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Original Research

Consumer WEEE Recycling Awareness in Portugal: Progression toward a Circular Economy

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Abstract: Waste electrical and electronic equipment (WEEE) has become the fastest-growing waste stream, and consumer WEEE recycling is detrimental to the success of circular economy principles. However, consumer awareness of and willingness to cooperate in WEEE recycling is a core pillar of success as end users determine the ultimate fate of waste. This study presents the results of a survey distributed via social media in Portugal (n = 509) to determine consumer knowledge of and compliance or noncompliance with circular economy goals for WEEE as well as actionable insights for policy decision-makers and managers. Results show that the overall knowledge of WEEE posing health and environmental hazards is very high and that higher storage rates at home exist in younger demographics, students, and higher-income brackets. Our research highlights that not only are proximity to a recycling center and awareness of the location influencing factors required for recycling but also that recycling activities are mostly based on intrinsic motivation to protect the environment, with financial incentives only attracting a relatively small share of the study participants. While most studies on WEEE focus on developing countries, this study offers a distinct perspective by covering a mature EU economy.

Keywords: *Portugal, WEEE, SDGs, e-Waste, Consumer Awareness, Recycling, Circular Economy, Sustainability Transition*

Introduction

Countries are confronted with growing waste electrical and electronic equipment (WEEE) that will only continue due to technological advancements (Ramanayaka, Keerthanan, and Vithanage 2020). WEEE has become one of the fastest-growing wastes, and, in 2019, about 9.5 million tons (18.5 kg per inhabitant) of WEEE were generated in the EU (Forti et al. 2020). With the increasing consumption of electronics, decreasing product life cycle lengths, and existing limitations on non-manufacturer product repair, attainment of, for example, the UN Sustainable Development Goals (SDGs), which include a directive for the reuse and recycling of WEEE (Eurostat, n.d.), will be challenging (Forti et al. 2020). To further address the topic from a policy perspective of combating issues associated with raw material dependency and improving economic profitability, the European Commission adopted the circular economy policy (Morone, Falcone, and Lopolito 2019). The optimization of WEEE

handling is vital as countries transition to a circular economy framework, and Kemp and van Lente (2011) argue that in driving a sustainable transition, one of the two challenges is handling by consumers.

In 2017, Europe was the second-largest generator of WEEE and had been leading in collection (Ramanayaka, Keerthanan, and Vithanage 2020). Although Portugal recycled 43.5 percent of e-waste in 2017 (European Parliament News 2020), which was above EU averages, more needs to be done to reach SDG targets. According to the Sustainable Development Report (Sachs et al. 2022), in 2019, Portugal was listed under "major challenges remain" for e-waste. Although waste levels remained stable above EU averages between 2019 and 2020, at 513 kg/cap, recycling levels from 2016 to 2020 only show negligible change (European Environment Agency 2022). Against this backdrop, to advance governmental initiatives regarding e-waste recycling and a CE, all stakeholders—government, producers, sellers, and end consumers—need to be included. As end users are responsible for where e-waste ultimately lands, they are crucial in closing the loop of CE (Parajuly et al. 2019) as they are the ones who generate the waste (Kwatra, Pandey, and Sharma 2014) and decide the fate of the waste (Pérez-Belis et al. 2017). With increasing EEE sales, stagnant recycling levels, and CE policy changes, understanding the end user's knowledge and awareness of recycling for WEEE is vital in improving sustainability transitions toward a circular system (Islam et al. 2021; Istudor et al. 2023).

As recycling behaviors differ by country (Colesca, Ciocoiu, and Popescu 2014), we frame our research on the sustainable transition of Portugal's WEEE recycling knowledge. Our article contributes to the empirical literature on e-waste by identifying awareness and recycling knowledge contributing to end users' willingness to recycle e-waste via government-certified centers across Portugal. In addition, the research provides insights useful for the management of end-user e-waste. A part of fulfilling national plans is end-user contribution, while organizations require national plans to develop their own strategies (Louw and Venter 2021). Therefore, the results of this study will appeal to government organizations, recycling organizations, and private organizations looking to improve recycling awareness and effectiveness.

