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CIRCULAR BEHAVIOURS OF POLISH CONSUMERS IN RELATION TO ELECTRICAL AND ELECTRONIC PRODUCTS

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Abstract

The article presents the concept of circular behaviours as part of the implementation of the circular economy in the daily life of households. These behaviours are considered in relation to electrical and electronic products. The aim of this article is to analyse the relationship between the taking up of certain behaviours in relation to these types of products and their selected effects in the form of benefits perceived by the household. The article presents the results of the research carried out among Polish households in two regions (N=400). Using statistical analysis methods (i.e., analysis of correlation, Chi² independence test, Kruskal-Wallis ANOVA, U Mann-Whitney Test), three research hypotheses were inferred in relation to 13 circular behaviours and 4 benefits. The results showed that: (1) more frequent circular behaviour for one product results in repetition of this type of behaviour for others, (2) households undertaking circular behaviour more frequently (whether in general or specific) experience higher levels of benefit to their household, (3) socio-demographic characteristics differentiate households' adoption of circular behaviour to a limited extent, which applies only to selected aspects or to selected behaviours.

Keywords: Circular behaviours, electronic equipment, households, statistical analysis, Poland.

JEL Classification: D12, D16, D91

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Introduction

Circular economy is seen as a new approach to the way the economy works. Unlike the linear way, based on the principle: 'take-make-waste', the circular economy assumes the reuse of raw materials after they have been consumed in the original product. They thus re-enter a closed loop. This process is largely concerned with the way companies design and produce products, but a key aspect is also the inclusion of users who, by adopting certain behaviours, can contribute to reducing the need for ever more resources. This is important from the point of view of both reducing waste and preserving often non-renewable natural resources for future generations. The increasing amount of electronic waste, for the production of which rare earth metals are used, is a global problem. Therefore, the question may arise as to what would reduce this increasing amount of waste and thus prevent the need to consume more and more resources that are difficult to renew. Related to this question is also the role of the various types of entity that uses these resources. The answer may lie in designing a usage system that allows for: extending the life of such equipment, and thus reducing the need for new equipment (reduce); easy repair or replacement of damaged, faulty components (reuse); return of such equipment at the end of its life (recycle). Such an approach would involve extending not only producer responsibility, which is otherwise very desirable, but also user responsibility. This responsibility can be expressed by engaging in behaviours that can be described as circular. They represent the efforts of households to implement the idea of a circular economy. Circular behaviours in households are mentioned much less frequently than circular actions taken up by enterprises. However, some of the authors address this topic in their research (Lakatos, 2016; Borrello et al., 2017; Muranko et al., 2017; Korsunova, Horn and Vainio, 2021; Szczygieł, 2020; 2021; Gomes, Moreira and Ometto, 2022). The authors noted that these behaviors are carried out in different areas and can be related to the circular economy at its different levels (for example, the concept 9R). Although these authors indicate that these behaviours are related to the circular economy, some of them include them in the broader trend of pro-environmental or sustainable behaviours (Corsini, Gusmerotti and Frey, 2020). In this case, however, it is important to note that circular behaviour is related to the reduction of resource consumption, and this link appears to be crucial.

This article deals with this type of behavior that households in Poland practice with regard to electrical and electronic products/equipment (EEE). The aim of this article is to verify the link between the undertaking of circular behaviours in relation to electrical and electronic products and the perception of specific benefits. The use of EE products is mentioned quite frequently in the literature, but only partly in the context of a circular economy (Manomaivibool and Vassanadumrongdee, 2012; Parajuly and Wenzel, 2017; Corsini, Gusmerotti and Frey, 2020; Rizos and Bryhn, 2022). However, what is lacking are research results on the implementation of circular behaviours in relation to EE products in relation to the benefits experienced by households. This constitutes a kind of research gap, which this article will try to fill. In the article, the problem of the amount of electrical and electronic waste will be presented, and the results of the author's own research on the specific behaviour of household members undertaken to reduce the number of discarded items included in this group will be analysed. The analysis will focus on identifying the relationship between engaging in circular behaviours relating to EE products and experiencing tangible benefits for the household, and on identifying what promotes increased circular behaviours among them. This article is the seventh in the series of publications devoted to circular economy and sustainable development issues.

1. Review of the scientific literature

1.1. Electrical and electronic equipment waste (EEEW)

Batteries, cathode ray tubes, photovoltaic cells, central processing units, microwave ovens, computers, and liquid crystal displays are just some of the everyday items used by the majority of people in developed countries. No one is surprised by the light bulbs, infrared detectors, mobile phones, memory cards, or thermostats that we use every day. However, just like every common object, these items also have a certain lifespan, and when they reach the end of their useful life and cannot fulfil their function, they are usually replaced by new ones. This results in a special category of waste: electrical and electronic equipment waste (EEEW), known as e-waste for short (Cucchiella et al., 2015; Baxter et al., 2016; Borthakur and Govind, 2018b; Shittu, Williams and Shaw, 2020).

It is estimated that every year the world generates more than 50 million metric tons (Mt) of EEEW and this figure is increasing annually by 3-5% per year (Shittu, Williams and Shaw, 2020). Asia is the largest producer of electro-waste, producing almost half of it (24.9 Mt) (Forti et al., 2020). In Europe, by comparison, around 12 Mt is produced, which equates to around 16,2 kg *per capita*. Unfortunately, on a *per capita* basis, this rate is much higher than for Asian countries (5.6 kg *per capita*) (Table 1).

Table no. 1. E-waste generated and recycled

Continent	e-waste generated in Mt	e-waste generated <i>per capita</i>	e-waste recycled in Mt	e-waste recycled rate (in %)
Africa	2.9	2.5	0.03	0.9
Asia	24.9	5.6	2.9	11.7
Americas	13.1	13.3	1.2	9.4
Europe	12.0	16.2	5.1	42.5
Oceania	0.7	16.1	0.06	8.8

Source: Forti et al., 2020, p. 25.

