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Evolution of Waste Electric and Electronic Equipment in the EU

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Abstract

Waste electrical and electronic equipment (WEEE) represents the fastest growing type of waste in Europe. The increasing levels of electronic waste, its inappropriate elimination and insecure treatment are posing significant risks to the environment and to human health. Over the last decades, the ever higher amount of waste electrical and electronic equipment has become a major problem worldwide. The European Union elaborated Directive 2012/19/EU in order to have a unitary approach regarding the environmental problems related to the correct management of this particular type of dangerous waste. To this effect, specific objectives were set for reusing, recycling and recuperating the waste electrical and electronic equipment, which the Member States should include in their national policies. Recycling waste electrical and electronic equipment is an important issue, not only in terms of waste treatment, but also for the recuperation of valuable materials. Characterising the waste flow is highly important for developing a profitable and ecological recycling system within the framework of the circular economy. The present paper aims at analysing how putting on and withdrawing from the market electrical and electronic equipment has evolved in the context of the circular economy within the European Union. To this purpose, we have used the information on Eurostat for the 2014-2017 period.

Keywords: waste management, electrical and electronic equipment, environmental management, circular economy, recycling

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1. Introduction

Over the last two decades, the global market of electrical energy and electronic equipment (EEE) has seen an exponential growth, while the lifespan of these products is becoming shorter and shorter [8]-[10].

As a consequence, waste management has to cope with a new challenge and is being given considerable attention by decision makers.

It is likely that the number of electrical devices with continue to increase on a global scale [6].

Waste electrical and electronic equipment is regulated through the 2012/19/EU Directive (the Directive on WEEE), which amended Directive 2002/96/EC and was supposed to be put into practice by the Member States by 14 February 2014.

The present paper deals with the implementation of the European Directives regarding the quantity of waste put on the market and collected. The specialised literature on recycling flows is scarce and it does not directly address the issue of obtaining a high recycling rate. The recycling rate suggests the existence or inexistence of coherent public policies [1].

From the viewpoint of the life cycle, developed economies (Germany, Sweden and Italy) have to manage a bigger quantity of waste as compared to developing countries, such as Romania and Bulgaria [2].

The measures for preventing and reducing the quantity of waste electrical and electronic equipment were stricter in 2013 than they used to be in 2007.

Between 2007-2014, developed countries collected a higher quantity than the annual WEEE collecting target of 4 kg/capita, while in developing countries the collection is still difficult.

According to the estimates of the United Nations environment programme, electrical and electronic waste is considered one of the problems leading to the fastest growth of pollution all over the world. This surge is influenced by the planned withdrawal of the product from the market, by the decrease in prices and the changing lifestyles.

Electrical and electronic waste is made up of precious metals, as well as of environment contaminants, especially polybrominated diphenyl ethers and polychlorinated bi-phenyls. The chemical composition of electrical and electronic waste changes with the innovation of the new technologies and under the pressure of environmental organisations.

The recycling of waste electrical and electronic equipment is important not only from the point of view of waste treatment, but also for the recovery of precious metals [4].

Up until 2014, recycling was the preferred option for the treatment of waste electrical and electronic equipment in a proportion of over 80 % irrespective of the country. Each country made efforts to create special collection points, as well as to develop recycling equipment and support instruments.

Electrical and electronic waste has experienced the fastest growth in the EU and is expected to go up to over 12 million tonnes by 2020.

2. Materials and Methods

The proposed analysis will use the information provided by Eurostat regarding the evolution of electrical and electronic waste in the European Union Member States.

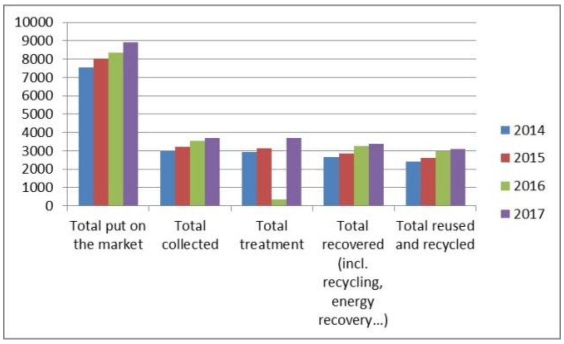
The next table showcases the evolution of waste electrical and electronic equipment put on the market, sold and collected within the European Union between 2014-2017.