To promote sustainable development and reduce environmental impacts, the concept of circular economy has gained increased attention in recent years. At its core, the circular economy aims to close material loops through product design and processes that minimize waste and enable the recovery and reuse of materials and resources. This represents a significant shift away from the traditional linear model of "take–make–waste" and moves toward a regenerative system where waste is seen as a valuable resource that can be used to create new products (McDonough and Braungart 2002). In the context of electrical and electronic equipment, this approach can yield significant benefits, as products often contain valuable resources that can be extracted for reuse or repurpose in other products (OECD 2019).

e-Waste is defined as "electrical or electronic equipment which is waste including all components, sub-assemblies and consumables, which are part of the product at the time of discarding" (European Environment Agency 2003), and there are about 900 distinct types of electrical and electronic equipment (Forti, Baldé, and Kuehr 2018). Once an electrical product is no longer used due to replacement or malfunction, it becomes WEEE. In 2019, global WEEE was estimated at 53.6 million tons and is forecast to grow to 74.7 million tons by 2030 (Forti et al. 2020). With advancements in science and technology causing shorter life cycles, increased household consumption, shorter product life spans, limited electrical and electronic equipment repair options, and changes in consumer behavior, the demand for new products and, thus, the rate of WEEE will only increase more quickly and become a greater global problem (Murthy and Ramakrishna 2022; Thukral, Shree, and Singhal 2022; Gu et al. 2016). For example, students continuously upgrading their mobile phones were reported as high e-waste contributors (Ongondo and Williams 2011). The ten classifications of electrical and electronic equipment according to EU directive 2012/19/EU (European Parliament 2012) on waste management are as follows:

1. Large household appliances, including refrigerators, washing machines, and stoves.
2. Small household appliances, including vacuum cleaners, toasters, and beauty appliances.
3. IT and telecommunications equipment, including mainframes, personal computers, printers, mobile phones, and tablets.
4. Consumer equipment and photovoltaic panels, including televisions, radios, and musical instruments.
5. Lighting equipment, including luminaires, fluorescent lamps, and sodium lamps.
6. Electrical and electronic tools, excluding large-scale stationary industrial tools and including drills, saws, gardening, and industrial machines.
7. Toys, leisure, and sports equipment, including video games, gaming consoles, and electronic sports equipment.
8. Medical devices, excluding implanted/infected products and including radiotherapy and cardiology equipment and ventilators.
9. Monitoring and control instruments, including smoke detectors, thermostats, and heating regulators.
10. Automatic dispensers, including various products like hot or cold drinks, solid products, or money.

Not only is the overall number of pieces of electrical and electronic equipment in these categories increasing in sales but the WEEE is also growing. In addition, these items contain many recyclable valuable resources (copper, gold, silver, aluminum), while some e-waste contains critical and near critical raw materials (cobalt, antimony, tungsten, gallium, silver, lithium), as defined by the EU (Işıldar et al. 2019; Tsamis and Coyne 2015). Base metals (e.g.,

copper, tin, zinc) constitute about 30 percent of WEEE waste (Rai et al. 2021). However, there are also substances in WEEE requiring very specific handling as they are linked to health and environmental issues (e.g., lead, mercury, arsenic) (Straif et al. 2009; Zhang and Xu 2016). Although the value of the raw materials in WEEE was estimated to be 55 billion euros in 2016 (Baldé et al. 2017), most e-waste lands in landfills (Robinson 2009).

Due to the value of e-waste resources and the threat of import restrictions for critical raw materials, the recovery of these resources is essential as it helps ensure supply and reduce energy consumption and CO_2 emissions (Banaszkiewicz et al. 2022). Therefore, the recycling of e-waste not only supports the SDG of establishing a circular economy, which the EU defines as "maintain[ing] the value of products, materials and resources for as long as possible by returning them into the product cycle at the end of their use, while minimizing the generation of waste" (Eurostat, n.d.), but also helps counter any future import restrictions.

In Portugal, there are two major recycling services: European Recycling Platform (ERP) and Rede Electrão (RE). Table 1 depicts the e-waste collection locations by state based on data from each company. The number of recycling centers equates to about 1,950 inhabitants per center or about 0.06 collection centers per square kilometer.

Table 1: e-Waste Collection Locations in Portugal in 2020

	North	*Center*	*MA Lisbon*	*Algarve*	*Alentejo*	*Azores*	*Madeira*	*Total*
ERP	1,091	1,071	1,338	208	230	105	36	4,079
RE	395	322	280	105	65	34	13	1,214
Total	1,486	1,393	1,618	313	295	139	49	5,293

Source: European Recycling Platform, n.d.; Onde Reciclar, n.d.

