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SOCIAL ATTITUDES TOWARDS ELECTRONIC WASTE AND THE IMPLEMENTATION OF CIRCULAR ECONOMY PRINCIPLES

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ABSTRACT: This article addresses the issue of electro-waste and the role of the consumer of electrical and electronic equipment within the organisation of a circular economy. The aim of the article is (i) to identify the attitudes of the consumers surveyed towards unused electrical and electronic equipment, (ii) to assess the consistency of the attitudes displayed with the principles of the circular economy, and (iii) to identify the most important factors influencing these attitudes. The theoretical part approaches issues such as consumers' subjective perception of electro-waste, the increasing amount of electro-waste globally, and the problems associated with limited recycling opportunities. The conducted study revealed the potential of the surveyed consumers for the organisation of the circular economy in the field of electro-waste management, as well as the risk factors in the form of depositing electro-waste into the municipal waste stream. The analysis also showed a correlation between attitudes towards electro-waste with factors such as age, gender and education. In the concluding part, the most underlying consumer problems related to electro-waste management were systematised; more thorough research was also signalled.

KEYWORDS: circular economy, e-waste, consumer behaviour

Introduction

One of the biggest challenges in building a sustainable economy is reducing environmental impact. This impact is linked to resource extraction on the one hand and the need to dispose of waste on the other. The linear model of production and consumption, based on the pathway from raw material to waste, has generated an entire spectrum of negative environmental effects (Korhonen et al., 2018; Hanumante et al., 2019; Puntillo et al., 2021). The widely observed accumulation of waste in the environment demonstrates the inefficiency of waste management systems. These systems are becoming increasingly inefficient in the face of the ever-increasing waste stream volume, which is an inevitable consequence of the linear model of production and consumption (Jørgensen & Pedersen, 2018). Escalating the capacity of waste management systems – while desirable – can only bring temporary improvements. The solution to this dilemma is seen in the development of the circular economy, which is an alternative production and consumption model (Corona et al., 2019; Camilleri, 2020). This model emphasises changes in design and production processes (den Hollander et al., 2017; Talens Peiró et al., 2017), as well as in the realm of consumer attitudes (Hazen et al., 2017; Romero-Hernandez & Romero, 2018). These attitudes may show variability depending on socio-economic factors. This issue becomes particularly relevant for products with a high environmental footprint, which includes electrical and electronic appliances. The production and disposal of such products are also strongly related to the issues of energy consumption and greenhouse gas emissions (Zu et al., 2012). Reducing the negative environmental impact of these products depends primarily on the attitudes of their users. This article aims to verify how Polish consumers manage electrical and electronic equipment, identify the most critical factors influencing this process, and assess its consistency with the assumptions of a circular economy. The research method included the analysis of literature and empirical research. The literature analysis focused on publications focusing on the issues of circular economy or e-waste. The empirical part focuses on analysing data obtained from a survey conducted among Polish consumers.

This topic is particularly important in the case of countries where organised methods of e-waste management have been introduced relatively recently (for example, in Poland). The present research's particular importance is related to the recognition of the degree of consumer adoption of modern forms of dealing with electro-waste (such as the use of specialised collection points). An essential part of the research is also the assessment of the consolidation of habits developed in the absence of an organised waste management system. Some of these habits are unsustainable (for example,

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throwing electrical waste into municipal waste). Other habits, on the other hand, may have a decidedly positive impact on the environment (for example, repairing broken appliances). The widespread occurrence of such attitudes may become an unexpected advantage for Polish consumers and be an essential element in implementing the circular economy model. In this context, the article raises the relatively poorly researched issue of social determinants of implementing the circular economy in post-socialist countries. Identifying such conditions can contribute to developing a well-adjusted, and thus effective, circular economy implementation strategy (Gradinaru & Maricut, 2022). Implementing the circular economy by the EU Member States will bring closer the achievement of EU strategic goals, such as reducing the volume of unmanaged waste, reducing dependence on imported raw materials and implementing climate policy (Tomić & Schneider, 2020).