Table 1. Electrical and electronic equipment (EEE) put on the market and waste EEE collected and treated, European Union, 2014–2017 (thousand tonnes)

	2014	**2015**	**2016**	**2017**
Total put on the market	7.549	8.038	8.360	8.906
Total collected	2.961	3.223	3.548	3.700
Total treatment	2.917	3.146	3.530	3.698
Total recovered (incl. recycling, energy recovery...)	2.643	2.839	3.245	3.368
Total reused and recycled	2.425	2.604	2.986	3.095

Source: https://ec.europa.eu/eurostat

The evolution of electrical and electronic equipment put on the market and collected within the European Union between 2014 and 2017 is easier to see in the following graphic presentation (Figure 1):



Source: Own contribution

Figure 1. Electrical and electronic equipment (EEE) put on the market and waste EEE collected and treated, European Union, 2014–2017 (thousand tonnes)

One method of estimating a dimension is that of the estimation using confidence intervals. More often than not, indicating an isolated (punctual) estimated value cannot be satisfactory without referring to the variation domain and to the corresponding probability. Since the sample estimators are random variables, one of the most important issues that arises consists in expressing the estimate accuracy or the estimate probability. However, the value of the P probability covers a certain interval (x_1, x_2) according to the relation [3], [20]:

$$P = \text{Prob}(x_1 < X < x_2) = \int f(x)\text{d}x \quad (1)$$

to which the respective parameter belongs. In this way, a certain interval is established, called a confidence interval, has the property of containing the true value of the respective dimension with the P probability.

Let a_0 be the true value of a characteristic for which a punctual estimate $\hat{a}$ is obtained through sampling experiments.

We consider that the deviation $|\hat{a}\text{-}a_0|$ is lower than a ε value with a very high β probability (0.90, 0.95 or 0.99):

$$P(|\hat{a} - a_0| < \varepsilon) = \beta \quad (2)$$

or

$$P(\hat{a} - \varepsilon < a_0 < \hat{a} - \varepsilon) = \beta = 1 - \alpha \quad (3)$$

. The punctual value $\hat{a}$ is calculated based on a sample and it defines the limits of the confidence interval:

$a_1 = \hat{a} - \varepsilon$ and $a_2 = \hat{a} + \varepsilon$.

Considering the risks for the lower part α_i and the upper part α_s to be unequal, the interval limits are defined by the relations $P(a_0 > a_2) = \alpha_s$ and $P(a_0 > a_1) = \alpha_i$, with the significance level $\alpha = \alpha_i + \alpha_s$.

In order to analyse the confidence interval for the values presented above in Table 1, the confidence interval will be analysed for the theoretical mean μ of a characteristic with normal distribution, where the dispersion σ is known.

The necessary stages are the following:

a. We take a population to be analysed with an X characteristic having a normal distribution $N(\mu, \sigma^2)$.
b. A volume sample n is extracted from this population. Let us estimate the □ mean with a 95 % confidence interval with symmetrical bilateral risk. The significance level is □=0.05.
c. We know that the sample mean $\bar{x}$ has a normal distribution $N(\mu, \sigma^2 n)$.
d. Since the □ parameter is unknown, a confidence interval will be built for this dimension, its (-z, z) limits being established with the help of the Laplace distribution.
   We know that the random variable:

$$z = \frac{\mu - \bar{x}}{\sigma/\sqrt{n}} \quad (4)$$

   has a normal distribution N(0,1).
e. According to the distribution table, the 95% probability is defined as the (1.96; +1.96) interval.

