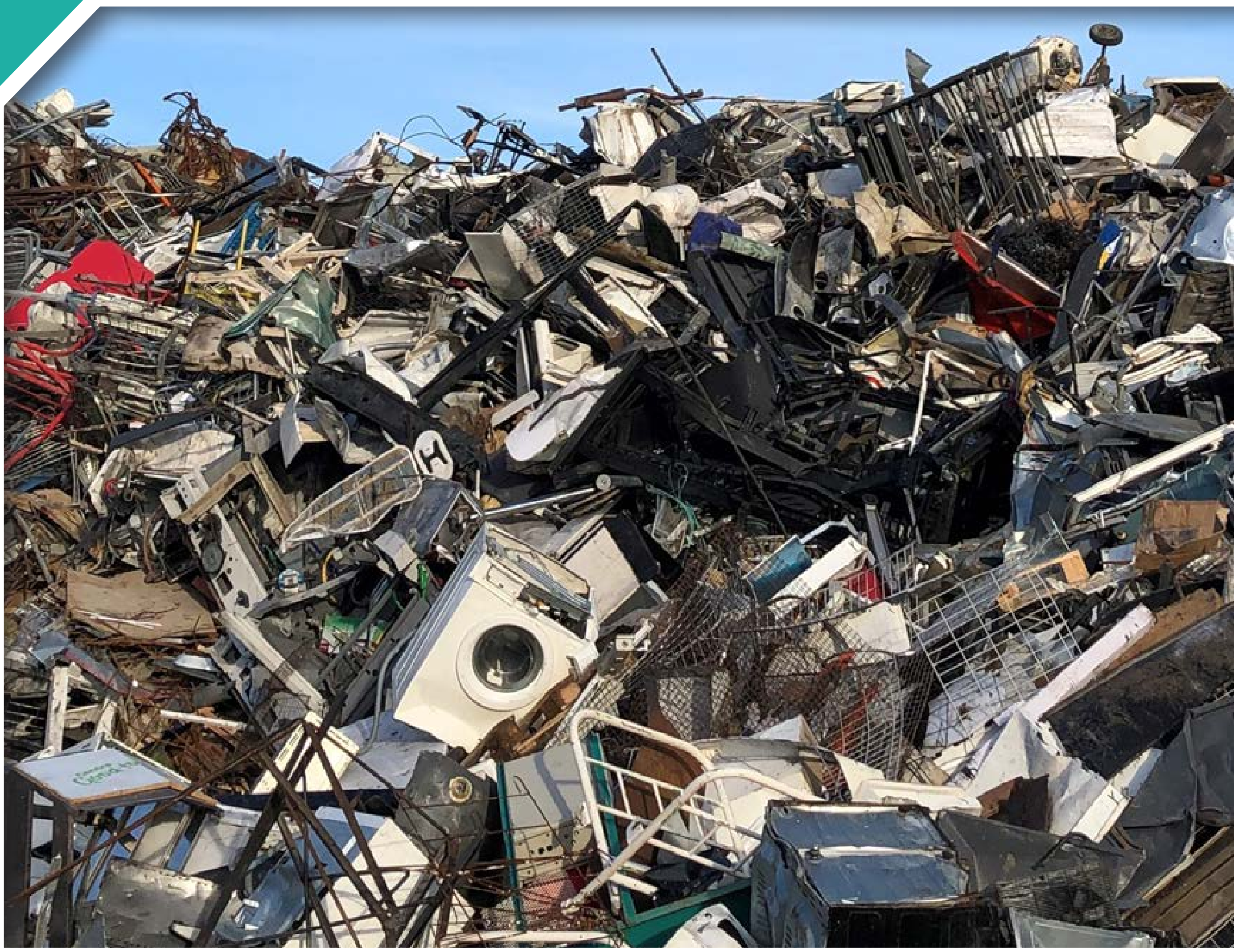
Report No.366

Climate - Water - Sustainability

Identifying pressures • Informing policy • Developing solutions

An Investigation into WEEE Arising and Not Arising in Ireland (EEE2WEEE)

Authors: Yvonne Ryan-Fogarty, Katherine Casey, Damian Coughlan, Maria Lichrou, Lisa O'Malley and Colin Fitzpatrick



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ENVIRONMENTAL PROTECTION AGENCY

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- Office of Environmental Enforcement
- Office of Evidence and Assessment
- Office of Radiation Protection and Environmental Monitoring
- Office of Communications and Corporate Services

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EPA RESEARCH PROGRAMME 2014–2020

An Investigation into WEEE Arising and Not Arising in Ireland (EEE2WEEE)

(2017-RE-MS-9)

EPA Research Report

Prepared for the Environmental Protection Agency

by

University of Limerick

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Executive Summary

The ambitious collection targets set by the recast Waste Electrical and Electronic Equipment (WEEE) Directive (2012/19/EU) have laid down new challenges for all stakeholders in the WEEE domain. This report provides additional insight into the WEEE system in Ireland and in particular into "complementary flows" outside the formal collection system. It provides this through consumer and business surveys, the development of a method to estimate WEEE arising in metal scrap and an examination of the European Union (EU) WEEE Calculation Tool in order to assess Ireland's capacity to achieve WEEE collection targets.

Consumer and business behaviour contribute to WEEE arising in complementary flows outside compliant WEEE collection and treatment. Consumer surveys confirmed, in a quantitative manner, several of the qualitative findings from the ColectWEEE project. Frugality and waste avoidance are overwhelming drivers for consumers to continue to store used electrical and electronic equipment that they have stopped using. Combining this with the general lack of connection between long-term storage and extra pressure on virgin raw material extraction means that this is likely to persist. The accumulation of items in this manner combined with a significant number of those surveyed finding recycling inconvenient leads to items ultimately being disposed of at "critical moments" with a high "push factor" for this material to enter a complementary stream if disposed of via skip hire or casual waste collectors during "clear-outs" or indeed using their own waste bin.

The organisational research also unearthed some interesting themes. Compared with other waste, WEEE is typically a very small stream of waste for many organisations and therefore does not command much attention from those responsible for its management and disposal. Trust is placed in waste contractors to collect and dispose of information and communications technology (ICT) WEEE appropriately, including data destruction, but other items of WEEE are not given much attention beyond having them removed by a waste contractor once they accumulate.

To understand the quantity and composition of WEEE arising in metal scrap, 415 tonnes of iron, steel and mixed metals from construction and demolition and municipal waste were sampled. An estimated 3.91% ± 1.88% of this contained WEEE. This equates to 10,950 tonnes or 2.28 kg/capita (± 1.1 kg/capita) based on 2018 waste data returns to the National Waste Collection Permit Office (NWCPO); this is very significant in national terms, representing over 20% of compliant WEEE collected (based on 2017 Eurostat data for waste collected). The prevalence of central heating boilers suggests that home renovations are critical moments in the disposal of WEEE. Another finding of interest is the quantity of small appliances – again, indicative of domestic renewal. Large household appliances are also highly significant by weight. The arising of a non-trivial quantity of data-bearing devices is worrying from data protection perspectives as well as the critical raw material resource loss due to inappropriate treatment. Although the quantities are low enough to suggest that the information technology asset disposition (ITAD) services are largely working well, the small to medium-sized enterprises sector should be targeted for improvement.

The EU WEEE Calculation Tool was reviewed for target setting and it was found that, although the method makes logical sense, it is critically dependent on the availability of high-quality data for quantities of equipment placed on the market paired with appropriate surveys and policy insights to define product lifetimes. The work revealed concerns with respect to both placed on the market and WEEE-generated outputs. Nonetheless, it is not advisable to discard it entirely. Its importance may lie as a useful cross-reference tool for identification of free riders as well as new emergent technologies and their likely impact on target achievement. In particular, the likely widespread sales of photovoltaic panels in coming years (with lifespans long in excess of 3 years) will create unreachable targets using the method of 65% of the average placed on the market in the previous 3 years.

Recommendations include measures to increase the convenience and visibility of WEEE recycling and

provide a "preparation for reuse" option for consumers. This would assist consumers and businesses to make connections to appropriate treatment rather than waste avoidance through storage. Another key recommendation is to incentivise skip hire companies, waste collectors and scrap metal facilities to direct WEEE into the formal recycling system. This would aid in removing WEEE from complementary flows when consumers act inappropriately at "critical moments". Finally, a hybrid approach to target setting should be explored, using data available to Ireland and aspects of the WEEE Calculation Tool.

1 Introduction

1.1 Research Background

Waste electrical and electronic equipment (WEEE, or e-waste) is the fastest growing waste stream in Europe, growing at 3% to 5% per year. If handled incorrectly it can be extremely hazardous, causing major health and environmental problems (European Commission, 2019). Nonetheless, it contains many precious and critical raw materials, which are strategically important to the development of European industry as part of the circular economy (Huisman *et al*., 2017). For these reasons, the collection and treatment of WEEE has been a high priority for national and European policymakers for many years.

Prior to the WEEE Directive [2002/96/EC (EU, 2003a)] coming into force, there was no formal electrical or electronic recycling system in Ireland. Given this low base as a starting point, it could be argued that Ireland did remarkably well in achieving, and far exceeding, the target within a short time period. However, in spite of these drivers, collection rates for WEEE through official channels are very low across Europe, and it is estimated that only one-third of WEEE is being reported as separately collected and appropriately treated by compliance schemes (Huisman *et al*., 2015).

The flat 4 kg/person/year target was criticised in the review of the original WEEE Directive as not providing any incentive for further improvement, particularly in western European countries, which could exceed this target comfortably on account of high levels of consumption (Huisman *et al*., 2008). As a result, the recast of the WEEE Directive required Member States to transition to a target of either 45% of the average weight of electrical and electronic equipment (EEE) placed on the market in the previous 3 years from 2016, rising to 65% by 2019, or 85% of WEEE arising by 2019 as shown in Figure 1.1.

Notwithstanding this newer regime of higher targets, WEEE has continued to be problematic to collect and treat properly. According to the *Countering WEEE Illegal Trade (CWIT) Report* (Huisman *et al*., 2015), in 2012 only 35% of all the WEEE discarded in Europe ended up in the officially reported amounts of collection and recycling systems. The balance of this material was exported (16%), recycled under non-compliant conditions in Europe (33%), scavenged for valuable parts (8%) or simply thrown in waste bins (8%).

Likewise, Figure 1.2 shows data from Eurostat. Eurostat calculated for each European Union (EU) Member State how its WEEE collection in 2016 measures up to the 65% average weight of EEE placed on the market in the previous 3 years.

Where countries are in excess of the collection targets, anomalies can be explained by lack of "placed on the market" (POM) data, customs agreements at borders and other data collection restrictions. For the majority of Member States, this new target and methods for its calculation are creating pressures to re-examine their WEEE management regimes and to shed light on the gaps in their knowledge about the exact nature of WEEE flows, with a view to adapting these regimes to the realities of the higher targets.

The EEE2WEEE project is a direct response to this pressure and delves into some of the key areas that have been informed by the research call and project steering committee as being potentially responsible for WEEE flows that are not being captured as part of the formal WEEE management system in Ireland.