Literature overview

Any device which, for various reasons, has lost its usefulness (Elektro-Eko, 2022) is classified as electronic waste (e-waste/electro-waste). The reasons for classifying a device as electro-waste are varied. The most common reasons include the following:

- physical damage, precluding the possibility of repair and making further operation completely impossible,
- physical damage that is potentially repairable but not economically viable (for example, when the cost of repair exceeds the price of a new device),
- partial damage, causing loss of part of the appliance's functionality or inconvenience in its use (for instance, difficult switching on and off),
- the presence of visible, natural traces of wear and tear (scratches and scrapes on the surface, cracks and splinters, losses) that reduce the aesthetic value of the product,
- loss of functionality as a result of technological change (e.g., media players withdrawn from the market by manufacturers, TV not adapted to new transmission standards),
- a desire for enhanced functionality that is only available in new equipment (for example, software that is incompatible with older generation equipment),
- too high level of energy consumption compared to new equipment,
- lack of availability of necessary consumables necessary for the continued use of the equipment (for example, printer cartridges),
- lack of availability of necessary spare parts necessary for the continued use of the appliance (e.g. charger suitable for a particular type of socket, filters adapted to a particular household appliance).

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The variety of reasons for discontinuing the use of appliances, along with the increasing number of appliances being equipped in households, results in an ever-growing volume of electro-waste. In 2019, the volume of electro-waste generated globally reached 53.6 million metric tonnes, and the level projected for 2030 was expected to be close to 75.0 million metric tonnes (Forti et al., 2020).

Electro-waste falls into the hazardous waste category, requiring a unique approach from waste management systems. Such an approach is necessary due to the presence of heavy metals such as zinc, cadmium, nickel and mercury (Shuptar-Poryvaieva et al., 2020), as well as chlorofluorocarbons, hydrochlorofluorocarbons and brominated flame retardants as well as other substances with an irritant, toxic and carcinogenic effects (Chakrabaty & Nandi, 2021; Santato & Alarco, 2022). On the other hand, electro-waste also contains many valuable raw materials, most notably precious metals and Rare Earth Elements (REE) (Pitron, 2019; Althaf et al., 2021). Moreover, other raw materials such as copper and steel are present in this type of waste, the recovery of which is mainly determined by economic factors (the cost of the resources required to separate and purify them). Plastics – serving as housing components and insulation material – are also a significant part of electro-waste. Due to their complex chemical composition, these plastics can release a number of substances hazardous to health and the environment (Lam et al., 2012). Physical fragmentation of such plastics, leading to the formation of microplastics, is also a growing problem (Jung et al., 2022). The inability to physically reprocess and use this type of substance is one of the critical arguments regarding the possibility of fully implementing the circular economy principles (Cullen, 2017; Moreau et al., 2017).

Waste management in a circular economy is defined by a set of general principles. These principles, sometimes referred to as strategies, describe a hierarchy of actions to be taken for efficient waste management. This hierarchy is defined with varying degrees of precision. It can take the form of nine principles (Potting et al., 2017), although the most commonly cited hierarchy consists of three core activities: reduce, reuse and recycle (Goyal et al., 2018; Li, 2012).

Reduction in the case of electro-waste refers to any activity aimed at eliminating the need to purchase a new device. This should primarily include the repair of broken devices but also the abandonment of the purchase of products deemed to be actually unnecessary. This activity is, however, relatively demanding on the user of the appliance. Here, it becomes necessary to use technical knowledge and skills or to make use of specialised maintenance services. In the first case, in addition to the necessary skills, the user must have the necessary tools, a place to carry out the repair (problematic in the case of small-scale housing conditions), as well as free time and readiness to

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spend it on repairing the device. If a repair service is used, the cost of the service and transport have to be taken into account.

