will be scraped at the age of 20 years. How many of them will be found in illegal scraping points – it is not known. We may suppose that at least 800 thousand cars will be illegally scraped.

WASTE BATTERIES AND CELLS

Market of production of batteries and cells in Poland and in Europe

According to GIOŚ (Chief Inspectorate for Environmental Protection in Poland), the quantity of batteries and cells, imported to Poland in 2018, as compared to 2010, increased from 9866 Mg to 13192 Mg i.e. by more than 33.7%. In respect of the number

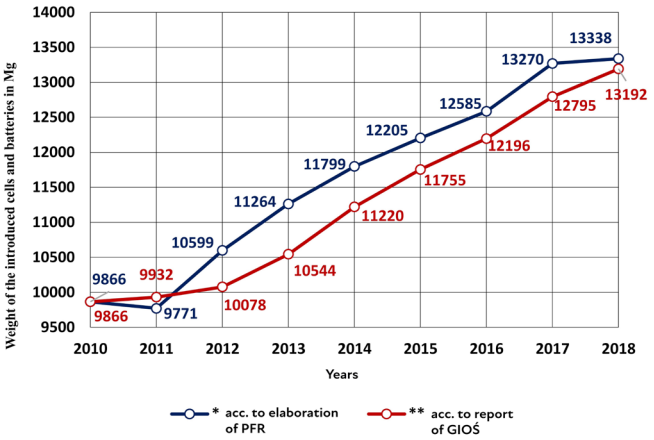

Fig. 18. Weight of the batteries and cells, introduced to the market of Poland in 2010–2018 according to elaboration by PFR [17] and report of GIOŚ ** [18]*
*Data: * acc. to elaboration of PFR – Polish Development Fund, based upon the data of Annual detailed enterprise statistics for industry (NACE Rev.2, B-E) [sbs_na_ind_r2) [17]*

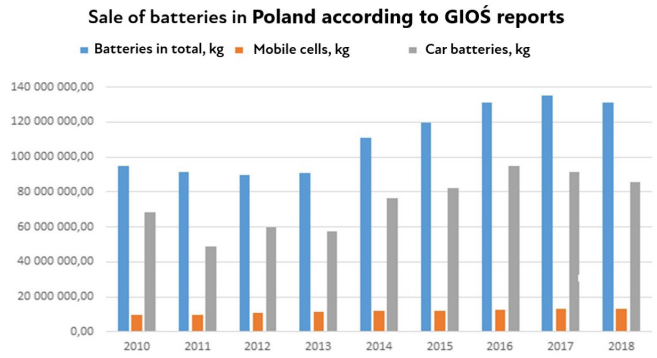

Fig. 20. The sale of cells and batteries in Poland, in kg, in 2010–2018 [18]

of batteries and cells introduced to the market, Poland occupies the fifth place from among the European countries (Fig. 20). According to elaboration of PRF (Polish Development Fund) dating to the same year (2018), we collected 10706 Mg of waste batteries and cells what gives us the 4th place from among the European countries. The weight of batteries and cells introduced to the Polish market is illustrated in Fig. 18. The diagram shows the data coming from 2 sources: publications of PFR and GIOŚ. Polish Development Fund elaboration was based upon the data of Annual detailed enterprise statistics for industry (NACE Rev.2, B-E [sbs_na_ind_r2] – Eurostat [17]. Fig. 19 shows the number of batteries, being introduced to the markets in the European Countries.