It is worth noting that economic development encourages the generation of more electro-waste (Kumar, Holuszko and Espinosa, 2017; Awasthi et al., 2018). According to data for 2019 from the survey The Global E-waste Monitor 2020 (Forti et al., 2020) and National Footprint and Biocapacity Accounts (Global Footprint Network, 2019), Pearson's linear correlation coefficient between the amount of electro-waste in kg *per capita* and the value of the Human Development Index is 0.902 (Table no. 2). The results of this simple analysis also indicate that the more affluent the society and the more developed the production and consumption, the stronger the link with the generation of electro-waste. Furthermore, the number of Earth Globes that are needed to meet needs at this level (Esposito, Tse and Soufani, 2017; Sariatli, 2017; Szczygiel, 2021a ;) is also positively correlated with the generation of more electro-waste.

Table no. 2. Pearson's linear correlation coefficient (*r*) between selected variables and e-waste generated (kg/*per capita*) in 2019

Variable	<i>r</i>
Human Development Index	0.902118
GDP <i>per capita</i>	0.852607
Number of Earths required	0.752443
Total Ecological Footprint (Production)	0.637416
Total Ecological Footprint (Consumption)	0.752443

Source: Author's own elaboration

The country with the highest number of e-waste *per capita* in the world is Norway (26 kg). In comparison, in Romania and Poland, these rates are half as high, standing at, respectively, 11.4 kg and 11.7 kg *per capita*. Compared to the figures quoted in the Forti et al. report (2020), the Eurostat data indicate a lower volume of generated electronic waste (10 kg *per capita*), although a similar recycling rate (42.1%) (Eurostat, 2022a; 2022b). This last aspect is one of the most important factors on which a concerted effort should now be made to implement (Barreiro-Gen and Lozano, 2020). According to the United Nations, 'the world generated 53.6 million metric tons (Mt) in 2019, and only 17.4% of this was officially documented as properly collected and recycled' (Forti et al., 2020, p. 9). This recycling process in many cases is informal and is based on the export of electronic waste from industrialised countries to developing countries (Ntapanta, 2021). This creates large-scale informal e-waste recycling sites, where unsafe practices are used during 'recycling', such as dismantling in open areas, incineration of e-waste, uncontrolled acid leaching or landfilling (Tembhare et al., 2022). In these places, workers are exposed to many harmful agents, including heavy metals or persistent organic pollutants. Based on a review of the literature, Tembhare et al. (2022) list the effects of 20 such factors on human life, including Lead (Pb), Cadmium (Cd), Chromium (Cr), Copper (Cu), Nickel (Ni), Indium (In), Lithium (Li), or Arsenic (As). A study carried out in Agbogbloshie (Ghana) by Yang et al. (2020) found that for the latter element, Arsenic alone, workers sorting illegal e-waste significantly exceeded tolerable concentration standards for this element, resulting in exposure to cancer development. This element is found in circuit boards, light-emitting diodes, batteries, and cathode ray tubes, among others, and can cause lung cancer, liver cancer, bladder cancer, skin cancer, or leukemia (Tembhare et al., 2022). Similar results were produced by the study by Julander et al. (2014), which found that workers in electronic waste segregation facilities have 10-30 times more exposure to heavy metals than office workers.

Unfortunately, economic considerations and the stimulation of demand for more and more new versions of EEE result in manufacturers undertaking the unethical practice of designing them to function for a certain period of time, after which "ceases to function (end-of-life) or performs sub-optimally (obsolescence)" (Shittu, Williams and Shaw, 2020, p. 550). This practice leads to forcing the user to behave in a certain way, i.e. to throw it away or dispose of it. In this way, such appliances, which contain many resources (rare earth metals, metal components, plastic, glass, etc.) become EEEW. Ethical doubts are raised not only by the practice of profit at all costs (by creating fashions for new things and disregarding the possibility of repair), but also by illegal procedures for disposing of e-waste in a situation of inefficient recycling procedures in the country of use, or by exposing those who 'process' it in developing countries to harmful working conditions (without proper procedures or equipment). What is crucial in the context of a circular economy is the overuse of rare natural resources in the name of consumption without considering future generations.

1.1. Consumer behaviours for electrical and electronic equipment

Each piece of electrical or electronic equipment has a specific life span, which is highly dependent on both the characteristics imparted during the production process (design, quality of manufacture, etc.) and how it is used by the end user. In research on EEE, a lot of attention is paid to end-of-life and recovery activities. An example of such equipment that is mentioned quite often is mobile phones. Surveys conducted in Finland (Ylä-Mella, Keiski and Pongrácz, 2015) show that 89% of respondents (N=53) had end-of-use mobile phones at home. Almost a third of them kept one spare phone at home and almost half had several. The respondents keep them as spare phones, but some of them said that they have not yet come to return them