Reuse is the disposal of an unused appliance. A distinction can be made between the situation where the item is given away free of charge (usually to family or friends) and where it is offered for sale. Activities focused on extending the product lifespan are the basic mechanisms for reducing environmental impact in the circular economy model (Xavier et al., 2021). In cases where reuse is no longer possible (either because the item is completely unusable or because it is not possible to find people interested in owning it), the product is passed on for reprocessing/recycling.

The first step in this process is the transfer of e-waste to specialised collection points. These collection points can be public facilities (managed by local governments) or private, functioning as part of reverse supply chains (Sasikumar & Kannan, 2008).

For all the activities described, the device's size is an important factor. The classification of electro-waste in this respect is set out in Directive (2012) and includes:

- bulky waste, with dimensions exceeding 50 cm (for example, large household appliances, large power tools, vending machines and others),
- small volume waste, not exceeding 50 cm (for example, small household appliances, smaller power tools, toys and others),
- small-sized waste of IT and telecommunications equipment with dimensions not exceeding 50 cm,
- heating and cooling equipment,
- lamps,
- devices with screens larger than 100 cm^2.

The most problematic electro-waste is bulky waste, the transport of which is usually beyond the capacity of the individual consumer. On the one hand, this situation provides an incentive to undertake on-site repairs, while on the other, it contributes to the phenomenon of long-term storage of unused equipment. The problems associated with small-scale electro-waste are related, by contrast to the previous case, to its ease of handling. This results in infiltration into the municipal waste stream and consequent diversion to incineration or landfill. In industrialised countries, the scale of this phenomenon is estimated at 8% of the total volume of electro-waste generated, and this type of waste is also found in segregated waste such as plastic and metal (Forti et al., 2020).

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Research Methodology

The data used in the study has been obtained in the project "The role of social capital in the strategy of sustainable development of highly urbanised and industrialised regions on the example of the Silesian Province." The study was conducted in several stages.

In the first stage, a survey was conducted on a group of 300 adult consumers from the Silesian Voivodeship. A specialised research centre surveyed respondents from its panel. As a result, 300 completely completed questionnaires were obtained (although some of the respondents refused to specify their monthly income). The demographic profile of the study group is presented in Table 1.

Table 1. Socio-economic profile of respondents

gender	women	55.0%
	men	45.0%
age	18-25	25.0%
	26-39	33.0%
	40-65	25.0%
	66 and above	17.0%
education level	basic	6.7%
	lower secondary	0.7%
	vocational	13.0%
	secondary	30.3%
	post-secondary	6.3%
	bachelor/engineer	13.3%
	higher	29.7%
place of residence	house	43.0%
	flat	57.0%
monthly income	less than PLN 1000	6.3%
	PLN 1000-1999	12.7%
	PLN 2000-2999	27.3%
	PLN 3000-3999	11.6%
	PLN 4000-4999	3.0%
	PLN 5000 and above	12.0%
	no income	12.0%
	refuse to answer	15.1%

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In the second stage, the data obtained were narrowed down to variables relating to handling electrical and electronic equipment. The respondents could indicate the following ways of handling unused or damaged equipment:

- disposing of municipal waste,
- disposing into bags or containers for further recycling,
- giving away to other people,
- delivery to collection points,
- repair and continue to use.

The third and final stage of the study was to obtain a statistical picture. For this purpose, the percentages of individual answers and the correlation coefficients between the research and demographic variables were calculated. All calculations were performed using the STATISTICA package.

Results and discussion

In the surveys carried out, the most important issue is to find out what attitudes towards damaged or unused electrical and electronic equipment are manifested by consumers. This is summarised in Figure 1 (the respondents could mark more than one answer).