The key areas addressed as part of this study include (1) the question of how consumers and businesses are disposing of their equipment at the end of life;

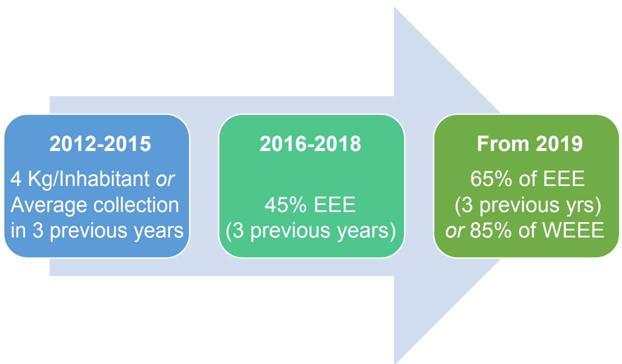

Figure 1.1. Targets development in the revised WEEE Directive.

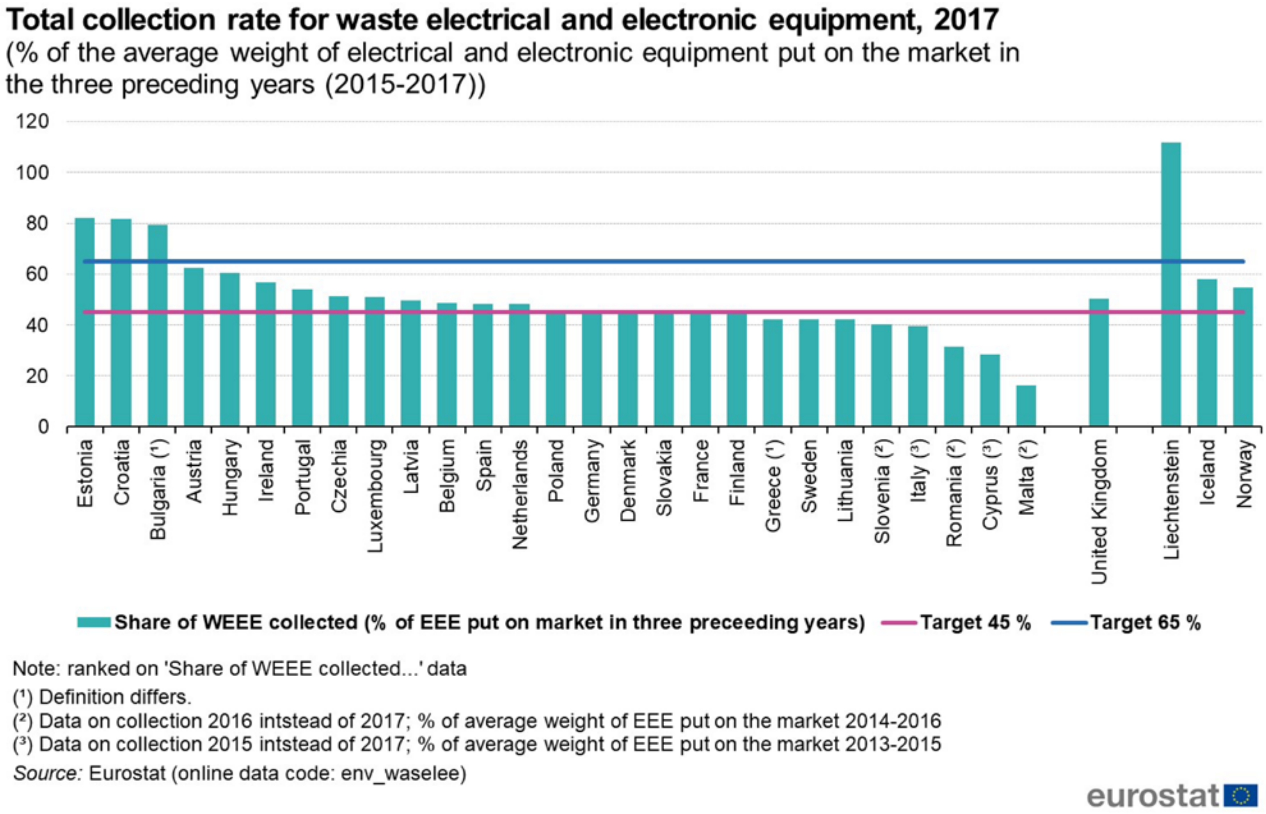

Figure 1.2. 2016 Collection rates as an average of EEE placed on the market in the previous 3 years. Source: Eurostat, 2017a.

(2) the question of how the WEEE arising method as set out in the WEEE Directive can inform WEEE target setting in Ireland and if it can be used to explore which product categories are performing well from a collection perspective and which are not; and (3) a quantitative analysis of what WEEE is presenting at scrap metal facilities.

For the first key area, the report begins with a quantitative study on consumers' behaviours surrounding WEEE disposal, which has been informed by the previous ColectWEEE project, and then proceeds to a qualitative study of businesses to unearth recurring themes in their practices when dealing with end-of-life equipment.

From here the report switches to the second key area, in which a sampling methodology to calculate the mass of WEEE that is presenting at scrap facilities mixed with other scrap metals is developed and applied.

The report finishes with the third key area, which examines the WEEE Calculation Tool provided by the European Commission and what insights are possible from its application with Ireland-specific data.

1.2 European Regulatory Landscape

Europe's WEEE generation will exceed 12 million tonnes by 2020 (European Commission, 2019); it is Europe's fastest growing waste stream, increasing at 3% to 5% per year (Huisman, 2010; BIO Intelligence Service, 2013; Johnson and Fitzpatrick, 2016). Characterised by hazardous components such as chlorinated biphenyls and brominated flame retardants, if improperly treated, WEEE is highly toxic to humans and the environment. WEEE disposal is therefore an area that has drawn much attention from the EU. In 2005 the first EU Directive on WEEE was transposed into Irish law via three statutory instruments: the Waste Management (EEE) Regulations [S.I. No. 290 of 2005 (Government of Ireland, 2005a)], the Waste Management (WEEE) Regulations [S.I. No. 340 of 2005 (Government of Ireland, 2005b)] and the Waste Management (Restriction of Certain Hazardous Substances in Electrical and Electronic Equipment) Regulations

[S.I. No. 341 of 2005 (Government of Ireland, 2005c)]. Together with the Restriction of Hazardous Substances (RoHS) Directive [2002/95/EC (EU, 2003b)] and the Energy-using Products (EuP) Directive [2005/32/EC (EU, 2005)], the WEEE Directive (2002) was designed to "address ever-increasing volumes of EEE waste generated, to improve recovery and recycling rates and processes; and to minimize the quantities of hazardous substances used in electrical components" through a suite of harmonised operational principles (Cahill *et al*., 2011, p. 456).

Specifically, the stated purpose of the WEEE Directive (2002) was the prevention of WEEE, the promotion of reuse, recycling and other forms of recovery of such wastes to reduce the disposal of waste, and the minimisation of the environmental risks and impacts associated with waste treatment (Johnson and Fitzpatrick, 2016). The Restriction of Hazardous Substances Directive (2002/95/EC) also sought to better "the environmental performance of all operators involved in the life cycle of electrical and electronic equipment" (Article 1 of Directive 2002/95/EC) through the assignation of responsibility for the environmentally sound management of end-of-life products to producers, a principle that is termed extended producer responsibility (EPR), or the "polluter pays" principle. Article 3 defines a producer as any person who

> irrespective of the selling technique used, including by means of distance communication … (i) manufactures and sells electrical and electronic equipment under his own brand, (ii) resells under his own brand equipment produced by other suppliers, (iii) imports or exports electrical and electronic equipment on a professional basis into a Member State. (Directive 2002/96/EC)

The concept of EPR was introduced in the early 1990s to relieve municipalities of the financial burden of waste management and to incentivise the use of secondary materials, the reduced use of virgin resources and the production of eco-efficient products. Once the directive was transposed into Irish law, end-of-life EEE could be deposited at retailers, gratis, when purchasing a replacement product in "the same quantity, of an equivalent type and fulfilling the same functions, as that purchased by the consumer" (Ecologic, 2009, p. 23). Additionally, producers and importers are obliged to finance the collection, treatment and management of WEEE from both households and businesses. Consumers can also deposit WEEE at local authority civic amenity sites free of charge. Civic amenity sites are purpose-built facilities to which the public brings various types of waste (including metal, cardboard and fabric items) for a fee and WEEE and batteries free of charge. These sites are run either by or on behalf of local authorities.

In the 2002 directive, WEEE is defined as "electrical or electronic equipment which is waste … including all components, subassemblies and consumables which are part of the product at the time of discarding" (Directive 2002/96/EC). Applicable product categories are detailed in Annex IA of the WEEE Directive (2002/96/EC). Historical WEEE refers to products that were put on the market before 13 August 2005 (Johnson and Fitzpatrick, 2016). Historic WEEE has proven difficult to quantify because of a lack of available information; it is estimated that as of 2015 historic WEEE accounts for 50% of all materials in the formal WEEE take-back channels in Ireland (Johnson and Fitzpatrick, 2016).

The 2002 WEEE Directive was repealed in 2012; the (recast) WEEE Directive [2012/19/EU (EU, 2012)] of the European Parliament and Council on WEEE was transposed into Irish law via the EU (WEEE) Regulations 2014 [S.I. No. 149 of 2014 (Government of Ireland, 2014)]. The WEEE Directive 2012/19/EU has similar objectives and scope to that of its precursor. However, it also seeks to "to contribute to the efficient use of resources and the retrieval of valuable secondary raw materials" (preamble, Directive 2012/19/EU) – this reflects a shift in EU policy towards a circular economy. Designed to address issues that had arisen or become evident in the years after the original directive's transposition, the new directive streamlined definitions, established new targets, redefined WEEE categories and strengthened provisions around WEEE shipments, reporting requirements and the development of standardised calculation methodologies (BIO Intelligence Service, 2013; Magalini *et al*., 2014; Johnson and Fitzpatrick, 2016).

The most substantive and heavily debated changes concern the redefinition of the collection targets. The original WEEE Directive (2002/96/EC) was drafted in the 1990s; in the interim electronics have grown ever more central to everyday life. The revised targets, now based on the percentage of EEE POM as opposed to a universal flat rate, both reflect this growth and accommodate the economic differences between Member States. The new minimum collection rate is 45%, calculated as a percentage of the average weight of EEE POM across the preceding 3 years. From 2019 onwards Member States must collect 65%, calculated as a percentage of the average weight of EEE POM across the preceding 3 years, or 85% of WEEE generated in that Member State. Recovery and recycling targets have also been revised.

Member States have the autonomy to choose which way they wish to measure the target reported. To aid in the estimation of tonnes of WEEE generated and product POM, a WEEE Calculation Tool was developed (K. Baldé *et al*., 2017).

Finally, the new directive extends the free take-back scheme to include very small household appliances (with an external dimension of less than 25 cm), where the retail outlet in question has a sales area of at least 400 m^2, regardless of whether or not the consumer purchases a new equivalent.