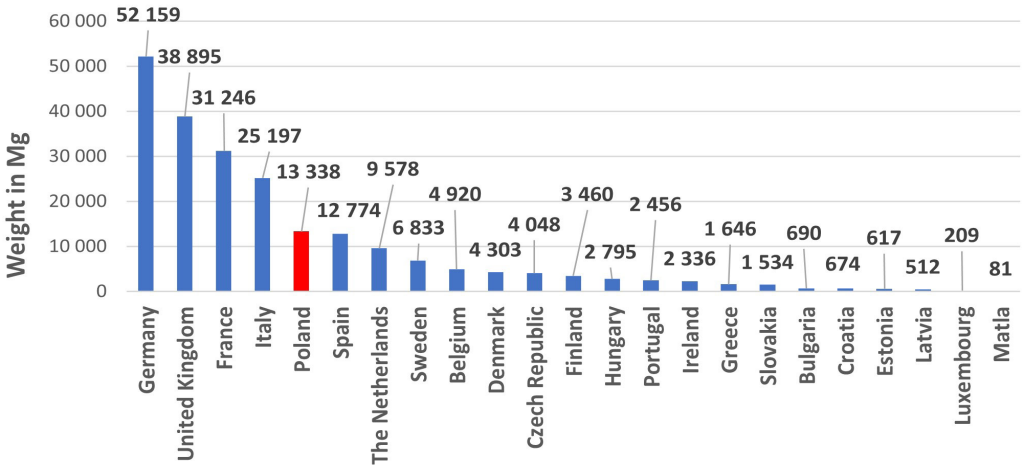

Fig. 19. Weight of batteries and cells, as introduced to the market in the European countries in 2018 acc. to PFR (Polish Development Fund) elaboration on the grounds of the data Annual detailed enterprise statistics for industry (NACE Rev.2, B-E) [sbs_na_ind_r2) [17]

Collection of waste and batteries in Poland and in Europe

According to GIOŚ report (2018), there were 10554 Mg of waste batteries and cells collected in Poland in 2018. In relation to the weight of the introduced batteries and cells to the national market, the recycling index was equal to 80%. It means that Poland has exceeded by 35% the level of collecting the waste batteries and cells, at the required level of 45%. From year to year, the collection of the cells and batteries was increasing; as compared to 2010, it has been by 6 times increased. Fig. 22 shows the collection of waste batteries and cells in Poland in the period of 2010–2018. Their collection in the European countries is illustrated in Fig. 23.

At present, the following chemical power sources are functioning in our country:

- acid-cadmium batteries;
- nickel-cadmium batteries;

- zinc-manganese cells;
- mercury cells;
- lithium-primary cells;
- lithium-ionic batteries;;
- lithium-polymer batteries;
- thionyl cells.

As it can be seen from the diagram in Fig. 21, the data concerning the collection of waste batteries and cells in Poland differ significantly each other. The reason for such differences is unknown. The greatest differences occurred in the years 2015–2016: by more than 45% to above 100% in relation to GIOŚ data. The mentioned difference between the data published in elaborations and reports generates a problem in determination of the state of waste management in Poland. In the discussed years, the enterprises reported to GIOŚ and the reported data were processed by the analysts. At present, there is a different system if reporting on the collection of the data on the waste, i.e. Base of date on Wastes (in Polish: BDO) which assumes unification and tightening os the system for data transfer, and liquidation of differences in the records.

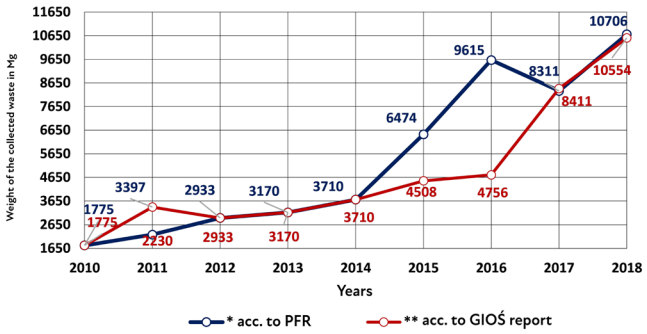

Fig. 21. Weight of waste batteries and cells, collected in Poland in 2010 – 2018 according to elaboration of PFR and GIOŚ report***

*Data: *) according to PFR (Polish Development Fund) elaboration on the grounds of the data Annual detailed enterprise statistics for industry (NACE Rev.2, B-E) [sbs_na_ind_r2) [17], **) according to GIOŚ report*