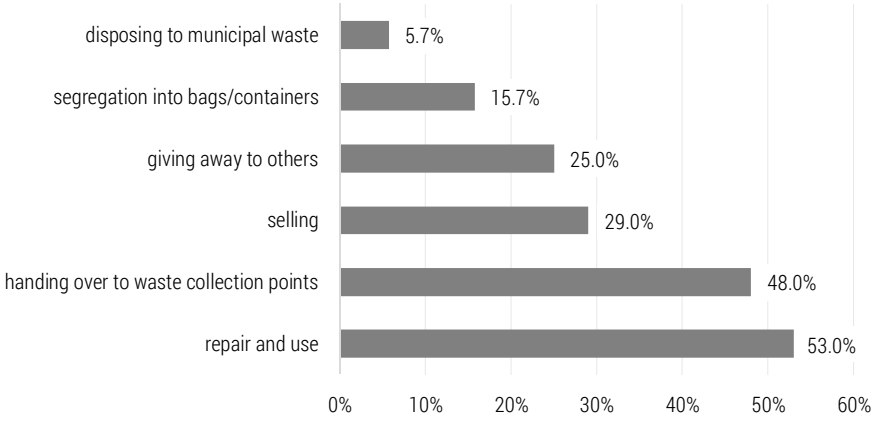

Figure 1. The popularity of attitudes towards unused electrical and electronic equipment

The analysis of the responses shows that the most common attitude, indicated by more than half of the respondents (53%), is repair and continued use. This attitude should be assessed as converging with the principles of circular economy. In the correlation analysis carried out (Table 2), no factors were found that clearly correlated with the declaration of this attitude.

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Table 2. Correlation analysis of user attitudes and socioeconomic factors

	Disposal to municipal waste	Segregation into containers/bags	Giving away to others	Sales	Delivery to collection points (communal or in stores)	Repair and use
Age factors						
18-25	x	x	X	x	0.15	x
26-39	x	0.15	X	x	0.18	x
over 66	x	-0.15	-0.20	-0.21	-0.29	x
Education factors						
Basic	x	x	x	x	-0.18	x
Lower secondary	0.16	x	x	x	x	x
Vocational	x	-0.14	x	x	-0.23	x
Post-secondary	x	x	x	x	0.16	x
Higher	x	x	x	x	0.12	x
Bachelor/Engineer	x	0.13	x	x	0.11	x
Income factors						
Income PLN 3000-3999	x	x	x	x	0.19	x
Income PLN 4000-4999	x	x	0.17	x	x	x
Professional status factors						
Pupil/student	x	X	x	0.27	x	0.13
Farmer	0.16	X	x	x	X	x
Teacher	x	0.14	x	x	X	x
Pensioner/retiree	x	-0.17	-0.22	-0.19	-0.29	x
White collar worker	x	X	x	x	0.18	x
Trade worker	x	X	x	x	0.14	x
Labourer	x	X	x	x	-0.14	x
Manager	x	X	x	x	0.14	x
Business owner	x	X	x	x	-0.13	x
Other profession	x	X	x	-0.15	x	x
Other factors						
Female	x	X	0.12	x	0.24	0.20
Living in flat	x	X	x	x	x	-0.17

x – no correlation, $p<0.05$.

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A positive correlation was found for women (0.20) and pupils and students (0.13). The shape of the survey questionnaire does not allow to determine whether repairs are carried out independently at home or with the use of service points. A negative correlation emerged for residents of townhouses and blocks of flats, which is presumably related to the limited possibilities for repairs in a limited area. It should be added that carrying out repairs at home, without adequate preparation, promotes secondary damage, as well as fragmentation of the appliance, the components of which may then end up in a municipal waste or be used as recyclable materials. In the conducted survey, disposal of whole appliances or their components in this way was declared by 5.7% of respondents for municipal waste and 15.7% for recyclables.