Portuguese Law no. 230/2004, regulating the production, distribution, and disposal of e-waste, was passed in 2004 (Food and Agriculture Organization of the United Nations [FAO] 2004). This law established the National Waste Plan, which set out goals for collection, recycling, and other management activities for e-waste. In 2009, Portugal adopted the EU's Directive on Waste Electrical and Electronic Equipment to strengthen existing measures and further advance the management of e-waste. The directive set out the goal for collection rates of e-waste to reach 65 percent by 2016. To reach this goal, Portugal implemented several measures, most notably the establishment of a national take-back system, which allowed consumers to return their e-waste to retailers or collection points (Ministério do Ambiente e do Ordenamento do Território 2004). In 2017, Law no. 152-D/2017 was passed to officiate producer responsibility schemes, which require manufacturers to assume responsibility for the proper collection and disposal of their e-waste (Ministério Público, n.d.).

Islam et al. (2021) have listed four options for consumers that comply with a circular economy: "(1) maintained/prolonged use, including sharing and repair, (2) reuse and

distribution, (3) remanufacture/refurbishment, and (4) recycling." However, end users may also be inclined to simply store the product, for example, at home or dispose of it, both of which do not contribute to a circular economy. This raises questions regarding what options citizens are aware of and undertake as well as what would promote greater WEEE recycling. This means researching if the citizens are "ready" to recycle WEEE.

Venkatesh et al. (2003) tested a model for determining user readiness with one aspect—facilitating conditions, which are "the degree to which an individual believes that an organizational and technical infrastructure exists to support the adoption and use of a system." Awareness of recycling centers is, as claimed by Ofori and Mensah (2022), a facilitating condition. In waste management, facilitating conditions include "supporting policies, infrastructure, public awareness programs and incentive schemes." This means that not knowing where to recycle WEEE can lead to a lack of action due to limitations in facilitating conditions.

An established recycling system that consumers are unaware of or that is not used for other reasons generates no value in terms of SDGs or a circular economy. Therefore, to establish an effective e-waste recycling system, it is crucial to understand the Portuguese public with regard to electronic and electrical waste: how consumers manage their e-waste, what factors influence their e-waste management behavior, and what could incentivize them to improve their e-waste management behavior. The article aims to shed light on these aspects by presenting the results of a survey conducted with Portuguese consumers. The key objectives include the following:

- Identifying the overall level of awareness of WEEE, including recycling centers and WEEE management—the facilitating conditions (Venkatesh et al. 2003)
- Understanding how e-waste is disposed of in Portugal, in terms of compliance or noncompliance with circular economy requirements, as outlined by Islam et al. (2021)
- Identifying the main causes of electronic and electrical equipment waste
- Understanding the differences in awareness and behavior regarding e-waste among different demographics (age, gender, life stage, income)
  Determining how socio-economic factors play a role in e-waste disposal and knowledge regarding WEEE .
- Identifying starting points for improving WEEE circularity

By exploring these issues, this study provides valuable insights into the challenges and opportunities of e-waste management in Portugal. Furthermore, by identifying starting points for improvements in the sustainability transition of end users, this study can inform policies and initiatives aimed at promoting more sustainable e-waste management behaviors.

Methodology

A survey was conducted in Portugal via social media to understand public knowledge and awareness related to WEEE. Prior to its launch, the survey was pilot tested with five respondents for efficacy verification. These responses were not included in the end results but did enable question refinement. The structured questionnaire applied for the survey consisted of two sections: The first section collected demographic information of the participants in terms of gender, age, education level, income, and occupation. The second section assessed participant knowledge and awareness of WEEE and their current electrical and electronic equipment recycling behavior. The survey was distributed online for greater reach across all of Portugal during February 2022 and was only available in Portuguese. Data was collected using Google Forms via different social media platforms: WhatsApp, Instagram, and LinkedIn. In 2022, the daily internet usage rate in Portugal was 80 percent (Eurostat 2023), and approximately 67 percent of the Portuguese population used the internet for social media purposes (Eurostat 2024). This, in combination with the link between internet penetration and e-waste (Kalia, Zia, and Mladenović 2021), supported conducting the survey online, as it enabled greater targeting of those consuming electronic and electrical equipment. The survey consisted of close-ended questions; where rating was required, a Likert scale response with five options (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree) was used.