or that recycling was problematic. However, 17% did not know where to take old phones. As the researchers pointed out, the opportunity to give back an old phone was through, for example, collection points organised at various locations, recycling centres or special collection campaigns through the public postal service. Significantly, half of those surveyed considered recycling to be important because of the recovery of materials, especially in the form of metal recycling, and because of the possibility of reusing functional components or even whole appliances. Therefore, it is possible to see the declarativeness of statements that are not followed by concrete actions. This may be due to the lack of direct benefits felt by the respondents. A survey of Irish consumers (Casey et al., 2019) found that respondents do not see their unused or even unwanted electrical or electronic equipment as “waste”, but rather as “stuff”. As the authors write, small EEEs are first ignored (as a category of stuff), then they are not identified as a category of WEEE and finally the users often try to divest them (via the general waste). Importantly, users are oriented towards convenient disposal of small EEE and do not often take advantage of the services available in shops (e.g. the possibility to return individual old items when buying new ones). The storage of small equipment is also highlighted by Borthakur and Govind (2018a). Only one in five respondents said they give this equipment to a shop and one in ten to a recycling centre. It is worth noting that almost 20% of the respondents “sell them to scrap dealers or ‘kawariwalas’ at a certain cost”. This type of practice raises the issue of the risk to health or life mentioned above. As in the research previously discussed, despite the high declared willingness of consumers to undertake repair (80%) or recycling (85.3%), only 4.3% of the respondents knew how to recycle EEE in a formal way. Similarly, knowledge of the legislation governing recycling was low (7.4%). Wang, Guo and Wang, research (2016) among Chinese consumers shows that WEEE recycling behavior intentions are positively influenced by environmental awareness and attitudes towards recycling. Income, cost of recycling, or awareness of the possibility of illegal recycling influence negatively. Similar positive effects of awareness are indicated by the results of studies conducted by Aboelmaged (2020), where the intention of recycling electronic waste was mainly driven by the significant positive influence of the attitude toward recycling electronic waste and recycling habits. The importance of awareness and knowledge of EEE recycling is also indicated by the results of the survey conducted by Otto et al. (2018). The authors highlight the relevance of factors related to household benefits and costs (financial incentives and social incentives) and structural factors that determine the feasibility of such activities. Corsini, Gusmerotti and Frey (2020) analysed the results of a study on the potential for different factors to influence the undertaking of repair or recycling of EEE. These included economic factors, among them income, which significantly influenced the willingness to participate in the recycling process. The relevance of income in the process of undertaking recycling activities is indicated by the results of the Romanian study (Colesca, Ciocoiu and Popescu, 2014). The authors indicated that a more frequent recycling of EEE in richer households may also mean that poorer households simply used EEE for longer. In this respect, it would be important to analyse how these devices can be used by households, which leads to the question of how the principles of the circular economy can be implemented in households not only at the end of the life span of the EEE.

1.2. Circular behaviours as an element of Circular Economy

The circular economy used to be analysed as a domain of corporate action, focusing particular attention on the process of production and provision of goods and services and the subsequent disposal of waste. The stage between these processes is consumption, which is primarily the

responsibility of the users (consumers). However, the rules of use are not separate from the product and are largely derived from its design and functionality. For example, the possibility of replacing a worn component in a product will depend on the circular design of the product (Szczygieł, 2020). Likewise, the possibility of a safe end-of-life will depend on the options provided by the producer (e.g. reverse logistics). The actions of consumers, undertaken as far as possible resulting from the designed product or service, and related to the limitation of the use of further resources in the economy, can be described as circular. In the most general terms, circular behaviour can be assumed to be that type of pro-environmental behaviour whose long-term effect is to reduce the demand for resources. Taking into account the levels of circularity (Kirchherr, Reike and Hekkerts, 2017; Czikkely et al., 2018), it can be indicated that the least complex activities will be those related to energy recovery (e.g., sorting waste fractions into wet and dry). The higher the degree of circularity, the more complex the actions taken by consumers tend to be and may also involve additional costs (e.g., installing solar panels to harness solar energy). At the same time, it can be assumed that the second dimension of behaviour considered as circular will be time, considered as the effects of a given action in the short or long term. If one looks at the effect of resource limitation as a circular behaviour, one would have to consider those that cause an effect in the long term (Figure no. 1).

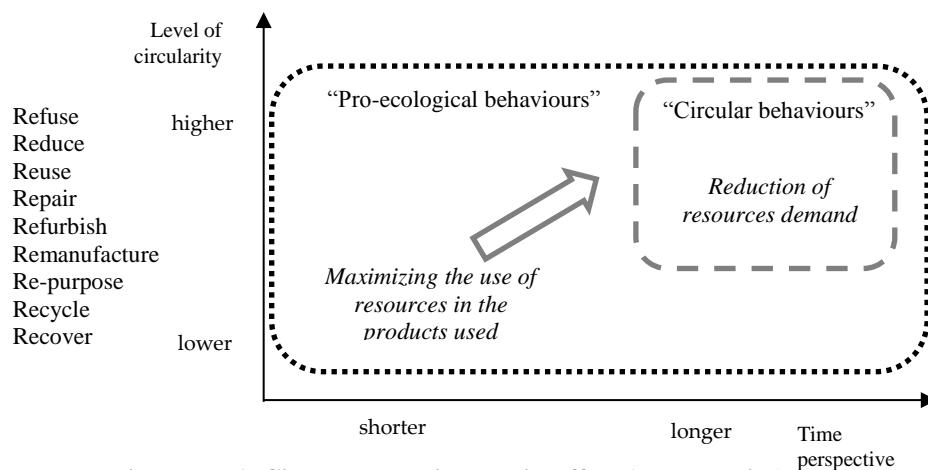


Figure no. 1. Circular behavior and its effect (resource limit)
Source: The author's own elaboration published in (Szczygieł, 2021b)

However, if one accepts the timing of the effect, it seems reasonable to consider some of the behaviours as circular already in the short term (Figure no. 2).

In this way, some of the behaviours undertaken by households can have the effect of reducing the need for resources already in the short term (e.g., the use of reusable bags or one-sided printed sheets of paper for note). However, the degree of circularity of such activities will be lower than that of those that have a long-term effect. From the entire range of behaviours undertaken by households, it is possible to distinguish those that will contribute to a greater or lesser extent to the implementation of the circular economy idea in practice. It is important to remember that the resources that are saved are not only the physical components of the product (e.g., plastic, metal, glass), but also the energy for use (e.g., communication or entertainment services). In a broader perspective, they can also be indirect resources, such as consumer money. In this regard, however, we are talking about the so-called economical

effect of undertaken circular behaviours. It is, next to the so-called ecological effect, it seems to be the second key motive for undertaking circular behaviours (Szczygieł, 2021b). This article will refer to these effects by analysing the benefits of taking circular actions in the field of electrical and electronic products.