The second most common attitude is the transfer of unused appliances to specialised collection points (43% of responses). In order to correctly assess the consistency of this approach with circular economy principles, it is necessary to distinguish whether the transferred appliances are repairable or whether the owners do not intend to continue using them. Unfortunately, the survey design does not make it possible to distinguish between these situations. As for appliance repairs, the strongest correlation was shown for women (0.24). The other factors correlating positively were secondary and higher education, performing a job related to intellectual work and the younger age of the respondents. The negatively correlating factors were retirement age, primary and vocational education and having an occupation associated with manual work. Among people of retirement age, there is a general trend of not wanting to dispose of electro-waste in any way. This may indicate a lower need to use such appliances or ingrained habits such as keeping faulty or unused appliances for long periods of time to use them in some unspecified way in the future.

The sale and free transfer of electrical and electronic equipment are far less popular attitudes. Both activities are characterised by a similar level of popularity among users (29% of responses for selling and 25% for giving away for free). Another common feature is a negative correlation in the case of people of retirement age. The highest propensity for selling is found among pupils and students and for giving away free of charge among women (0.13).

Conclusions

In light of the research conducted, the degree of compliance of consumers' attitudes using electrical and electronic appliances with the principles of the circular economy should be assessed as relatively good, nevertheless certainly not sufficient. Although the repair of electrical and electronic equip-

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ment for further use is declared by more than half of the respondents, a significant proportion of consumers do not show interest in such activity. The reasons for this approach can be varied: lack of necessary skills, safety concerns during repair and subsequent use, lack of suitable conditions (equipment and premises), negative experiences from previous repairs, lack of technical possibility of repair or its economic unviability. However, determining the impact of individual reasons on consumer attitudes requires more detailed research in this area.

Directing unused equipment to collection points is the second most popular declared attitude. Polish consumers thus have the potential to participate in reverse supply chains, ensuring that electro-waste can be appropriately managed. On the other hand, the source of electro-waste infiltration into municipal and segregated waste was also confirmed. Disposing small-scale electro-waste by throwing it into municipal waste is much simpler than handing it over to a collection point. Reducing this phenomenon will primarily be a challenge in terms of changing awareness. Disseminating information on the dangers of this phenomenon will undoubtedly contribute to reducing it, albeit it is doubtful that it will allow it to be eliminated. Changing attitudes is complicated for people with established habits. In the research carried out, a trace of such conditioning is revealed in the case of some elderly people, who are likely to practice their ways of dealing with electro-waste (such as long-term storage).

Selling, as well as free transferring, are attitudes which are less frequently declared. The likely causes for this are the need to find someone interested in purchasing or receiving a used device. This situation points to the limited possibilities for implementing the so-called sharing economy. This fact proves that not all mechanisms to support the circular economy have equal potential. Product life extension and reverse supply chains are the most favoured mechanisms for electrical and electronic equipment consumers. The development of these mechanisms is primarily the responsibility of enterprises.

Nonetheless, state economic policy is also not insignificant. This policy could provide for stimulus instruments (for instance, in the form of concessions for companies carrying out such initiatives). As a result, it would be possible to develop a consumer-oriented offer in the form of increasing the number of collection points, on-site collection and transport of large appliances, assistance in the disposal of problematic electro-waste (e.g., significant heating and cooling appliances), which could contribute to solving the issue of electro-waste penetrating the environment.

One of the basic principles of the circular economy is the prevention of waste generation. This principle is related to several activities aimed at extending the product's lifespan (such as repairing broken devices or giving

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unused devices to others) but also to all attitudes related to resignation from the purchase and use of the device. While the first group of attitudes was included in the study, attitudes related to resignation were not examined. The future direction of research, in addition to identifying the presence of such an attitude, should also include the determination of related factors. These factors include economic conditions, the level of consumer and environmental awareness, the level of electricity prices and other factors. Another research direction is related to the relative perception of electrical and electronic devices as waste. Again, such a study should determine whether there are socio-economic factors related to the perception of a given device as waste and its discontinuation.

The contribution of the authors

Elżbieta Lorek – 50%.
Paweł Lorek – 50%.