The questionnaire was based on literature about current recycling options and methods within Portugal. The authors selected Portugal due to the limited studies analyzing Portuguese awareness and behavior in terms of e-waste recycling, as most WEEE studies focus on developing countries or large countries (Cao et al. 2016; Kwatra, Pandey, and Sharma 2014; Ofori and Mensah 2022; Saphores et al. 2009). Due to the distribution method, the study adopted a quantitative survey design to generalize the results. In total, the survey generated 509 valid responses, all of which were anonymous.

Results and Discussion

A summary of the respondents' demographic and socio-economic data is presented in Table 2. The majority (60.7%, n = 309) of respondents were female, while 38.7 percent (n = 197) were male and 0.6 percent (n = 3) were diverse. The median reported age was 37.5, with a range of 18 to 83. The age distribution shows that most respondents were under the age of 30 (44.4%). The age of the respondents aligns with reported social media users typically being younger than 34 in Portugal (European Commission, n.d.). The mode age of 23 coincides with 22.6 percent of the respondents being students. All the students reported either no income or income of less than 1,000€ per month—-the minimum wage at the time of the study being 705€ (Pordata, n.d.). More than 31 percent of the respondents were within the median income range—median income in 2021 being about 1,600€ (OECD.Stat,, n.d.). The

relationship between the number of students and income below 605€ per month was high at 84.3 percent. The highest representation was from the Metropolitan Area of Lisbon (71.5%). Weaker representation in the above 65 age bracket, states having smaller metropolitan areas, and rural areas, was probably linked to the online distribution of the survey as well as internet connectivity in parts of Portugal.

Table 2: Demographic and Socio-Economic Profile of the Respondents (n = 509)

Demographic & Socio-Economic Variables	*Description*	*Frequency*	*Percentage*
Gender	Male	197	38.7
	Female	309	60.7
	Diverse	3	0.6
Age	18–30	226	44.4
	31–50	168	33.0
	>51	115	22.6
Education level	Secondary	147	28.9
	University (BA)	237	46.6
	Post-university (e.g. MA or higher)	125	24.6
Geographic location	North	37	7.3
	Center	81	15.9
	Alentejo	11	2.2
	MA Lisbon	364	71.5
	Azores	4	0.8
	Madeira	12	2.4
	Algarve	9	1.8
Occupation	Student	115	22.6
	Employed	299	58.7
	Self-employed	65	12.8
	Retired	19	3.7
	Caring for family	11	2.2
Income (per month)	None-1,000€	238	46.8
	1,001–2,000€	160	31.4
	>2,000€	68	13.4
	No answer	43	8.4

Research by Wang et al. (2011) had highlighted the convenience of recycling facilities and services as a primary factor influencing willingness to recycle. Most respondents, 54.6 percent, indicated that they were not aware of waste disposal centers close to their place of

residence. Of those not knowing about local recycling options (n = 278), 52.4 percent (n = 162) were female and 58.4 percent (n = 115) were male. The largest age bracket unaware of local recycling facilities was 18 to 30-year-olds. In the Occupation demographic, those claiming being Employed reported the highest levels of unawareness of recycling facilities, regardless of gender. Income level and not knowing of local recycling facilities were distorted as about half of both females and males indicating monthly income less than 1,000€ were students. Table 3 details participants indicating lack of knowledge of local recycling centers by demographic and socio-economic variables.

Table 3: No Knowledge of Local Recycling Center

Demographic & Socio-Economic Variables	*Description*	*Male n = 115*	*Female n = 162*
Age	18–30	53.0% (n = 61)	45.7% (n = 74)
	31–50	27.0% (n = 31)	38.3% (n = 62)
	>51	20.0% (n = 23)	16.0% (n = 26)
Education level	Secondary	26.1% (n = 30)	20.4% (n = 33)
	University (BA)	40.1% (n = 47)	43.2% (n = 70)
	Post-university (e.g. MA)	21.7% (n = 25)	24.0% (n = 39)
Geographic location	North	4.3% (n = 5)	4.9% (n = 8)
	Center	13.0% (n = 15)	15.4% (n = 28)
	Alentejo	1.7% (n = 2)	1.2% (n = 2)
	MA Lisbon	76.5% (n = 88)	70.4% (n = 114)
	Azores	0% (n = 0)	1.9% (n = 3)
	Madeira	1.7% (n = 2)	3.1% (n = 5)
	Algarve	1.7% (n = 2)	1.2% (n = 2)
Occupation	Student	24.3% (n = 28)	22.8% (n = 37)
	Employed	54.8% (n = 63)	60.5% (n = 98)
	Self-employed	16.5% (n = 19)	11.1% (n = 18)
	Retired	4.3% (n = 5)	2.5% (n = 4)
	Caring for family	0% (n = 0)	3.1% (n = 5)
Income (per month)	None to 1,000€	45.2% (n = 52)	52.5% (n = 85)
	1,001–2,000€	29.6% (n = 34)	28.2% (n = 46)
	>2,000€	18.3% (n = 21)	11.7% (n = 19)
	No answer	7.0% (n = 8)	7.4% (n = 12)

