TUJISE Turkish Journal of Islamic Economics

Proposing Circular Economy for Enhancing the e-Waste Recycling in Turkiye

Ayman Mohammad Bakr*
Mohamed Cherif El Amri
Mustafa Omar Mohammed
Hüsrev Kastacı
Turan Erol

Abstract: Wastes from electrical and electronics equipment (WEEE), also referred to as e-waste, contain high-value of precious metals. Yet WEEE has huge adverse environmental threats and health hazards. Several literatures have examined the adverse effects of WEEE, and few have proposed remedial measures for mitigating these e-waste risks. The measures have focused on recycling the precious metals within e-waste back into the economy. These studies have, however, acknowledged that the current recycling processes tend to be costly, and their results are not viable for the economy. The present study proposes a shift in recycling from a linear to a circular economy in Turkiye. It has adopted a qualitative method in the form of interviews with 13 experts on the subject. The major findings of the study show that: 1) Turkiye lacks the efficiency, proper planning, and adequate law related to e-waste management; 2) The legal regulations related to WEEE management are stale and undeveloped, 3) Recycling in Turkiye is underdeveloped. This study provides valuable information for future research on the factors that will help to improve recycling in Turkiye.

Keywords: e-Waste, WEEE, Recycling, Circular economy, Turkiye, Environmental Threats, Health Hazard.

JEL: L63, O13, Q01, Q53, Q56, Q58

* Corresponding Author

PhD., Istanbul Sabahattin Zaim University, bakr.ayman@std.izu.edu.tr, 0000-0002-1902-3195
Asst. Prof., Istanbul Sabahattin Zaim University, mohamed.amri@izu.edu.tr, 0000-0003-4607-2926
Assoc. Prof., Al Qasimia University, momar@alqasimia.ac.ae, 0000-0002-3328-1369
PhD., Istanbul Sabahattin Zaim University, husrev.kastaci@outlook.com, 0000-0002-4681-5905
Prof., Istanbul Sabahattin Zaim University, turan.erol@izu.edu.tr, 0000-0001-8025-2395

Bakr, M. A., El Amri, C. M., Mohammed, O. M., Kastacı, H. & Erol, T. (2024).Proposing Circular Economy for Enhancing the e-Waste Recycling in Turkiye. Turkish Journal of Islamic Economics, 11(2), 166-192.

DOİ: dx.doi.org/10.26414/A4173
TUJISE, 11(2), 2024, 166-192
tujise.org

Received: 16.08.2023
Revised: 30.01.2024
Accepted: 01.02.2024

Introduction

The waste electrical electronic equipment (WEEE) is "one of the fastest growing streams" of wastes at present (Directorate-General for Environment, 2023; Tasbirul Islam & Huda, 2018, p. 49), and has been recently attracting attention all over the globe. Yet, WEEE has huge adverse environmental threats and health hazards. This is due to the fact that WEEE contains toxic metals and hazardous substances (Cucchiella et al., 2015, p. 264). According to "The Global E-waste Monitor 2024" published by International Telecommunications Union (ITU) and United Nations Institute for Training and Research (UNITAR), the amount of WEEE generated worldwide grew to a staggering 62 million metric tonnes (Mt) in 2022, which is an equivalent of 7.8 kilogram per capita (kg/C) up from 7.3 kg/C in 2019 and 6.1 kg/C in 2016 (Balde et al., 2017; Baldé et al., 2024; Forti, et al., 2020). This figure has grown beyond the expected in 2022 to an amount of about 59.6 Mt determined in the 2019 report (Forti et al., 2020).

There is a consensus in the literature about what constitutes WEEE. Its definition includes a wide range of products, such as the equipment to be disposed of, that either depends on electric current or magnetic field to operate, or that generates, transfers, or measures such currents and fields (Glossary: Waste Electrical and Electronic Equipment (WEEE), n.d.). Thus, this definition incorporates a very wide range of electrical and electronic equipment covering all that pertains to both personal and industrial ones. On the other hand, few studies have provided the definition of WEEE with limited scope. For example, such definitions are confined to products such as: "*computers, refrigerators, and automobiles, collectively known as e-waste*" (Dutta et al., 2018, p.3694).

The increased consumption and endless desire for technology caused the production of these devices to proliferate over the years. With the current take-make-use-dispose economic model (Bocken et al., 2016, p. 308), this resulted in the ever-growing stream of WEEE. The ill-effects of such a linear model are becoming very evident and a shift to a circular economy, where materials flow is enhanced in a closed loop system, becomes more pressing. However, although the concept of circular economy is becoming increasingly very significant, its definition is inconsistent.

In their survey of the literature, Kirchherr, Reike, & Hekkert (2017, p.228) gathered 114 definitions for circular economy. This has serious consequences on research. Consequently, it is found in the literature that recycling WEEE has been heavily prescribed as a means for contributing to the circular economy (D'adamo *et* *al*., 2019; Golsteijn & Valencia Martinez, 2017; Reuter *et al*., 2013; Tasbirul Islam & Huda, 2018). Cursory evidence shows that this linkage between recycling and circular economy is due to a direct consequence of the ambiguity in the definition of the latter. In 2021, Turkiye recycled short of 54 percent of its wastes, while disposing more than 42 percent of the same (Ministry of Environment Urbanization and Climate Change of the Republic of Turkiye, 2023, p. 4). Even though Turkiye follows recycling standards and has national regulations in force, the percentage of disposal raises questions about the viability of current recycling processes for a circular economy. Turkiye, as such, forms an interesting case and provides a good ground for further investigation of the aforementioned.

Preliminary investigation on the challenges of WEEE management can shed some lights on the above issues. WEEE require special processing and handling that can prove costly, which makes it very challenging for recycling. Lack of awareness of proper recycling processes and handling of WEEE is a huge impediment to a sustainable environment and proper extraction of valuable materials. According to Awasthi, Li, Koh, & Ogunseitan (2019, p. 86), environmental pollution has been reported in certain regions of the world due to informal e-waste resource recovery. In some developing countries recycling is even done in a very primitive way while storage of such e-wastes is improper due to lack of awareness. For example, it is reported that e-waste is manually dismantled in one of the markets in Accra, Ghana whereas stockpiles of e-wastes are ever growing in the outskirts of Beijing, China (Awasthi et al., 2019, p. 86). Practically, recycling is a very complex process, and it does not go without its own problems. Loss of precious elements is inevitable, cost might be very high rendering recycling unfeasible, sustaining the environment might become very challenging, and product development becomes an issue as quality can be compromised. The alternative studies to recycling were deemed impractical. These studies were restricted to products that had not yet reached their end of life (EOL). The assumption is that this scenario creates opportunities, such as reselling these products or transferring them to poor or developing countries. For instance, Sauvé, Bernard, & Sloan (2016, p. 53) discussed a model of production based on a circular economy that may seek to delay the end-of-use of the product by favoring repairing, refurbishing, and reusing it before its end-of-life. However, despite the significant research in the area of alternative end-of-life options there is still a substantial lack of evidence into the technological and business potential of such options based on reuse, repair, and remanufacturing (Angouria-Tsorochidou et al., 2018, p. 986). Another research explored the possibility of creating new products from WEEE as an alternative to recycling (Bakr et al., 2020). While that study concluded the great potential progress for a circular economy creating new products from WEEE would achieve, it nonetheless stated the tremendous challenges encountered by moving into such a model.