In this way, we obtain the confidence interval with the P probability $P(-1.96 < z < 1.96) = 0.95$

Starting from this relation, we can write the double inequality:

$$-1.96 < \frac{\mu-\bar{x}}{\sigma/\sqrt{n}} < 1.96 \quad (5)$$

which leads us to the interval limits (see Figure 2):

$$\bar{x} - 1.96\frac{\sigma}{\sqrt{n}} < \mu < \bar{x} + 1.96\frac{\sigma}{\sqrt{n}} \quad (6)$$

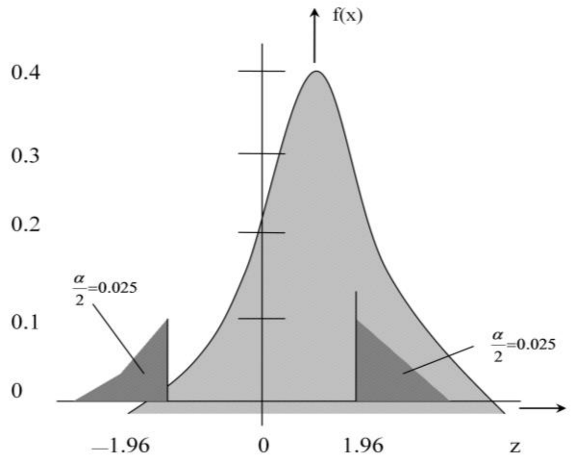


Figure 2. Confidence interval with symmetrical bilateral risk interval having the significance level α=0.05.

f. The 95 % confidence interval has thus been built for. The result can also be expressed as:

$$\mu = \bar{x} \pm 1.96\frac{\sigma}{\sqrt{n}} \quad (7)$$

the interval being symmetrical in relation to the $\bar{x}$ value.

3. Results

As we mentioned before, waste electrical and electronic equipment is a complex mix of materials and components which, because of their dangerous composition, can produce major environmental and health problems unless it is properly managed. Moreover, the manufacturing of modern electrical and electronic equipment implies using rare and costly resources. In order to improve the environmental management of waste electrical and electronic equipment , to contribute to a circular economy and to increase resource efficiency, it is essential to improve the collection, treatment and recycling of electronic waste at the end of its life.

The management of waste electrical and electronic waste is regulated by Directive 2012/19 /EU of the European Parliament and of the Council of 4 July 2012 on WEEE.

Annex I to Directive 2012/19/EU defines 10 categories of waste electrical and electronic equipment which are regulated by the Directive:

- Large household appliances;
- Small household appliances;
- IT and telecommunications equipment;
- Consumer equipment and photovoltaic panels;
- Lighting equipment;
- Electrical and electronic tools (with the exception of large-scale stationary industrial tools);
- Toys, leisure and sports equipment;
- Medical devices (with the exception of all implanted and infected products);
- Monitoring and control instruments;
- Automatic dispensers.

The evolution of waste electrical and electronic equipment in the EU Member States over the last few years can lead to an analysis of its evolution in the next years. The regulations refer to the management of WEEE through recycling the materials using safe and adequate measures, due to the generation of massive quantities of WEEE [7].

In order to apply the methodology described above, the main indicators have to be calculated.

The next table shows the values of the mean and of the dispersion in relation to the values of WEEE in EU countries for the analysed years.

Table 2. Mean and dispersion values

	$\bar{x}$	σ
Total put on the market	8213,25	569,61
Total collected	3358,00	331,11
Total treatment	2528,50	1486,92
Total recovered (incl. recycling, energy recovery…)	3023,75	339,88
Total reused and recycled	2777,50	315,51

Source: Own contribution

Considering the previously presented baseline values, the confidence interval that can be calculated for μ is 95 % (Table 3).

Table 3. Confidence intervals

	$\bar{x} - 1{,}96\frac{\sigma}{\sqrt{n}} < \mu < \bar{x} + 1{,}96\frac{\sigma}{\sqrt{n}}$
Total put on the market	$7655.03 < \mu < 8771.47$
Total collected	$3033.51 < \mu < 3682.49$
Total treatment	$1071.32 < \mu < 3985.68$
Total recovered (incl. recycling, energy recovery…)	$2690.66 < \mu < 3356.84$
Total reused and recycled	$2468.30 < \mu < 3086.70$

Source: Own contribution

It can be observed that the intervals corresponding to the analysed categories indicate that the electrical and electronic equipment which was put on the market has a much higher value in all the analysed years as compared to what was recuperated and treated. All this is happening within the framework in which, at the end of the year 2015, the European Commission adopted a set of measures regarding the circular economy with a view to stimulating competitiveness, creating jobs and generating sustainable development.