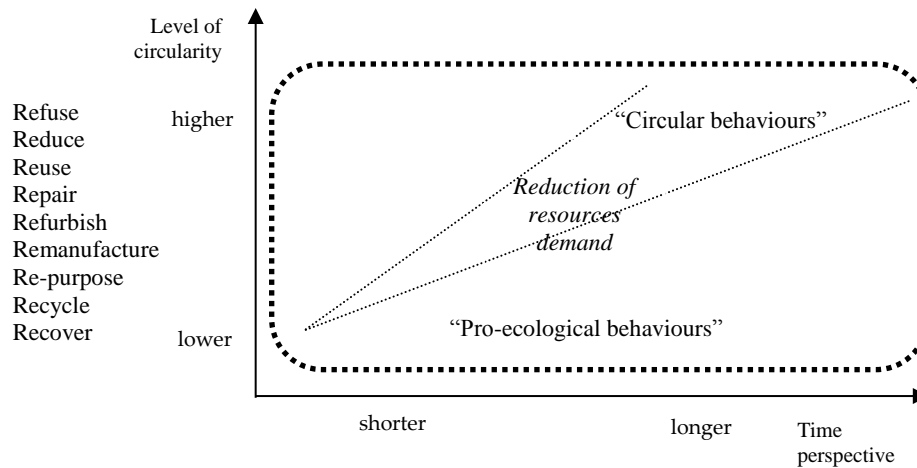


Figure no. 2. Circular behaviours and the time of the effect

Source: Author's own elaboration

2. Research methodology

The main objective of this study is to identify the link between the actions taken to promote circular behavior in relation to electrical and electronic products and the perceived benefits of the home. For the analysis, 13 of the 37 circular behaviors considered were selected from the finished research (Author's own project mentioned in Acknowledgments; Szczygieł, 2021b). Only 13 of the 37 behaviours are related to electrical and electronic products. They included the following statements:

- [1] Before throwing things away, I remove the components that I think may be useful.
- [2] I collect parts from other products to be able to create the product I need.
- [3] I repair broken small electronic and technical equipment (e.g., telephone, electric kettle, iron).
- [4] I repair large electronic and technical equipment (e.g., computer, TV, washing machine, fridge).
- [5] I use the services to service the products I use.
- [6] I take care of small electronic and technical equipment, thus extending its useful life.
- [7] I use used electronic and technical equipment (e.g., a second-hand telephone, a leased laptop).

- [8] When choosing electronic and technical equipment, I am guided by its energy class.
- [9] I disconnect devices from the contact when I do not use them (e.g., remove the phone charger after charging the phone).
- [10] I do not use the standby function in electrical appliances.
- [11] I use rechargeable batteries.
- [12] I use solar panels or photovoltaic collectors at home.
- [13] I use renewable energy resources.

These behaviours were selected and ordered according to increasing levels of circularity. The respondents indicated the frequency of a particular behaviour in their lives according to a 5-point scale (from 1 to 5): where “1” means *Never*, and “5” means *Always*.

Four of the 12 benefits analysed throughout the research project were selected as the benefits considered:

- [B.1] Saving resources (not needing many things).
- [B.2] Using less electricity.
- [B.3] Generating less waste.
- [B.4] Financial savings in EEE (spending much less on purchasing electronic and technical equipment).

The respondents could indicate the presence or absence of perceived benefit (binary variable). The selected benefits are directly related to the 13 behaviours analysed. The remaining benefits not included in this study (8 in total) (Szczygiel et al., 2022) relate to other spheres and do not result from the use of electrical and electronic products in a certain way.

The main thesis assumed in the present article is the following: households that engage in circular behaviours in relation to electrical and electronic products experience a number of tangible benefits from doing so and are aware of them.

On this basis assumption, three hypotheses were accepted for testing:

H_1 – Engaging in circular behaviour in relation to one electrical or electronic product encourages such behaviours toward other products of this type in the household (these behaviors are related to each other).

H_2 – The overall level of circularity is higher in households that perceived the benefits of their efforts.

H_3 – Undertaking circular behaviours in relation to electrical or electronic products is dependent on the socio-demographic characteristics of the household.

To verify these hypotheses, the Chi² Test of Independence, the U Mann-Whitney Test and Kruskal-Wallis ANOVA were used ($\alpha=0.05$, $p<\alpha$), as well as Pearson’s linear correlation coefficient and Spearman’s rank coefficient were used. The following terms for statistical significance were adopted: $p<0.05$ – existing (*), $p<0.01$ – high (**) and $p<0.001$ – very high (***). The data used in the article came from the original research conducted by the author in December 2020 on the territory of two Polish Voivodships (provinces): Małopolskie and

Podkarpackie (N=400 households). The sampling was random and stratified, and the sample was representative of the two voivodships indicated. The error margin of the survey was 5%.

3. Results and discussion

Analysis of the 13 selected household behaviors related to electrical and electronic products indicated that most of them are positively correlated with others, and the correlation is mostly statistically significant (Table no. 3). However, it should be noted that the value of Pearson's linear correlation coefficient is not significantly high, which may indicate a predominantly weak or average relationship in this respect (Stanisz, 1998). It is worth noting that in two cases the relationship is high or very high. In the first case, it concerns the correlation between the reparation of small and large electrical appliances (behaviour no. 3 and no. 4; $r=0.59$), while in the second case it concerns the use of solar panels and renewable energy sources (behaviour no. 12 and no. 13, $r=0.78$).