Despite the issues that surround recycling of WEEE, the knowledge of recycling WEEE has significantly grown over the past decade. In addition to its disagreement on what circular economy is, the literature also lacks sufficient discussion of how a circular economy model can be applied to WEEE and has rather focused on the current recycling processes. Meanwhile the objectives of this paper are to investigate the issues of recycling WEEE in Turkiye in relation to circular economy, examine the challenges of improving recycling the industry is confronted with, and thus explore ways for developing recycling. Such exploration would enhance recycling with the hope of facilitating the circular economy. Henceforth, the paper is divided into five sections as follows: section 2 provides a review of the literature, section 3 discusses the research design and methodology, followed by section 4 which analyzes the findings and discusses the results, and finally section 5 which discusses the conclusion.

Literature Review

WEEE and Circular Economy

Since WEEE contains hazardous substances (Chancerel et al., 2009, p. 792), special attention must be given to them and mechanisms for carefully handling and eliminating them must be sought. In describing the tremendous increase in WEEE, Cucchiella, D'adamo, Koh, & Rosa (2015, p.264) stated that about 30 to 50 million tonnes of WEEE are disposed globally each year. Furthermore, D'adamo et al. (2019, p.455) cited a figure showing that WEEE reached 41.8 million tonnes in 2014. Today, we know that this figure has grown beyond 62 million Mt (Baldé et al., 2024).

The current linear economy model which is characterized by take-make-use-dispose approach (Bocken et al., 2016, p. 308) is known to generate significant wastes (SUN, Ellen MacArthur Foundation, & McKinsey Center for Business and Environment, 2015, p. 16) and therefore is deemed to be a direct cause for the accelerated growth of WEEE. There is, therefore, a pressing need to shift to a closed-loop system, a circular economy, that enhances materials flow and departs from the linear economic model. Such a closed-loop system aspires to eliminate waste by enhancing product design that leads to reduced usage of natural resources and thereby decreases the impact on the environment (Angouria-Tsorochidou et al., 2018, p.986). In a report sponsored by SUN in collaboration with Ellen MacArthur Foundation and McKinsey Center for Business and Environment (2015, p.14), the authors concluded the importance of circular economy in that it could lead to better welfare, GDP, and employment outcomes than current development path; it could further greatly benefit the environment and improve competitiveness. Yet, few literatures have taken interest in the area of e-waste and circular economy.

Perhaps the reason for that is the lack of a united understanding and inconsistency in the definition of circular economy. García-Barragán et al. (2019, p. 369) maintain that there is no consensus on previously suggested definitions. The absence of a clear definition of circular economy on the one hand, and its close relation to recycling on the other hand, led researchers and practitioners to discuss both concepts (circular economy and recycling) interchangeably. However, García-Barragán et al. (2019, p. 369) warn that "*a direct implementation of recycling indicators as metrics of circular economy activity is methodologically unsatisfactory*". Other definitions that depart from confining circular economy to recycling include:

> *"a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling." (Geissdoerfer, Savaget, Bocken, & Hultink, 2017, p. 759).*

The above definition seems comprehensive. It tries to include renowned concepts and dimensions that are cited by most literature. For example, "*industrial economy that is restorative by intent and design*" (Ellen MacArthur Foundation (EMF), 2013, p. 14), "*the realization of a closed loop of material flows*" (Geng & Doberstein, 2008, p. 231), and "*slowing, closing, and narrowing resource loops*" (Bocken et al., 2016, p. 317). The purpose of slowing material and energy loops is to extend the period of product utilization (Bocken et al., 2016, p. 317); and that can mainly be achieved by long-lasting design. On the other hand, according to Bocken et al. (2016, p. 309) the purpose of closing resource loops is to create a circular flow of resources between post-use and production through recycling; whereas narrowing resources implicates efficient use of resources by involving fewer resources per product.

WEEE and Circular Economy in Turkiye

With more categories of electrical and electronics equipment approaching their end of life, like the solar/photovoltaic cells, the number of disposed WEEE will multiply even further. Table 1 shows the number of generated e-wastes in kilograms/Capita (kg/C) and in kilotons (kt) for a few countries. Table 1 is adapted from the "The Global E-waste Monitor 2024" report which is based on 2022 statistics (Baldé et al., 2024, pp. 133–134).

Table 1

Domestic e-Waste Generated Per Country (2022) For a Sample of Countries.

Country / Economy	Region	E-waste generated in 2022 (kg/C)	E-waste generated in 2022 (kt)	National regulation in force
Timor-Leste	Asia	1.6	2	No
Togo	Africa	0.9	8	No
Tonga	Oceania	4	0	No
Trinidad and Tobago	Americas	15.4	24	No
Tunisia	Africa	6.9	85	No
Turkiye	Asia	12.7	1077	Yes
Tuvalu	Oceania	2.4	0	No
Uganda	Africa	0.9	41	Yes
Ukraine	Europe	8.9	385	Yes
United Arab Emirates	Asia	18.9	178	Yes
United Kingdom of Great Britain and Northern Ireland	Europe	24.5	1652	Yes
United States of America	Americas	21.3	7188	Yes

Note. Adapted From "The Global E-waste Monitor 2024" (Baldé et al., 2024, pp. 133–134)

From Table 1, for example Turkiye generated 1.077 million tonnes of e-waste in 2022 up from 0.847 million tonnes according to 2019 statistics. Comparing with the same base years, each inhabitant generated on average 12.7 kg of e-waste in 2022 up from 10.2 kg in 2019. These figures are worrying as they are greater than even the worldwide average of 7.8 kg/C according to 2022 statistics (Baldé et al., 2024, p. 118). That figure is reached despite the fact that Turkiye has national regulations in force and formal procedures and laws for handling e-waste. As of 2021, the total volume of hazardous waste reached slightly over 3 million tonnes, a significant increase from 1.5 million tonnes reported in 2018—more than doubling the amount (Ministry of Environment Urbanization and Climate Change of the Republic of Turkiye, 2023, p. 2). Similarly, non-hazardous waste quantities rose to over 29.5 million tonnes in 2021, up from approximately 15 million tonnes in 2018 (Ministry of Environment Urbanization and Climate Change of the Republic of Turkiye, 2023, p. 3). Accordingly, Turkiye generates e-waste to a tune of 3.8 percent of the total amount of wastes. The percentage is considerable and alarming because the issue is manifested by the existence of hazardous substances within WEEE which raise serious environmental concerns and can cause serious health problems and risk to human beings as well as other living things. The fact that Turkiye has regulations in force but yet a considerable amount is still disposed, raises concerns about the efficiency of recycling WEEE in Turkiye and calls for an urging need to shift from a take-make-use-dispose system to a circular economy.

Adverse Effects of WEEE

WEEE is becoming an emerging issue owing to adverse consequences on the natural environment and human health (Kumar Awasthi et al., 2018, p. 46). That is because they contain substances like mercury, cadmium, lead (Pb), chromium, poly/brominated flame retardants, and ozone-depleting chemicals such as CFC etc. (Chaine et al., 2022; Tasbirul Islam & Huda, 2018, p. 50) that are known to be environmentally hazardous. Preschool children from Guiyu in China, one of the largest e-waste destinations and recycling areas in the world and known to have high concentrations of Pb in the air, soil, water, sediment, and plants, were found to have higher Pb levels and natural killer (NK) cells than their counterparts from another reference area (Zhang et al., 2016, p. 143). Although China has a formal industry for collecting and recycling WEEE, nonetheless due to social and economic considerations, the informal business of collecting and recycling WEEE is leading to, and very often causes, detrimental effects on the environment and health (Balde et al., 2017, p. 68; Chaine et al., 2022, p. 1).