Public awareness programs influence awareness of recycling centers. Although 54.6 percent of the participants indicated knowing of local WEEE recycling centers, 79.8 percent (n = 406) of the total participants claimed not having seen promotion from an institution that

collects WEEE. This implies that improved facilitating conditions, in terms of generating awareness by the collection agencies, are warranted to not detract from expected behavior. This also supports the conclusion by Dagiliūtė et al. (2019) that infrastructure and consumer knowledge are the key elements for efficient waste management.

Despite the rates for being unaware of local recycling centers, 90.8 percent indicated awareness of electronic waste requiring special management and treatment, and 86.1 percent indicated knowledge of health risks associated with e-waste. Regarding awareness of risks posed by substances from e-waste, 94.3 percent responded positively. Further, 95.3 percent would like additional information and education about e-waste. These results indicate that the participants are aware of the consequences of e-waste concerning health and the environment; however, there is a lack of awareness regarding disposal centers and their location. This differs from the results of studies from developing countries highlighting a lack of awareness about e-waste recycling as a contributing factor to the recycling problem, for example, Ichikowitz and Hattingh (2020) and Kwatra, Pandey, and Sharma (2014). Awareness of the issues is present in Portugal, but lack of awareness of where to take WEEE products for recycling shows communication improvement is warranted or the number of recycling depositories needs to be increased.

One factor supporting awareness of local recycling centers is the need for the service. Most participants (46.2%, $n = 235$) indicated having one to five electronic items at home that were not used. The second most common selection was six to ten items by 116 participants (22.8%), followed by more than ten items by 112 participants (22.0%). The fewest claimed to have no electronic items at home that were not being used (9.0%, $n = 46$). This means that over 90 percent of the survey participants indicated having e-waste—that is, equipment that was not being used and may or may not be functioning—stored in their residence. Table 4 depicts waste storage where percentages are calculated based on the description classification of demographic and socio-economic variables. Calculations were not made for "description" classification when the participation count was below thirty.

Students and participants in the North had very low storage of WEEE at home. The groups with the highest percentage of having more than ten units of WEEE at their place of residence were 18- to 30-year-olds, students (who were mostly in the 18- to 30-year-old category), and those earning more than 2,000€ per month. Data indicates that a heavier focus on targeting under 30-year-olds and students could yield positive results. Gilal et al. (2019) have observed that positive Word of Mouth communication about WEEE recycling increases proper disposal behavior. When combined with the very high interest in obtaining more knowledge about e-waste, this could be interpreted with the data here, that a stronger focus within and by the educational system could lead to greater recycling by families.

