

WHY DO (W)EEE HOARD? THE EFFECT OF CONSUMER BEHAVIOUR ON THE RELEASE OF HOME ENTERTAINMENT PRODUCTS INTO THE CIRCULAR ECONOMY

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ABSTRACT

Waste electrical and electronic equipment (WEEE) continues to grow due to rising consumer demand for technologically advanced and affordable electronic products. Home entertainment (HE) products are particularly rich in metals and plastics and thus have enormous potential as a source of materials from the anthroposphere, especially from within Distinct Urban Mines (DUMs). Consumers' end-of-life (EoL) management decisions (i.e. stockpiling, hoarding, reusing, discarding of WEEE) strongly influence the exploitation potential of a DUM. This study aimed to assess the effect of consumer behaviour on the release of HE (W)EEE into the circular economy. A survey was undertaken in Southampton (Hampshire, UK) to assess perceptions and behaviours relating to the EoL management of HE (W)EEE. The study provides previously unavailable data and critical evaluation on the ownership, use and hoarding levels of HE EEE in a typical city DUM, and the reasons behind their hoarding. Results indicated that ownership levels were very high, with an average of 12 home entertainment items owned per household. This makes urban areas extremely plausible as DUMs; we estimate that there are over 1 million HE devices owned and ~440,000 HE devices hoarded in Southampton and >150 million HE EEE owned and ~61 million HE devices hoarded in UK households. Hoarding is common, especially for smaller or older equipment, due to their perceived residual value. HE product lifecycles averaged 4-5 years. The most common EoL routes were donating to relatives, friends or charities; hoarding; recycling via Household Waste Recycling Centres; or discarding items in general refuse. To encourage the recovery of EoL HE equipment in a DUM: i) convenient and accessible WEEE collection points should be established for regular (periodic) harvesting and ii) promoted via awareness campaigns and incentives.

1. INTRODUCTION

1.1 Hoarding of WEEE

The rapid technological advancements of the past decades, a growing market of affordable Electrical and Electronic Equipment (EEE) and shorter product lifespans have resulted in huge quantities of electronic waste (e-waste) being produced globally (Imran et al., 2017; Ongondo & Williams, 2012). At present, e-waste (also known as waste electrical and electronic equipment, WEEE) is one of the fastest-growing waste streams in the world, with 40-50 million tonnes being produced globally every year at an annual growth rate of 4-5% (Golev et al., 2016). WEEE poses an unavoidable waste management challenge for both developed and developing countries. Its huge global quantities,

impacts on natural resources, as well as the potential human health, environmental and ethical concerns associated with its end-of-life (EoL) management if treated through rudimentary means (i.e. 'backyard recycling'), make the sustainable management of WEEE a global issue (Baldé et al., 2015; Hursthouse et al., 2017; Lodhia et al., 2017). EEE come to their EoL when they cease to function or be of any value to their owners, at which point they become WEEE (Ongondo & Williams, 2011a).

Market forces (e.g. technological advances or fashion), consumer behaviour and product features such as their material composition, condition, or reusability stimulate the generation of WEEE in throwaway societies (van Barneveld et al., 2016; Benton, 2015). Promoting a slower rate of consumption and the reuse of EEE purchases can



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help alleviate current challenges associated with WEEE production. Indeed, reuse of products has come into fashion again (Williams & Shaw, 2017) with the emergence of the so-called 'sharing economy', in which underutilized possessions are shared (or re-sold) through peer-to-peer exchanges, enabling more efficient use of products alongside economic and social benefits (Fletcher & Dunk, 2018; Cherry and Pidgeon, 2018; Martin, 2016). In the United Kingdom, the charity retail sector is becoming an increasingly significant player in terms of demonstrating the benefits of reuse and how it can be practically realized (Osterley & Williams, 2019). Under a sustainable closed-loop circular economy, resources within WEEE such as plastics, glass and metals are recovered, ultimately reducing the need for further extraction of raw materials (Schlupe et al., 2009; Ongondo & Williams, 2012). Modern high-tech EEE such as home entertainment equipment are especially rich in metals and critical raw materials (e.g. platinum group metals and rare earth elements) and make up a large proportion of anthropogenic stocks (Massari & Ruberti, 2013; Golev et al., 2016; Williams, 2016). These secondary resources may be exploited via urban mining, helping the transition towards a circular economy (Izzat et al., 2014; Ongondo et al., 2015; Simon & Holm, 2018). Ideal locations for urban mining – known as Distinct Urban Mines (DUMs) – include urban hubs such as cities and universities, which have clear geographical boundaries, localised populations and quantifiable anthropogenic (W)EEE stocks as well as material flows (Pierron et al., 2017). Material stocks can be associated with in-use and hibernating (hoarded or stockpiled) (W)EEE in society, while material flows involve the reuse, recycling and discarding of EoL electronics (Pierron et al., 2017). To ensure the recovery of material stocks within a DUM, it is important to recognise potential hindrances to the circular flow of products and resources.

Poor recovery efforts for (W)EEE currently dictate that the majority of this waste stream is improperly disposed of, stockpiled or hoarded in society, or illegally exported to developing countries (van Barneveld et al., 2016; Imran et al., 2017; Pierron et al., 2017; Osibanjo & Nnorom, 2007). These factors generate serious environmental concerns, as they prevent the exploitation of a large proportion of material stocks, resulting in the extraction of additional natural resources to meet product demand (Ongondo & Williams, 2011a). In the EU alone, it is reported that from the 12 million tonnes of WEEE disposed of annually, only 30% is properly collected and recycled (Williams, 2016); with most small WEEE such as Universal Serial Bus (USB) sticks, mobile phones, electric toothbrushes, or lamps ending up in the general waste (Baldé et al., 2015). Consumer behaviours associated with their intent to sell, reuse, recycle, discard, or hoard (W)EEE determines the extent of an urban mine's exploitation.

Hoarding occurs when consumers indefinitely store obsolete EEE that are no longer used or wanted. This is a major barrier to accessing an urban mine and releasing exploitable materials into the CE. The average household in the United States of America (USA) hoards 4.1 small (>4.5kg) and 2.4 large electronic items in their attic or basement, mainly due to ample storage space, preventing their

recycling or reuse (Saphores et al., 2009). In Europe and the United Kingdom (UK), hoarding is common for (W)EEE with a perceived residual value (e.g. monetary, functional, sentimental), such as mobile phones (Ongondo & Williams, 2011a). Access to an urban mine primarily depends on the availability of resources for a given type of (W)EEE. Hoarded items that are currently unavailable (hibernating stocks) greatly reduce the exploitation potential of anthropogenic resources since they are stored in homes indefinitely. Ideally, (W)EEE should be stockpiled/hoarded with the intent of releasing it into the CE instead; which will ensure future access to a DUM's unexploited resource stocks. To gain insight on a DUM and facilitate a closed loop system for resource and material flows, it is essential to quantify the ownership and use levels for (W)EEE as well as the EoL practices and dispositions of consumers.

The primary aim of this study was to assess the effect of EoL consumer behaviours on the release of home entertainment (HE) (W)EEE into the circular economy. The objectives were to: i) determine the technological advances in HE EEE through time by producing evolutionary timelines for audio, visual and interactive electronic devices; ii) identify and evaluate the types and quantities of HE (W)EEE that consumers own, use and hoard; iii) establish and analyse the reasons behind consumer hoarding; and iv) evaluate and critically discuss consumer purchasing, hoarding, gifting, selling and disposing behaviours for HE (W)EEE, to establish how they might be addressed to achieve a CE.

We critically discuss findings in the context of the technological and fashion-related evolution of HE electronic products, whilst considering urban areas as a potential DUM under the framework discussed by Pierron et al. (2017), using the city of Southampton as an exemplar.

1.2 Evolution of home entertainment technologies

Since their invention, HE systems in the form of audio devices (speakers and radios), televisions, video players and games consoles have revolutionised the market economy globally. Through the decades, the growing demand for the production of electronic goods within developed economies has been gradually reinforcing the principles of a "throwaway society", which are associated with rapid product replacement and high market competition (Williams, 2016). An analysis of the evolution of HE EEE from 1861 until the present day is depicted in Appendix 1, which documents and illustrates how audio speakers, televisions and video players, and game consoles have evolved from inception to the present day. Insight on the technological advancements and fashion-related evolution of such products contributes to the understanding of current HE EEE, the relationship between manufacturers and consumers and EoL behaviours.