The concept of circular economy is becoming increasingly very significant to address environmental problems, such as biodiversity loss and excessive land use; economic challenges manifested by the increasingly frequent financial and economic instabilities; and other sustainability issues, (Geissdoerfer et al., 2017, pp. 757–758). While WEEE forms an important area in the discussion of circular economy in Norway (Golsteijn & Valencia Martinez, 2017, p. 1), notwithstanding many other parts of the world still lack the adequate connection between WEEE and circular economy. Like most of the literature, Golsteijn & Valencia Martinez (2017) focus on recycling as a means for a circular economy. Yet, they admit that recycling is far from perfect and suggest measures for further closing the loop by improving collection of WEEE and quality of recycling material (Golsteijn & Valencia Martinez, 2017, p. 5). But they miss the opportunity of considering enhancing each stage of the processes of recycling. The latter of which can eliminate the inevitable pollution caused by recycling procedures.

Challenges of e-Waste Management

WEEE management requires a systematized or formal system for handling e-wastes in a scientifically as well as environmental-friendly manner (Wath et al., 2011, p. 257). The challenge is to "*identify, track, and control the e-waste generation*" (Yong et al., 2019, p. 153) while avoiding polluting the environment and risking human health. For example, Yong et al. (2019, p. 154) cite that industries in Malaysia employ an online portal to record the generation, collection, storage, disposal and recovery of scheduled e-waste before being transported to recovery facilities. However, similar legislation framework does not exist for e-wastes generated from households. In fact, it is proving greatly challenging to foster strategies to manage WEEE effectively (Shittu et al., 2021) and, therefore, the latter cannot be tracked or predicted. This can lead to what Suja, Abdul Rahman, Yusof, & Masdar (2014, p. 5) describe as illegal backyard operators without proper facilities and illegal WEEE exportation. Some of the implications of this is the leakage of pollutants to the environment despite the existence of legislative forces.

When examining the above challenges, the literature is found again to focus its discussion of the issues from the recycling lens. For example, "*many full recyclers are not able to operate at full capacity due to lack of e-waste*" (Suja et al., 2014, p. 5) and "*producers…of EEE… have to pay a certain amount as recycling fees for every unit manufactured*" (Yong et al., 2019, p. 155). In as much as these challenges affect recycling, nonetheless, the lack of e-waste supply and the difficulty of tracking WEEE can also negatively impact the motivation to improve recycling.

Challenges of Recycling WEEE

Cucchiella et al. (2015, p. 271) maintain that, as of 2015, the potential revenue coming from recycling e-wastes in the European market was estimated to be 2.15 billion euros projected to increase in future to 3.67 billion euros because WEEE contain precious metals (like gold, silver, and palladium) and special metals. The assumption is that recovering such substances proves to be economically feasible. In other words, the value of the recovered materials should surpass the cost of recovering them. A supportive argument of this assumption notes that the amount of gold that can be extracted from a ton of WEEE exceeds the amount mined from its ores. Compared with less than 10 g/t of mined gold, the concentration of gold in PCBs of personal computers is at 250 g/t; this makes the importance of recovering gold from WEEE very obvious (Chancerel et al., 2009, p. 793).

However, the current e-waste disposal and recycling pose a great challenge since improper operations during the dismantling and deposition of e-waste may lead to various pollutants such as heavy metals being discharged into the nearby environment (Bao et al., 2020, p. 2). Recycling complexity can be unraveled by examining the following issues: processes, economic feasibility, and technical design. Recycling starts with collection process, followed by pre-processing, and ends with disposing or end-processing. Pre-processing consists of disassembly, shredding, separation (physical: density, magnetism, and weight; metallurgical processes: pyrometallurgy, hydrometallurgy, electrometallurgy, biometallurgy, or a mix of them), and refining (D'adamo et al., 2019, p. 457). Certain processes are critical and need careful attention, otherwise certain elements can be lost. For example, it is most likely that shredding has a negative impact on the recovery of precious metals (Chancerel et al., 2009, p. 802). Moreover, since the precious, special, and base metals exist within complex components in small concentrations per unit, any sorting of any specific target substance of these into the incorrect output stream from pre-processing, in most cases leads to its loss during the end-processing (Chancerel et al., 2009, pp. 792–793).

On the other hand, recycling might turn out to be economically unfeasible from two perspectives. First, the benefits from recycling certain WEEE may not cover the process costs. For example, photovoltaic (PV) panels is scarce in embedded valuable substances and the recycling cost of recycled PV panels usually overweighs their recoverable value (Cucchiella et al., 2015, p. 264). Likewise, despite its opportunity of reducing environmental pollution, recycling of used batteries has not been an attractive business due to its low economic benefits (Deep et al., 2011,

p. 10551). Second, environmental sustainability mandates put additional strains on the profit margins of recycling companies. Cucchiella et al. (2015, p. 264) maintain that the toxic metals and hazardous substances within WEEE require dedicated recycling processes to avoid environmental and health problems. Such processes come with added cost. Such higher costs are the reason for making environmental sustainability very difficult.

The issue of recycling WEEE even goes beyond the mere profit-cost analysis. Complex electronic devices require a high degree of raw material purity. Such technical design restrictions make electronic device production from secondary sources, such as raw materials from recycled WEEE, unappealing. In recycling, the relationship between purity requirements and the number of recovered substances is inversely proportional. The higher the purity requirements, which is definitely what an electronic manufacturer looks for, the more amount of substance is lost during the recycling process. This relationship is depicted in Figure 1, the grade-recovery curve. It is worth noting that this graph is not to scale but is based on conservative estimates.

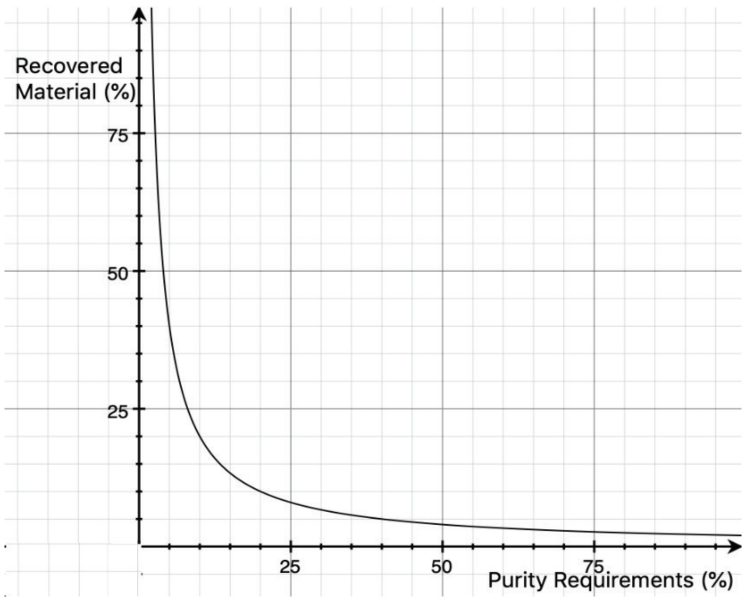

Figure 1. Grade-Recovery Curve (Not to Scale: Based on Conservative Estimates)

Source: Authors

All the aforementioned issues for recycling call for adopting directives and regulations that support its continuity and encourage the proper disposal of WEEE while sustaining the environment. Unlike the EU, many countries lack such directives and regulations. According to 2024 report, 112 countries out of 193 have no national WEEE regulations in force (Baldé et al., 2024, pp. 62–100). In Africa, about 80 percent of the countries have no regulations in force; in Oceania, only 1 country out of 14 countries has a regulation in force; whereas about 67 percent and about 63 percent have no national regulations in force in Americas and Asia respectively (Baldé et al., 2024, pp. 62–100). Table 2 below shows these results.