References

Althaf, S., Babbitt, C., & Chen, R. (2021). The evolution of consumer electronic waste in the United States. Journal of Industrial Ecology, 25(3), 693-706. https://doi.org/10.1111/jiec.13074

Camilleri, M. A. (2020). European environment policy for the circular economy: Implications for business and industry stakeholders. Sustainable Development, 28(6), 1804-1812. https://doi.org/10.1002/sd.2113

Chakrabarty, A., & Nandi, S. (2021). Electronic waste vulnerability: circular economy as a strategic solution. Clean Technologies and Environmental Policy, 23, 429-443. https://doi.org/10.1007/s10098-020-01976-y

Corona, B., Shen, L., Reike, D., Carreón, J. R., & Worrel, E. (2019). Towards sustainable development through the circular economy – A review and critical assessment on current circularity metrics. Resources, Conservation & Recycling, 151. https://doi.org/10.1016/j.resconrec.2019.104498

Cullen, J. (2017). Circular Economy – Theoretical Benchmark or Perpetual Motion Machine? Journal of Industrial Ecology, 21(3), 483-486. https://doi.org/10.1111/jiec.12599

den Hollander, M., Bakker, C. A., & Hultink, E. J. (2017). Product design in a Circular Economy. Journal of Industrial Ecology, 21(3), 517-525. https://doi.org/10.1111/jiec.12610

Directive (EU) 2012/19/EU of the European Parliament and the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE), Pub. L. No. 32012 L0019, 197 OJ L (2012). http://data.europa.eu/eli/dir/2012/19/oj

ElektroEko. (2022, May 16). *Co to są elektrośmieci?* https://elektrosmieci.pl/co-to-sa-elektrosmieci

DOI: 10.34659/eis.2022.83.4.531

Forti, V., Baldé, C. P., Kuehr, R., & Bel, G. (2020). *The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential.* United Nations University (UNU)/United Nations Institute for Training and Research (UNITAR) – co-hosted SCYCLE Programme, International Telecommunication Union (ITU) & International Solid Waste Association (ISWA). Bonn/Geneva/Rotterdam. https://www.itu.int/en/ITU-D/Environment/Documents/Toolbox/GEM_2020_def.pdf

Goyal, S., Esposito, M., & Kapoor, A. (2018). Circular economy business models in developing economies: Lessons from India on reduce, recycle, and reuse paradigms. Thunderbird International Business Review, 60(5), 729-740. https://doi.org/10.1002/tie.21883

Gradinaru, G., & Maricut, A. C. (2022). From the rebound effect to the perspective of circular economy: a structure changes analysis among EU countries. Economic Computation & Economic Cybernetics Studies & Research, 56(1), 257-272. https://doi.org/10.24818/18423264/56.1.22.16

Hanumante, N., Shastri, Y., & Hoadley, A. (2019). Assessment of circular economy for global sustainability using an integrated model. Resources, Conservation & Recycling, 151. https://doi.org/10.1016/j.resconrec.2019.104460

Hazen, B., Mollenkopf, D., & Wang, Y. (2017). Remanufacturing for the Circular Economy. An Examination of Consumer Switching Behavior. Business Strategy and the Environment, 26(4), 451-464. https://doi.org/10.1002/bse.1929

Jørgensen, S., & Pedersen, L. J. T. (2018). The Circular Rather than Linear Economy. In P. Schrivastava & L. Zsolnai (Eds.), *RESTART Sustainable Business Model Innovation* (pp. 103-120). Palgrave MacMillan. https://doi.org/10.1007/978-3-319-91971-3_8

Jung, Y. S., Sampath, V., Prunicki, M., Aguilera, J., Allen, H., LaBeaud, D., Veidis, E., Barry, M., Erny, B., Patel, L., Akdis, C., Akdis, M., & Nadeau, K. (2022). Characterization and regulation of microplastic pollution for protecting planetary and human health. Environmental Pollution, 315. https://doi.org/10.1016/j.envpol.2022.120442