In Ireland, the EU (WEEE) Regulations 2014 (S.I. No. 149 of 2014) replaced the relevant Statutory Instruments, S.I. No. 340 and S.I. No. 290 of 2005 and related amendments. It specifies that:

- Retailers can no longer use civic amenity sites to dispose of WEEE.
- Distance sellers must authorise a local agent to take responsibility for their WEEE obligations.
- There is detailed guidance as to how information is provided to EEE users and consumers, including specific requirements as regards the signage and other information that retailers display or provide.
- Retailers must keep records of WEEE collected and given to compliance schemes for at least 2 years.
- Visible environmental management costs (vEMCs) were reintroduced for some categories of WEEE (as a result of several studies that indicated that historical WEEE had been underestimated; Huisman *et al*., 2008; Johnson and Fitzpatrick, 2016) and will run until 2021.

Transboundary WEEE shipments within the EU are governed by the EU's Waste Shipment Regulation (WSR), which stipulates a ban on the export of hazardous waste from Europe to non-Organisation for Economic Co-operation and Development (OECD) countries [Regulation (EC) No 1013/2006 of 14 June 2006]. The WSR requires of Member States that they regulate waste shipments, penalising organisations that fail to comply with WSR provisions. Member States determine WSR implementation and decide how to cooperate with other jurisdictions. Transboundary movements of waste for disposal are more tightly restricted than movements of waste that is being recycled – the processing method, type of waste (toxic wastes are treated more strictly) and country of destination determine how the waste will be treated (Geeraerts *et al*., 2015).

1.3 WEEE in Context

The WEEE Directive differentiates between B2C (business to consumer/household WEEE) and B2B (business to business/professional WEEE) for the purposes of financing collection. B2B WEEE should not enter the municipal WEEE stream; instead an alternative system has been established and commercial WEEE is collected by private B2B recycling operators. B2B WEEE collection has received scant academic attention (Peagam *et al*., 2013). Huisman *et al*. (2012, p. 11) suggest that "100% of WEEE originating from businesses results in complementary streams." In this case, "complementary" refers to waste streams that operate outside the system. The European Commission has recommended that Member States start to take action to account for these complementary waste flows so that they "can be counted toward achievement of overall targets" (European Commission *et al*., 2017). Ireland is among several countries that aspire to enact an "all actors report" model, which includes metal scrap traders and recyclers that work outside the producer compliance programmes, such as refurbishers and second-hand shops, to register volumes (C.P. Baldé *et al*., 2017). However, WEEE is entering waste collection points in mixed waste streams and is therefore not reported (see Figure 1.3).

As identified in Darby and Obara's (2005) influential UK study, small WEEE is a particularly problematic category of waste, as people tend to store or stockpile

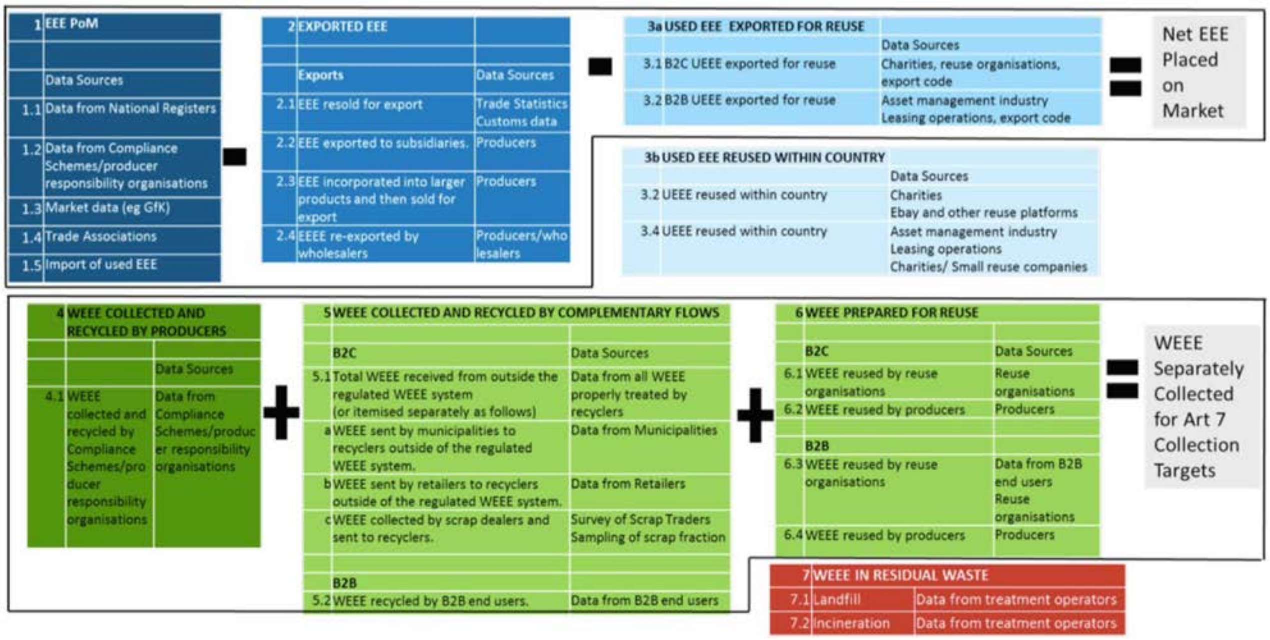

Figure 1.3. All EEE flows. Reproduced from Digital Europe (2017) with permission.

these objects in their houses or even improperly dispose of them. The new recast WEEE Directive (2012/19/EU) attempts to address this issue by making small WEEE more visible as a specific category, with streamlined definitions, new targets and redefined WEEE categories. However, although awareness of small WEEE stockpiling and improper disposal behaviours exists, less attention has been given to the meanings people ascribe to their electronic and electrical possessions, even when these are disused or broken.

Efficient infrastructures are indispensable to the success of recycling campaigns; however, consumers are the most important and dynamic element of WEEE recycling initiatives (Gurauskienė, 2008; Dwivedy and Mittal, 2013; Sivathanu, 2016). Researchers have tried to understand the barriers and motivations of consumer recycling behaviour and the determinants that might predict how consumers dispose of their waste (Abeliotis *et al*., 2006; Martin *et al*., 2006; Pérez-Belis *et al*., 2017). Several prominent issues have been identified across the literature streams, including consumers' tendency to store obsolete[1] or inoperative WEEE (Abeliotis *et al*., 2006; Ongondo and Williams, 2011b; Saritha *et al*., 2015; Speake and Nchawa Yangke, 2015; Pérez-Belis *et al*., 2017), consumer willingness to pay for recycling or improved WEEE collection methods (Nixon and Saphores, 2007; Afroz *et al*., 2013; La Barbera *et al*., 2014; Song *et al*., 2016), willingness to recycle WEEE (Saphores *et al*., 2006; Nnorom *et al*., 2009; B. Li *et al*., 2012; Dwivedy and Mittal, 2013; Speake and Nchawa Yangke, 2015; Song *et al*., 2016) and willingness to pay more for environmentally friendly products (Saphores *et al*., 2007; Speake and Nchawa Yangke, 2015). These have all been explored in depth.

Thus far, apart from mobile phones, small WEEE has been neglected in the literature even though it is proving to be a significant WEEE stream. In Europe, large household WEEE constitutes the majority of WEEE by weight; however, small and medium-sized WEEE is more numerous and less likely to be disposed of responsibly. In 2015 the collection rates were as follows: 2.2 million tonnes of large household WEEE (52% of the total WEEE collected); 639,984 tonnes of information and communications technology (ICT) equipment (17% of the total WEEE collected); 599,050 tonnes of consumer equipment (15% of the total WEEE collected); 368,493 tonnes of small household appliances (10% of the total WEEE

1 "Obsolete" does not necessarily mean that the products are inoperative, rather, that they are perceived as technologically lacking. These products are referred to as "end-of-use" equipment, indicating their potential use value (Ongondo and Williams, 2011a; Ylä-Mella *et al*., 2015).

collected); and 267,355 tonnes of all "other" types of WEEE (7% of the total WEEE collected) (Eurostat, 2017b). Given the range of products that fall into the small WEEE category, their short lifespan and the prevalence of such products in modern homes, the amount of small WEEE collected is low (Wilkinson and Duffy, 2003). Research suggests several possible reasons for this disparity, including a lack of awareness on the part of consumers about the recyclability of small WEEE goods, the perception that individual disposal fees are disproportionately high (Wilkinson and Duffy, 2003) and the fact that small WEEE is often disposable products, not designed to be upgraded, repaired or reused (Darby and Obara, 2005). Consumers using informal collection channels may also explain the low collection rates for small WEEE (Martinho *et al*., 2017). The final relevant factor is the WEEE flow – the time between when the item is made obsolete and when it is delivered for recycling (Martinho *et al*., 2017). WEEE Ireland's latest environmental report (2017) found that 80% of people have small WEEE or unused gadgets stored in their homes.

Within the broader category of small WEEE, mobile phones have emerged as being particularly problematic, primarily because of the WEEE flow (Ongondo and Williams, 2011b; Speake and Nchawa Yangke, 2015; Wilson *et al*., 2017), i.e. mobile phones are regularly replaced but retain a high residual value. Thus, consumers tend to store them (Darby and Obara, 2005; Speake and Nchawa Yangke, 2015; Wilson *et al*., 2017). In 2015, the number of stockpiled mobile phones was estimated to be about 70 million in the UK alone; approximately 25% of retired mobile phones are recovered via take-back schemes (Speake and Nchawa Yangke, 2015). Ylä-Mella *et al*. (2015) approximate that approximately 85% of consumers store idle mobile phones. Speake and Nchawa Yangke (2015) explored consumers' reasoning for storing their old phones. Their findings indicate that the most commonly cited response was "no reason", followed by "as a backup", "it's obsolete", "because of its value" and finally because they "do not know where or how to recycle it". Ylä-Mella *et al*. (2015) and Ongondo and Williams (2011a) are consistent in their findings that 17% and 30%, respectively, of their respondents, stated that they stockpile their phones because they do not know what to do with them, a finding which was further corroborated in the broader context of WEEE in a Jordanian study (Fraige *et al*., 2012). Remarkably, Ylä-Mella *et al*. (2015) found that, despite the respondents being aware that mobile phones should be recycled, 85% of the respondents stockpiled their old phones. Welfens *et al*. (2016) ascertained that the strong emotional identification that consumers tend to form with their mobile phones later influences their decision not to discard or recycle their mobile phones. On a practical level, they argue that many consumers tend to store photographs and other personal data on their phones, despite the prevalence of cloud storage. Speake and Nchawa Yangke (2015) found that, in the context of mobile phones, take-back schemes are still underused; in fact, only 38% of their respondents were aware of take-back schemes, despite their being advertised on the internet, in newspapers and on the television.

Regardless of motivation, this is a problematic practice, as mobile phones are both a source of valuable secondary raw materials and a hazardous waste stream (Speake and Nchawa Yangke, 2015). Mobile phones are often composed of over 40 metals, many of which are precious or critical raw materials (Ongondo and Williams, 2011a). Hence, although only 4% of mobile phones are disposed of via general waste, they represent one of the most valuable electronic products present in general waste streams (Dalrymple *et al*., 2007; Speake and Nchawa Yangke, 2015). Additionally, technological advancement has increased electronics consumption and reduced the lifespan of various products, none more so than mobile phones, which have become the fastest growing constituent of WEEE (Speake and Nchawa Yangke, 2015). Meanwhile, Makov and Font Vivanco (2018) discussed the rebound effects of smartphone reuse due to imperfect substitution between recirculated and new products and re-spending on account of economic savings and found a rebound effect of 29% on average. "Rebound effect" describes the phenomenon where circular economy activities result in increased overall production and use of products, thus decreasing the environmental benefit of the circular economy (Zink and Geyer, 2017).