Table 2

Number of Countries Having a National WEEE Regulation in Force Classified Per Continent

National regulation in force in 2022	Count
no	112
Africa	43
Americas	24
Asia	31
Europe	1
Oceania	13
yes	**81**
Africa	11
Americas	12
Asia	18
Europe	39
Oceania	1
Grand Total	**193**

Note. Adapted From (Baldé et al., 2024, pp. 62–100).

Table 2 is divided into two main sections: countries who have no national regulations in force (no) amounting to 112 in total, and those that have national regulations in force (yes) amounting to 81 in total. Each main section is subdivided into regions to show the number of countries in each region that pertains to that section; that is having or not having national regulations in force. Lack of such directives and regulations makes recycling WEEE an unattractive business. With the absence of such guidelines and enforcement, manufacturers of electronic equipment will keep acquiring raw materials from primary sources to ensure higher quality product development. Yet sustaining the environment becomes threatened. Conversely, few researches looked at alternatives to recycling like refurbishing and reusing; for instance (Sauvé et al., 2016). But there is a lack of evidence into the business potential of such alternatives (Angouria-Tsorochidou et al., 2018, p. 986). Per se, no study examined a real remedy beyond the current processes of recycling. Instead, the researchers propose the need for improving recycling to shift from a linear to a circular economy.

Research Methodology

This research paper has conducted a qualitative research method using semi-structured interviews to explore the topic and issues in hand. According to Miles & Huberman (1994, p. 10) qualitative researches "often have been advocated as the best strategy for discovery, exploring a new area...". The use of semi-structured interviews is appropriate because they evolve in a conversational manner offering participants a chance to explore what they feel is important (Longhurst, 2016, p. 143). This paper lends itself to exploratory study because the extant knowledge and literature lack the in-depth discussion of shifting recycling to a true circular economy. This is consistent with Neuman's (2014, p. 38) description that the purpose of exploratory research is to examine a little understood issue or phenomenon and to develop preliminary ideas about it. Such a design is appropriate for this exploratory research because qualitative approaches give chance to be innovative, more creative, and to work more within researcher-designed frameworks (Creswell, 2009, p. 19). Additionally, with exploratory research, one is not confined to a particular data collection technique but is rather open to formal approaches, such as in-depth interviews, and informal approaches, such as informal discussions.

The target population for this study was experts in electronics engineering, circular economy, recycling regulations, and industrial processes. The area of WEEE and circular economy requires deep knowledge of electronics devices, materials processing and engineering, regulations, commerce, and economics. There was thus a clear need for multi-disciplinary collaboration with experts from various fields. Graneheim, Lindgren, & Lundman (2017, p. 33) assert that the participants in a study should probably have experiences of the phenomenon under study and are able to talk about it in order to achieve credibility. For this paper, the participants were identified to be experts working in the industry (who can provide insider's view about the issues of recycling), experts working in academia (who can provide insights about WEEE and circular economy), economists (who can provide information about circular economy and integrating WEEE with it). They were selected based on their "substantive area expertise (...) by virtue of their command of a field of knowledge" (Sandelowski, 1998, p. 468). They are people believed to possess the knowledge through some form of experience of the event under investigation. "This kind of expertise is integral to member checking or member validation, where research participants are asked to warrant the accuracy and researchers' interpretations of data" (Sandelowski, 1998, p. 468).

The sampling technique used was purposive sampling coupled with some form of snowball sampling. The choice was based on the nature of this exploratory research because "Purposive sampling (...) is a valuable sampling type for special situations. It is used in exploratory research..." (Neuman, 2014, p. 273). Moreover, purposive sampling is appropriate to select cases that are especially informative and requires in-depth investigation to gain deeper understanding (Neuman, 2014, p. 274). On the other hand, snowball sampling was valuable since we were seeking referrals to an inside network of experts. This was particularly worthwhile to identify economists and participants from the industry.

As for participants from academia, professors from nine local Turkish universities were contacted based on their profiles which were closely checked via the universities' websites and through their close work in the industry. Participants thought to be highly informative in the field were identified and selected based on their close research with materials science, electronics devices, circular economy and/or waste management. Out of the nine universities, responses were received from seven universities: Koç University (KU), Istanbul Sabahattin Zaim University (IZU), Yıldız Technical University (YTU), Giresun University, Selçuk University, Adıyaman University, and Kırıkkale University. Sample size is not considered an issue since the research involved an in-depth qualitative approach. According to Boddy (2016, p. 430) "Qualitative research often concerns developing a depth of understanding (...) As such (...) in these cases a single case study involving a single research participant can be of importance and can generate great insight". Logically, he maintains that the smallest acceptable size in in-depth qualitative research is a sample of one! Thirteen experts, in this research, out of the 30 approached participated in the study as interviewees. The other 17 did not respond. Nonetheless, the sample size is assumed to be sufficient for the purpose of this study.

The interview questionnaire mainly consisted of open-ended questions because they provide the participants with the freedom to offer any answer they wish to the question (Neuman, 2014, p. 331). The questions in the questionnaire consisted of issues related to product development from WEEE, recycling, and circular economy. The questions, depicted in Table 3, were validated by two professors in the Department of Islamic Economics and Finance. These professors are considered experts in this type of research and such validation goes hand in hand with the description of Sandelowski (1998, p. 471) “Outsider-experts can help researchers ask better questions of their data, lead them to new ways of analyzing data…”.

Table 3

Interview Questions

No.	Interview Questions
1.	What’s your view on the possibility of creating a completely new product out of WEEE instead of recycling, reusing, or refurbishing them?
2.	In the case of waste management in other areas, there has been progressing in converting this waste into a new product. However, in the case of e-waste, most of the processes have been related to recycling. Why has not there been progress in developing technics for converting e-waste into a new product?
3.	What are the new products that can currently be created from WEEE and what are the potential areas of creating new products from WEEE that need further studies?
4.	What is the potential market size and growth of new products from WEEE?
5.	To what extent is the new product from WEEE cheaper than its equivalence in the market? What segment of the market would benefit from such a product?
6.	To what extent can such new products from WEEE contribute to job creation, the manufacturing industry, technology industry, and economic development?
7.	Why is the circular economy important for e-waste management especially in relation to producing new products from WEEE?
8.	To what extent do you think the idea of producing a new product from WEEE is environmentally friendly?
9.	Only a few countries in the world have national regulation in force for e-waste management. Why is this the case and why do you think such regulations are very important for managing e-waste?
10.	Presently, there are companies that use in their lab old equipment that is by products of e-waste. How useful and durable is this equipment?
11.	What are these by-products, their sources, and commercial values?