2. METHODS

2.1 Postal survey

Primary data was collected from residents of the city of Southampton (Hampshire, UK) via a postal survey, during the course of 3 months in January-March 2018. The design of the survey built upon the approach used in pre-

vious studies (e.g. Bergland and Matti, 2006; Timlett and Williams, 2009, Ongondo & Williams, 2011b). The self-administered questionnaire (Appendix 2) incorporated questions to: (a) assess community perceptions, behaviours, and dispositions related to the EoL management of HE (W)EEE; (b) establish the types of HE (W)EEE consumers own, use, and stockpile/hoard in their homes; and (c) determine the reasons behind these tendencies. The questionnaire sought information on respondents' demographic characteristics, household size and storage space. Respondents' dispositions and behavioural tendencies were determined to distinguish between respondents' intent to act and past actions. The survey was permitted via the University of Southampton's standard procedures for risk assessment (code FEERA 15034) and ethical approval (code ERGO II 40143).

The questionnaire was piloted among twelve participants from the target population prior to data collection, to ensure ease-of-understanding, ease-of-use, and content validity. Questions were modified as a consequence of feedback received from the pilot survey. A participant information sheet was attached to the final questionnaire to provide simple instructions and to answer potential participant queries.

Seven hundred and twenty questionnaires were hand-delivered across Southampton households within four pre-selected wards. These locations were selected to ensure a representative sample incorporating all levels of household affluence, as determined by the UK's Index of Multiple Deprivation (IMD) of 2015 (OpenDataCommunities.org, 2015). The four wards represented levels of high (Redbridge ward: 10% most deprived), average-high (Swaythling ward: 30-40% most deprived), average-low (Bargate ward: 50% least deprived) and low (Upper Shirley ward: 10-20% least deprived) deprivation within the city.

One hundred and eighty questionnaires were posted in each ward across randomly selected households and collected in person a week after delivery. To encourage a higher response rate, three collection attempts were made per household. Questionnaires were coded by ward, and household numbers were documented separately to enable future collection attempts.

2.2 Statistical analysis

The results were analysed using SPSS 20 (IBM Ltd). Non-parametric tests were applied to examine hoarding habits and reasons behind such behaviour, and compare between hoarding reasons, home entertainment (W)EEE gifting, selling and disposal routes, as well as according to respondent demographics.

A chi-square test was carried out for association between age, gender, educational level, deprivation zone, household size, household storage space and hoarding habits (whether respondents hoarded or not). Z-scores from the chi-square cross-tabulation table were compared to examine the relationship of the significant associations.

Kruskal-Wallis tests were performed to assess for a significant difference between respondent demographic variables (age, gender, educational level, deprivation zone, household size, household storage space) and

hoarding reasons (functional, social, sentimental, monetary and lack-of-awareness reasons). A series of post-hoc Mann-Whitney U tests were performed on the significant results, to examine where the significance lies within each demographic variable and hoarding reason.

A Friedman's analysis of variance test was performed to examine whether hoarding reasons differ significantly from one another. Wilcoxon signed-rank tests were applied to rank hoarding reasons in order of their influence on respondents' hoarding dispositions. A Friedman's analysis of variance test was also carried out to examine the significance between home entertainment (W)EEE gifting, selling and disposal routes. Wilcoxon signed-rank tests were subsequently applied to rank the gifting, selling and disposal routes in order of likelihood of opting for each route, as indicated by survey respondents.

3. RESULTS

A total of 139 useable questionnaires were collected (19% response rate). The results of the survey are presented in the following sections. Respondent behaviours (previous past actions; sections 3.1 and 3.2) and dispositions (intent to act; section 3.3) have been analysed separately, to differentiate between past consumer hoarding practices and behavioural tendencies. The results were broadly representative for each deprivation zone and gender, although more respondents from the younger age groups completed the survey than from the older (61% of respondents were 18-24 and 25-44 years, whereas only 12% of respondents were 65+ years).

3.1 Behaviours and practices

All respondents owned and used at least one HE EEE. Of those, approximately 75% hoarded home entertainment electronic products that they no longer wanted or used, 60% gifted, sold or disposed (GSD) of at least one HE electronic product since 2012, and 42% GSD of a HE electronic product since 2015.

Respondents owned more HE electronics than they used in every product category (Figure 1). Most respondents owned at least one TV (96%), audio device (89%), video player (62%), and Nintendo game console (62%). Of those, the most commonly owned products were Plasma TVs (81%), portable speakers (65%), Smart TVs (60%), radios (54%), DVD players (50%) and the Nintendo Wii (42%). Smart TVs had the highest use-to-ownership ratio. No respondents used their black and white TV. Overall, products that accompanied TV sets (e.g. video players, TiVo & set-top boxes, or audio devices) had higher ownership and use rates than most game consoles. The Nintendo Wii and DS had the highest game console ownership rates, yet they also had the smallest use rates. The Sony PlayStation 4 had the highest use-to-ownership ratio for game consoles. The HE categories with the lowest ownership rate were black and white TVs and virtual reality (VR) sets.

On average respondents owned 2.8 TV sets (1.6 Plasma TVs, 1 Smart TV), 1.4 video players, 1.1 TiVo and set-top boxes, 2.6 audio entertainment devices (1.1 portable speakers) and 0.2 game consoles, with a total of 11.8

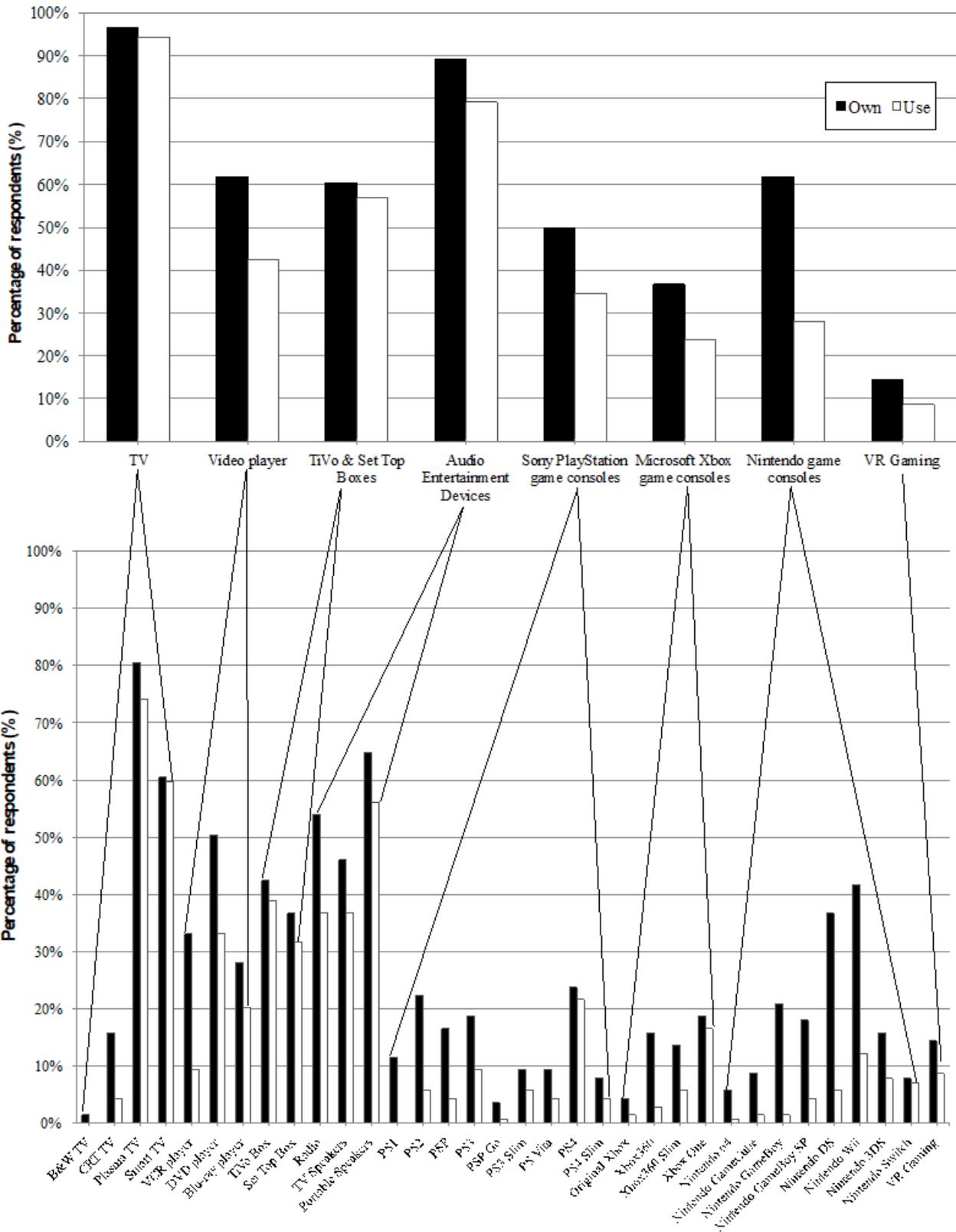


FIGURE 1: Proportion of respondents owning and using at least one home entertainment electronic product in Southampton in 2018 (n=139).