Darby and Obara (2005) note that many of their UK-based respondents indicated that they had never given the disposal of small WEEE any real thought; they found that 26% of small WEEE is disposed of via general waste. This seems to be common practice, although the reported figures vary, depending on the context of each study. In Spain, Pérez-Belis *et al*. (2017) found that 91% of their respondents indicated that they threw their small WEEE in the domestic waste (only 7% recycled it), whereas a figure of 73% was reported in India (Saritha *et al*., 2015). Abeliotis *et al*. (2006) reported similar findings in Greece, where 82% of their respondents disposed of their small WEEE via general waste. In Ireland, estimates suggest that 11% of householders dispose of their small WEEE in the general waste (WEEE Ireland, 2017). The authors speculate that consumers may dispose of their small WEEE in this manner purely because of the items' size, i.e. small WEEE is easier to dispose of via general waste (Darby and Obara, 2005). Respondents in one study attributed some of their irresponsible waste management behaviours to their personality (Davies *et al*., 2005). However, the researchers noted that the traits that the interviewees described as determined by personality were actually habits and therefore flexible (Davies *et al*., 2005). Consumer recycling habits are "notoriously difficult to change" (Darby and Obara, 2005, p. 25), and thus it is imperative that we develop a clear understanding of the barriers that must be overcome for the WEEE Directive to be successful.

Consumers' reasons for disposing of EEE have attracted some attention (Abeliotis *et al*., 2006; Gutiérrez *et al*., 2011a; Dindarian *et al*., 2012; J. Li *et al*., 2012). These studies contribute to knowledge about barriers to recycling WEEE as well as the amount and type of WEEE, the lifetime of EEE and hurdles to reusing WEEE (Pérez-Belis *et al*., 2017). Small EEE tends to last between 4 and 8 years (Chi *et al*., 2014; Pérez-Belis *et al*., 2017), whereas larger EEE (refrigerators, televisions) tends to last longer (Gutiérrez *et al*., 2011b). Research findings are conflicted as to why EEE is replaced – malfunction is cited as a recurring impetus, as is technological obsolescence (Gutiérrez *et al*., 2011b; Afroz *et al*., 2013; Saritha *et al*., 2015; Islam *et al*., 2016). This may be dependent on the appliance in question; for example, mobile phones are very often replaced merely because the service providers offer the consumers an upgrade (Speake and Nchawa Yangke, 2015). Consumers cite the cost of repair as the primary reason for not repairing EEE, as some EEE products are simply cheaper to replace.

Research indicates that both suitable infrastructure and appropriate information are required if consumers are to successfully recycle (Darby and Obara, 2005; Davies *et al*., 2005; Byrne and O'Regan, 2014; Ylä-Mella *et al*., 2014; Speake and Nchawa Yangke, 2015). Davies *et al*. (2005) found that householders want more information about recycling. Consequently, recommendations for fostering positive waste management behaviours tend to include the provision of suitable information (Darby and Obara, 2005; Davies *et al*., 2005). However, content is important – respondents said that they would appreciate "appropriate" information. Darby and Obara (2005) clarified this further; their findings indicated that householders "do not want information on *why* they need to recycle but are more interested in *how* they can recycle" (p. 33).

Furthermore, research has identified a lack of consciousness around small WEEE. For example, respondents in the study of Darby and Obara (2005) reported a lack of reflection regarding the disposal of small WEEE – many did not consider small WEEE to be a "waste" akin to glass or paper, both of which had been targeted by local authorities and required ongoing participation. In the same study (Darby and Obara, 2005), respondents claimed they were ill-informed of how to recycle small WEEE and disclosed that they most often dispose of it via the household refuse or general waste (landfills), as charity shops do not accept it. Increasing knowledge of how consumers can recycle WEEE and the barriers to their participation in WEEE recycling will help determine the most suitable information. Thus, these initiatives can be tailored for relevant households. There are many avenues that authorities could explore as to the information distributed; for example, several authors have suggested that consumers need to be educated as to the negative environmental impact of WEEE (Abeliotis *et al*., 2006; Wang *et al*., 2011).

It is also suggested that the development of appropriate infrastructures would increase participation (Darby and Obara, 2005; Davies *et al*., 2005). In general, small WEEE is either disposed of via general household waste (Darby and Obara, 2005; Dimitrakakis *et al*., 2009; Pérez-Belis *et al*., 2017) or placed in storage (Pérez-Belis *et al*., 2017). To address this, several authors have suggested financial incentives – this warrants more detailed research. Currently, WEEE is understood and researched as an independent waste stream. Darby and Obara (2005) call for an integrated approach, arguing that integration is necessary if the targets in the WEEE Directive are to be met. Given that one of the most consistent findings in the whole research stream revolves around the “spillover” effect (i.e. recycling other items appears to influence behaviour when it comes to disposal of small WEEE). It would seem that WEEE recycling should be considered in the context of general recycling.

Context seems to shape how consumers think about and behave towards WEEE recycling. First, research into attitudes and behaviours has concluded that pro-environmental attitudes do not necessarily translate into positive behaviours (the famous attitude–behaviour gap). This is evident in the existence of persistent irresponsible small WEEE disposal practices, including disposing of small WEEE via the general household waste. Second, institutional and structural factors affect individual behaviour. This is evident in the apparent difficulty so far in establishing consistent demographic characteristics across different studies. This raises the issue of context, as consumers’ everyday disposition behaviours are dependent on the socio-technical and cultural contexts in which these behaviours occur.

2 Consumer and Organisational EEE Disposal

2.1 Context

This research project emerged from the findings reported in *A Community-based Social Marketing Approach for Increased Participation in WEEE Recycling (ColectWEEE)* (Casey *et al*., 2018). ColectWEEE was a qualitative research project that explored how consumers experience EEE through to WEEE. Data collection consisted of in-depth interviews with consumers in their homes, observations at WEEE collection points (recycling events, civic amenity sites) and participants' observation in returning WEEE to stores (on both one-for-one and one-for-zero bases). The project generated several insights concerning how consumers experience buying, owning and then disposing of (W)EEE.

This two-pronged project first explores WEEE disposal at an organisational level and second seeks to confirm the ColectWEEE findings (Casey *et al*., 2018). Thus, this research addresses two contexts and requires the application of two methodological approaches. A qualitative, interview-based approach was taken to the organisational context, whereas a quantitative survey approach was used to elicit descriptive statistics verifying ColectWEEE findings. The following sections describe the objectives of this research and the research design and give a brief description of the challenges associated with this project.

2.2 Study Design

2.2.1 Consumer quantitative research design

The quantitative prong investigates consumer behaviour around WEEE disposal and consumer attitudes towards WEEE recycling. The research is confirmatory in nature and was thus designed to examine the findings reported in ColectWEEE (Casey *et al*., 2018). The questionnaire focuses on two essential elements of the divestment process: (1) why do consumers retain objects? and (2) how do consumers *really* dispose of WEEE? We also explored attitudes to related topics such as general recycling, e-waste recycling and the perceived relationship between the environment and e-waste recycling. When designing questionnaires researchers need to be cognisant of the subject matter; for example, consumers sometimes overreport their recycling activities because of a social desirability bias. Recycling, or rather not recycling, falls into a category of behaviours that are not socially acceptable. Additionally, even where respondents report holding environmentally conscious opinions, people often fall short of their attitudes – a phenomenon branded the attitude–behaviour gap (Oates and McDonald, 2014; Johnstone and Tan, 2015; Caruana *et al*., 2016).

This research overcomes the attitude–behaviour gap and aims to reduce the social desirability bias through survey design; an example is asking if a respondent has ever engaged in an activity before asking whether they currently engage in it (Bradburn *et al*., 2015). One way to access accurate descriptions of routine behaviours, such as waste disposal, is to ask respondents to focus on a single instance of that behaviour. The questionnaire design reflects this approach. This research is confirmatory; for example, ColectWEEE found that participants did not draw a connection between storing their disused EEE and environmental decline. One objective of this research was thus to uncover whether or not this was a widely held view by asking respondents to respond to two statements: (1) "storing old or unused electrical or electronic devices is harmless for the environment" and (2) "storing old or unused electrical or electronic devices is harmful for the environment". Other examples of this approach are given in Table 2.1.

Questionnaire distribution

The questionnaire was distributed via an agency that specialises in online surveying. In total, 702 successful responses were collected. The sample, of which 50% of respondents were male and 50% were female, was distributed by age, location and employment, as displayed in Figures 2.1–2.3.

Table 2.1. Examples of how findings from ColectWEEE were expressed in the survey

ColectWEEE finding	Objective	Expressed in the survey
Participants had some knowledge about the WEEE recycling process, meaning that they were aware of one or more of the recycling channels	Explore whether or not consumers are aware of the WEEE recycling options	When asked why replaced EEE is kept, respondents were given “I don’t know where to take it” as an option
Consumers view recycling functional items as wasteful	Explore whether or not consumers view recycling functional items as wasteful	We asked respondents to agree or disagree with the following statement: “Recycling functional electronic items is wasteful”
Consumers are unaware of the one-for-zero means of returning WEEE to large stores	To query whether or not consumers are aware of the one-for-zero means of returning WEEE to large stores	This was addressed in two questions. It was included in the means of disposing disused EEE question as an option and respondents were also asked to respond to the following statement: “Electronic or electrical items can be deposited at large electronic stores without any purchase”

2.2.2 *Organisation Qualitative Research Design*

The purpose of the research was to explore WEEE disposal from the point of view of organisational consumers of EEE. Specifically, researchers employed qualitative face-to-face interviews with relevant personnel from a range of different types of companies in terms of size, sector and industry. Given the exploratory nature of the study, researchers did not predetermine the quantity of desired respondents in the sample but focused instead on the following criteria: first, the inclusion of a range of organisational contexts, to allow insight into different practices, policies and attitudes; and, second, the selection of qualified participants (i.e. environmental managers and waste managers), to allow an informed discussion on the topic. Consequently, researchers utilised snowball sampling, where initial informants, approached through the researchers’ professional networks, were asked to provide referrals to recruit further informants. Forty potential informants were approached via email or phone, from a variety of sectors. Nine agreed to be interviewed. Among the participants, one responded via email, one agreed to an unrecorded but extensive phone interview and one agreed to an unrecorded face-to-face interview from which the researcher kept field notes.