The data was collected through emails, telephone, and semi-structured face-to-face interviews. Initially the respondents were approached via email with an explanation of the study and the set of questions. The advantage of this approach is that it creates an ice-breaker situation and ensures a good degree of accuracy of the information provided. The disadvantage is that in most of the cases, the respondents misunderstood the purpose and needed further explanation. As such, the selected participants were contacted via email to arrange for the time and location of the interview. The in-depth interviews lasted for about 30 minutes on average. The first 5 to 10 minutes were used by the interviewers to explain the purpose of this study and its nature pertaining to e-wastes and circular economy. This was necessary as an icebreaker and in order to have the participants grasp the whole idea of the research problem. For some unknown reason, some of the audio recordings via mobile phone failed. Nonetheless as suggested by Creswell (2009, p. 183) notes were also taken during the interviews in order to mitigate such a case. Therefore, there was no significant loss of data. The information provided by the interviewees were carefully jotted via laptops to ensure that the answers are preserved. Interference during the conversation was made to a minimum in order to minimize any kind of guiding bias and was only made when explanation was necessary. The collected answers were repeated to the respondents in order to ensure the accuracy of understanding and to further confirm that what has been typed is exactly what the respondents intended.

The data were analyzed taking into consideration the circular economy perspective. The exploratory nature of this study dictated that the coding and thematic development followed from the content of the data. To counteract the methodological concern that thematic analysis might oversimplify data, the research team employed a nuanced approach to coding and theme development. This approach was carefully designed to capture the subtleties and complexities within the data, thereby reducing the risk of overgeneralization and ensuring a comprehensive understanding of the dataset. Therefore, as indicated by Krippendorff (1989, p. 406), unitization was used as the first step of the content analysis that followed the design in order to determine the appropriate unit of analysis. In this study the basic units of analysis were the sub-categories that emerged from the text. For instance, some interviewees expressed feasibility concerns due to the fast changes in technology. Information of this kind would be coded as "Advancement in technology makes new product creation from WEEE unfeasible and irrational". Another example pertains to the view of some of the interviewees that WEEE sources for new product development is unsustainable. This would be coded "New product creation from WEEE cannot be sustained". So, all the data collected, and notes taken during the interviews, were coded that way and was checked by one expert researcher to provide inter-coder reliability checks. Such coding protocols have had the effect of mitigating bias and ensuring consistency across the analysis. Despite the absence of universally standardized guidelines for conducting thematic analysis, this study adhered to established best practices and methodological frameworks to maintain a high level of quality and rigor. Thus, the theme development was conducted using the six phases of thematic analysis suggested by Braun & Clarke (2006, p. 87).

Results

This section presents and analyzes the overall findings from the qualitative data collected for exploring the shifting of recycling towards circular economy. There are two sub-sections. The first shows the profiles of the interviewed experts and the second discusses the qualitative data results from the interviews with those experts.

Profile of Participants

Table 4 provides the profiles of the interviewees by gender, qualification, profession, and organization. The participants have been coded with 'E' for Expert followed by a number. So, Expert 1 would be coded E1, Expert 2 would be coded E2, and so on until Expert 13 who will be coded E13.

Table 4

Interviewee Profile

Expert	Gender	Qualification	Profession	Institution
E1	M	PhD in Materials Science & Engineering	Assistant Professor	Koç University
E2	M	PhD in EEE[a]	Assistant Professor	IZU
E3	M	PhD in EEE	Assistant Professor	IZU
E4	M	PhD in EEE	Assistant Professor	IZU
E5	M	Bachelor's in Business Administration	Project Coordinator	RNGroup

E6	M	PhD in Chemical Engineering	Associate Professor	Yıldız Technical University
E7	M	_	Shareholder	Eroglu Environmental Industrial Waste Management
E8	M	PhD in Political Science and Public Administration	Associate Professor	Giresun University
E9	M	PhD in Public Administration	Dr. Lecturer	Selçuk University
E10	M	PhD in Environmental Engineering	Dr. Lecturer	Adıyaman University
E11	M	PhD in Industrial Engineering	Associate Professor	Kırıkkale University
E12	M	_	E-waste Expert	Süreko Inc. Environmental Industrial Waste Management
E13	M	PhD in Chemistry	Professor	Yıldız Technical University

Note. [a] EEE = Electrical Electronics Engineering.

All the respondents were males. Such gender bias occurs because generally the field of electronics industry and recycling tend to be predominantly male professionals. Ten out of the 13 participants are holders of a PhD degree – three in electrical and electronics engineering, one in materials science and engineering, one in environmental engineering, two in political science and public administration (with research expertise in government municipal service quality and solid waste management), one in industrial engineering, one in chemistry, and one in chemical engineering. while one is a holder of a PhD degree in chemistry and the remaining at least hold bachelor's degrees in business administration. From these results, more than 75 percent of the participants hold academic positions in universities. The participants vary by institutions; more than 75 percent of them are from academia and less than 25 percent are from the industry.

The backgrounds of the participants show that they are suitable and relevant for this study. Nearly all of them have sufficient experience in the field of electrical and electronics equipment and their wastes, which are important for in-depth understanding of research related to WEEE. Hence, they were able to provide valuable, credible, accurate and rich information on the subject during the interview sessions. Such backgrounds are very important for the validity of the data, and the trustworthiness of the research conducted (Graneheim et al., 2017, p. 33).

Analysis of the Qualitative Data

The thematic analysis of the interview extracts resulted in three main themes – Issues of Recycling in Turkiye Affecting Circular Economy, Barriers to Improving Recycling in Turkiye, and Factors to Improve Recycling. Table 5 shows the themes with their corresponding research objectives. The analyses in the subsequent subsections are conducted based on these three themes.

Table 5

Theme Mapping to the Research Objectives

Theme	**Research Objective**
Issues of Recycling in Turkiye Affecting Circular Economy	Investigate the issues of recycling WEEE in Turkiye in relation to circular economy
Barriers to Improving Recycling in Turkiye	Examine the challenges that confront the industry for improving recycling
Factors to Improve Recycling	Explore ways for developing recycling

It is worth mentioning though that there was an emergent theme relating to the barriers of creating new products from WEEE. The majority of the experts, 10 out of 13, are of the opinion that there are technology barriers for such an endeavor. E2 states that "*technology changes very fast*". Experts E3 and E4 are of the same opinion. As such new products from WEEE are comparatively old and will not be able to compete in quality with newly manufactured products. In fact, expert E7 notes that "*the frequency of replacing electronic equipment increased*" even though that these devices have not reached their end of life. More than half of the experts believe that the market demand for such products is low. Expert E11 believes that there is "*no way for market size growth from e-waste made products*". Even fifty percent of the experts are of the opinion that e-waste made products are of lower quality than manufacturer-made products. Also, fifty percent think that the cost will be very high. This emerging theme is in line with a previous study conducted on the feasibility of producing new products from e-waste (Bakr et al., 2020).

Issues of Recycling in Turkiye Affecting Circular Economy

The underlying issues of recycling in Turkiye mainly relate to the cost of collecting WEEE, inadequate regulations and legislations that were imported from the European code but do not suit the Turkish case, and the sophistication of recycling that requires high expertise.

"Collection of e-waste is very costly" E10.

"…[Recycling is done as per the regulations] exactly at the same level done in EU" E7.

"This area requires deep knowledge of electronic devices" E1.