Korhonen, J., Honkasalo, A., & Seppälä, J. (2018). Circular Economy: The Concept and its Limitations. Ecological Economics, 143, 37-46. https://doi.org/10.1016/j.ecolecon.2017.06.041

Lam, C., Lim, S. R., & Schoenung, J. M. (2012). Linking Material Flow Analysis with Environmental Impact Potential. Journal of Industrial Ecology, 17(2), 299-309. https://doi.org/10.1111/j.1530-9290.2012.00513.x

Li, Z. (2012). On the Establishment of Ecological Circular Economy Under the Guidance of Sustainable Development Concept. Advanced Materials Research, 524-527, 3647-3650. https://doi.org/10.4028/www.scientific.net/AMR.524-527.3647

Moreau, V., Sahakian, M., van Griethuysen, P., & Vuille, F. (2017). Why social and Institutional Dimensions Matter for the Circular Economy. Journal of Industrial Ecology, 21(3), 497-506. https://doi.org/10.1111/jiec.12598

Pitron, G. (2019). *Wojna o metale rzadkie.* Warszawa: Kogut.

Potting, J., Hekkert, M., Worell, E., & Hanemaaijer, A. (2017). *Circular economy: measuring innovation in the product chain*. PBL Netherlands Environmental Assessment Agency.

Puntillo, P., Gulluscio, C., Huisingh, D., & Veltri, S. (2021). Reevaluating waste as a resource under a circular economy approach from system perspective: Findings from a case study. Business Strategy and the Environment, 30(2), 968-984. https://doi.org/10.1002/bse.2664

Romero-Hernandez, O., & Romero, S. (2018). Maximizing the value of waste: From waste management to the circular economy. Thunderbird International Business Review, 60(5), 754-764. https://doi.org/10.1002/tie.21968

Santato, C., & Alarco, P. J. (2022). The Global Challenge of Electronics: Managing the Present and Preparing the Future. Advanced Materials Technologies, 7(2). https://doi.org/10.1002/admt.202101265

Sasikumar, P., & Kannan, G. (2008). Issues in reverse supply chains, part I: end-of-life product recovery and inventory management – an overview. International Journal of Sustainable Engineering, 1(3), 154-172. https://doi.org/10.1080/19397030802433860

Shuptar-Poryvaieva, N. Y., Gubanova, E. R., Andryeyeva, N. M., & Shevchenko, T. I. (2020). Examining of portable betteries externalities with focus on consumption and disposal phases. *Ekonomia I Środowisko – Economics and Environment*, 75(4), 24-37. https://www.ekonomiaisrodowisko.pl/journal/article/view/4

Talens Peiró, L., Ardente, F., & Mathieux, F. (2017). Design for Disassembly Criteria in EU Product Policies for a More Circular Economy. Journal of Industrial Ecology, 21(3), 731-741. https://doi.org/10.1111/jiec.12608

Tomić, T., & Schneider, D. (2020). Circular economy in waste management – Socio-economic effect of changes in waste management system structure. Journal of Environmental Management, 267, 110564. https://doi.org/10.1016/j.jenvman.2020.110564

Woo, S. H., Lee, D. S., & Lim, S. R. (2015). Potential Resource and Toxicity Impacts from Metals in Waste Electronic Devices. Integrated Environmental Assessment and Management, 12(2), 364-370. https://doi.org/10.1002/ieam.1710

Xavier, L. H., Giese, E. C., Ribeiro-Duthie, A. C., & Lins, F. A. F. (2021). Sustainability and the circular economy: A theoretical approach focused on e-waste urban mining. Resources Policy, 74, 101467. https://doi.org/10.1016/j.resourpol.2019.101467

Zu, Y. X., Li, Z., Jia, Y., & Jia, S. S. (2012). Study on the Production and Trend of the Electronic Waste in China Based on Grey Prediction Model. Advanced Materials Research, 599, 551-555. https://doi.org/10.4028/www.scientific.net/AMR.599.551

DOI: 10.34659/eis.2022.83.4.531