Access to participants proved unusually challenging. In addition to the expected reluctance of organisational members to participate in research, on account of

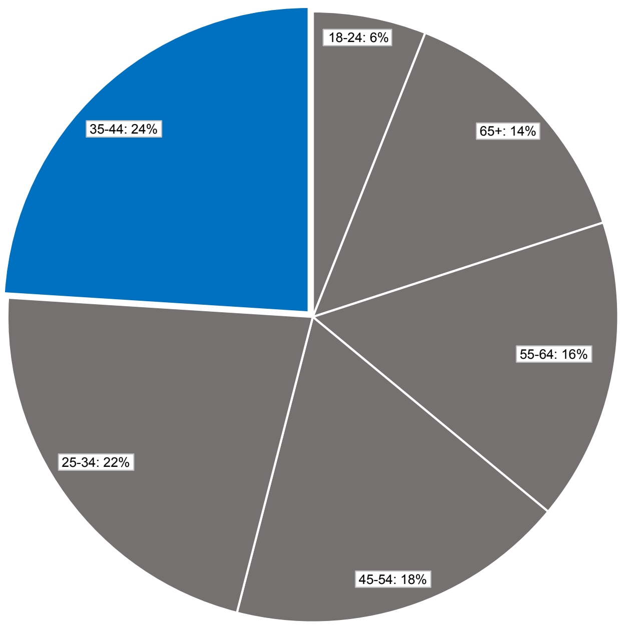

Figure 2.1. Age distribution.

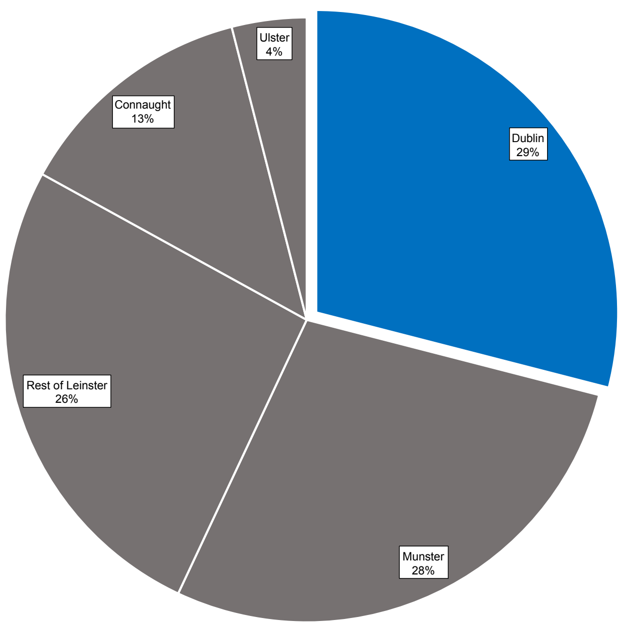

Figure 2.2. Geographical distribution.

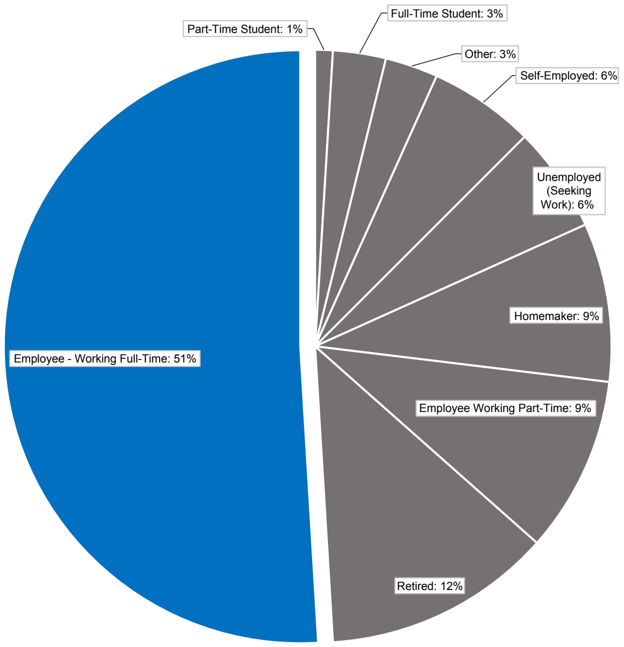

Figure 2.3. Distribution of employment situation.

time and other restrictions, in this case many contacts who refused to participate reported handling very low volumes of WEEE as the reason. As discussed in the findings, those who agreed to participate also reported handling low volumes of WEEE when compared with other waste streams.

With the exceptions mentioned previously, interviews were conducted on site with relevant members. They were recorded, transcribed and analysed. The interview duration ranged between 20 minutes and 2 hours, including tours of the organisation's disposal compounds and facilities where appropriate. These purposeful conversations addressed how WEEE is approached in an organisational context, documented the processes through which these organisations ensure that their e-waste is properly recycled, and explored how organisations make decisions around when to dispose of WEEE and how many staff are involved in the process. Interviews were an appropriate place to start, as little research has been conducted in the field. Interviews are exploratory in nature and they are used to access insider accounts, thereby facilitating the emergence of a holistic account of the social or human problem at hand (Creswell, 2003). The informant profile is depicted in Table 2.2.

2.3 Findings

2.3.1 Consumer research

As indicated in the methodology, this research was underpinned by the findings of ColectWEEE, the results of which are presented in Figure 2.4 (Casey *et al*., 2019). This four-stage process reflects how small EEE is treated after use.

Stage 1 – inactive EEE

Disused or broken EEE is stored in the home. If consumers perceive the object to retain utilitarian or emotional value, it is stored with care. However, not all inactive EEE is valued; some is merely abandoned. This category of EEE fades into the background and essentially becomes invisible. Peripherals often fall into this category. Additionally, because abandoned EEE is not valued, its future is rarely considered and consumers tend to neglect these objects. Eventually, the value of both categories of inactive EEE diminishes. Thus, inactive EEE is stored or abandoned until doing so becomes more bothersome than recycling or discarding it.

Table 2.2. Organisational participants

Organisation	Description	Number of employees
1	Government department	> 300
2	Public body – service provider	> 1200
3	Public body – third-level education provider	> 2500
4	Public body – third-level education provider	> 2500
5	SME – hospitality	> 230
6	International – construction	> 250 (on site)
7	Public body – third-level education provider	> 2500
8	MNC – food and beverages	> 400 (on site)
9	International – aviation industry	> 600

MNC, multinational corporation; SME, small to medium-sized enterprise.

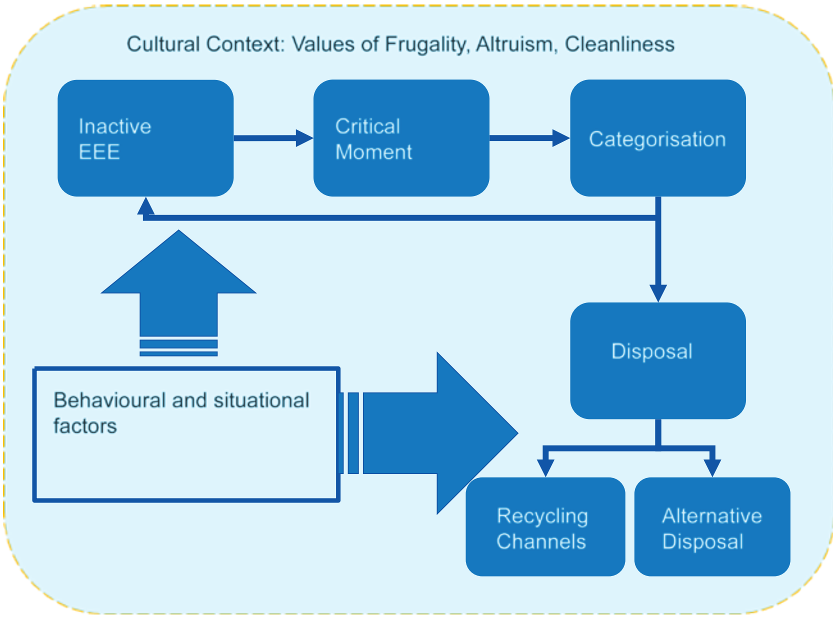

Figure 2.4. The WEEE divestment process. Reproduced from Casey *et al.* (2019), copyright 2019, with permission from Elsevier.

Stage 2 – critical moment

Life transition circumstances (e.g. moving or renovation) as well as some external triggers (e.g. charity campaigns) compel consumers to confront their stored or hoarded possessions and to then reflect on their value. These triggers are termed "critical moments" and tend to urge consumers to reflect on their stored, disused EEE. Evidence suggested that critical moments can be successfully instigated via appropriate interventions.

Stage 3 – categorisation

Following a critical moment, consumers critically evaluate their possessions to determine their value. At this stage consumers decide, based on that determination, whether an item is still EEE or whether it has become WEEE. Those items deemed to be EEE are kept and stage 1 commences again.

Stage 4 – divestment

Those items that are now considered waste must at this stage be disposed of – via either appropriate recycling facilities or other routes. Factors that seem to impact how consumers dispose of their WEEE include convenience and familiarity with recycling facilities and practices.

Survey Findings

All 702 respondents reported purchasing small EEE in the previous 12 months. Of these, 73% replaced existing products and, of those, 54% of the sample (274 respondents) retained the object they had replaced, meaning that a total of 39% of the respondents had stored or just not disposed of this disused EEE. The reasons for retaining disused EEE are summarised in Table 2.3.

Table 2.3. Answers to the question "Why have you kept this item?"

Answer	Number of times selected
It still works – it seems wasteful to dispose of functional items	81
I am keeping it as a spare	78
I intend to dispose of it later	70
I don't know where to take it	40
I may have use for it in the future	33
I intend to gift it to a friend or relative	25
I have not thought about it	24
Other (please specify)	17
I have security concerns about the item's contents	16
I may use some part of it	14
It provides storage for my data	14
Total	412

The most common reason stated for disused EEE storage was waste avoidance, suggesting that consumers view disposing of functional items as wasteful. This position is supported by the participants selecting similar or parallel reasoning for EEE storage; for example, the second-most selected reason is "I am keeping it as a spare" (78 responses). "I may have some use for it in the future"/"I may use some part of it" accounted for a further 47 of the 412 total responses. This aligns with the consumer research literature, which finds that people do not dispose of things that they still value (Schultz *et al*., 1989). Lastovicka *et al*. (1999) attribute this behaviour to an underresearched consumer trait: frugality. Frugality is defined as "restraint in acquiring and in resourcefully using economic goods and services to achieve longer term goals" (Lastovicka *et al*., 1999, p. 88). Thus, consumers keep goods for longer than one might expect to extract as much value as possible, even if the item only retains *potential* use value. The desire to avoid waste also influences how respondents perceive recycling functional EEE. Over 40% of the respondents agreed or strongly agreed with the statement that recycling functional electronic items is wasteful; a further 19% were indifferent to the statement (see Figure 2.5). Thus, it can be surmised that where an object retains use value or potential use value it is not considered *waste* and recycling in that situation is, in turn, wasteful. This finding identifies a chasm between how these items are viewed by policymakers and how they are viewed by their owners and should be considered when approaching historical WEEE.

Furthermore, when asked if "Storing old or unused electrical or electronic devices is harmful for the environment", only 34% agreed or strongly agreed (see Figure 2.6). The vast majority were indifferent or disagreed; this was borne out again by responses to the statement "Storing old or unused electrical or electronic devices is harmless for the environment." Thus, storage is largely viewed as a neutral activity to which (W)EEE is well suited; it does not perish and it is often relatively small. The fact that most respondents do not draw an explicit connection between (W)EEE storage and environmental degradation compounds the issue around stored disused EEE. Taken together, these findings are somewhat troubling, as the volumes of EEE POM are set to increase in the coming years and stored or abandoned EEE is likely to mirror that increase (Pérez-Belis *et al*., 2015).