It is worth noting that one of the participants (E10) considered that the regulations in force in Turkiye are fine because it adopts the European code. However, as will be seen in the next subsection, Barriers to Improving Recycling in Turkiye, these regulations were created to suit the European case and, instead, act as a barrier for improvement in the Turkish case.

Out of the above main issues, the third related to the sophistication of recycling and the need for high expertise is the most thought-provoking. For instance, due to lack of expertise and the complexity involved, one of the experts (E7) explained that 5 to 6 percent of e-waste cannot be processed in Turkiye. Therefore, these WEEE have to be sent to Europe for further processing. Moreover, moving to management practices that promote circular economy will require well-controlled processes. In order to reduce the dependency on natural resources, bring pollution to the minimum possible, and deal with hazardous materials safely, one expert (E10) noted that "*e-waste should be collected, stored, and disposed suitably and be well-controlled*."

Perhaps the most conspicuous of the complexity of recycling in Turkiye mentioned by one of the experts (E10) is that e-waste "*components have to be extracted one by one manually*".

Barriers to Improving Recycling in Turkiye

Figure 2 portrays a thematic model for the core barriers to improving recycling in Turkiye as concluded from the interview results. The expert extracts led to five main barriers – lack of awareness and training in circular economy (CE) and WEEE; high processing and extraction costs; lack of municipal efficiency, planning, and law enforcement; recycling is underdeveloped; and stale and undeveloped legal regulations. The first (lack of awareness...in circular economy & WEEE) and the third (lack of municipal efficiency...& law enforcement) further form two sub-themes.

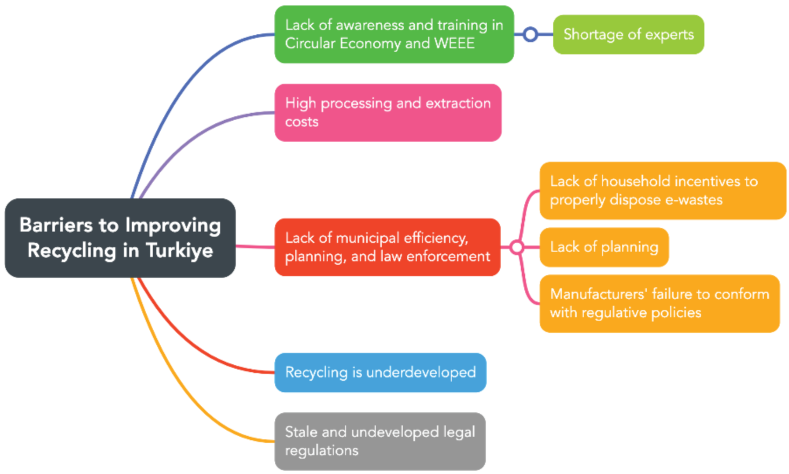

Figure 2. Barriers to improving recycling in Turkiye

Source: Authors

Lack of awareness and training in CE and WEEE has been mentioned by three experts (E8, E9, and E10). The underlying factor leading to this sub-theme is the shortage of experts in the field that can help raise the awareness of CE and integrating recycling WEEE with CE. For instance, E8 stresses "*The expert should know everything*". The difficulty of attaining this vast knowledge requirement interprets into shortage of experts. Further, E8 emphasizes the importance of awareness related to regulations of WEEE: "*These types of regulations should be managed with more clarity on the responsibilities of each stakeholder.*" E9, on the other hand, believes that "*awareness and education are needed to implement circular economy and e-waste management.*" He agrees with E10 that education is an important factor for raising the awareness and establishing a culture of practices indicative of a circular economy.

The high processing and extraction costs as barriers to improving recycling have been noted by E10 and E11. E11 described the high costs of extracting materials from WEEE during recycling. In contrast, E10 pointed to the high costs involved in the different levels of recycling processes.

The underlying barriers of the sub-theme (lack of municipal efficiency…& law enforcement) relate to lack of household incentives to properly dispose e-wastes, lack of planning, and manufacturers' failure to conform with regulative policies.

"Incentives have to be given to people to encourage them to properly dispose the e-waste" E8.

"The whole process should be planned" E11.

"There is a responsibility on the manufacturing side about aligning the e-waste with the legislative policies" E8.

Interestingly, expert E8 summarizes this sub-theme with "*The duty of the municipality in this process is very crucial*".

The fourth main barrier is that recycling in Turkiye is underdeveloped. The fact that 5 to 6 percent of e-waste cannot be processed in Turkiye and the fact that "*only a portion of the raw materials are used in only some sectors*" (E8), strongly depicts this issue. Expert E11 prescribes a solution for this barrier "*We have to learn from the implementation of developed countries*."

The last main barrier relates to stale and undeveloped legal regulations evident in extensive references made by four experts (E8, E9, E10, and E11). This barrier has been mentioned earlier in the previous subsection. There is a general consensus among these four experts that the regulations in Turkiye need to be developed.

Factors that Help Improve Recycling in Turkiye

The analysis of the interviews of the experts culminated in a thematic framework that addresses six main factors that can help improve recycling in Turkiye. The first is to promote the merits of recycling in order to raise awareness and encourage the industry.

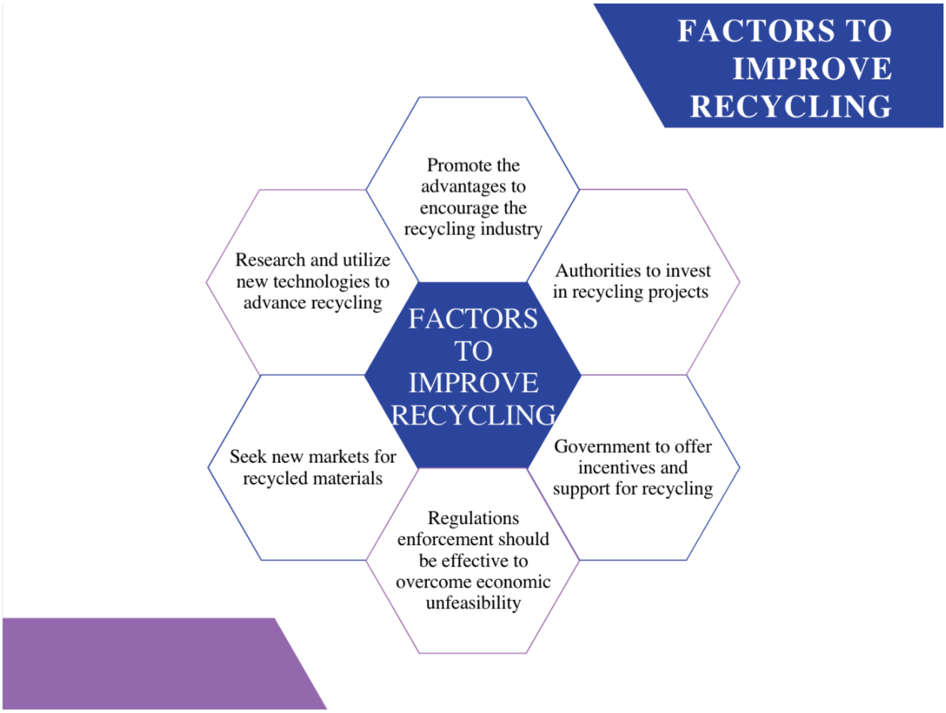

Figure 3. Factors that help improve recycling in Turkiye

Source: Authors

Two experts, E10 and E12, mentioned the merits of recycling in contributing to the economy. Expert E9 even noted that recycling will help improve the country's trade balance as "*the current account will be improved*". Experts E9, E10, and E12 also agreed about the importance of recycling for the environment and the ecosystem.