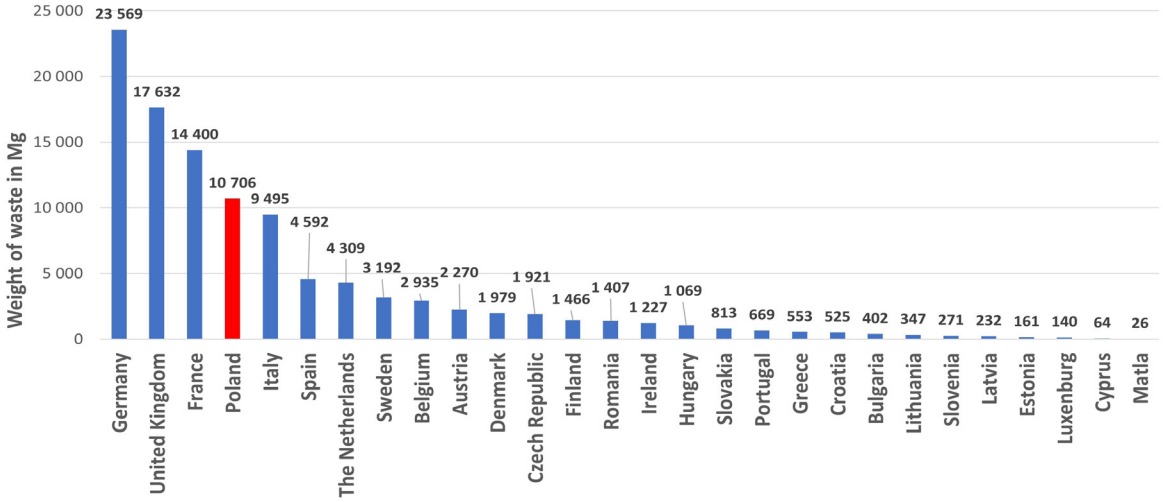

Fig. 22. Weight of waste batteries and cells collected in the European countries in 2018 [17]

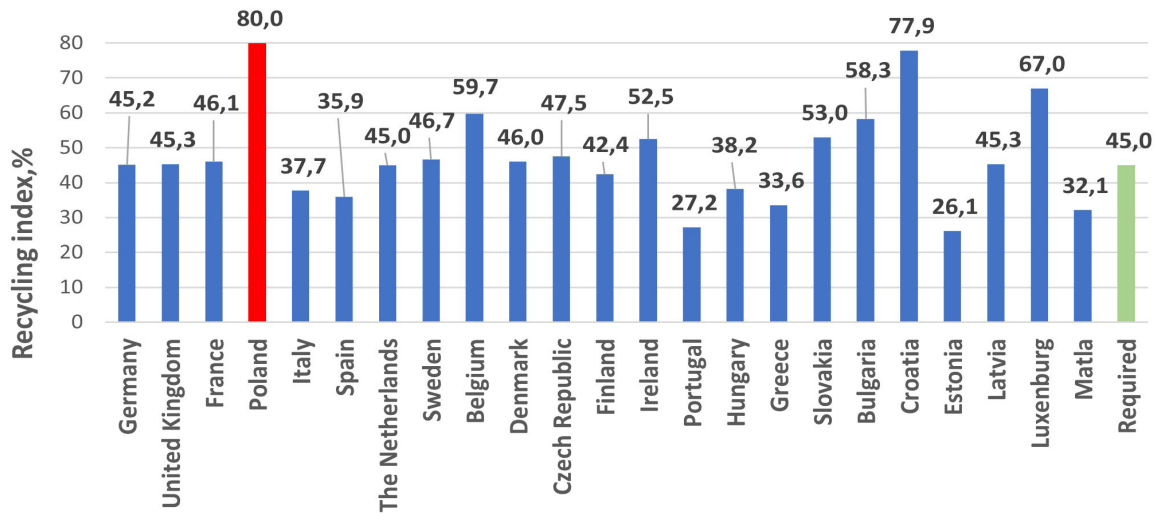

Fig. 23. Index of recycling of waste batteries and cells in the European countries in 2018. Own development based upon the literature data [17].

Recycling of waste batteries and cells

Batteries and cells contain metals and non-metals in different forms which may be utilized in the industry. Waste batteries and cells are hazardous waste and cannot be found in natural environment.

Materials, constituting the composition of batteries and cells:

- Aluminium – in metallic or oxide form,
- Zinc – in metallic or oxide form,
- Cadmium – in metallic or oxide form,
- Cobalt – in metallic or oxide form,
- Lithium – in metallic or oxide form,
- Manganese – in oxide form,
- Copper – in metallic or oxide form,
- Brass – in metallic form,
- Nickel – in metallic or oxide form,
- Lead – in metallic or oxide form,
- Mercury – in oxide form,
- Steel – in metallic form, and
- Plastics and paper for R&D production.