Interestingly, "security concerns" constituted only 6% of the total set of responses regarding reasons for not disposing of WEEE. Although the respondents did not express concern in this regard, it should be recognised that data security is an increasingly important issue, especially given the centrality of ICT in everyday life (Alghazo *et al*., 2018). The implementation of the

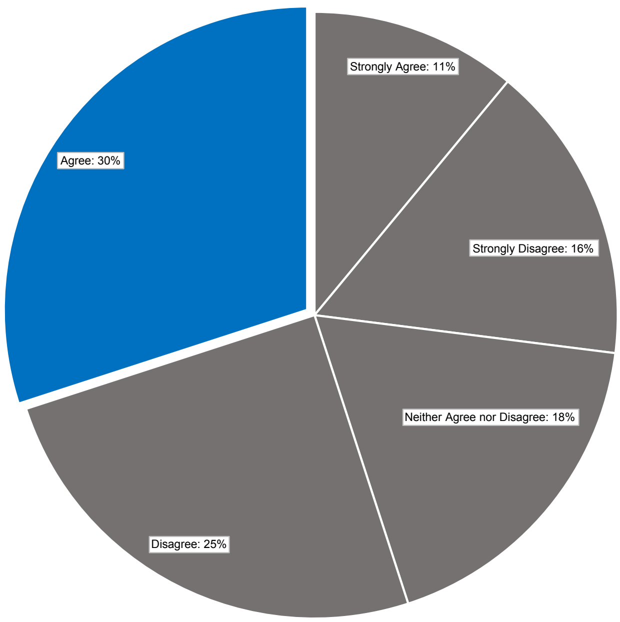

Figure 2.5. Answers to the statement "Recycling functional electronic items is wasteful."

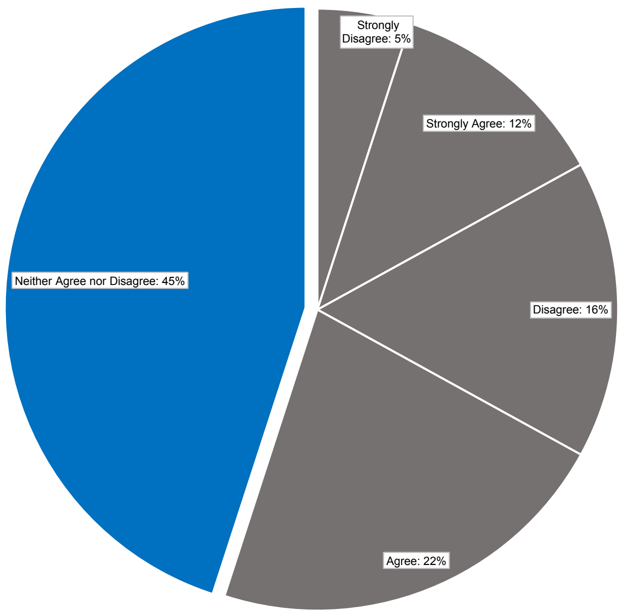

Figure 2.6. Answers to the statement "Storing old or unused electrical or electronic devices is harmful for the environment."

General Data Protection Regulation (GDPR) reflects a mounting "political awareness of data protection and is radically shifting expectations of data governance" (Carr, 2019, p. 157) and represents an array of complex challenges to WEEE recycling agents.

These findings relate to EEE that has been consciously stored and which is valued from an either emotional or utilitarian perspective and is therefore curated and then forgotten. However, "I have not thought about it" or "I intend to dispose of it later" was cited 94 (out of 412) times (Table 2.3), indicating that in these cases consumers have not actively stored their disused EEE. This means that 23% of the responses collected cited future intention or apathy as the reason for EEE retention. Abandoned EEE fades into the household landscape and is overlooked; this kind of EEE is not consciously "stored" and is rarely the subject of debate or deliberate decision-making (Casey *et al*., 2019).

There is one kind of (W)EEE that is very often abandoned, namely the peripherals. These are the wiring and cabling that are included with EEE when purchased and which tend to disappear into drawers and boxes throughout consumers' homes (Casey *et al*., 2019). This is evidenced by the 35% of respondents who had never disposed of any unwanted cables, even though 86% reported disposing of an electronic or electrical item. Additionally, of the 274 respondents who had kept a replaced product, 165 had also kept the associated cables. This represents 95% of those respondents whose item had a cable. Findings around why consumers keep cables (see Table 2.4) mirror earlier findings around (W)EEE retention. Consumers tend to avoid waste and future expenditure and so they retain items with use or potential use value.

Despite respondents' evident desire to store (W)EEE, the majority of participants consistently expressed positive attitudes towards recycling. For example, 70% disagreed or strongly disagreed that recycling makes little difference to the environment (see Figure 2.7), 82% agreed or strongly agreed that disposing of a mobile phone in the household waste is unacceptable and 73% disagreed or strongly disagreed with the statement "Putting a kettle in the bin does not harm the environment."

It should be noted that only 40 consumers stated that they were unaware as to where to bring their e-waste; this translates to less than 5% of the total population, indicating that the respondents are knowledgeable about how and where to dispose of the WEEE. This challenges the perceived knowledge that "there is little consumer engagement in the proper management of WEEE, mainly due to the lack of public awareness" (Pérez-Belis *et al*., 2015, p. 278). To combat this information deficit, current policy embodies the commonly accepted "ABC" approach – attitude, behaviour and choice. This approach tends to favour information campaigns designed to raise awareness and encourage positive attitudes through the

Table 2.4. Answers to the question "Why have you kept the cables that you used with the object you replaced?"

Answer	Number of times selected
I am keeping them as spares	69
They still work – it seems wasteful to dispose of functional items	63
I may have some use for them in the future	38
I intend to dispose of them later	21
I don't know where to take them	20
I intend to gift them to a friend or relative	18
I have not thought about them	15
Other (please specify)	4
Total	248

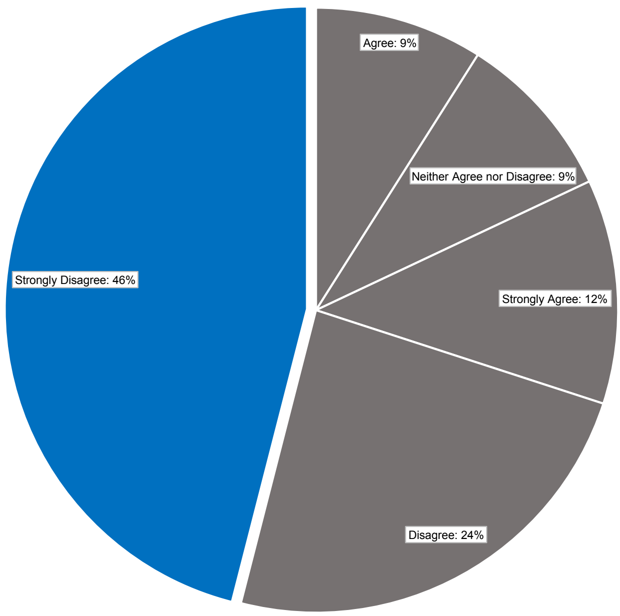

Figure 2.7. Answers to the statement "Recycling e-waste makes little difference to the environment".

dissemination of relevant information (Shove, 2010; Pérez-Belis *et al*., 2015). However, these findings suggest that effective policy is likely to move beyond the individual responsibility and the alleged information deficit.

Once consumers have determined that an item is waste, they must decide how to dispose of it; 86% of respondents could recall disposing of a specific piece of e-waste. The majority of respondents (74%) reported recycling their WEEE via the following methods: (1) the store's like-for-like policy (27%); (2) at the recycling centre (42%); or (3) by bringing it to an alternative store (5%) (see Table 2.5). Respondents are consistent in their support for WEEE recycling; for example, 74% reported a willingness to go "out of [their] way" to recycle WEEE and 88% agreed or strongly agreed with the statement "Recycling, even small electronic items, is worthwhile." Interestingly, only 5% of respondents took advantage of the in-store deposit of WEEE on a one-for-zero basis. When asked, 63% of the respondents agreed or strongly agreed with the statement "Electronic or electrical items can be deposited at large electronic stores without any purchase". However, this figure changes dramatically from region to region; for example, in Dublin 64% of respondents agreed or strongly agreed versus only 38% in Ulster and 47% in both Munster and the rest of Leinster. This indicates that the one-for-zero scheme has not been well communicated outside Dublin.

Recall that these questions follow one item, which then reflects general behaviour; here, 10% of the sample

Table 2.5. Answers to the question "Can you recall how you disposed of a piece of WEEE?"

Answer	Number of times selected	%
Brought it to a recycling centre	264	42
Brought it back/sent it to the store at which you bought your new product	174	27
Put it in your household waste/bin	65	10
Brought it to store other than the one at which I purchased it	32	5
Gifted it to a friend or relative	23	4
Sold it	23	4
Other (please specify)	22	3
Donated it to charity	19	3
Put it in the household recycling	14	2
Total	636	100

described putting that piece of WEEE in the household waste. When asked specifically, 28% of the population reported having disposed of WEEE in the household waste and 21% of the entire sample (64% of those who reported disposing of WEEE in the household waste) reported having disposed of WEEE via the household waste between one and three times in the past 12 months. These figures increase substantially in relation to peripherals, where 54% reported disposing of cabling or wiring in the household waste and 28% of the entire sample (70% of those who reported disposing of cables/wiring in the household waste) reported doing so between one and three times in the past 12 months. In fact, the household bin (whether recycling or landfill waste) was the most popular means of disposing of cabling or peripherals (see Figure 2.8). Although cabling is not the most valuable waste, the cumulative impact of this conduct is worth considering.

A significant percentage of respondents (42% of WEEE products, 36% of cables/wiring) brought their WEEE to a recycling centre, indicating that there is strong engagement with the WEEE recycling process. A slight majority (51%) of respondents agreed or strongly agreed with the statement "It is convenient to recycle e-waste" (see Figure 2.9) but 23% stated that they do not view WEEE recycling as convenient. A considerable number of respondents (26%) neither agreed nor disagreed that WEEE recycling is convenient; this group may represent an opportunity (as they do not have strong feelings either way). Wang *et al*. (2011, 2018) argue that increased convenience and awareness of that convenience generates a positive view of WEEE recycling, thereby increasing engagement. This research implies that the one-for-zero basis is underutilised, as 5% of respondents participated and just over 50% of consumers were aware of the scheme. A targeted campaign highlighting this scheme may encourage greater participation, as consumers will be made aware of the scheme, which may positively impact their attitude towards e-waste recycling and thereby improve engagement.