HE devices owned per household. The products with the highest proportion of multiple devices were plasma TVs (43%), portable speakers (27%), radios (20%) and smart TVs (19%). The game console with the highest proportion

of multiple devices was the Nintendo DS (10%).

Almost all respondents (97%) purchased their HE EEE through an electronics retailer as brand new products, and approximately a quarter of respondents were gifted HE

products. Only a small minority of respondents opted to purchase second-hand EEE (i.e. from eBay, CeX shop, second-hand shop - Table 1).

Since 2012, 81% of respondents had purchased new HE products in addition to what they already owned (not as replacements - Table 2), and 19% had only purchased new products to replace their old ones. The most common additionally purchased products were TVs (60%) and specifically smart TVs (37%), followed by Sony PlayStation game consoles (see Appendix 3 for a complete breakdown of additionally purchased products). Almost no respondents had purchased additional audio entertainment devices.

Most respondents (60%) reported not planning any HE EEE purchases for 2018. The rest indicated plans of purchasing new TVs (mostly smart TVs), Sony PlayStations (mostly PlayStation 5), VR gaming sets and Set-Top Boxes (Table 3).

Approximately 60% of respondents had gifted, sold or

disposed (GSD) of at least one HE electronic item since 2012 (5 years ago) and 42% had GSD of items since 2015 (2 years ago). TVs were the most commonly GSD of devices in both instances, followed by audio entertainment devices and Nintendo game consoles (Figure 2).

Specifically, plasma TVs, radios, and Nintendo Wii consoles were the most frequently GSD of HE electronic products. The majority of respondents had gifted products to family and friends, taken them to Household Waste Recycling Centres (HWRCs), or thrown them out via general waste bin (Table 4). It was common for relatively newer models of EEE such as plasma TVs or PlayStation 3 consoles to be gifted to family or friends, whereas older products such as black and white TVs, CRT TVs and VCR players to be taken to HWRCs.

The majority of respondents (39%) reported gifting, selling or disposing of new/relatively new HE EEE because they wanted a more up-to-date model (Table 5). Respond-

TABLE 1: Respondents' purchasing options for home entertainment electronics in Southampton in 2018 (n=139).

Purchasing Options	Number of respondents (N)	Proportion of respondents (%)
Electronics retailer	134	96.4
Second-hand shop	5	3.6
CeX shop	4	2.9
Gifted from family and friends	35	25.2
Bought from family and friends	13	9.4
eBay	1	0.7

TABLE 2: Home entertainment (HE) electronic products additionally purchased (not purchased as replacement products) by respondents since 2012 (n=138).

HE EEE Categories	Number of respondents (N)	Proportion of respondents (%)
TV	82	59.4
Video Player	11	8.0
TiVo & Set-Top Boxes	25	18.1
Audio Entertainment Devices	42	0.1
Sony PlayStation game consoles	28	20.3
Microsoft Xbox game consoles	15	10.9
Nintendo game consoles	16	11.6
VR Gaming	5	3.6
Other	3	2.2
No additional items bought (only replacements)	26	18.8

TABLE 3: Respondents' planned purchases for home entertainment (HE) electronic products in 2018 (n=139) products) by respondents since 2012 (n=138).

HE EEE Categories	Number of respondents (N)	Proportion of respondents (%)
TV	27	19.4
Video player	0	0.0
TiVo & Set-Top Boxes	11	7.9
Audio Entertainment	9	6
Game consoles & VR	26	18.7
Other	5	3.6
Not planning on purchasing anything	83	59.7

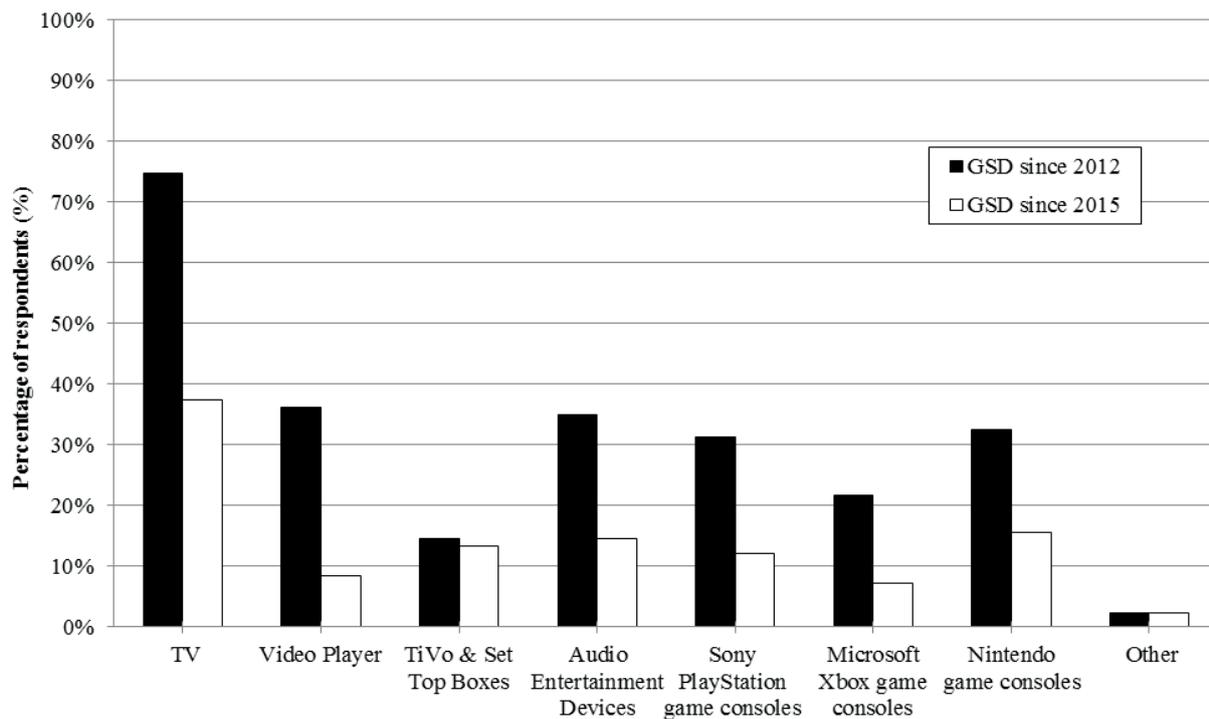


FIGURE 2: Proportion of respondents who gifted, sold or disposed (GSD) of home entertainment electronics of since 2012 and 2015.

ents also commonly disposed of HE products because they did not need them anymore.

3.2 Hoarding practices

Overall, 75% of respondents reported hoarding HE EEE, of which 55% and 32% (respectively) were also storing vide-

otape and DVD products that they no longer used or wanted (Table 6). A high proportion of respondents hoarded game consoles and audio entertainment devices (Figure 3). The most commonly hoarded items were videotape products (42% of respondents hoarded at least one), Nintendo DS consoles (31%), Nintendo Wii consoles (29%), VCR Play-

TABLE 4: Gifting, selling and disposing routes for end-of-life (EoL) home entertainment (HE) electronics (n=83).

EoL routes of HE EEE	Number of respondents (N)	Proportion of respondents (%)
Sold online	6	7.2
Gave to family or friends	57	68.7
Sold to CeX shop	7	8.4
Threw out via general waste bin	14	16.9
Sold to family or friends	3	3.6
Gave to charities	10	12.0
Dumped away from house	1	1.2
Gave away via online free recycling	0	0.0
Took to HWRC	24	28.9
Left outside house	8	9.6
Threw out via recycling bin	12	14.5

TABLE 5: Reasons for gifting, selling and disposing of end-of-life home entertainment electronics (n=83).

Reasons	Number of respondents (N)	Proportion of respondents (%)
The item was dated and broken and needed replacing	17	20.5
The item was working properly, but I wanted a more up-to-date model	32	38.6
The item was new/relatively new but had stopped working and needed replacing	2	2.4
I was gifted a more up-to-date model	9	10.8
I decided I did not need it nor did I need a replacement	23	27.7

TABLE 6: Respondent responses on the ownership and use of videotape and DVD products (n=104).

Responses	Videotape products		DVD products	
	No. of respondents (N)	Proportion of respondents (%)	No. of respondents (N)	Proportion of respondents (%)
Yes, and I still use them	15	13.9	64	59.3
Yes, and I no longer want them	59	54.6	34	31.5
No, I have given them all away	34	31.5	10	9.3
Total	108	100.0	108	100.0

ers (24%), Nintendo GameBoy consoles (19%), DVD players (17%), PlayStation 2 consoles (17%) and radios (17%) (Figure 2). On average respondents hoarded 1.5 Nintendo consoles, 0.8 Sony PlayStation consoles and audio devices, and 0.6 TVs and video players, with a total of 4.8 HE devices hoarded per household. The products with the highest proportion of multiple hoarded devices were Nintendo DS consoles (9%), portable speakers (7%) and radios (7%).