The second factor relates to the involvement of authorities in investing in recycling projects. One of the experts (E9) referred to this factor. Another two experts, E1 and E6 emphasized the importance of the role of the government in incentivizing and supporting recycling as a third factor. For instance, E6 says, "*Government is giving incentives and support for recycling*". Yet another very related factor is the effective enforcement of regulations to overcome any potential economic unfeasibility of recycling. Without such enforcements certain hazardous materials will not be recovered as they are deemed unprofitable. E1 supports this idea, "*Hazardous materials such as lead need to be recovered… due to a new regulation*".

The fifth factor looks at seeking new markets for recycled materials. This has been brought up by expert E6 as he suggests using recycled components in [new areas like] defense and renewable energy sectors. The sixth, and last, factor concluded from the interviews is researching and utilizing new technologies to advance recycling. While one expert (E10) believes that recycling "*is OK for the level of technology available*", another expert (E7) asserts that recycling "*needs a very high level of technology*". One can see how this can be connected to address the issue of high complexity of recycling discussed in the first subsection, Issues of Recycling in Turkiye Affecting Circular Economy. For example, using new technologies, automation via artificial intelligence can be used to increase the efficiency of recycling and directly address the issue of 'component extraction has to be done manually' delineated in the first subsection, Issues of Recycling in Turkiye Affecting Circular Economy.

Conclusion and Policy Recommendations

While Turkiye has taken steps to align with standards for managing WEEE, our research reveals a multitude of challenges impeding the improvement of its recycling framework. These challenges encompass not only economic and efficiency concerns but also extend to deficiencies in expertise and the underdevelopment of both recycling infrastructure and regulatory frameworks. Consequently, the transitioning of current recycling practices towards a circular economy within the country is anticipated to confront a host of intricate complexities.

These challenges are not isolated; they are corroborated by extensive discourse within the existing literature, as revealed through rigorous thematic analysis. Specifically, our findings concerning the challenges encountered in recycling and the creation of new products from WEEE align closely with the insights gleaned from previous scholarly investigations (Chancerel et al., 2009, pp. 792–793; Cucchiella et al., 2015, p. 264; Deep et al., 2011, p. 10551; Shittu et al., 2021). Among the myriad challenges confronting the recycling landscape, one of the most pivotal is the economic feasibility of recycling and the associated high costs. Cucchiella et al. (2015) underscored this concern, demonstrating how recycling costs often surpass the recoverable value of circuit components. Additionally, stringent environmental sustainability mandates exert further pressure on recycling companies' profit margins. This renders recycling endeavors increasingly unattractive, as noted by one of the interviewed experts. Consequently, sustained government intervention becomes imperative for the continuity of WEEE recycling businesses. Governments must provide ongoing incentives and support to bolster recycling efforts. However, to alleviate the burden on such redistribution public expenditures, incentivizing recycling could be coupled with attracting investments in novel projects, startups, and innovations aimed at revolutionizing recycling processes.

Conversely, as elucidated by Shittu et al. (2021), formulating effective strategies to manage WEEE poses significant challenges. According to a panel of experts, these challenges stem from various factors, including difficulties in enforcing regulations and standards among recycling companies, inadequate planning, tracking unregistered entities and the black market, and engaging households in the recycling process. Developing an efficient strategy for managing WEEE effectively has the potential to substantially reduce recycling costs.

To achieve this goal, several initiatives can be pursued. While EU regulations on WEEE management are considered highly advanced globally, it's crucial to tailor these regulations to fit Turkiye's unique socio-economic context and infrastructure. This necessitates the reevaluation and adaptation of EU regulation codes by Turkiye's Ministry of Environment, Urbanization, and Climate Change to formulate better policies and enforcement plans.

Furthermore, municipalities must allocate budgets for comprehensive awareness campaigns to transition passive household behavior toward active participation in electronic waste disposal. Combining targeted household awareness with incentives can significantly enhance household engagement in recycling initiatives.

Moreover, insights from the interviewed experts revealed that a significant portion of electronic materials, approximately 5 to 6 percent, is exported to the EU for further recycling due to inadequate technology and automation. To capitalize on the valuable extracts from this unrecycled material, the government must invest in research and development to enhance existing recycling equipment. Universities could play a vital role in this endeavor by developing interdisciplinary research programs and cultivating knowledgeable experts capable of spearheading innovation in recycling technology.

Looking ahead, the authors acknowledge the potential for further enrichment of this study through the integration of quantitative methodologies. By complementing qualitative approaches with quantitative analysis, researchers can gain a more comprehensive understanding of the circular economy and e-waste recycling landscape. Quantitative methods offer invaluable insights into correlations and patterns that may not be immediately discernible through qualitative exploration alone, paving the way for more nuanced and informed future research endeavors.

References

Angouria-Tsorochidou, E., Cimpan, C., & Parajuly, K. (2018). Optimized collection of EoL electronic products for Circular economy: A techno-economic assessment. *Procedia CIRP*, *69*, 986–991. https://doi.org/10.1016/j.procir.2017.11.020

Awasthi, A. K., Li, J., Koh, L., & Ogunseitan, O. A. (2019). Circular economy and electronic waste. *Nature Electronics*, *2*(3), 86–89. https://doi.org/10.1038/s41928-019-0225-2

Bakr, A. M., Mohammed, M. O., El Amri, M. C., Kastaci, H., & Erol, T. (2020). A Feasibility Study on the Use of e-Waste to Develop New Products in Turkey and the Implications for Circular Economy. *12th International Conference on Islamic Economics and Finance (ICIEF): Sustainable Development for Real Economy*. Istanbul: Istanbul Sabahattin Zaim University.

Balde, C. P., Forti, V., Gray, V., Kuehr, R., & Stegmann, P. (2017). The global e-waste monitor 2017. In *United Nations University (UNU), International Telecommunication Union (ITU) & International Solid Waste Association (ISWA)*. https://doi.org/10.1016/j.proci.2014.05.148

Baldé, C. P., Kuehr, R., Yamamoto, T., Mcdonald, R., D'Angelo, E., Althaf, S., … Wagner, M. (2024). The Global E-waste Monitor 2024. In *International Telecommunications Union (ITU) and United Nations Institute for Training and Research (UNITAR)*. Geneva/Bonn.

Bao, S., Pan, B., Wang, L., Cheng, Z., Liu, X., Zhou, Z., & Nie, X. (2020). Adverse effects in Daphnia magna exposed to e-waste leachate: Assessment based on life trait changes and responses of detoxification-related genes. *Environmental Research*, *188*(June), 109821. https://doi.org/10.1016/j.envres.2020.109821

Bocken, N. M. P., de Pauw, I., Bakker, C., & van der Grinten, B. (2016). Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering*, *33*(5), 308–320. https://doi.org/10.1080/21681015.2016.1172124

Boddy, C. R. (2016). Sample size for qualitative research. *Qualitative Market Research: An International Journal*, *19*(4), 426–432. https://doi.org/10.2307/40269124

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/https://doi.org/10.1191/1478088706qp063oa

Chaine, C., Hursthouse, A. S., McLean, B., McLellan, I., McMahon, B., McNulty, J., … Viza, E. (2022). Recycling Plastics from WEEE: A Review of the Environmental and Human Health Challenges Associated with Brominated Flame Retardants. *International Journal of Environmental Research and Public Health*, *19*(2). https://doi.org/10.3390/ijerph19020766

Chancerel, P., Meskers, C. E. M., Hagelüken, C., & Rotter, V. S. (2009). Assessment of Precious Metal Flows During Preprocessing of Waste Electrical and Electronic Equipment. *Journal of Industrial Ecology*, *13*(5), 791–810. https://doi.org/10.1111/j.1530-9290.2009.00171.x

Creswell, J. W. (2009). *Research design qualitative, quantitative, and mixed methods approaches* (Third). California: Sage Publications, Inc.