This set of measures stipulated that one of the main components of the transition to the circular economy should be the transformation of waste into resources.

Within this context, it can be observed that the quantity of WEEE introduced on the market in 2017 presents and upward trend, the values of the different categories of electric and electronic equipment reflecting the consumption model in EU Member States, as well as in other reporting countries.

Large household appliances (Category 1) are the dominant category of products in all the analysed countries. In 2017, the share of the total quantity of electrical and electronic equipment put on the market varied between 40.9 % in Germany to 72.4 % in Bulgaria.

Within the EU, large household appliances accounted for 52.4 %. IT and telecommunications equipment (category 3) were the second largest category of products in most countries, ranging between 5.0 % in Bulgaria and 16.2 % in Austria, with an average share of 11.0 % in the EU.

Within the European Union, the third category, that of small household appliances ranked third, with 9.8 %, while consumer equipment (category 4) was on the fourth place, with 8.0 %.

Medical devices (category 8), Monitoring and control equipment (category 9) and Automatic dispensers (category 10) represent a very small share of the total electrical and electronic equipment which was put on the market.

Together, these three categories account for 3.4 % of the EU total amount. 17 of the 27 Member States reported even lower amounts than the EU total for these three categories combined in the year 2017.

For the presentation of the next statistic data, the following legend has been created:

Category 1: Large household appliances
Category 2: Small household appliances
Category 3: ITand telecommunications
Category 4: Consumer equipment
Category 5: Lighting / gas discharge lamps
Category 6: Electrical and electronic tools

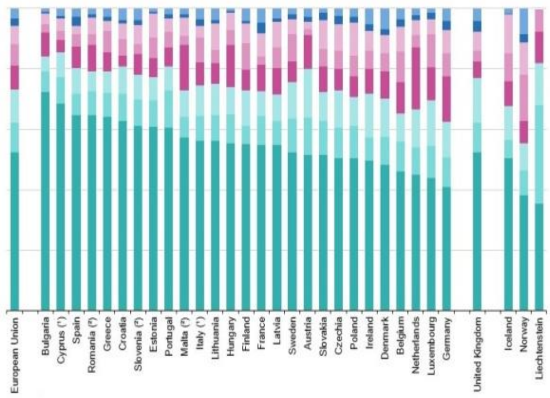
In Table 4, the categories of equipment were identified with letters from a to f, so that the information could be presented in a clear manner.

Table 4. Electrical and electronic equipment put on the market, by category, 2017

	a	b	c	d	e	f
EU	52.4	9.8	11.0	8.0	7.1	6.0
BG	72.4	6.8	5.0	7.8	2.7	3.6
CY(1)	68.5	8.9	8.2	4.0	2.9	4.3
ES	64.7	7.2	8.5	6.9	4.2	2.8
RO(2)	**64.6**	**8.1**	**6.6**	**8.8**	**3.5**	**5.5**
EL	64.1	8.0	7.1	6.2	7.1	3.4
HR	62.8	8.9	9.2	3.4	5.4	5.2
SI(2)	61.2	8.7	8.2	6.9	3.2	6.3
EE	60.9	8.6	7.8	6.2	6.8	7.8
PT	60.4	12.4	7.9	6.3	5.3	4.4
MT(2)	57.3	6.7	8.8	15.0	3.2	5.8
IT(1)	56.3	8.2	10.0	7.8	8.2	3.8
LT	56.2	8.6	10.3	6.8	4.5	8.7
HU	55.4	9.7	8.8	14.0	4.9	5.8
FI	55.2	5.9	11.9	6.6	8.9	6.4
FR	54.8	9.6	8.2	8.9	2.7	7.5
LV	54.8	8.0	8.8	8.8	6.7	8.5
SE	52.3	11.4	11.9	7.0	9.0	4.8
AT	51.7	12.0	16.2	11.2	2.0	2.4
CS	51.6	11.2	9.5	8.4	5.8	9.6
CZ	50.6	10.1	12.0	7.2	6.0	9.0
PL	50.4	10.7	9.6	6.9	6.7	10.9
IE	49.6	7.7	14.3	8.4	6.0	6.5
DK	48.2	9.4	12.5	9.1	5.9	6.0
BE	45.9	9.9	9.4	10.3	10.1	8.3
NL	44.9	9.0	12.5	20.6	4.1	5.1
LU	43.8	10.7	15.1	11.1	10.9	4.8
DE	40.9	9.8	11.8	15.0	7.7	7.5
UK	52.4	9.9	14.7	5.5	3.7	6.1
IS	50.4	5.9	11.4	8.0	9.4	12.9
NO	38.0	8.3	9.0	7.5	15.2	10.7
LI	35.3	32.8	13.8	10.4	7.4	:

(1) Data for 2015 instead of 2017.
(2) Data for 2015 instead of 2017.
Source: https://ec.europa.eu/eurostat

The totals estimated are very well illustrated in the following graph:



(1) Data for 2015 instead of 2017.
(2) Data for 2016 instead of 2017.
Source: https://ec.europa.eu/eurostat

Figure 3: Electrical and electronic equipment put on the market, by category, 2017 (% of total weight)

Also, in the year 2017, the total quantity of waste electrical and electronic equipment collected varied considerably in the EU Member States. Thus, it ranged between 2.4 kg/capita in Romania (data from 2016) and 14.1 kg/capita in Sweden. The variation in the collected amounts reflects the different consumption levels of electrical and electronic equipment in the various countries, as well as the effectiveness of the collection schemes for that particular waste.

Out of the total quantity of collected waste electrical and electronic equipment collected in 2017, large household appliances represented almost 2 million tonnes, which means 52.7 %. Consumer equipment and photovoltaic panels with 14.6 % and IT and telecommunications equipment accounting for 14.1 % rank second and third when it comes to the collection of WEEE in the European Union, representing 540 and 523 million tonnes respectively.

Small household appliances contributed with almost 376 thousand tonnes, which corresponds to 10.1 % of the total WEEE collected in the EU in 2017.

The other categories taken together ("Other waste electrical and electronic equipment") totalled a bit over 311 thousand tonnes, or 8.4 % of the waste electrical and electronic equipment collected. The quantity of waste electric and electronic equipment collected in 2017 is presented in Table 5.

For the presentation of the next statistic data, the following legend has been created [11]-[17]:

Category 1: Large household appliances
Category 2: Small household appliances
Category 3: IT & telecommunications
Category 4: Consumer equipment

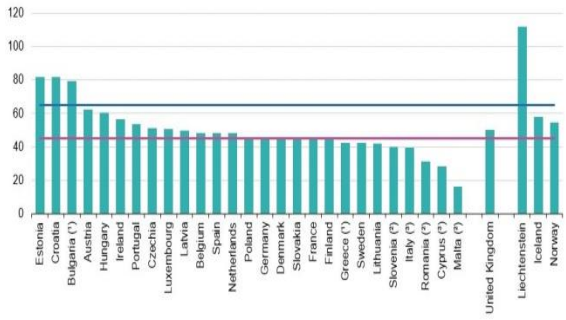
To this purpose, the equipment categories were identified by letters: a,b,c,d in the table, so that the information could be presented in a clearer manner.