The functional value ('I may need it someday') placed on HE EEE is the most important factor influencing respondent hoarding habits (Figure 4). Both sentimental ('I'm too attached to the item') and social ('One day I'll find someone to give it to, who will really want it') reasons for hoarding ranked as second most important influencing factors. Approximately 45% of respondents agreed that lack-of-awareness (LoA) of what else to do with the item was an important influencing factor for hoarding of HE electronics. Monetary reasons for hoarding ('I paid too much money just to get rid of it') were ranked the least important hoarding factor.

3.3 Dispositions, tendencies and opinions

The functional value ('I may need it someday') placed on HE EEE was the most important influencing factor for

respondent hoarding tendencies (Figure 5). For hoarding tendencies, social reasons to hoard ('One day I'll find someone to give it to, who will really want it') were ranked higher than sentimental reasons ('I'm too attached to the item'). Lack-of-Awareness ('I don't know what else to do with it, so I keep it') was ranked third most important influencing factor alongside sentimental hoarding reasons. Monetary reasons were ranked as the least important influencing factor for respondent hoarding tendencies.

When gifted a new HE electronic product, the majority of respondents indicated that they would keep both the old and newly gifted products, signifying a tendency to hoard (Figure 6). More than half of respondents also reported that they would get rid of the old product once gifted a newer model. Hardly any respondents reported that they would keep the old product and dispose of the newly gifted model.

Similar to hoarding practices vs. tendencies, the gifting, selling and disposing tendencies of HE electronics were also examined to ensure responses from all participants (n=139), including the ones who hadn't previously gifted, sold or disposed of products (n=53). When examining respondent tendencies on the EoL management routes, the majority of respondents (86%) reported that they would opt

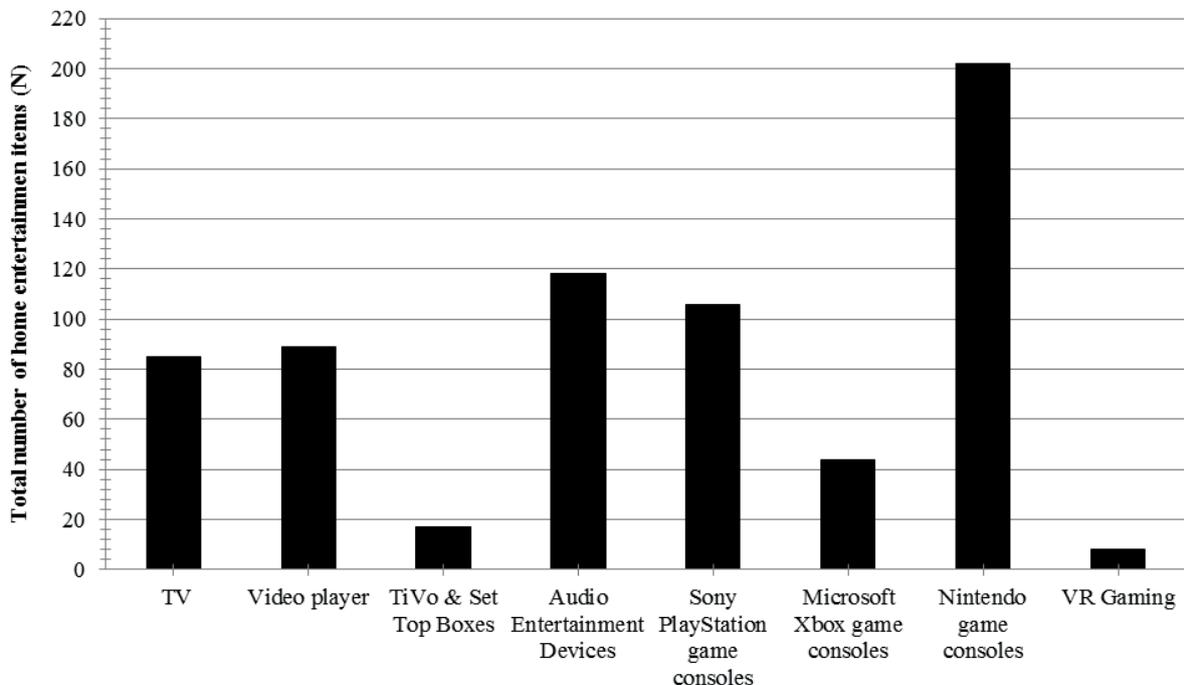


FIGURE 3: Total number of home entertainment items hoarded by respondents (n=104).

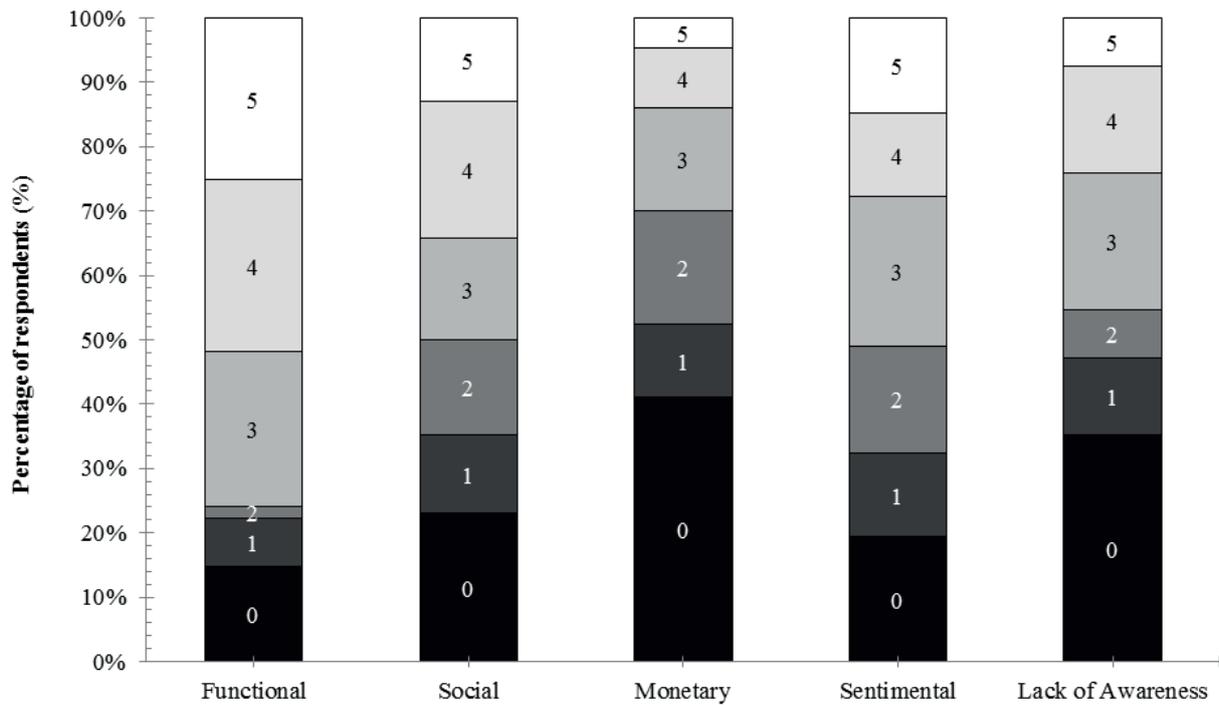


FIGURE 4: Reasons influencing respondent hoarding practices (Proportion of respondents who disagree: 0, to completely agree: 5, n=104).