The current WEEE collection infrastructure includes a limited number of e-waste banks, consisting of large cages in which WEEE is collected, at one large EEE retailer with stores only in Dublin. This is an incredibly convenient means of proper WEEE disposal. The availability of an e-waste bank reduces the unpleasant experiential elements of bringing WEEE to stores

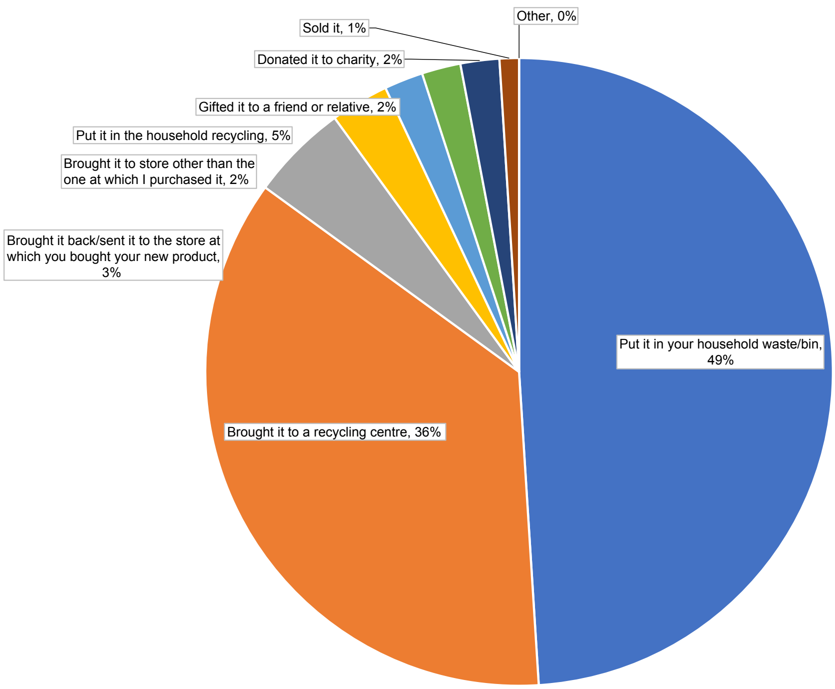

Figure 2.8. Answers to the question "How did you dispose of your unwanted cable?" (*n* = 459).

(discussed in Casey *et al*., 2018). However, only 34% of the sample had ever seen an e-waste bank and only a mere 19% had used one. This figure changes dramatically when Dublin is removed from the sample (see Figure 2.10).

As can be seen in Figure 2.10, outside Dublin/ Leinster between 75% and 80% of respondents had

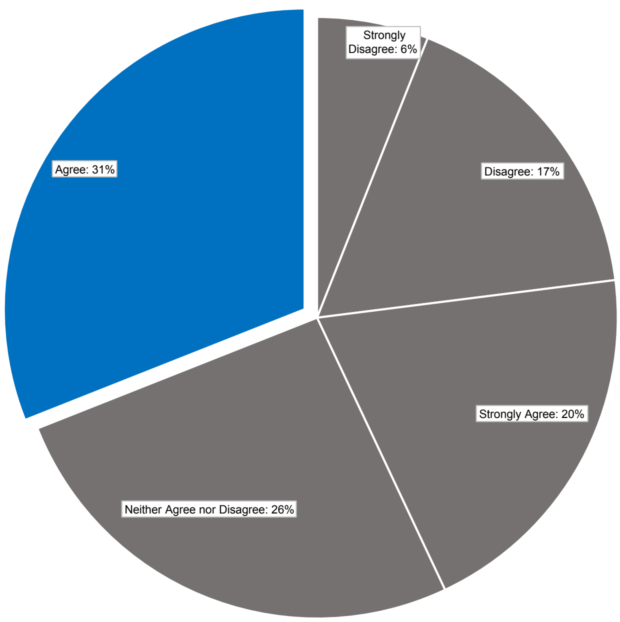

Figure 2.9. Answers to the statement "It is convenient to recycle e-waste."

never seen an in-store e-waste bank (a photo of an in-store e-waste bank, identical to that provided by a well-known electrical retailer in Dublin, was included with the survey) and a total of 19% of the whole population had used an e-waste bank, but only 4% of those were outside Leinster and Dublin. This is interesting, especially given that these consumers do, on average, engage with this kind of infrastructure, if one compares the scheme with that of the battery box, which had been seen by 95% and used by 74% of the population. Respondents' limited participation in the e-waste bank scheme may be explained by the fact that, although 79% of the sample had visited an "electronic superstore" in the 12 months prior to the survey (28% had visited the specific chain which tends to have e-waste banks), 76% of those had only visited only between one and five times in that 12-month period. Hence, visiting a superstore is hardly a routine behaviour.

2.3.2 Organisational research

This section summarises the findings from the organisational research context. Close analysis revealed several themes which emerged across the interviews. Themes included charitable donations, data protection, internal approach to EEE replacement, environmentalism, change and the WEEE process.

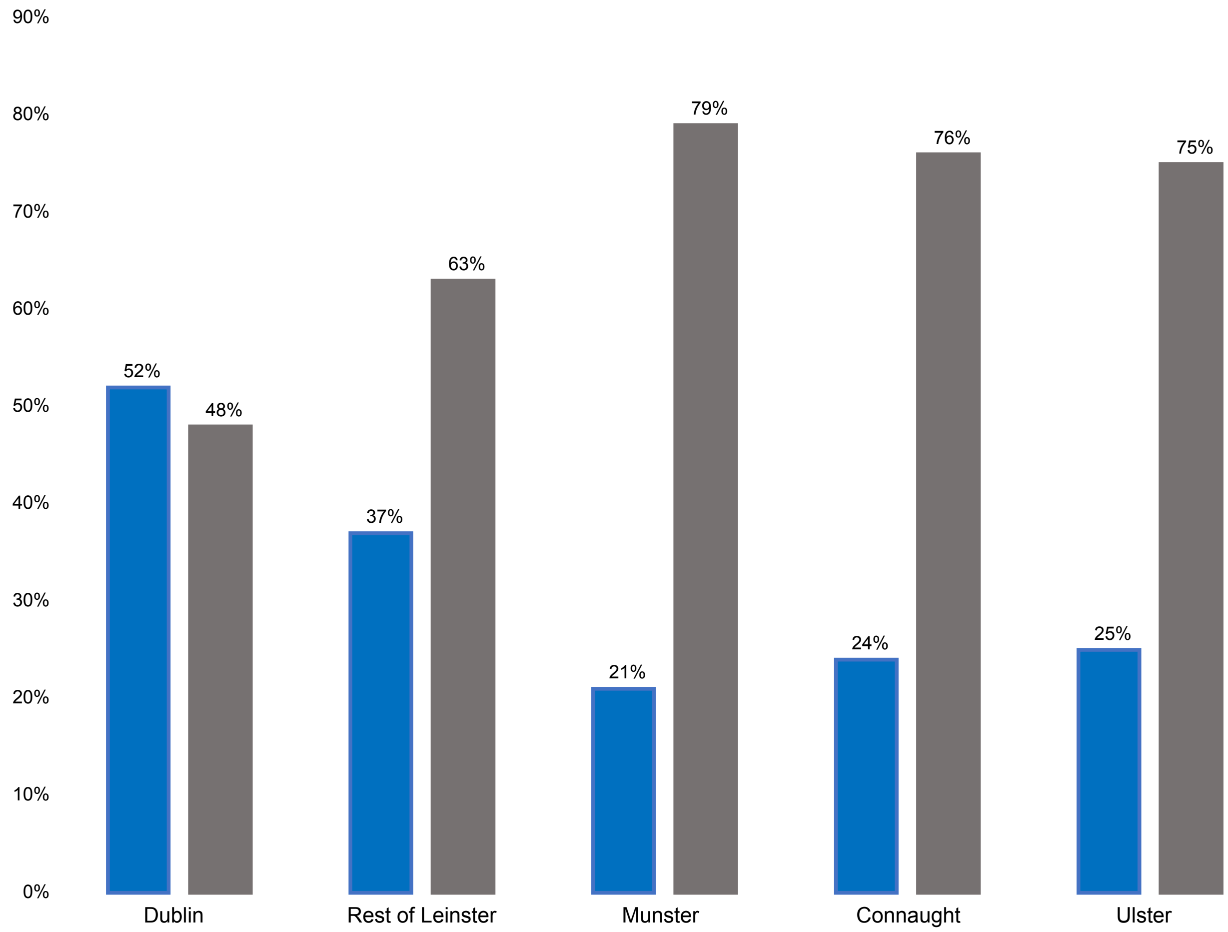

Figure 2.10. Answers to the question "Have you ever seen an e-waste bank?". Yes (blue bars), No (grey bars).

Information or data removal proved crucial across all the organisations; in this study, all but one organisation engaged subcontractors to ensure that all data were removed and employees were issued a certificate as evidence that the ICT had been completely wiped. Organisation 3 relies on employees to inform the information technology (IT) department of broken, obsolete or discarded EEE. On being informed, the IT department wipes the ICT but leaves it in the office. The employee then uses an online form to contact the ICT provider. Organisation 1 is privy to extremely sensitive information; where it cannot be certified that the data have been removed, the hard drives are destroyed. This finding is an example of the difference between consumer and organisational approaches to WEEE, as consumers are not as concerned about data/privacy.

Another key difference is how (W)EEE is evaluated, as most of the organisations have clear rules about how and when EEE is replaced. Several organisations had policies around when EEE is replaced or refreshed (typically between 3 and 5 years; Organisations 1, 2, 6 and 8). Depending on the nature of the equipment, e.g. office equipment versus heavy-duty tools, some organisations tracked how often an item was repaired, deciding to replace it when it became cost-prohibitive to maintain (Organisations 6 and 7). B2B EEE appears to last longer than B2C EEE (Peagam *et al*., 2013). EEE is carefully tracked as valuable assets; this is particularly evident in how industrial or plant (W)EEE is treated. Organisation 6 is an interesting case study. There, running logs are maintained on the machinery and if any machines are not used sufficiently to justify their presence, they are offered to other members of the broader organisation. Based on these logs, independent auditors review the sites, creating an online catalogue depicting plant machinery that are also available to other plants within the organisation. Additionally, Organisation 6 has developed a central hub in Dublin that refurbishes and catalogues equipment for distribution. Organisation 5 also harvests the useful components of industrial WEEE, stores it and uses it to repair other, similar machinery. Organisation 5 often deposits dual-purpose WEEE (usable by both consumers and businesses) with their local EEE supplier and thus it joins the municipal flow.

All but one organisation (Organisation 5) employ subcontractors to collect ICT or small WEEE on given dates, when it reaches critical mass, i.e. after an office has been refurbished, or at the behest of an employee. In some cases, employees habitually bring WEEE to dedicated locations (compounds – see Figures 2.11 and 2.12) or alternatively an email is sent to all of the employees, who then bring their WEEE to a collection point.

Organisation 8 has taken this approach a little further. A subcontractor in London is responsible for its ICT; it also leases its photocopiers and is thus not responsible for ICT WEEE recycling. Regarding its plant WEEE, it also collects it on site until it reaches critical mass. In almost every case ICT WEEE collection was initiated by employees; however, most organisations did not actively train their staff about WEEE collection. Only one organisation included waste disposal in its induction (the emphasis was not on WEEE). Additionally, Organisation 2 has "awareness campaigns in the context of a campaign set up in the canteen when you inform people about how long it takes certain things to decompose" (again, the emphasis is not on WEEE). There is some recognition that creating more employee awareness around WEEE may be beneficial; for example, one participant suggested that a responsibility tree/ WEEE disposal routine be included in the employee

Figure 2.11. Compound at Organisation 2.

Figure 2.12. Compound at Organisation 2.

induction so as to create a new habit at a "moment of change" (Organisation 3). This is particularly pertinent to Organisation 3, given reliance on individual employees.