**Table no. 3. Pearson's linear correlation coefficient (r)
between analysed circular behaviours (CB)**

CB	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1.00												
2	0.43	1.00											
3	0.31	0.37	1.00										
4	0.28	0.26	0.59	1.00									
5	0.39	0.37	0.32	0.34	1.00								
6	0.21	0.14	0.39	0.39	0.26	1.00							
7	0.39	0.42	0.37	0.18	0.28	<i>0.07</i>	1.00						
8	0.17	0.12	0.26	0.27	0.29	0.44	<i>0.05</i>	1.00					
9	0.23	0.13	0.20	0.25	0.22	0.46	0.11	0.37	1.00				
10	0.24	0.24	0.18	0.19	0.17	0.35	0.16	0.24	0.39	1.00			
11	0.28	0.25	0.21	0.17	0.32	0.35	0.21	0.36	0.28	0.20	1.00		
12	0.19	0.20	<i>0.09</i>	<i>0.03</i>	0.17	<i>-0.04</i>	0.17	<i>-0.06</i>	<i>-0.05</i>	<i>0.09</i>	0.12	1.00	
13	0.23	0.27	0.11	<i>0.01</i>	0.17	<i>-0.05</i>	0.19	<i>-0.05</i>	<i>-0.01</i>	0.15	0.12	0.78	1.00

Note: statistically significant is in bold; statistically insignificant in italics

Source: Author's own elaboration

Therefore, it can be assumed on this basis that the first research hypothesis (H_1 – Engaging in circular behavior in relation to one electrical or electronic product encourages such behaviours towards other products of this type in the home - these behaviors are related to each other) was confirmed in the study group. It is important to note, however, that the correlations between individual behaviours are average, although social research emphasises that they tend to be lower than in the sciences. Therefore, for individual data (with which one is dealing here) at values of $r=0.5$ it can therefore be said of a strong correlation (Wiktorowicz, Grzelak and Grzeszkiewicz-Radulska, 2020). This may suggest that the correlations obtained between individual behaviours are indicative of the hypothesised regularity, and their statistical significance may confirm it.

Analysis of the relationship between circular behaviours and the perceived benefits of doing them showed that the correlation calculated using Pearson's linear correlation coefficient was weak (Table no. 4). The highest value of this coefficient was recorded for the relationship between taking care of small electronic and technical equipment (behaviour no. 6) and using less electricity ($r=0.28$). In the case of experiencing financial benefits, only a statistically

significant relationship was found for a few behaviours. This may suggest a more elaborate nature of the relationship between behaviour and perceived benefits (e.g., the need to take into account perceived financial benefits, which is dependent on individual household cost accounting).

Table no. 4. Pearson’s linear correlation coefficient (*r*) between analysed circular behaviours (CB) and perceived benefits (B.1-B.4)

CB	B.1. Saving resources	B.2. Using less electricity	B.3. Generating less waste	B.4. Financial savings on EEE
1	0.1373	0.1117	0.1958	<i>0.0942</i>
2	<i>0.0921</i>	<i>-0.0333</i>	<i>0.0457</i>	<i>0.0273</i>
3	0.1645	0.1369	<i>0.0449</i>	0.1326
4	0.1532	0.1352	<i>0.0969</i>	0.1404
5	0.1256	<i>0.0734</i>	0.1368	<i>0.0540</i>
6	0.1453	0.2851	0.1836	0.2230
7	0.1439	<i>0.0148</i>	0.1297	<i>0.0472</i>
8	0.1194	0.1994	0.1496	<i>0.2415</i>
9	0.1032	0.2781	0.1825	<i>0.2043</i>
10	0.1164	0.1094	0.1082	<i>0.0756</i>
11	0.1514	0.1119	0.1496	0.0992
12	<i>0.0614</i>	<i>0.0187</i>	<i>0.0852</i>	<i>-0.0490</i>
13	0.1195	<i>-0.0328</i>	<i>0.0968</i>	<i>-0.0447</i>

Note: statistically significant is in bold; statistically insignificant in italics

Source: Author’s own elaboration

There are significant differences between households that report feeling the benefits of undertaking circular behavior in relation to electrical and electronic products (Table no. 5). The average level of 13 circular behaviours carried out was higher in households that declared feeling the benefits of carrying out such behaviours (max. value was 5.0). The difference between non-declaring and declaring households was statistically significant. This result may indicate that household members who carry out circular activities are aware of their effects.

Table no. 5. Mean value of the frequency of circular behaviours (CB) and U Mann-Whitney test results between households that perceived or did not perceive the benefits

Benefits	Mean of CB when declaring benefits		<i>p</i> -value
	No	Yes	
B.1. Saving resources	3.01	3.30	0.000004***
B.2. Using less electricity	3.02	3.26	0.000052***
B.3. Generating less waste	2.98	3.29	0.000001***
B.4. Financial savings on EEE	3.08	3.30	0.002544**

Note: The mean was calculated as the average level for all circular behaviours for each household.

Source: Author’s own elaboration

It should be noted that households that indicated that they were experiencing tangible benefits were more likely to engage in circular behaviours than those that did not. The average difference was around 0.3 points (on a scale of up to 5.0).

Referring to each behavior, again there were apparent differences in the assessment of benefits between the households that performed the behaviour (Tables no. 6 and 7).

Table no. 6. Mean value of circular behaviours (CB) due to perception of benefits

CB	Mean of CB when declaring benefits							
	B.1. Saving resources		B.2. Using less electricity		B.3. Generating less waste		B.4. Financial savings on EEE	
	No	Yes	No	Yes	No	Yes	No	Yes
1	2.78	3.10	2.79	3.06	2.68	3.14	2.86	3.10
2	2.32	2.51	2.48	2.38	2.38	2.45	2.41	2.45
3	3.28	3.65	3.29	3.60	3.40	3.53	3.37	3.67
4	3.40	3.72	3.41	3.69	3.43	3.67	3.46	3.77
5	3.03	3.30	3.06	3.25	2.99	3.30	3.13	3.24
6	3.93	4.23	3.76	4.33	3.86	4.26	3.93	4.38
7	2.41	2.76	2.55	2.62	2.41	2.73	2.54	2.68
8	3.67	3.93	3.55	4.00	3.59	3.97	3.63	4.14
9	3.77	4.03	3.55	4.17	3.64	4.10	3.76	4.18
10	3.12	3.38	3.12	3.35	3.09	3.37	3.20	3.35
11	3.25	3.57	3.28	3.52	3.24	3.55	3.35	3.55
12	1.99	2.19	2.03	2.14	1.91	2.23	2.12	2.05
13	2.16	2.48	2.35	2.31	2.16	2.45	2.35	2.28