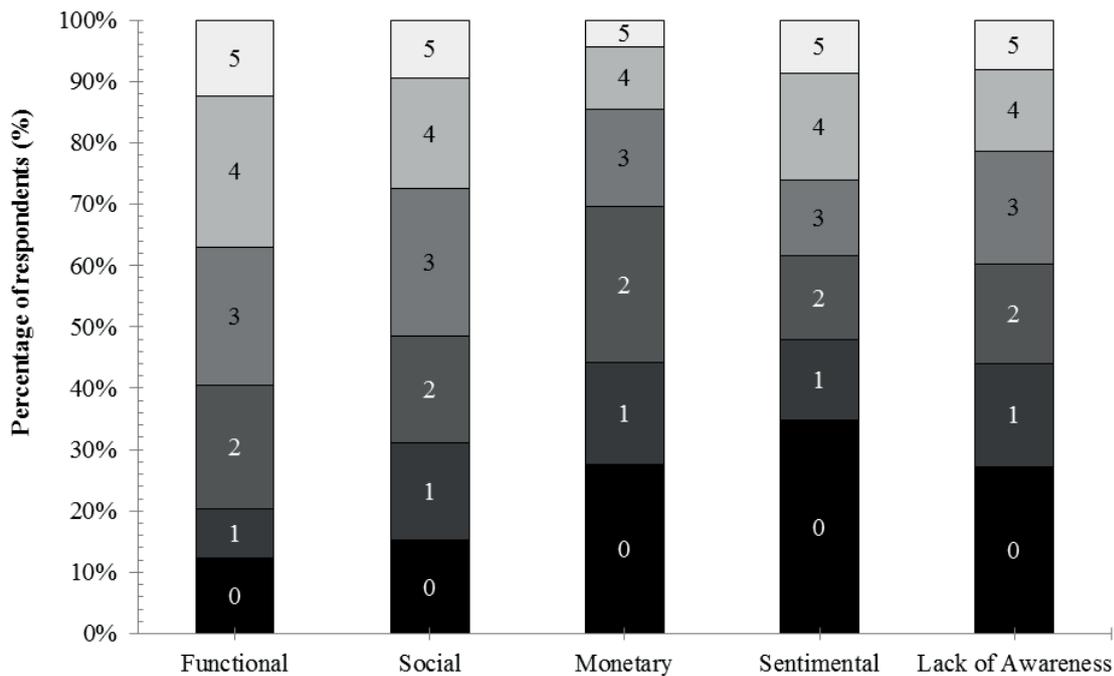


FIGURE 5: Reasons influencing respondent hoarding tendencies (Proportion of respondents who disagree: 0, to completely agree: 5, n=139).

to 'give away' their products, first to family and friends, and then to charities (Figure 7). Respondents would sell their unwanted EEE as their second most common EoL management option, with 49% opting to sell items online, 30% to friends and family and 23% to a reuse shop (e.g. CeX).

The third most common route for respondents' EoL management tendencies was recycling of WEEE, with approximately 38% opting to take them to a HWRC, 25% using

online recycling and 20% throwing them out via recycling bin (Figure 7). Fewer respondents reported tendencies of throwing WEEE out via general waste bin, or leaving them outside/away from their house.

When it came to purchasing HE electronics, 74% of respondents agreed that they would wait for their EEE to stop working before purchasing a newer model; 61% agreed that they would wait for their EEE to become dated before mak-

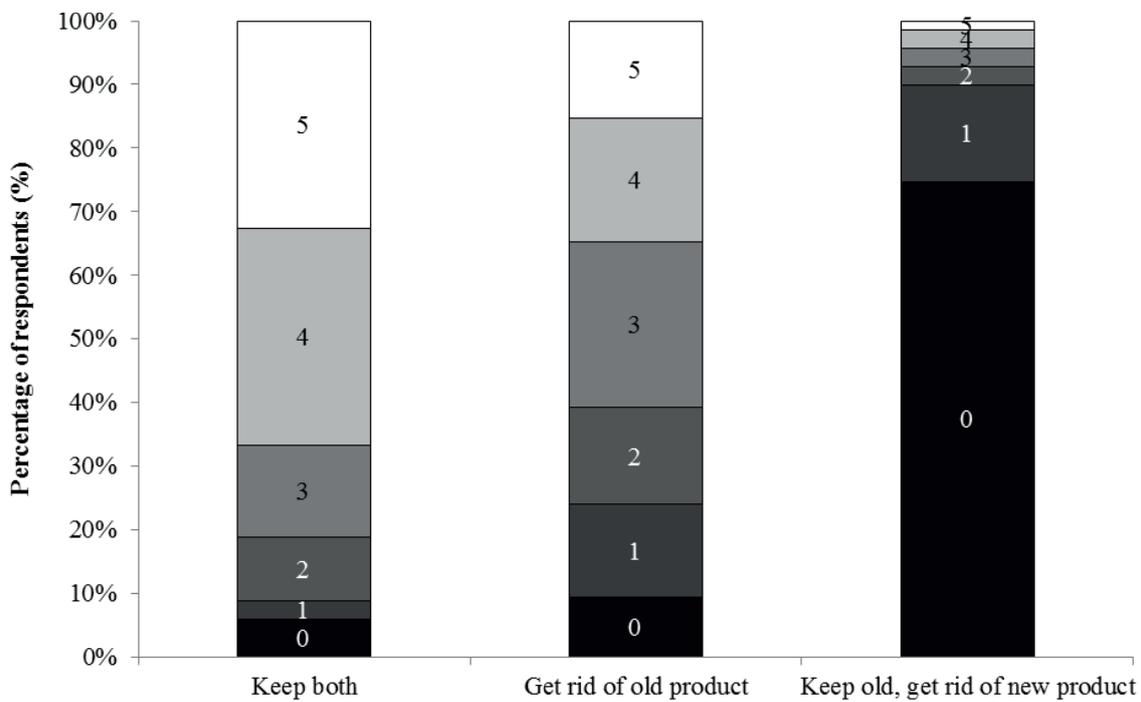


FIGURE 6: Respondent tendencies for the end-of-life management of their old home entertainment electronic products when gifted a newer model (Proportion of respondents who disagree: 0, to completely agree: 5, n=139).

ing a new purchase; and 37% agreed that they like to purchase the newest model of HE equipment that is currently on the market. Around 16% of respondents agreed that if they kept their HE EEE for long enough, their monetary value would increase. The majority of respondents (89%) would not dispose of their TV and only use their phone or tablet, even though 30% of them claimed to watch television via their phone or tablet more often than via their TV.

Based on replacement cycles, the most lifecycle of HE products was 4-5 years (Figure 8). No respondents believed that TVs and game consoles should be replaced every year, and just a small proportion (2.2%) would replace their products only once they stop working.

3.4 Demographic characteristics and hoarding

A statistically significant association was found between respondent age groups and hoarding (whether someone hoarded or no - Table 7) at the 0.05 level with a p-value of 0.019. Statistically fewer respondents than expected from the age group of 25-44 years hoarded, and statistically more respondents than expected from the age group of 45-65 years hoarded HE WEEE. No association was found between all other demographic variables (gender, deprivation level, educational level, household size and storage space) and hoarding habits.

A statistically significant difference was determined between hoarding reasons (i.e. functional, social, sentimental, monetary and lack of awareness) at the 0.05 level (DF=4, p-value<0.0005). It was determined that significantly more respondents considered functional reasons ("I may need it someday") as important influencing factors for hoarding when compared to all other hoarding reasons (Table 8). Fewer respondents rated monetary reasons as important

influencing factors for the hoarding of HE EEE, habits when compared to functional, social and sentimental reasons.

A statistically significant difference was found between respondent's age group and two of the five hoarding reasons, namely monetary and lack-of-awareness (LoA) reasons (Table 9). Significantly more respondents from the youngest age group (18-24 years) considered LoA as an important influencing factor for hoarding, compared to all other age groups (Table 10). Similarly, significantly more respondents from the younger age groups (18-24 and 25-44 years) agreed that monetary reasons influenced their hoarding of HE (W)EEE when compared to the 65+ age group. No significant difference was found between all other demographic variables and hoarding reasons.

3.5 End-of-life routes

A significant difference was found between the EoL management routes of gifting, selling and disposing at the 0.05 level (DF=10, p<0.0005). Significantly more respondents would opt for giving to family and friends as their primary EoL management route. Similarly, more respondents would choose for giving to charities, selling online and taking HE (W)EEE to the HWRC as their second, third and fourth EoL management routes. Overall, no significant difference was found between all other routes (e.g. selling to CeX, throwing out via recycling bin, etc.).