Table 4: Home Storage of WEEE, Percentages Calculated by Description

Demographic & Socio-Economic Variables	*Description*	*Number of Items Stored at Home*			
		None (*n* = 46)	*1–5* (*n* = 235)	*6–10* (*n* = 116)	*10+* (*n* = 112)
Gender	Female (*n* = 309)	10.3% (*n* = 32)	48.9% (*n* = 151)	23.0% (*n* = 71)	17.8% (*n* = 55)
	Male (*n* = 197)	7.1% (*n* = 14)	41.6% (*n* = 82)	22.8% (*n* = 45)	28.4% (*n* = 56)
Age	18–30 (*n* = 226)	4.0% (*n* = 9)	44.7% (*n* = 101)	23.9% (*n* = 54)	27.4% (*n* = 62)
	31–50 (*n* = 168)	10.7% (*n* = 18)	48.2% (*n* = 81)	22.0% (*n* = 37)	19.0% (*n* = 32)
	>51 (*n* = 115)	16.5% (*n* = 19)	46.1% (*n* = 53)	21.7% (*n* = 25)	15.7% (*n* = 18)
Education level	Secondary (*n* = 147)	10.9% (*n* = 16)	45.6% (*n* = 67)	15.0% (*n* = 22)	17.0% (*n* = 25)
	University (BA) (*n* = 237)	7.6% (*n* = 18)	40.5% (*n* = 96)	28.3% (*n* = 67)	23.6% (*n* = 56)
	Post-university (e.g. MA) (*n* = 125)	4.8% (*n* = 6)	49.6% (*n* = 62)	23.2% (*n* = 29)	22.4% (*n* = 28)
Geographic location	North (*n* = 37)	0% (*n* = 0)	51.4% (*n* = 19)	24.3% (*n* = 9)	24.3% (*n* = 9)
	Center (*n* = 81)	13.6% (*n* = 11)	44.4% (*n* = 36)	19.8% (*n* = 16)	22.2% (*n* = 18)
	MA Lisbon (*n* = 355)	8.2% (*n* = 29)	45.9% (*n* = 163)	23.7% (*n* = 84)	22.3% (*n* = 79)
Occupation	Student (*n* = 115)	0.9% (*n* = 1)	49.6% (*n* = 57)	20.9% (*n* = 24)	28.7% (*n* = 33)
	Employed (*n* = 299)	10.7% (*n* = 32)	44.5% (*n* = 133)	22.7% (*n* = 68)	22.1% (*n* = 66)
	Self-employed (*n* = 65)	7.7% (*n* = 5)	50.8% (*n* = 33)	24.6% (*n* = 16)	16.9% (*n* = 11)
Income (per month)	None to 1,000€ (*n* = 238)	5.9% (*n* = 14)	47.9% (*n* = 114)	22.7% (*n* = 54)	23.5% (*n* = 56)
	1,001–2,000€ (*n* = 160)	12.5% (*n* = 20)	46.9% (*n* = 75)	21.9% (*n* = 35)	18.8% (*n* = 30)
	>2,000€ (*n* = 68)	7.4% (*n* = 5)	36.8% (*n* = 25)	27.9% (*n* = 19)	27.9% (*n* = 19)
	No answer (*n* = 43)	15.2% (*n* = 7)	45.7% (*n* = 21)	17.4% (*n* = 8)	15.2% (*n* = 7)

Selling, donating, or recycling are methods to promote a circular economy for electrical and electronic equipment. The anti-circular economy option and the one most harmful to health is the disposal of WEEE in common trash. However, for functional electrical and electronic equipment, this was reported as the outcome at least sometimes for 20 percent of the respondents and nonfunctional WEEE nearly 26 percent, with a comparable percentage of the respondents claiming to never recycle. Table 5 depicts the results for the handling of functional and nonfunctional WEEE. Nearly 60 percent of participants claimed to never have disposed of functioning and non-functioning WEEE in common trash. This supports the prominent level of awareness of health and environmental damage caused by WEEE. Although our study did not focus on the recycling of one singular product, the data collected could support the results of Ongondo and Williams (2011), that a large number of mobile phones are stored at home by students. The reasoning for supporting the study's results is that, in our study, 44.4 percent of the participants were under 30 percent and 40.5 percent were students, and Table 5 shows a higher percentage of responses for keeping WEEE at home, particularly functioning items.

Table 5: Consumer Handling of Functioning and Non-Functioning e-Waste

Handling of Functional Electronic Items	*Responses*				
	Never %	*Rarely %*	*Sometimes %*	*Often %*	*Always %*
Sell online	47.5	20.2	20.2	9.6	2.4
Keep at home	13.2	19.1	31.6	28.3	7.9
Offer to friends/family	12.8	21.2	44.4	18.7	2.9
Donate to people/organizations	14.5	26.5	39.9	16.3	2.8
Recycle	27.7	27.3	28.1	13.4	3.5
Throw away in common trash	59.3	20.8	15.9	3.5	0.4
Sell to recyclers	82.3	11.2	4.7	1.4	0.4
Handling of Nonfunctional Electronic Items	*Responses*				
	Never %	*Rarely %*	*Sometimes %*	*Often %*	*Always %*
Sell online	82.9	10.2	5.1	1.4	0.4
Keep at home	34.2	19.3	27.9	14.3	4.3
Offer to friends/family	75.0	15.1	8.1	1.2	0.6
Donate to people/organizations	78.2	11.6	8.1	1.0	1.2
I try to fix them	17.5	22.6	40.9	13.0	6.1
Recycle	26.1	20.6	28.7	16.5	8.1
Throw away in common trash	57.0	17.1	16.7	5.9	3.3
Sell to recyclers	79.2	11.0	7.9	1.0	1.0