Source: Author's own elaboration

In 48 cases of 52 combinations analysed, the average frequency of circular behaviour undertaken was higher in those households that perceived the listed benefits. Only in 4 cases was the frequency lower, but these differences were not statistically significant (Table no. 7). These results are consistent with the expectation that circular behaviours are conducive to perceived benefits. These results, moreover, present a detailed reference to all the behaviours analysed, rather than their average level as shown in Table no. 3. This may be due to the fact that for some circular activities, household members undertook them more often than others, and the frequency of the former influenced the average level of the overall behaviours.

Table no. 7. Differences in the mean level of circular behaviours (CB) due to perceived benefits - U Mann-Whitney test results

CB	<i>p</i> -value			
	B.1. Saving resources	B.2. Using less electricity	B.3. Generating less waste	B.4. Financial savings on EEE
1	0.006113**	0.025706*	0.000092***	0.060060
2	0.065875	0.506037	0.361515	0.585193
3	0.001021**	0.006237**	0.370041	0.008094**
4	0.002218**	0.006912**	0.053025	0.005058**
5	0.012141*	0.142746	0.006286**	0.280671
6	0.003704**	0.000000***	0.000245***	0.000008***
7	0.004059**	0.767491	0.009603**	0.345717
8	0.017093*	0.000068***	0.002807**	0.000001***
9	0.039390*	0.000000***	0.000268***	0.000045***
10	0.020072*	0.028847*	0.030777*	0.131365
11	0.002493**	0.025431*	0.002816**	0.047661*
12	0.220199	0.709119	0.088698	0.328333
13	0.017035*	0.512627	0.053163	0.372159

Note: statistically significant is in bold; statistically insignificant is in italics.

Source: Author's own elaboration

It should be noted that statistically significant differences in the perception of the four benefits analysed related to four behaviours ([6] I take care of small electronic and technical equipment, thus extending its life; [8] When choosing electronic and technical equipment, I am guided by its energy class; [9] I disconnect devices from the contact when I do not use them; [11] I use rechargeable batteries). These are fairly straightforward and rather more common behaviours among Polish consumers. Also, for four additional behaviors, respondents experienced at least three of the benefits analysed. This points to the relevance of analysing benefits from the point of view of individual behaviours to identify what might motivate consumers to engage in them.

It should be noted that the positive reference to waste segregation and the average frequency of segregation also varies according to the perceived benefits (Table no. 8). Households that feel the benefits of undertaking circular behavior are more positive about the idea of waste separation and are more likely to separate waste (and the difference is statistically significant).

Table no. 8. Mean value of positive way of thinking about segregation and mean level of segregation due to perception of benefits (U Mann-Whitney test)

Benefits	Mean of positive perception of waste segregation			Mean level of segregation		
	No	Yes	p-value	No	Yes	p-value
B.1. Saving resources	3.95	4.31	0.000000***	3.82	4.21	0.000004***
B.2. Using less electricity	3.90	4.32	0.000000***	3.77	4.20	0.000000***
B.3. Generating less waste	3.84	4.37	0.000000***	3.75	4.22	0.000001***
B.4. Financial savings on EEE	4.03	4.34	0.000004***	3.92	4.21	0.000442***

Source: Author's own elaboration

The average level of positive perception of the waste separation process was calculated taking into account seven statements (i.e., *waste separation helps protect the environment and save resources*, or *segregated recyclable waste can be sold to generate additional income*). These statements were reviewed by the respondents surveyed along with the negative statements. As the results indicate, the average level of positive perception of waste segregation was statistically significantly higher when the household felt a benefit from undertaking circular behaviour than when no benefit was felt. Similarly, segregation itself was more frequent among households that experienced benefits than among those who did not, and this difference was statistically significant.

Thus, the second of the research hypotheses to be verified can be confirmed in the study group (H_2 – *The overall level of circularity is higher in the households which perceived the benefits from their undertaken*), and, in addition, the hypothesis can be deepened to address not only the average frequency of undertaking these behaviours, but also each of them specifically.

In analysing potential differences in characteristics between households that may be relevant to the undertaking of circular behaviours in relation to electrical and electronic products, the following socio-demographic variables were adopted for analysis:

- Sex [*Male; Female*]

- Age group [*18 - 29 years old; 30 - 39 years old; 40 - 49 years old; 50 - 59 years old; 60 years and more*]
- Place of residence [*Village; City up to 20k residents; City from 20k to 50k; City from 50k to 100k; City from 100k to 500k; City over 500k*]
- Education [*Elementary; Grammar school; Vocational; Secondary; Undergraduates; Higher*]
- Labour market status [*The person during the studies; Unemployed person; Working person; A person running a farm; A person running his/her own business; Retirees; Pensioner*] (The household of retirees is those whose exclusive or main (prevailing) source of maintenance is old age pension. Household of pensioners are those whose exclusive or main (prevailing) source of maintenance is any other type of pension than old age pension.)
- Personal composition of the household [*Single person; Marriage/couple without children; Marriage/couple with 1 child; Marriage/couple with 2 children; Marriage/couple with 3 or more children; Single parent*]
- Material status [*Very bad, Bad, Average, Good, Very good*]

“Segregation of used batteries and electronic equipment” was used as an additional variable. The variable refers to the frequency with which this activity is carried out [*Never, Rarely, Sometimes, Often, Always*].