4. DISCUSSION

4.1 Evolution of HE electronics

HE electronics have evolved from analogue to digital, to 'smart' and interactive technologies. The timelines (Appendix 1) show that although consumer-based audio and

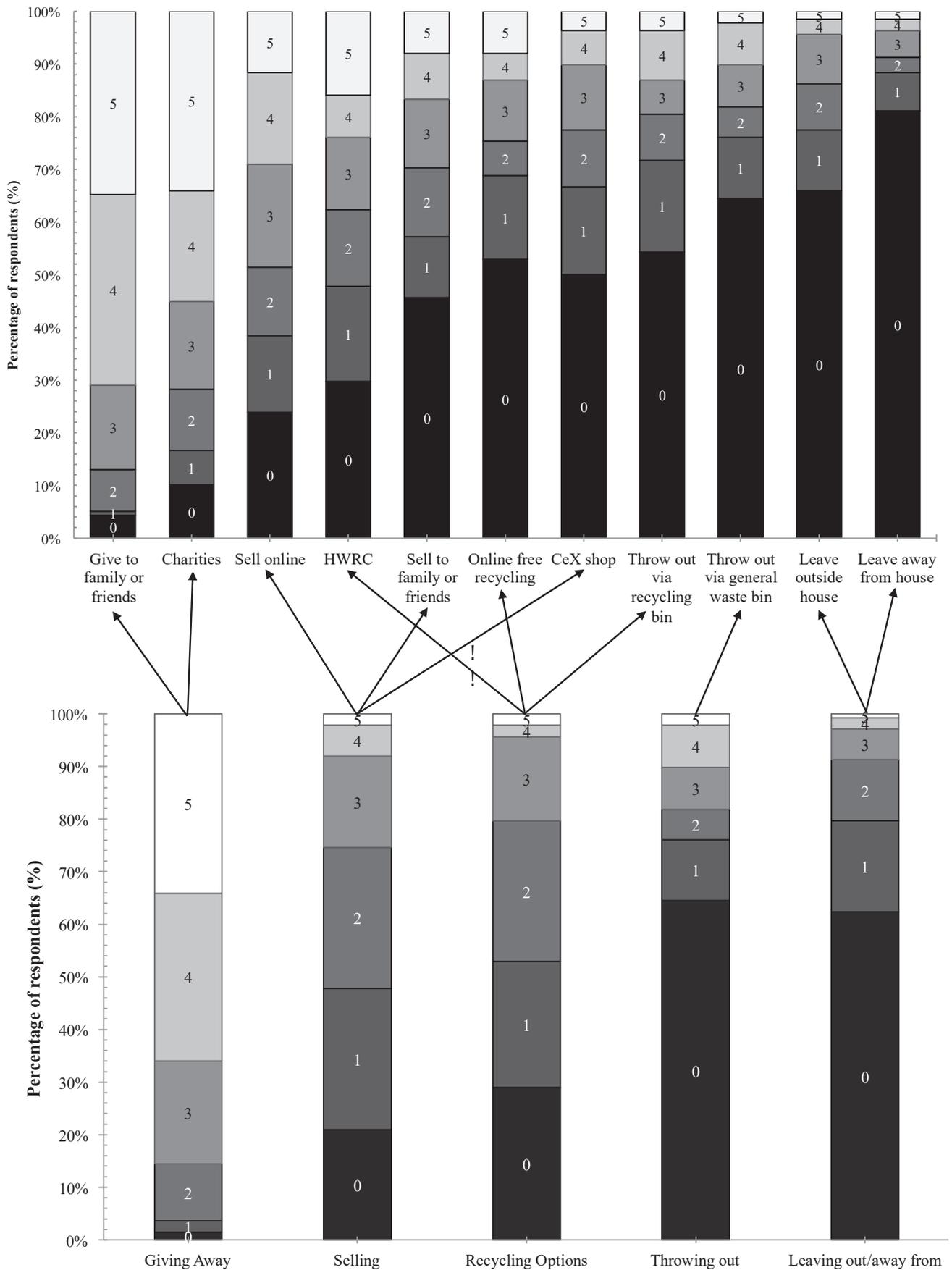


FIGURE 7: Respondent thoughts on the GSD routes of end-of-life management of home entertainment EEE (Proportion of respondents who disagree: 0, to completely agree: 5, n=139).

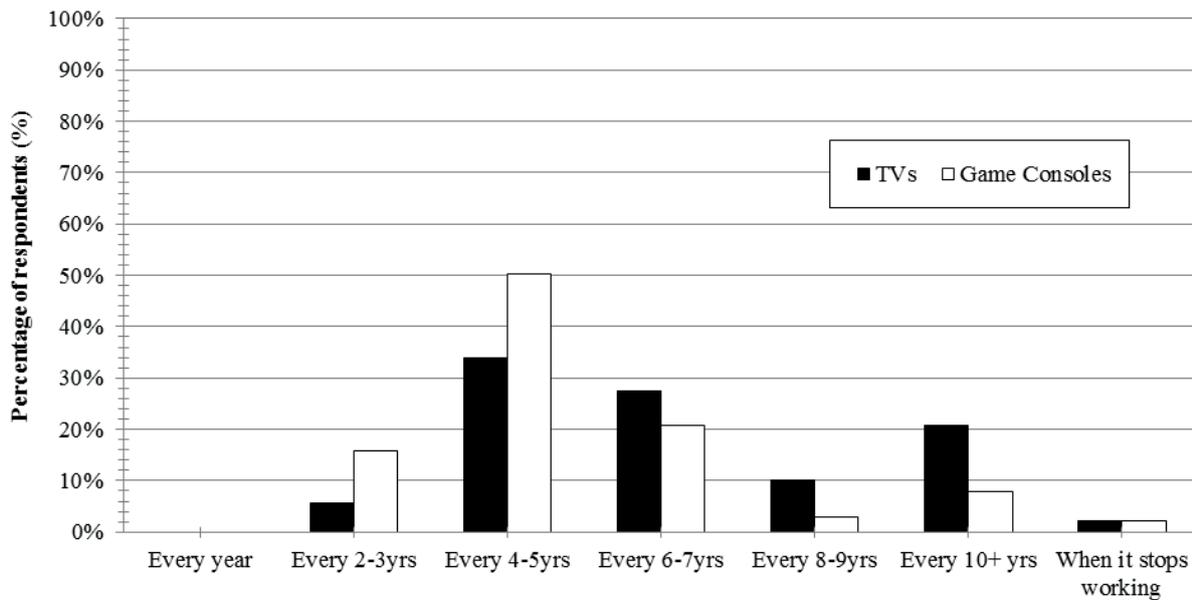


FIGURE 8: Appropriate replacement time for home entertainment electronics (years) (n=139).

television technologies were emerging in the early 1900s, their production flourished after WWII when HE products became a staple in consumer households. Technological advancements were accompanied by growing consumer demand and competition between manufacturers for market dominance. It wasn't until the 1980s when the industry properly manifested itself into a consumer-oriented economy, following the onset of the first compact disc players, video recorders and games consoles, which sold countless of units worldwide (Kang & Schoenung, 2005). At that time, many companies that previously dominated the market like RCA or Atari were replaced by emerging companies such as Sony, Nintendo and Samsung. These new companies

transformed HE EEE into an essential part of consumers' lives. Since the 1980s, features and capabilities of EEE have evolved using cheaper materials, while manufactured under higher technological standards and complexity (Kang & Schoenung, 2005). Shorter product lifespans and quicker adoptions of new technologies have triggered subsequent upsurges in electronic waste (McCollough, 2009; Ongondo & Williams, 2011a). Similar to the replacement of analogue technologies by digital devices during the digital switchover of 2012, it can be predicted that the increase in purchases of affordable 'smart' technologies that begun in 2015 will result in the replacement of digital devices like plasma/LCD TVs or DVD players in the near future (Ongondo et al., 2011b).

TABLE 7: Chi-square results for association between age groups and hoarding habits for home entertainment WEEE (n=139).

	Hoarded	Not hoarded	Total
18-24 years	38	9	47
	35.2	11.8	
	1.2	-1.2	
25-44 years	22	16	38
	28.4	9.6	
	-2.8	2.8	
45-64 years	33	5	38
	28.4	9.6	
	2.0	-2.0	
65+ years	11	5	16
	12	4	
	-0.6	0.6	
Total	35	104	139

Chi-square= 9.914, DF=3, p-value= 0.019

For all age groups, top row figures are observed counts, middle row are expected counts, and bottom row are residual Z-scores. For Z-scores a value of >1.96 indicates statistical significance.

In current 'throwaway societies' consumers often replace EEE because they are no longer attracted to/satisfied by them (fashion obsolescence), or because a technologically superior product is introduced on the market (technological obsolescence) (McCollough, 2009). The concept of obsolescence is reflected in this study's results since the majority of respondents discarded HE EEE that were working properly because they wanted a more up-to-date model (Table 5). The concept of planned product obsolescence driven by manufacturers who knowingly produce 'disposable goods' to promote repetitive consumption is often discussed in current literature (Williams, 2016; McCollough, 2009; Ongondo & Williams, 2011a). However, findings from this study show that less than 3% of respondents discarded items that were new but had stopped working (Table 5), indicating that fashion and technological obsolescence were more prevalent across the surveyed sample instead. On average, respondents replaced game consoles more frequently than TVs, suggesting that planned obsolescence is more common amongst smaller HE devices (i.e. game consoles) rather than larger products such as TVs.

To achieve sustainable consumption under a CE and enhance resource efficiency, product lifespans must be

TABLE 8: Chi-square results for association between age groups and hoarding habits for home entertainment WEEE (n=139).