Most participants (50.1%) indicated that the primary reason that would lead them to recycle is environmental protection. The second most selected response (19.6%) was to free up space at home. The offering of a monetary incentive was selected by only 11.6 percent of participants, and a free pick-up service was only selected by the fewest at 0.2 percent (see Table 6). These results highlight the strong health and environmental awareness reported in previous questions. Although this result seems contradictory to the research by Bucciol, Montinari, and Piovesan (2015) citing an increase in recycling when monetary incentives are used, it does not exclude the possibility of recycling rates rising when environmental issues are combined with monetary incentives. However, Wang, Guo, and Wang (2016) also identified environmental awareness as a key influencing factor for WEEE recycling behavior intention.

Table 6: Reasons Why Participants Would Recycle Electrical and Electronic Equipment That They Have at Home

	#	%
Environment protection	255	50.1
Exchange system for money	59	11.6
Free pick-up service	1	0.2
Free up space at home	100	19.6
Initiatives of repurposing for second hand	54	10.6
No reason but I recycle	33	6.5
Other	7	1.4

Responses to what would motivate to increase the level of WEEE recycling placed home pick-up services as the most likely factor. When viewing the combination of "likely" and "very likely" responses, then the proximity of recycling collection points is the greatest motivator (see Table 7). No participants wrote in other factors for motivating them to increase their level of WEEE recycling.

Table 7: Responses to Factors for Increasing WEEE Recycling (n = 509)

	Very Unlikely	*Unlikely*	*Potentially*	*Likely*	*Very Likely*
Recycling points closer to home	3.7	4.3	5.7	30.1	56.2
System of e-waste pick-up at home	5.1	6.1	6.9	25.0	57.0
More information on how and where to recycle	4.5	6.9	11.0	42.6	35.0
Exchange system of e-waste for money	5.7	7.9	7.5	30.3	48.7
Initiatives of repurposing for second hand	4.1	6.7	11.6	39.5	38.1
Repairing initiatives for damaged equipment	4.9	9.4	12.6	36.9	36.1

The high survey participation rate among under 30-year-olds (44.4%), who are unaware of local recycling centers, combined with 50.1 percent of the participants listing the primary reason to recycle WEEE for environmental protection, confirms Saphores et al.'s (2006) research recommending targeting education programs.

Besides only highlighting the lack of participant recycling, the survey allowed for the identification of potential opportunities for improvement. The survey data shows that the lack of availability and proximity of collection points are the primary obstacles to increasing recycling rates. However, this lack of, or lack of unawareness of, local recycling locations also presents an opportunity. The findings of the study indicated that more than 80 percent of the participants expressed a higher propensity to recycle their electronic and electrical equipment if recycling facilities were conveniently located near their residences or if a pick-up service was available. While the implementation of a pick-up service option may entail numerous logistical challenges, offering more locally situated recycling options would be a simpler yet effective strategy, based on the survey, to enhance recycling rates and contribute positively to sustainability and circularity objectives.

For example, one potential approach to facilitate proper disposal of electronic and electrical equipment stored at home would be the introduction of recycling bins. Currently, trash cans are present in every condominium and surrounding housing blocks in Portugal, with separate receptacles for paper, glass, plastic, common waste, and biological waste. Situating a bin adjacent to the "regular" bins could alleviate the inconvenience of recycling for individuals. These bins could be provided, like the other bins, by the public authorities responsible for waste management or by existing or new e-waste handling companies, thereby enhancing accessibility. An additional or alternative option would be the placement of such bins in supermarkets, shopping centers, and other high-traffic locations, including workplaces with a substantial workforce. The greater the number of recycling bin locations near frequently visited areas, the greater the likelihood that these bins would be recognized and utilized by the public. This means the convenience is improved by shortening the distance to transport WEEE. The distance to recycling locations has been shown to impact willingness to recycle (Cao and Liu 2019).

According to the questionnaire results, one of the most popular methods for promoting recycling willingness was the exchange of electronic items for monetary compensation. This approach could prove particularly beneficial for retail companies specializing in electronic and electrical items, such as the Portuguese company Worten, which was repeatedly mentioned by participants when queried about e-waste disposal centers. An incentivized system that allows consumers to bring in their unused items, regardless of their functional state, in exchange for, for example, store credit or a predetermined sum of money could be a viable option. Although a direct monetary payment is simplest in scope, research proposing an electronic bonus card system would warrant review by practitioners (Shevchenko, Laitala, and Danko 2019). However, Wang, Zhang, and Sun (2021) identified no significant

difference between monetary and nonmonetary incentives, but that both yielded positive participation. In comparison, Lu and Wang (2022) claimed monetary incentive to be effective. However, monetary incentive research does not seem to be conclusive regarding WEEE for a developed country with recycling knowledge and interest.