Among the study group, women made up the majority (52%), which is in line with the mapping of society in the voivodships (provinces) studied. The percentage of respondents by age group was as follows: *18 - 29 years old* (22%), *30 - 39 years old* (19%), *40 - 49 years old* (16%), *50 - 59 years old* (17%) and *60 years and older* (27%). Regarding the place of residence, the percentage of respondents was: *Village* (37%), *City up to 20k residents* (10%), *City from 20k to 50k* (14%), *City from 50k to 100k* (11%), *City from 100k to 500k* (11%) and *City over 500k* (17%). According to Education level, *Elementary* had 1%, *Grammar school* finished 2%, *Vocational* level had 9%, *Secondary* had 39%; *Undergraduates* consisted of 8% and *Higher* educational level had 41% of respondents. The percentage of respondents by labour market status was as follows: *people during the studies* (7%), *unemployed* (8%), *working* (52%), *running a farm* (2%), *running his/her own business* (6%), *retirees* (22%) and *pensioners* (4%). According to household personal composition, within the research there were 16% of *single persons*, 19% of *marriages/couples without children*, 19% of *marriages/couples with 1 child*, and 32% of *marriages/couples with 2 children*, 10% of *marriages/couples with 3 or more children* and 2% of *single parents*. The percentage of respondents who assessed their material status was the following: *Very bad* (2%), *Bad* (12%), *Average* (46%), *Good* (32%) and *Very good* (8%).

The difference between the circular behaviours due to socio-economic characteristics mentioned above is statistically significant for the following categories (Table no. 9).

Table no. 9. The result of statistically significant differences between circular behaviours and the socio-economic characteristics (Chi² test, $p < \alpha$)

Circular Behaviors	p-value
<i>Sex</i>	
6. I take care of small electronic and technical equipment, thus extending its useful life.	0.03228*
9. I disconnect the devices from the contact when I do not use them.	0.02862*
10. I do not use the standby function on electrical appliances.	0.02087*
<i>Age group</i>	
8. When choosing electronic and technical equipment, I am guided by its energy class.	0.00689**
11. I use rechargeable batteries	0.03232*
13. I use renewable energy resources.	0.04725*
<i>Place of residence</i>	
1. Before throwing things away, I remove the components that I think may be useful.	0.02163*
7. I use used electronic and technical equipment.	0.03956*
10. I do not use the standby function on electrical appliances.	0.03490*
13. I use renewable energy resources.	0.00129**
<i>Education</i>	
11. I use rechargeable batteries	0.01328*
<i>Labour market status</i>	
11. I use rechargeable batteries	0.04104*
<i>Personal composition of the household</i>	
8. When choosing electronic and technical equipment, I am guided by its energy class.	0.04854*
13. I use renewable energy resources.	0.04420*
<i>Material situation</i>	
9. I disconnect the devices from the contact when I do not use them.	0.01155*

Source: Author's own elaboration

It should be noted that the gender of the head of the household matters with regard to the three behaviors and that women are more likely to engage in all of them (Table no. 9). They are the ones who mostly declare that they take care of the equipment, unplug it from the socket, or do not use the stand-by function. As far as age groups are concerned, it was the youngest respondents (18-29 years old) who indicated that they were guided by the energy class of the equipment when purchasing it. In the case of the use of rechargeable batteries, this behaviour is most often declared as *always* being undertaken by those in the oldest age group, as is the use of renewable energy resources. In the latter case, however, the vast majority of respondents declared that they use this way of obtaining energy occasionally (*Never, Rarely*), which is due to the costs and the need for considerable investment in such infrastructure. When it comes to their place of residence, it is the inhabitants of rural areas who more often declare dismantling various items from used appliances, using second-hand electronic accessories or unplugging electrical appliances when not using them, and using renewable energy sources. The latter may be related to having adequate space to install such an infrastructure. In the case of education and household composition, which differentiated respondents in terms of using rechargeable batteries only, it was those with secondary education and those in employment who declared the highest frequency of use. Married couples with two children, on the other hand, declared that they are most often guided by the energy class of the appliances when choosing them. This may be due to the fact that in such

families, it is usually the parents who earn money, while children do not contribute to the household budget, so savings are naturally sought. Similarly, the use of renewable energy sources (although not very often declared by respondents), the declaration that they *always* use them, was most often indicated among this group. People with an average material status declared most often that they unplug devices from the power socket, which seems to confirm the thesis that households are looking for possible areas of savings.

The last of the characteristics analyzed, the segregation of waste batteries and electronic equipment, differentiated the respondents to the highest degree (Table no. 10). The analysis of the results shows that the more often the respondents declared to segregate waste batteries and electronic equipment, the more often they conducted the circular behaviours analyzed with regard to electrical and electronic products. Interestingly, detailed data (not published as part of this article) show that respondents declared to segregate the above-mentioned waste items even in the absence of using solar panels (behaviour no. 12) and renewable sources (behaviour no. 13). The positive association between a higher frequency of segregating waste batteries and electronic equipment and a higher frequency of undertaking the circular behaviours analysed is also confirmed by Spearman’s rank correlation coefficients for each behaviour (statistically significant* except for the no. 12 and no. 13).

Table no. 10. The result of statistically significant differences between circular behaviours (CB) and the segregation of used batteries and electronic equipment (Chi² test, $p < \alpha$) and Spearman’s rank correlation coefficient

Segregation of used batteries and electronic equipment vs. circular behaviours (CB)	<i>p</i> -value	Spearman rank correlation
1. Before throwing things away, I remove the components that I think may be useful.	0.00088***	0.183595*
3. Repair small broken electronic and technical equipment.	0.00499**	0.208515*
4. I repair large electronic and technical equipment.		
5. I use the services to service the products that I use.	0.00000***	0.242263*
6. I take care of small electronic and technical equipment, thus extending its useful life.	0.00011***	0.234341*
8. When choosing electronic and technical equipment, I am guided by its energy class.	0.00000***	0.343686*
9. I disconnect the devices from the contact when I do not use them.	0.00000***	0.293220*
10. I do not use the standby function on electrical appliances.	0.00000***	0.300234*
11. I use rechargeable batteries.	0.00002***	0.204821*
12. I use solar panels or photovoltaic collectors at home.	0.00001***	0.264713*
13. I use renewable energy resources.	0.00096***	<i>0.011340</i>
	0.00173**	<i>0.002819</i>

Note: statistically significant is in bold; statistically insignificant in italics

Source: Author’s own elaboration

Considering the average level of circular behaviours relating to electrical and electronic products, an analysis of the influence of individual socio-demographic variables showed that the factors that significantly differentiate this average level of behaviours are: place of residence, household personal composition, and the segregation of batteries and waste electronic equipment (Table no. 11).