	Social	Sentimental	Monetary	Lack of Awareness
Functional	52	56	72	67
	24	23	13	23
	32	29	22	18
	-3.771	-3.334	-6.165	-4.310
	0.000	0.001	0.000	0.000
Social		45	48	50
		40	20	32
		23	39	26
		-0.104	-4.169	-1.797
		0.917	0.000	0.072
Sentimental			56	47
			21	31
			30	30
			-3.912	-1.819
			0.000	0.069
Monetary				27
				46
				34
				-1.859
				0.063

Series of Wilcoxon tests assessing significant differences between all hoarding reasons at the 0.005 level.

For each hoarding reason, the top-row figures are negative ranks (times that value of column < row). The second-row figures are positive ranks (times that value of column > row). The third-row figures are the rank ties (times that value of column = row). The fourth-row figures are the Z-scores (based on positive ranks) for each Wilcoxon test. The bottom row figures are the p-values for each Wilcoxon test; figures of 0.000 indicate a p value <0.0005.

extended through the use of more durable materials, while the standardisation of product size, shape and location of components will aid dismantling, prolong use and reuse, and ensure material recovery (Long et al., 2016). Current manufacturing techniques are driven by consumer demands and changes in fashion, making modern electronics challenging to disassemble and recover. To encourage the repair and reconditioning of HE EEE rather than their replacement, the cost of repair should be made cheaper than the purchase of new products (McCollough, 2009). Consumer perceptions on the stigma around the 'poorer quality' of reused, repaired or recycled products compared to new electronics should also be broken (Lin & Huang, 2012; Long et al., 2016).

TABLE 9: Results of Kruskal-Wallis test for statistical significance between age groups and hoarding reasons (n=139)

Functional	Social	Sentimental	Monetary	Lack of Awareness
3.537	0.667	4.348	9.284	18.524
0.316	0.881	0.226	0.026	0.000

DF=3, $\alpha=0.05$

Top row figures show the Kruskal-Wallis H, and the bottom row figures are the p-values; figures of 0.000 indicate a p value <0.0005.

TABLE 10: Results of Mann-Whitney U tests comparing between age groups and the monetary and lack-of-awareness hoarding factors (n=139).

	Monetary	Lack of Awareness
18-24 and 25-44 years	418.000	246.000
	-0.656	-3.282
	0.512	0.001
18-24 and 45-64 years	544.500	359.000
	-1.012	-3.320
	0.312	0.002
18-24 and 65+ years	97.500	85.000
	-2.719	-3.026
	0.007	0.002
25-44 and 45-64 years	336.000	422.500
	-1.422	747.500
	0.155	0.967
25-44 and 65+ years	62.000	120.500
	-2.728	-0.620
	0.006	0.535
45-64 and 65+ years	121.500	164.000
	-1.886	-0.656
	0.059	0.512
Total	35	104

For each age group pair, the top row figures show the Mann-Whitney-U H value, the middle rows are the Z-scores, and the bottom rows are the p-values; figures of 0.000 indicate a p value <0.0005.

4.2 Ownership and hoarding of HE electronics

4.2.1 Ownership levels

Ownership levels for EEE in economically developed nations have increased considerably over the past few decades, transforming cities into hugely exploitable potential DUMs (Pierron et al., 2017). The availability of EEE from in-use and hibernating stocks will affect the exploitability of a mine (Ongondo et al., 2015; Pierron et al., 2017). Ownership levels for HE EEE in the surveyed zones of Southampton were high; with an average of 12 and a maximum of 45 devices found per household. These results are translated into estimates for the exploitation potential of DUMs at local and national levels in Table 11. Overall, we estimate that there are over 1 million HE devices owned and ~440,000 HE devices hoarded in Southampton; scaling up these data suggests that there are >150 million HE EEE owned and ~61 million HE devices hoarded in UK households. The estimations reported in Table 11 may not be entirely representative at a national level due to the survey's small sample size but they provide a realistic order of magnitude value that shows the potential country-wide opportunity for circular economy resource mining. The results are broadly representative of Southampton since the city was randomly sampled across four different deprivation zones.

Almost all survey respondents owned at least one TV, TV-related item (i.e. video player, TiVo, set-top box) and an audio entertainment device (Figure 1). On average, each surveyed household owned 2.8 TV sets, 2.6 audio enter-

TABLE 11: Total number of home entertainment items owned and hoarded on average in Southampton and the United Kingdom (UK) (estimated from survey results).

Home Entertainment EEE	Southampton*		UK**	
	Owned	Hoarded	Owned	Hoarded
TVs	254,620	55,780	35,450,360	7,766,187
Video players	124,685	58,405	17,359,712	8,131,655
TiVo & Set Top Boxes	97,123	11,156	13,522,302	1,553,237
Audio Entertainment Devices	240,839	77,436	33,531,655	10,781,295
Sony PlayStation game consoles	121,404	69,561	16,902,878	9,684,892
Microsoft Xbox game consoles	54,468	28,874	7,583,453	4,020,144
Nintendo game consoles	173,247	132,560	24,120,863	18,456,115
VR Gaming	13,781	5,250	1,918,705	730,935
Total	1,080,167	439,023	150,389,928	61,124,460

*HCC (2008) **ONS (2016)

tainment devices, 1.4 video players, and 1.1 TiVo/set-top boxes. These findings broadly correspond with those reported by BARB (2018) and the Energy Saving Trust (2012), where 95.4% of households were considered 'digital/interactive TV homes' in 2018, with the average UK household owning 2.0-2.3 TV sets. Overall, ownership of game consoles was less common among respondents compared to TV-related equipment, although more common amongst the younger age groups. The most frequently owned game consoles were the Nintendo Wii, DS and PlayStation 4 (Figure 1). A UK-wide survey by Statista (2018) determined that 36% of consumers claimed to own at least one game console in 2017, of which the majority reported owning a Nintendo Wii and an Xbox360. The slight higher value of game console ownership from this study is probably due to the higher proportion of younger demographic that completed the survey. The study's findings indicated that the Nintendo Wii was the most frequently owned game console, which is in line with the Statista's survey results.

Determining ownership levels and use patterns is essential when evaluating the potential of DUMs. Knowledge gained can also assist in estimating the scale and types of soon-exploitable resources at both local and national levels. This way, waste-processing infrastructure can adapt their technological capacities to efficiently recover

the soon-available EEE types (Ongondo et al., 2015). The findings of this study can be used to give a broadly representative idea of the extent of ownership of HE EEE across Southampton and UK households (e.g. over 12 million UK households own at least one TV, and almost 8 million own at least one Nintendo game console; See Table 12).

4.2.2 Hoarding levels

Stockpiled and hoarded HE electronics represent currently inaccessible, high-grade, hibernating stocks, especially rich in metals (Golev et al., 2016). Similar to ownership, hoarding levels of HE EEE provide information on the scope of urban stocks and help map out the complete exploitation potential of a DUM. Hoarding of HE electronics was clearly evident in the surveyed zones of Southampton, with 75% of respondents claiming to have hoarded at least one type of HE device. Tables 11 and 12 translate hoarding levels into an estimate of the 'hibernating' stocks available locally and nationally, assuming that the survey results are representative. We predict that an average of 450,000 HE electronic devices are hoarded in Southampton and that over 61 million are hoarded across the UK (Table 11). We estimate that 71,530 Southampton households and almost 10 million UK households hoard at least one HE item, with at least 5 million households hoarding at least one TV,

TABLE 12: Total number of households owning and hoarding at least one home entertainment item across surveyed zones, including estimations for Southampton and the UK.

Home Entertainment EEE	Surveyed Zones		Southampton*		UK**	
	Owning	Hoarding	Owning	Hoarding	Owning	Hoarding
TVs	134	52	87,936	34,124	12,243,165	4,751,079
Video players	86	53	56,437	34,781	7,857,554	4,842,446
TiVo & set top boxes	84	16	55,124	10,500	7,674,820	1,461,871
Audio entertainment devices	124	58	81,374	38,062	11,329,496	5,299,281
Sony PlayStation consoles	69	47	45,281	30,843	6,304,317	4,294,245
Microsoft Xbox consoles	51	28	33,468	18,375	4,659,712	2,558,273
Nintendo game consoles	86	71	56,437	46,593	7,857,554	6,487,050
Virtual reality gaming	20	8	13,125	5,250	1,827,338	730,935
Total	139	109	91,217	71,530	12,700,000	9,958,993

*HCC (2008) **ONS (2016)

video player and game consoles (Table 12). The hoarding levels reported in Table 12 assume that each household only hoards one HE item from each product category, yet the survey results indicate that 20-36% of respondents actually hoarded more than one audio entertainment device, PlayStation and Nintendo game console, and 14% hoarded more than one TV. This suggests that the number of devices hoarded in reality across UK households could be closer to the estimates shown in Table 11.