Cells and batteries in Poland are processed by mechanical, thermal and hydrometallurgical methods:

- Mechanic method – disintegration and separation into particular fractions such as:
  - ferromagnetic – steel and other metals;
  - non-magnetic – paper and plastics;
  - paramagnetic – anode-cathode mass, carbon and others.
- Hydrometallurgical methods – it consists in recovery of materials, by the method of salvation in acids or alkalis.
- Thermal method – the recovery of materials is carried out by re-melting in the ovens at temperature of ca. 1400°C what results in obtaining metal or metal oxides.

WASTE PACKAGING

Within a meaning of the Law of 13.06.2013, packaging means "a product, including non-returnable product, made of any materials, intended for storage, protection, transport, delivery or presentation of goods, from raw materials to processed goods". The introducer of the products in packaging is understood as the entrepreneur who performs economic activity in respect of introducing the products in packages to the market.

During the recent years, the increase in the utilization of packaging has been recorded all over the world. It caused the increase of their production. The packages are made of different materials; they have to meet many parameters such as use safety, good quality and aesthetic appearance. Due to their application, the packages are, in many cases, a threat to natural environment. To decrease the mentioned risk, the producers try to use the materials which are the least harmful to the natural environment, and to meet the requirements of Circular Economy.

The waste packagings contain many different materials in their structure such as metals, plastics and paper.

The group of packages includes:

- steel packages (tins and others)
- aluminium (tins and others)
- multi-material packages (tetrapak, sweet packages, packaging of food products and others)
- plastic packages (film, containers and others)
- packages made of wood (boxes, pallets and others).

According to the Act of 13 June 2013 "on management of packaging and waste packaging" (Official Polish Journal of Laws dated 6 August 2013, item 888), there are the obligatory levels of recovery and recycling in Poland. In compliance with the mentioned Act, the level of recovery and recycling of all packages should constitute minimum 61%. The level of recycling which are binding in the country, are shown in Tab. 5.

Tab. 5. Targeted level of recovery and recycling of waste packaging, as specified in Annex 1 to the Law of 13 June 2013 "on management of packaging and waste packaging"

No.	Waste packaging (types)	Level of recovery[1] (%)	Level of recycling[1] (%)
1	Plastics	-	23,5
2	Aluminium	-	51
3	Steel, including steel sheets	-	51
4	Paper and cardboard	-	61
5	Glass	-	61
6	Wood	-	16
7	Multicomponential packaging	-	The level specified respectively in items 1-7 acc. to the type of the material, dominating in a given package
8	Packaging in total[2]	61	56

[1] it does not refer to packages having a direct (immediate) contact with medicinal products, specified in the rules of the Law of 6 September 2001. Pharmaceutical Law. (Official Journal of Laws of 2008, No 45, item 271, with later amendments)
[2] it concerns the sum of all packages, mentioned in items 1-7

The statistics of packaging, in all Polish elaborations as well as in those by Eurostat, includes the data maximum for 2018. It refers to the quantities of the packages introduced to the market as well as those ones collected as waste. In 2018, there were 5470407 Mg of packages introduced to the Polish market, including those subjected to recycling in amount of 3200211 Mg i.e. 58.7%. As compared to the previous year, in 2018 there was less by 4.2% packages introduced to the market. The level of recycling in 2017 was equal to 57.7%. The quantity of the packages introduced to the domestic market is illustrated in diagram (Fig. 24) whereas the obtained levels of recycling are shown in Fig. 25.