Further, many participants expressed an interest in repurposing products for the second-hand or upcycling market. This represents an opportunity for businesses to fulfill this demand in conjunction with the aforementioned pick-up systems or collection points. Embracing circularity offers several business-driven solutions that promote a financially sustainable approach to addressing the issue of e-waste.

Moreover, respondents stated that their primary motivation for recycling electronic and electrical equipment was to contribute to environmental protection and to free up space in their homes. In addition, most participants indicated that they desire more information and education on the topic of WEEE and how it could support circularity and sustainability. This information can be applied to the development of various educational interventions and targeted campaigns. Improvements in education regarding WEEE could be achieved through diverse strategies (such as greater inclusion in school curriculums and public advertising), while campaigns tailored to the key motivations of end consumers could create new incentives for recycling. By effectively communicating the environmental impact or the necessity of decluttering living spaces, potential avenues for encouraging people to recycle their products could be explored. Providing information that highlights the storage issues associated with unused electronic and electrical equipment at home, given that a substantial number of the participants seemed unaware of such challenges, could help due to the low awareness seen.

An examination of the survey data based on age groups revealed an additional observation that offers a market for focus. The 18- to 30-year-olds were found to be the most likely group to store electronic or electrical equipment at their place of residence, while also exhibiting the greatest interest in the concept of exchanging equipment for monetary compensation. Given that this group possesses the lowest disposable income, implementing a system of this nature through sellers, for example, could prove beneficial in motivating this segment to participate in greater levels of recycling. The data can also be interpreted to mean that targeting this demographic online and/or in proximity to universities would increase exposure and appeal.

Conclusion

By promoting the recovery of both reusable and hazardous materials, recycling supports the UN SDGs and a circular economy. The study contributes to existing WEEE literature by identifying consumer facilitating conditions in Portugal. To better understand the current situation of WEEE in Portugal and assess the awareness and behaviors of the Portuguese public, a survey was conducted, involving over 500 individuals from diverse regions, age

groups, and educational backgrounds. The findings of this survey offer valuable insights into the main barriers to a sustainable transition. The data provides insights into why recycling levels are not higher within the country as well as consumers' interest in the WEEE topic.

The survey results indicate that most consumers have e-waste stored at home and, in the absence of awareness of local recycling centers, about 20 percent of this ends up in general trash despite high consumer awareness of health and environmental issues caused by this disposal method. The data shows a strong public interest in the topic and a high level of awareness with regard to the harmful impacts of WEEE, but a noticeable lack of knowledge about where to dispose of WEEE. Therefore, improving knowledge of and expanding the count of recycling center locations are essential for the continued development of e-waste management systems in Portugal and appear to offer the possibility of the greatest increase in recycling rates. Although the practicalities of achieving this goal, such as location and type of collection points, require further research, ideally regularly collected WEEE at residences, particularly in cities, would eliminate depository center location issues and improve ease. It can be seen as positive that environmental protection as an intrinsic motivation clearly provides the most important impetus for recycling WEE. It is, therefore, all the more important to ensure that the appropriate recycling options are available. Derived from our research, there are a number of measures available for local governments to increase recycling rates and efficiency. The results presented should encourage recycling organizations and governments to focus on younger people with continuing education by placing collection points and advertising at universities.

Limitations to the study exist, thus creating avenues for further research. Specifically, this study highlights the need for data collection from individuals aged 65 and above as well as from regions outside the Metropolitan Area of Lisbon to gain a more comprehensive understanding of consumer behavior and knowledge. Additionally, the strategies outlined in this study are simplified and require further exploration and consideration of market specifications, frameworks, industry costs, governmental regulations, and business policies. Nevertheless, the insights into consumer e-waste recycling behaviors provided in this study can serve as a foundation for the development of respective WEEE recycling strategies.

The study can be seen as the foundation for further related research. This could include researching the effectiveness of educational interventions, the impact of age-specific strategies, and technological solutions for recycling awareness as well as the optimal placement of recycling bins. The data can also be used for comparative studies—comparing the results from Portugal with those of other countries or regions.

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