Table 5. Waste electrical and electronic equipment (WEEE), total collected, by EEE category, 2017 (tonnes)

	a	b	c	d	Other waste EEE
EU[1]	1,950,118	375,561	523,425	539,970	311,246
BE	56,187	14,234	21,591	21,149	10,850
BG	40,113	5,002	2,548	3,285	3,545
CZ	47,137	8,591	13,966	15,331	6,300
DK	38,624	5,776	10,468	10,707	4,195
DE	360,252	144,767	126,007	138,704	67,177
EE	7,522	1,180	1,236	2,447	282
IE	30,941	2,947	6,794	7,587	4,043
EL	36,220	3,090	5,439	7,522	3,560
SS	184,280	26,093	24,669	34,474	17,694
FR	445,331	43,736	97,414	93,677	62,175
HR	18,312	660	4,825	11,441	1,196
IT[2]	168,598	29,093	59,425	64,803	22,710
CY[2]	2,016	127	312	334	174
LV	5,160	895	855	790	1,639
LT	6,244	849	1,719	1,392	3,090
LU	3,077	470	688	1,203	627
HU	34,056	5,803	10,732	10,359	2,247
MT[3]	1,225	93	385	437	305
NL	85,499	20,486	27,803	21,163	11,238
AT	66,587	9,562	19,683	13,979	6,664
PL	114,670	26,120	33,493	23,881	48,296
PT	41,301	8,968	8,956	4,818	6,017
RO[3]	**29,592**	**1,320**	**5,645**	**7,063**	**3,034**
SI[3]	5,190	1,258	2,659	2,297	668
SK	15,234	2,300	4,347	4,392	3,557
FI	34,439	2,770	11,666	12,820	3,710
SE	71,746	9,367	20,729	24,033	15,503
UK	611,495	52,937	128,151	42,332	35,975
IS	2,685	260	588	586	1,154
LI[4]	166	154	65	49	36
NO	44,962	5,959	13,349	11,861	22,701

(1) Eurostat estimate.
(2) Data for 2015 instead of 2017.
(3) Data for 2016 instead of 2017.
(4) Definition differs.
Source: https://ec.europa.eu/eurostat

A clear image of this situation is reflected in the following graph:



(2) Data on collection 2016 instead of 2017; % of average weight of EEE put on the market 2014-2016
(3) Data on collection 2015 instead of 2017; % of average weight of EEE put on the market 2013-2015
Source: https://ec.europa.eu/eurostat

Figure 4. Waste electrical and electronic equipment (WEEE), total collected, by EEE category, 2017 (% of the average weight of electrical and electronic equipment put on the market in the three preceding years (2015-2017))

4. Discussion

The manufacturing of electrical and electronic equipment (EEE) is one of the fastest growing domains. This has resulted in an increase in the waste electrical and electronic equipment (WEEE).

Taking into consideration the environmental issues involved in the management of WEEE, many countries have adapted their national legislation so as to improve the reusing, recycling and other forms of collection of such waste, so that their elimination would be reduced. WEEE recycling is an important issue, not only as far as waste treatment is concerned, but also for the recuperation of valuable materials [5].

As a consequence of the aggressive use of resources, we must give up the current linear economic models and to adopt new models for sustainable management. Recycling is an essential part, ensuring the link between the beginning and the end of the process, by reintroducing the materials into the manufacturing process. This dynamic creates the circular economy, with consequences in terms of minimising the consumption of natural resources, creating business opportunities, optimising costs and creating jobs.

Europe should transform its economic model from a growth pattern of the “obtain, manufacture, use, eliminate” type — a linear model which starts from the premise that abundant resources are available and easy to eliminate — to a model which favours reusing, reparing, reconditioning and recycling the currently existing materials and products [18]-[19].

Keeping the value of the products and materials for as long as possible and generating less waste, the economy of the European Union can become more competitive and more resilient, reducing at the same time the pressure on the precious resources and on the environment.

5. Conclusions

The present paper was specifically written in order to identify the categories of equipment and the countries which have not reached their targets in terms of collecting WEEE. Unfortunately, there are countries in the EU, Romania included, which are lagging behind in this respect.

It is difficult to make a direct comparison among the EU Member States, because the individual strategies are based on different legal backgrounds, they cover various types and numbers of products and the resulting mass flows and the corresponding operational costs are variables which are highly dependent on the context.

Consequently, it is not possible to identify which European Union Member State's strategy is the most effective.

The analysis concludes that there are major differences among the EU Member States regarding the recuperation of waste electrical and electronic equipment and in order to reach the proposed recuperation targets new regulatory measures should be taken.

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