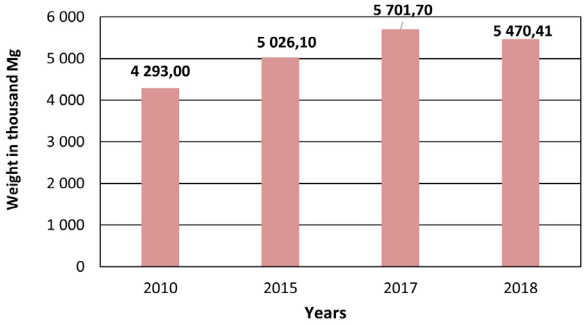

Fig. 24. Weight of the packages introduced to Poland in 2010–2018

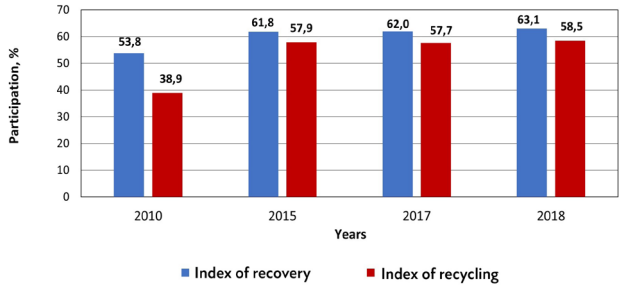

Fig. 25. Levels of recovery and recycling of waste packaging materials in Poland in 2010–2018

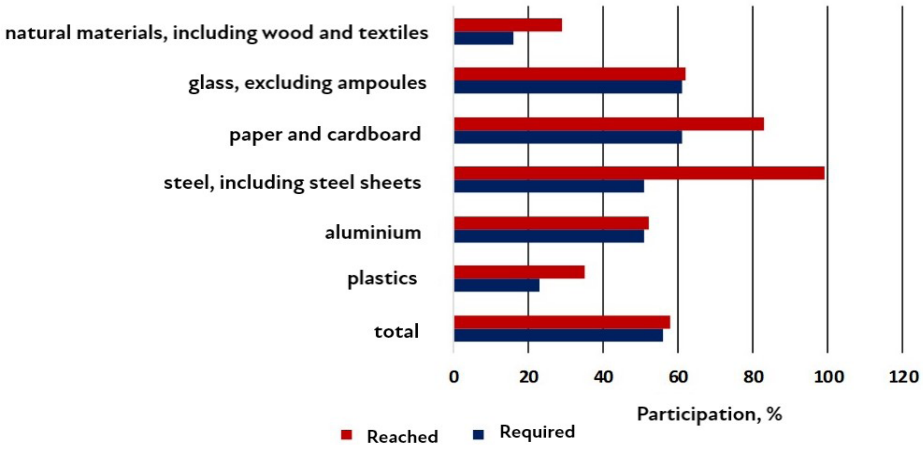

Fig. 26. The obtained (2018) and the required levels of recycling of waste packaging in Poland [23]

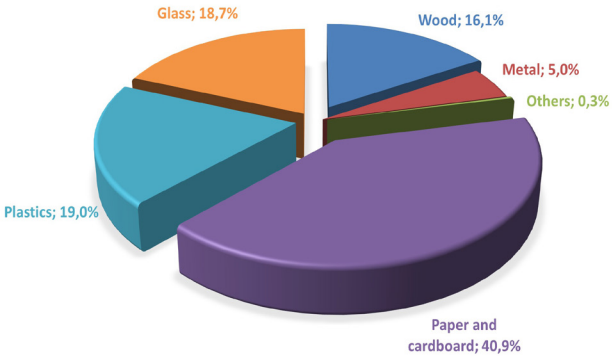

Fig. 27. The percentage of waste packaging according to the collected types in the EU in 2018

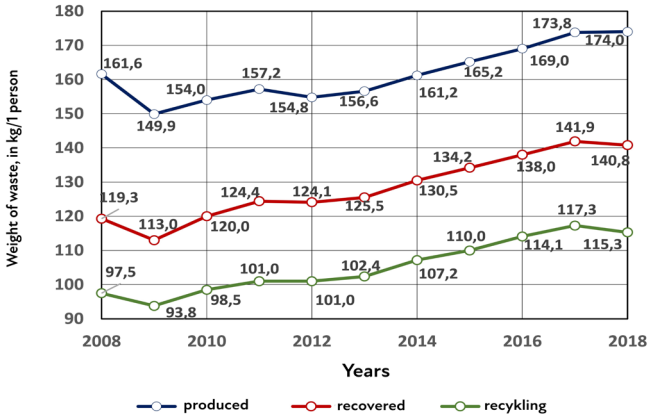

Fig. 28. Weight of the waste packaging, as being produced, collected and recycled in the EU (EU-12) in kg per 1 inhabitant in 2008–2018

When comparing the levels of recovery and recycling of waste packaging, being reached in the recent years, we may observe that the required level of recovery (61%) and recycling (56%) were reached in 2015. The required levels of recovery and recycling in the next years were also reached. The required levels of recycling for the particular fractions of waste packages were reached, as well.