Table no. 11. The result of statistically significant differences between the mean value of circular behaviours related to electric and electronic equipment and socio-economic characteristics (Kruskal-Wallis ANOVA, $p < \alpha$)

Socio-economic characteristic	<i>p</i> -value
Sex	<i>0.0755</i>
Age group	<i>0.5431</i>
Place of residence	0.0469*
Education	<i>0.7798</i>
Labour market status	<i>0.6762</i>
Personal composition of the household	0.0294*
Material situation	<i>0.6466</i>
Segregation of used batteries and electronic equipment	0.0000***

Note: statistically significant is in bold; statistically insignificant is in italics

Source: Author's own elaboration

In the case of place of residence, despite the differences between the households of those living in rural areas and the other respondents evident in the earlier results of the analysis (Chi² independent test for the declared frequency of the behaviours), multiple comparisons on mean ranks for all groups did not show any statistically significant differences between the sub-groups (although for the overall average level they were apparent). In the case of the personal composition of the household, the differences in the group were significant between a single person and a marriage / couple with 3 or more children ($p=0.008959$). Regarding the last of the elements analysed (*Segregation of used batteries and electronic equipment*), differences were observed between the group of households declaring that they *Always* separate such waste and the group that *Never* does it ($p=0.015508$) or does it *Rarely* ($p=0.000043$) or does it *Sometimes* ($p=0.000003$).

Thus, it can be indicated that only socio-economic variables and certain attitudes can differentiate selected circular behaviour relating to electrical and electronic products. It can be concluded that the third research hypothesis (H_3 - *Participating in circular behaviors in relation to electrical or electronic products is dependent on the socio-demographic characteristics of the household*) has been partially confirmed and that further research is necessary in this area. Previous research in this area has also confirmed only a partial relationship between socio-demographic characteristics and the adoption of circular behaviour (Szczygieł, 2021b).

Conclusions

The exercise of circular behavior with regard to electrical and electronic products is an element of the entire circular economy system. As demonstrated in this article, engaging in such behaviour in relation to just one product has consequences in terms of similar behaviour towards others. This suggests a consistency of behaviour and may favour the extension of such attitudes towards other products. The implementation of circular economy principles should encompass the whole system, of which the consumer is one element (Wastling, Charnley and Moreno, 2018). However, its role is not detached from the external conditions under which it operates. Several studies (Milovantseva and Saphores, 2013; Gholamrezai, Aliabadi and Ataei, 2021; Oke et al., 2021), including the results presented in this article, point to the key role of internal determinants of individuals undertaking circular or, more broadly, pro-environmental behaviours. This is important in the process of shaping attitudes

and developing habits. However, it is important to emphasize the need to involve other actors in creating a well-functioning system. Such factors can be system-wide regulations (Wang et al., 2021; Rizos and Bryhn, 2022), specific incentives leading to habit formation (Aboelmaged, 2020), support for social community building (Cuadrado et al., 2022), or specific infrastructure improvements (Otto et al., 2018; Oke et al., 2021). However, a systemic view of the implementation of the circular economy assumes that an in-depth understanding of the mechanisms that drive consumer behaviour is required (Parajuly et al., 2020; Oke et al., 2021). In this case, the benefits that motivate people to act should also be considered. Indeed, it turns out that it is not only the need to meet imposed standards (e.g., legal) that can be an effective motivator, but also the reward of a specific tangible benefit, which can be, for example, a financial benefit (Shevchenko, Laitala and Danko, 2019) or the avoidance of the costs of engaging in such behaviour (e.g., free recycling) (Otto et al., 2018). The results obtained in this study also confirm previous observations that a positive attitude towards environmental issues, or more specifically the recycling of electrical and electronic products, is an important element to support specific actions (Milovantseva and Saphores, 2013; Dhir et al., 2021). In this respect, it is necessary to carefully examine both which benefits will be relevant for which groups and which mechanisms foster circular behaviours. Regarding the latter, internal and external factors that describe specific communities and individuals are crucial. The results obtained in this study show that the factor that most differentiates the average frequency of undertaking all circular behaviours in relation to electrical and electronic products is the place of residence, the personal composition of the household, and the separation of waste batteries and electronic equipment. For individual behaviours, other descriptors were also relevant. Similar results have been found in other studies, where the key role of women in engaging in such behaviour has been indicated (Atik et al., 2022), the level of income or the age of the respondents. (Milovantseva and Saphores, 2013) or level of education (Pelău and Chinie, 2018). Therefore, this points to the need for more research to identify the factors that may determine desirable behaviour for a wide range of products, including electrical and electronic products, whose relevance in everyday life is increasing. A certain limitation of the results obtained may be their unrepresentativeness to European countries. The surveys are representative of the two named regions included in the study (although, in this case, due to the random nature of the sample, a conditional generalisation for Poland may be allowed). The second limitation is the scope of the subject matter. Selected behaviours were analysed in relation to selected EEE products (not all diagnosticable). A complete picture of the circular behaviour among household members in relation to EEE products would be possible on the basis of a full study with this purpose. For this reason, the results of such research should be used at every stage of the life cycle of such products to create a jointly efficient system for their circulation, allowing negative environmental effects to be minimised or even eliminated.

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