The survey indicated that the most commonly hoarded electronics were videotapes (VHS, Betamax), DVDs, Nintendo game consoles (DS, Wii and GameBoy), VCR players, DVD players and radios (Figure 3). The results show that game consoles were owned less frequently than TV sets, yet hoarded more. The most commonly hoarded items were smaller HE equipment (i.e. videotapes, DVDs, Nintendo DS etc.). This corresponds to other research that also determined the higher likelihood of storing small EEE (Darby & Obara, 2005; Ongondo et al., 2011b). The hoarding of non-digital devices (i.e. videotape products; VCR players) could potentially be explained by the lower level of consumer awareness on the effect of the digital switchover on VCR players, which led to their stockpile once the switchover was complete (Ongondo et al., 2011b). The electronic items hoarded the least (i.e. smart TVs, Nintendo Switch, Xbox One and PlayStation 4 game consoles) were relatively new models of HE electronics (less than five years old) that may yet be hoarded in the future.

Understanding the reasons behind consumer hoarding of HE EEE is very important when considering their EoL management, to tailor collection and take-back facilities in a way that addresses and alleviates hoarding barriers. In this study most respondents illustrated a significant tendency to hoard, mainly due to the attributed residual functional value they placed on HE EEE ("I may need it someday"), followed by their perceived social value ("One day I'll find someone to give it to, who will really want it") (Figure 5). This is reflected in other studies, where respondents stockpiled old (W)EEE mainly as 'back-ups' or with the aim of giving them to someone else (Ongondo et al., 2015; MFE, 2006; Ongondo & Williams, 2011a). Sentimental reasons to hoard were ranked more highly when respondents recalled past behaviours than when they reported on their hoarding dispositions, suggesting that consumers become attached to electronic products more often than they think they do. A significantly higher proportion of the younger age groups (18-24 years) considered lack-of-awareness (LoA) and product cost as important reasons to hoard their unwanted EEE (Table 10). Other studies reflected similar results, where the price of EEE and LoA were important influencing factors for stockpiling and EoL decisions of younger consumers (see Ongondo & Williams, 2011a; MFE, 2006; Ylä-Mella et al., 2015; Li et al., 2012; Pierron et al., 2017).

4.3 Current end-of-life EEE management practices

In the case of purchasing HE electronics, the majority of respondents would wait for a product to become dated/stop working before they purchased a newer model. More than a third of respondents were influenced by fashion and technological obsolescence, as they liked to purchase

the newest models on the market. Almost all respondents purchased their new products from electronic retailers, rather than second-hand shops, reinforcing the concept discussed by Long et al. (2016) on the perceived inferior quality of reused, repaired or recycled products. Recent purchasing habits commonly involved acquiring new smart TVs, portable speakers or PlayStation 4 consoles. These findings are in line with 2017 sales figures, where 82%, 74% and 76% of the market-share was attributed to smart TVs, PlayStation 4 consoles and portable speakers, respectively (J'son & Partners, 2017; D'Angelo, 2017; Business Wire, 2017).

The study indicated that when HE products were in working condition but of no use to their owners, they were most frequently given to relatives and friends or donated to charities. This decision can be attributed to the residual functional value assigned to HE products, which can be beneficial in prolonging the products' lifetime and encouraging reuse. Respondents also reported a disposition to sell their unwanted EEE online, or take them to HWRCs. The disposition to recycle EEE was evident among respondents, yet their disposal habits reflected a higher probability of discarding items via general refuse. Ongondo & Williams (2011a) determined that consumers tend to send bulkier items to HWRCs, while medium-sized items with residual value (such as HE electronics) are donated to charities or given to friends and family, which match this study's findings. Broken equipment or smaller items such as remote controls or game console handsets usually do not warrant a trip to the HWRC and are most often hoarded or disposed of in the general waste (Ongondo & Williams, 2011a; Pierron et al., 2017). It was also evident that respondents' perceived residual value of (W)EEE would cease once products became very dated or were broken.

The average replacement time for HE electronics was 4-5 years, with game consoles being replaced slightly sooner than TVs. Unless hoarded, this makes the majority of HE EEE purchased since 2012 soon-exploitable resources within a DUM. HE equipment lifecycles are also illustrated through respondents' purchasing and disposal habits. The majority of respondents had purchased additional HE products in the last 5 years, as well as disposed of old electronics, demonstrating a clear average 5-year lifecycle. These findings match the current literature, which suggests that most EEE are discarded within 3 to 6 years (Hursthouse et al., 2017; Ongondo et al., 2015; Cooper, 2002).

4.4 Distinct Urban Mine potential

The high ownership levels for HE electronics in Southampton make it an extremely plausible metal-specific DUM, abundant in ferrous metals, aluminium, copper and plastics (Haig et al., 2012). Its potential as a DUM is strongly influenced by the public's decision to hoard or dispose of their (W)EEE. Reuse and recycling are positive decisions for accessing the DUM whereas discarding and hoarding prevent the recovery of resources. It is essential to incorporate information on the EoL decisions of consumers into waste management efforts. Access to an urban mine is closely related to the prevention of stockpiling and thus the willingness of consumers to give up their products (Ongon-

do et al., 2015; Li et al., 2012). Promoting the collection and recycling of (W)EEE through awareness campaigns could help consumers associate EoL electronics with material recovery, and deter from their perceived residual value. Awareness campaigns can also be applied to improve public knowledge on the disposal methods for HE (W)EEE, by providing information on collection centres and schemes. To encourage recycling behaviour, recovery schemes must incorporate more accessible and convenient collection points, with proximity to commonly visited urban hubs (e.g. transport hubs or shopping precincts) (Ylä-Mella et al., 2015; Morris & Metternicht, 2016). Additionally, collection services could incorporate monetary incentives (e.g. cash payments or vouchers), to encourage participation of younger age groups who frequently hoard electronics due to monetary reasons (Ongondo & Williams, 2011b; Li et al., 2012). Such incentives could also promote the faster release of (W)EEE from consumers' homes, ensuring access to recoverable materials in a shorter timeframe. A study by Hursthouse et al. (2017) on the efficient recovery of critical raw material under a closed-loop economy, determined that working closely with local social enterprises and schools to collect (W)EEE might encourage higher recovery rates, due to their local dimension and trusted relationship with the public. Under the same concept, Ongondo et al. (2015) suggested that universities could be utilised as recovery centres for (W)EEE. Targeting the recovery of larger items (e.g. plasma TVs) or devices with a higher proportion of multiple hoarded devices (e.g. game consoles) might be an easier way to influence consumer hoarding due storage space constraints. This approach could gradually stimulate consumers to view the EoL of all (W)EEE differently (Hursthouse et al., 2017).

5. CONCLUSIONS

This study has assessed the effect of consumer behaviour on the release of HE (W)EEE into the circular economy. It provides original contributions to the current literature by establishing, presenting and analysing previously unavailable data on the ownership, use and hoarding levels of HE EEE in a typical city DUM, and the reasons behind their hoarding. In a city with a population of ~240,000 in the UK, ownership levels were very high, with an average of 12 home entertainment items owned per household. This makes urban areas extremely plausible as DUMs; we estimate that there are over 1 million HE devices owned and ~440,000 HE devices hoarded in Southampton and >150 million HE EEE owned and ~61 million HE devices hoarded in UK households. Hoarding is therefore common, especially for smaller or older equipment, due to their perceived residual value. HE product lifecycles averaged 4-5 years. The most common EoL routes were donating to relatives, friends or charities; hoarding; recycling via Household Waste Recycling Centres; or discarding items in general refuse. To encourage the recovery of EoL HE equipment in a DUM, convenient and accessible collection points should be promoted via awareness campaigns and incentives.

The most common respondent behaviours involved

hoarding of small (W)EEE, the recycling of larger products via HWRCs, and the gifting/donating of working EEE with perceived residual value. EoL HE equipment was often hoarded as a back-up (i.e. stockpiling) or with the aim of giving them away in the future. More respondents from younger age groups considered lack-of-awareness of disposal options and the steep price of purchased items as important influencing factors for hoarding. The study also quantified soon-exploitable and hibernating stocks within a large urban area's surveyed zones, to predict product and material yields that could be made available to a DUM in the near future. To ensure recovery of used EEE and WEEE, waste management efforts should:

- Promote the recycling and reuse through awareness campaigns on collection schemes for consumer electronics.
- Establish convenient and accessible used EEE and WEEE collection points to encourage regular (periodic) harvesting and incentives to encourage reuse / recycling behaviour, with potential monetary incentives.
- Target the recovery of items that take up more space in consumer households (larger equipment or with a higher proportion of multiple devices).
- Encourage faster reuse of EEE via donations to charities, relatives or friends in order to gradually stimulate consumers to view EoL WEEE differently.

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