In the countries of the European Union in 2017, 172.8 kg of waste packaging as calculated per 1 inhabitant were produced. Value of the mentioned index for the particular countries varied from 64.0 kg per one inhabitant in Bulgaria to 230.9 kg per 1 inhabitant in Luxembourg. Fr Poland, the mentioned index was equal to 154.0 kg of waste packaging per 1 inhabitant. In the EU countries, the highest quantities of the generated waste were as follows: paper and cardboard (41%), then plastics (19%), glass (19%), wood (16%) and metal (5%).

The obtained and required levels of recycling of waste packaging according to the type, as reached in our country in 2018 are shown in Fig. 26 [23].

The highest mean quantity of packages in the European Union in 2018 was collected in respect of paper and texture; almost 41%, then, plastics in the amount of 19%. The participation of metal was 5.0%. Metal type includes aluminium and steel tin cans. Multi-material waste such as tetrapack and film backed

with paper are considered as the waste paper and cardboard, as the paper is a dominating substance in the mentioned waste. The quantity of the waste generated in the EU countries as calculated per 1 person since 2008 to 2018 increased by 7%. On the other hand, the quantity of the collected and subjected-to-recycling waste in the same period increased by 18% of those recycled ones. The mentioned tendency is an evidence of the progress in the particular EU countries in respect of management of packaging waste and of the choice of the direction assumed in the Circular Economy.

Indices of recovery and recycling of packaging in the European Union countries

The highest index of recovery of waste packaging in Europe was obtained by Finland, as much as 114.6%; it indicates that more was recovered than introduced to the market. The next country, which can boast about the result, is Belgium (index of 99.6%). It means that almost the same quantity was recovered than the amount introduced to the market. Poland has a recovery index equal to 63.4% what gives us the 23rd place from among 12 European countries; we meet the requirements of the law which order obtaining the recovery index at the level of minimum 61%. The lowest recovery index from among EU-27 was reached by Malta (35.6%) and Hungary (55.1%).

As far as the coefficient of recycling is concerned, the highest one was obtained by Belgium (85.3%), then, the Netherlands (78.1%). Poland (58.7%) is found on the 21st place from among 27 EU countries. In the mentioned case, Poland has also met the requirements of the Law which determines obtaining the discussed index at the level of minimum 56%. the lowest recycling index was obtained also by Malta (35.5%) and Hungary (46.1%). the obtained recovery coefficient and index of recycling of waste packaging in 27 EU countries is presented in Tab. 6 and Fig. 29.

Tab. 6. Indices of recovery and recycling of waste packaging in EU-27 and the whole Union and in 4 countries, as obtained in 2018 [24]

No.	Country	Coefficient/index of: (%)		No.	Country	Coefficient/index of: (%)	
		recovery	recycling			recovery	recycling
1	Belgium	99,6	85,3	**17**	Hungary	55,1	46,1
2	Bulgaria	60,5	60,4	**18**	Malta	35,6	35,6
3	The Czech Republic	73,9	69,6	**19**	The Netherlands	95,5	78,1
4	Denmark	88,2	67,7	**20**	Austria	94,4	65,5
5	Germany	96,9	68,5	**21**	**Poland**	**63,4**	**58,7**
6	Estonia	86,5	60,4	**22**	Portugal	66,5	57,6
7	Ireland	90,9	63,9	**23**	Rumania	60,0	57,9
8	Greece	71,6	68,6	**24**	Slovenia	75,3	70,1
9	Spain	74,5	68,8	**25**	Slovakia	69,1	66,6
10	France	76,8	65,7	**26**	Finland	114,6	70,2
11	Croatia	58,4	58,4	**27**	Sweden	70,9	70,1
12	Italy	77,6	68,3	**28**	**European Union**	**80,9**	**66,3**
13	Cyprus	70,1	70,2	**29**	Great Britain	68,2	62,1
14	Latvia	64,3	55,8	**30**	Iceland	63,2	46,8
15	Lithuania	68,4	60,7	**31**	Lichtenstein	92,7	68,0
16	Luxembourg	94,1	70,9	**32**	Norway	94,2	52,9