Cucchiella, F., D'adamo, I., Koh, S. C. L., & Rosa, P. (2015). Recycling of WEEEs: An economic assessment of present and future e-waste streams. *Renewable and Sustainable Energy Reviews*, *51*, 263–272. https://doi.org/10.1016/j.rser.2015.06.010

D'adamo, I., Ferella, F., Gastaldi, M., Maggiore, F., Rosa, P., & Terzi, S. (2019). Towards sustainable recycling processes: Wasted printed circuit boards as a source of economic opportunities. *Resources, Conservation & Recycling*, *149*, 455–467. https://doi.org/10.1016/j.resconrec.2019.06.012

Deep, A., Kumar, K., Kumar, P., Kumar, P., Sharma, A. L., Gupta, B., & Bharadwaj, L. M. (2011). Recovery of Pure ZnO Nanoparticles from Spent Zn-MnO2 Alkaline Batteries. *Environmental Science & Technology*, *45*(24), 10551–10556. https://doi.org/10.1021/es201744t

Directorate-General for Environment. (2023). Waste from Electrical and Electronic Equipment (WEEE) - European Commission. Retrieved March 8, 2024, from European Commission website: https://bit.ly/3Itqeqn

Dutta, T., Kim, K.-H., Deep, A., Szulejko, J. E., Vellingiri, K., Kumar, S., … Yun, S.-T. (2018). Recovery of nanomaterials from battery and electronic wastes: A new paradigm of environmental waste management. *Renewable and Sustainable Energy Reviews*, *82*, 3694–3704. https://doi.org/10.1016/j.rser.2017.10.094

Ellen MacArthur Foundation (EMF). (2013). *Towards the circular economy* (Vol. 1).

Forti, V., Baldé, C. P., Kuehr, R., & Bel, G. (2020). The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential. In *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.

García-Barragán, J. F., Eyckmans, J., & Rousseau, S. (2019). Defining and Measuring the Circular Economy: A Mathematical Approach. *Ecological Economics*, *157*(April 2018), 369–372. https://doi.org/10.1016/j.ecolecon.2018.12.003

Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The Circular Economy – A new sustainability paradigm? *Journal of Cleaner Production*, *143*, 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048

Geng, Y., & Doberstein, B. (2008). Developing the circular economy in China: Challenges and opportunities for achieving "leapfrog development." *International Journal of Sustainable Development & World Ecology*, *15*(3), 231–239. https://doi.org/10.3843

Glossary: Waste electrical and electronic equipment (WEEE). (n.d.). Retrieved July 2, 2020, from Eurostat Statistics Explained website: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Waste_electrical_and_electronic_equipment_(WEEE)

Golsteijn, L., & Valencia Martinez, E. (2017). The Circular Economy of E-Waste in the Netherlands: Optimizing Material Recycling and Energy Recovery. *Journal of Engineering*, *2017*, 1–6. https://doi.org/10.1155/2017/8984013

Graneheim, U. H., Lindgren, B.-M., & Lundman, B. (2017). Methodological challenges in qualitative content analysis: A discussion paper. *Nurse Education Today*, *56*(June), 29–34. https://doi.org/10.1016/j.nedt.2017.06.002

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, *127*(April), 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005

Krippendorff, K. (1989). Content analysis. In *International encyclopedia of communication* (Vol. 1, pp. 403–407). Oxford University Press.

Kumar Awasthi, A., Cucchiella, F., D'adamo, I., Li, J., Rosa, P., Terzi, S., … Zeng, X. (2018). Modelling the correlations of e-waste quantity with economic increase. *Science of the Total Environment*, *613–614*, 46–53. https://doi.org/10.1016/j.scitotenv.2017.08.288

Longhurst, R. (2016). Semi-structured interviews and focus groups. In *Key methods in geography* (Third, pp. 143–156). Sage.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook* (Second). Thousand Oaks: Sage Publications, Inc.

Ministry of Environment Urbanization and Climate Change of the Republic of Turkiye. (2023). *ATIK İSTATİSTİKLERİ BÜLTENİ (2021)*.

Neuman, W. L. (2014). *Social Research Methods: Qualitative and Quantitative Approaches* (Seventh). Essex: Pearson Education Limited.

Reuter, M., Hudson, C., van Schaik, A., Heiskanen, K., Meskers, C., & Hagelüken, C. (2013). *Metal Recycling Opportunities, Limits, Infrastructure*.

Sandelowski, M. (1998). The Call to Experts in Qualitative Research. *Research in Nursing & Health*, *21*(5), 467–471. https://doi.org/10.1002/nur.4770170611

Sauvé, S., Bernard, S., & Sloan, P. (2016). Environmental sciences, sustainable development and circular economy: Alternative concepts for trans-disciplinary research. *Environmental Development*, *17*, 48–56. https://doi.org/10.1016/j.envdev.2015.09.002

Shittu, O. S., Williams, I. D., & Shaw, P. J. (2021). Global E-waste management: Can WEEE make a difference? A review of e-waste trends, legislation, contemporary issues and future challenges. *Waste Management*, *120*, 549–563. https://doi.org/10.1016/J.WASMAN.2020.10.016

Suja, F., Abdul Rahman, R., Yusof, A., & Masdar, M. S. (2014). e-Waste Management Scenarios in Malaysia. *Journal of Waste Management*, *2014*, 1–7. https://doi.org/10.1155/2014/609169

SUN, Ellen MacArthur Foundation, & McKinsey Center for Business and Environment. (2015). *GROWTH WITHIN: A CIRCULAR ECONOMY VISION FOR A COMPETITIVE EUROPE*.

Tasbirul Islam, M., & Huda, N. (2018). Reverse logistics and closed-loop supply chain of Waste Electrical and Electronic Equipment (WEEE)/E-waste: A comprehensive literature review. *Resources, Conservation & Recycling*, *137*, 48–75. https://doi.org/10.1016/j.resconrec.2018.05.026

Wath, S. B., Dutt, P. S., & Chakrabarti, T. (2011). E-waste scenario in India, its management and implications. *Environmental Monitoring and Assessment*, *172*(1–4), 249–262. https://doi.org/10.1007/s10661-010-1331-9

Yong, Y. S., Lim, Y. A., & Ilankoon, I. M. S. K. (2019). An analysis of electronic waste management strategies and recycling operations in Malaysia: Challenges and future prospects. *Journal of Cleaner Production*, *224*, 151–166. https://doi.org/10.1016/j.jclepro.2019.03.205

Zhang, Y., Huo, X., Cao, J., Yang, T., Xu, L., & Xu, X. (2016). Elevated lead levels and adverse effects on natural killer cells in children from an electronic waste recycling area. *Environmental Pollution*, *213*, 143–150. https://doi.org/10.1016/j.envpol.2016.02.004