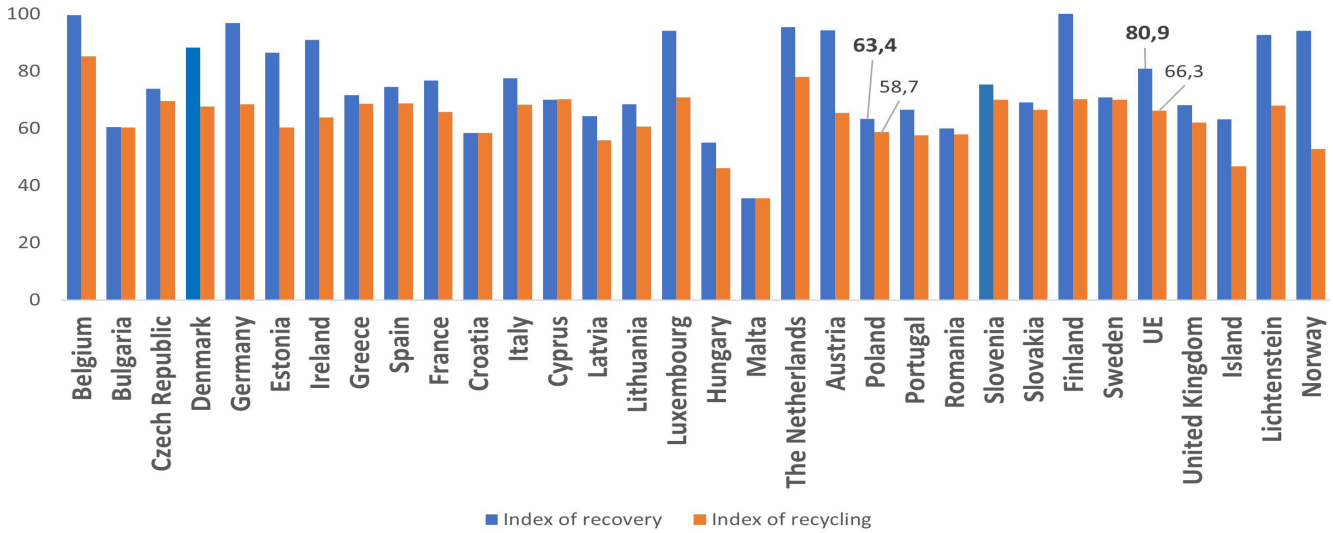

Fig. 26. The obtained (2018) and the required levels of recycling of waste packaging in Poland [23]

Summing up

The problems discussed in the publication include the basic information on waste management in Poland as compared to other EU countries and on the selected post-consumer waste, occurring in Poland.

Natural environment protection is treated as priority all over the world as to pay the attention to the hazardous effect of dangerous materials and substance on the environment and human body. Therefore, few years ago, the conception of Circular Economy was introduced. Its aim was to promote, to maximum degree, the waste-free technologies at manufacture of goods, limiting generation of the waste, harmful to the natural environment. On one hand, technical progress increases welfare of the societies but on the other hand, it is the reason for generation of greater quantity of the post-production as well as post-consumer waste. A dynamic development of industry in Poland, which occurred in the 90-ties of the 20th century, has contributed to increase of the demand on modern electric and electronic equipment; it was the effect of the increase of demand on raw materials. The weight of the waste on the landfills was increased. The Circular Economy assumes the increase of the participation of the recyclables in manufacture of the new products. According to the published data, the mean participation of the recycled metallic materials in the world production of metals is equal to more than 52%; in production of lead, ruthenium and niobium – ca. 50%, aluminium – ca. 36%, copper – ca. 37% and steel – ca. 52%.

Frequent technological changes of the produced goods and the increasing demand on them, requires a special approach to the process of their recycling in accordance with the requirement of the natural environment. Ensuring the appropriate collection of the waste and their processing at the territory of the country and the utilization of the mentioned resources is a factor which enables running the effective recycling process. The adaptation of good legal system and the respective rules in the system of waste management may be helpful in this respect. We should mention here the access to information concerning the waste management which becomes hardly available.

The average citizen, who is interested in problems of waste management, is missing balanced information on the state of waste management in our country. He is lacking information on the Internet pages (all is out-of-date, coming from 2017–2018). The problem of the lack of such information was also discussed during the Conference: Recycling of Waste Electric and Electronic Equipment held on April, 14, 2021 in Warsaw. It was stated that such situation made the functioning of the whole recycling sector difficult. It was also recognized that the published data were the approximate data, differing from the real ones.

When developing the present publication, the author found more available information in foreign materials, such as, *inter alia*, Eurostat, authorial publications as compared to the national sources. The ecological awareness of the citizens cannot be shaped without information on the state of environment.

We may hope that the introduction of BDO system (Base of the Data on Waste) will change the mentioned situation if the data from this system are made available universally for all who are interested in the problems of waste management and who care about the natural environment protection. It means fulfilment of the requirements, contained in the Circular Economy assumptions.

The published information is often out-of-date. There is also a lot of information, differing significantly, e.g. between Eurostat and the data, published in the domestic materials. The recent data date back to 2017, certain concern 2018 and the data of 2019 are unavailable. We have already the second quarter of 2021! Therefore, the attempts should be undertaken with the aim to accelerate the elaboration of the statistical data which help considerably not only the enterprises dealing with waste management but also the state administration institutions which prepare the appropriate regulations.

As we know, in January 2018, there was launched the electronic BOD system which is expected to improve the informational system in this respect. It is fit for not only the units which generate waste but also those transporting, recording and introducing new products to the market (packaging) or those which process the waste. They include companies of various sectors, such as shops, doctor's offices, car workshops, transport and disposal enterprises etc. There are different opinions on the system of introducing the data in BOD, for example, the use of this system brings many troubles, information of moving in the Base are unclear, non-precise and unpractical. The opinion-givers indicate that the system works slowly and is often suspended and waste service and recording consumes a lot of time. The troubles result from the necessity of permanent passage between many folders and many-times-repeated introduction of the same data. It will be possible to assess the effectiveness of the electronic BDO system after few years of its operation, improving meanwhile its defects. Creation of BDO system is a good idea and, after having removed the weak points, it will bring profits to the waste management and meet the requirements of Circular Economy.

At present, in Poland, there is a dominating model of recycling, based upon the separation and exportation of semi-products, resulting from processing of the waste. We should also develop the principle of repeated use of equipment what is successfully effective in other European countries and is supported by the European Union. The aim of improving the effectiveness of the system for collection and processing of after-consumer waste, containing metals, we should invest in educational activity. We should present the ecological consequences of the waste storage, or processing with the hazard to the natural environment. We should, via education, demonstrate that we have the technologies owing to which we may process the waste, generated by the society. Lack of waste segregation is often justified by a lack of appropriate technologies for their processing. It is opinion harmful for the society which, in majority, wishes to run the segregation for the sake of natural environment of Poland.

Apart from Circular Economy (GOZ), the problem of waste management in Poland has been also noticed in the recently developed programmes such as Project of Raw Materials Policy of the State, and Strategy in Favour of Sustainable Development which both assume the minimization of the waste generation and long-term economic policy of policy of Poland. The mentioned strategy is aimed at the country development based on the responsibility and solidarity. Its target includes entrepreneurship, inventiveness and productivity and maximum application of the materials, coming from recycling in manufacture of new products as a substitute of original raw materials. Technological and technical development of Poland and use of more and more devices of common use (e.g. electric cars, mobile telephones, computers etc.) impose the duty to seek for the innovative technical and technological solutions concerning the management of the mentioned equipment after their use period when they become a waste. The participants of the waste management system in Poland which include organizations, enterprises and the research institutes should cooperate closely when developing the innovative solutions for waste processing within the frames of the research projects, in accordance with the requirements of the natural environment and profit to the national economy.

The Łukasiewicz Research Network – Institute of Non-Ferrous Metals has conducted, for many years, the studies on the technologies of waste management in Poland; their solutions have been introduced in many enterprises. In respect of the size, the Łukasiewicz Research Network is found on the 3rd place in Europe. It supplies attractive, complete and competitive technological solutions. It offers the unique system of "challenges" to the business sector owing to which it accepts the business challenge for the period shorter than 15 working days; it submits, free-of-charge, direction of the solution and idea of the research project to the entrepreneur [29]. Within the frames of its activities, the mentioned Institute has developed many publications and monographs and public speeches during national seminars and conferences, supporting the implementation of Circular Economy.

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