Across the board WEEE represented a small percentage of the organisational waste stream (e.g. Organisation 5 – 2%; Organisation 2 – 3%). This has an important consequence for how WEEE is viewed by organisations, either as not part of their main waste streams (Organisation 9) or as not even recyclable (Organisation 5).

> We closely monitor our component supply chain in and out, but our services are refurbishment and replacement of engine parts rather than electronic components so the only electrical or electronic waste on site is from end-of-life equipment from the offices and on very rare occasions from the service floor. (Organisation 9)

> It's small in our overall waste stream, we concentrate heavily on bottles and we concentrate heavily on food and *we concentrate heavily on recyclables* and all that kind of stuff. [WEEE] probably gets the least amount of attention because it happens the least. (Organisation 5)

Other organisations initiated the interview by stating that "we don't have an awful lot of e-waste" (Organisation 8) or by explaining that they do recycle other materials. Consequently, WEEE does not receive as much attention as other forms of waste; in fact, Organisation 5 openly stated that a "scrap guy" collected its industrial WEEE once a year, including the "electrical components". It should be noted that this organisation is the only small to medium-sized enterprise (SME) represented in the data; future research should perhaps focus on SMEs, as the larger organisations tend to have more regimented and embedded approaches to waste disposal. WEEE becomes an afterthought, unless considered in terms of charitable donations.

> Charity, I'd say that's what happens to a lot of the stuff. We get back information about if [it] was used, if it contributed to a charity – [information about how the donated WEEE items were used] would be sent back, that. Guys like to hear that the phones went on and €4000 was donated to charity. (Organisation 6)

> One man's waste is another man's gold. (Organisation 5)

> In the last two years they refurbished about 30 of their labs, between about 600–900 PCs. A lot of their stuff would be end of life as opposed to end of use, I know that they've sent a certain amount of stuff off to Camara, X raised the question "is this a good thing to be doing? Because if its end of life you are basically sending waste out to Africa." (Organisation 3)

Whereas end-of-life (EoL) WEEE tended to be recycled, end-of-use (EoU) WEEE was very often donated to charity. Two defunct charities were mentioned (Smile Resource Exchange and the Jack and Jill Foundation) as well as Camara Education. This indicates that even in the context of commercial property people still prefer an item's use potential to be exhausted. Organisations were mindful of the difference between EoL WEEE and EoU WEEE, making a conscious effort to donate only that which was EoU. The charitable aspect of WEEE disposal was also evident in the consumer research conducted previously. Interestingly, charities offer ample opportunity for WEEE collection in both contexts.

Several participants stressed the importance of being "exemplars" as regards sustainability (Organisation 1) or an example of best business practices (Organisation 2) in all things environmental. Organisation 6 offers educational tours to school children. Several organisations (Organisations 3, 4 and 7) are involved in programmes such as the Green Campus programme and the Green Metric University rankings, which encourage environmentally sound practice. These programmes make models of campuses, sustainable practices and communities. They provide clear, holistic and achievable objectives around which organisations can build structures with clarity as well as with distinct timelines. They also engender community spirit (the participant described his involvement in the programme as "great fun"). Thus, they are effective changemaking tools.

Change emerged as a recurring theme, discussed in positive terms, with several participants communicating an organisational desire to go beyond legislative requirements (Organisations 1, 2 and 3). This "sea change" (Organisation 1) in environmental policy and legislation underpins a cultural change within several organisations as offices go paperless (Organisations 1, 5 and 6) and mixed recycling stations become an office norm (Organisations 1, 2, 3, 5, 6 and 7). However, two participants described more localised change. For example, Organisation 6 was recently "flipped onto a global network" when taken over by an multinational corporation; this resulted in a move away from a paper to a digital platform. Organisation 3 suggested that an attempt to attain a Green Flag in the area of waste disposal instigated a "hardening up of" WEEE collection processes.

> Getting the green flag has absolutely driven [us] getting our act together as regards waste management, but it has been supplemented by the fact that we have a grounds manager on board who sees the benefit of this. (Organisation 3)

In the case of Organisation 3, change was also triggered by the addition of two new team members – a grounds manager who was particularly interested in creating a waste compound and a Masters student who encouraged critical thinking. This brought different departments together to address WEEE collection, it brought new information to the fore and asked difficult questions about how things were being done. An understanding of the kinds of change that promoted the "hardening up" of WEEE processes across these institutions could help encourage change in other organisations.

2.4 Discussion and Recommendations

2.4.1 Consumer research

This research underlined several important findings presented in ColectWEEE (Casey *et al*., 2018), for example a consumer propensity towards frugality. Frugal consumers tend to store items that retain *use potential* (either in whole or in part), and thus where policymakers see waste, consumers see *stuff.* Furthermore, consumers see no connection between (W)EEE storage and environmental degradation and so there are no pertinent negatives to storing (W)EEE. Thus, where consumers see the neutral act of storage, policymakers see negative hoarding. If consumers are to be engaged fully in this process, there is a dire need to address these gaps in interpretation. For example, consumers' perception of WEEE as objects retaining use potential must be addressed in order to devise interventions that deter this kind of accidental acting in bad faith, whereby these items are stored and gradually slip into unconsciousness.

It is often argued that consumer engagement with WEEE recycling would probably increase if consumers were better informed about the carbon content of WEEE and the circular economy and if they understood how and where to dispose of their WEEE (Gurauskienė, 2008); however, this research implies that consumers are engaging with the process once they have characterised an item as waste. If WEEE is reinterpreted as a valued resource, consumers may readily recycle their WEEE. This research further challenges the received wisdom that consumers lack information – 73.9% of consumers reported disposing of WEEE via the correct channels. However, there is one avenue that seems underused, namely the new legislation allowing small WEEE to be deposited at specific stores. Only 5% of respondents took advantage of this scheme, despite it seemingly being the most convenient avenue. A targeted campaign aimed at improving this scheme's engagement may increase awareness around WEEE in-store recycling, thereby increasing overall collection. Similarly, nearly half of the respondents reported having never seen an e-waste bank (35% of Dublin-based respondents, in contrast to 3.5% outside Dublin/Leinster) and 66% of the Dublin-based respondents who had seen an e-waste bank had actually used the facility. This is a strong level of engagement that could be easily replicated. Previous research has found that depositing WEEE in store with the staff can feel uncomfortable; e-waste banks could potentially overcome this barrier (Casey *et al*., 2018). These findings suggest that e-waste banks could encourage greater deposits of small WEEE by consumers.

2.4.2 Organisational research

A dearth of research on B2B WEEE amounts to impoverished resources for policymakers, and this work offers some insight. However, this is an area that urgently requires further research, especially in relation to SMEs (although this will be a challenging population). This thematic analysis revealed several interesting insights. As regards the actual processes, there is a degree of uniformity across the participating organisations, with the notable exception of Organisation 5, which is the only SME. Organisation 5 disposed of both industrial electrical components and dual-purpose WEEE via inappropriate channels. In cases where commercial WEEE requires special treatment (e.g. photocopiers) an extra charge may be apt. However, in other cases there is no evident benefit from differentiation between B2B and B2C; it merely complicates compliance (Khetriwal *et al*., 2011). How SMEs dispose of dual-purpose WEEE requires investigation.

Several participants were their organisation's environmental officers. However, WEEE was simply not a concern; it represents a tiny percentage of commercial waste and is therefore an afterthought. A lack of organisational concern about WEEE becomes problematic when individual employees are responsible for WEEE disposal (i.e. as in Organisation 3, where employees inform the IT department of obsolete and disused EEE). Several organisations run regular employee induction programmes, which may be a useful way to encourage greater awareness. Additionally, WEEE is a particularly harmful waste. Although it would appear that larger organisations address it appropriately, smaller organisations may not be as diligent and, being an afterthought, appropriate disposition may not be a priority. Future research projects should focus on determining how much WEEE is generated by SMEs and where that WEEE goes.

3 Quantification of WEEE Presenting in Scrap Metal

3.1 Context: WEEE in "Complementary" Waste Streams

Not all WEEE is disposed of correctly. As evidenced by this research, both householders and organisations admit to non-compliant methods of EEE disposal. It is also a recognised phenomenon that WEEE is collected by agents other than producer compliance schemes and registered recyclers (Huisman and Baldé, 2012; Magalini *et al*., 2015). These occurrences can be accidental or intentional and ultimately lead to WEEE being mislabelled or integrated into metal scrap. This WEEE is then not identified as part of the general WEEE statistics, leading to problems for Member States in meeting collection targets (Magalini *et al*., 2014). The WEEE Directive indicates that Member States need to collect information on EEE POM, collected through all routes (EU, 2012). An FAQ document on the WEEE Directive acknowledges the complexity of WEEE flows and the difficulties presented by higher collection targets. In order to help Member States demonstrate achievement of collection targets, substantiated estimates that are "supported by independent scientific methodologies and be based as far as possible on real market data" may be used (European Commission and DG Environment, 2014). Notwithstanding Ireland's commitment to an "all actors report" model, WEELABEX standards and ambition to treat all WEEE to this standard, the generation of substantiated estimates of WEEE arising in metal scrap may provide further insight into collection blind spots, identify key intervention points and ultimately improve WEEE collection through compliance schemes (Magalini *et al*., 2014).

3.2 Establishing a Substantiated Estimate of WEEE Arising in Scrap Metal Collections

This chapter outlines the development of a method to establish substantiated estimates of WEEE arising in scrap metal collections from domestic and business customers. Section 3.2.1 describes the development of the sampling method in consultation with stakeholders, waste collectors and scrap metal processors. Section 3.2.2 presents the sampling locations and data analysis methods and section 3.2.3 details the method developed for establishing a population size and sample size using data available from the National Waste Collection Permit Office (NWCPO), the National TransFrontier Shipment Office (NTFSO) and the Environmental Protection Agency (EPA).

Figure 3.1 details the desk-based, consultative and field work dimensions to this research. Considerable work has been invested is establishing the knowledge base regarding complementary WEEE flows in the Irish system, particularly those leading to WEEE arising in scrap metal/metal recycling facilities.

3.2.1 Consultative research

To gain insights as to how WEEE presents in metal scrap and to guide the development of the substantiated estimate a range of stakeholders were consulted.

Waste management companies described how WEEE arises in domestic and business waste collections, particularly skip hire. Returning WEEE to the source is impossible (discovery is made late, customer is far away, customer loyalty needs to be ensured, etc.). The contractors subsequently sort metal-containing objects into "good" and "bad" scrap piles: items that have a high metal content (e.g. a washing machine) would go in the "good" scrap pile and small WEEE (mostly comprising plastics such as small household appliances) would be considered "bad" scrap. Because any metal is not immediately recoverable, such items are more than likely to be shredded to release their metal content. Both "good" and "bad" scrap is taken to a scrap metal processor, who may or may not pay a rate according to grade and the extent to which it is mixed with non-WEEE.

Scrap metal processors generally accept waste metal from waste management contractors and individual permitted collectors. They also accept waste from the public, commercial and industry sources. Processors aim to work towards an "end-of-waste" model; therefore, post processing the metal fractions are deemed "end of waste" and are essentially clean raw materials ready for reprocessing. They

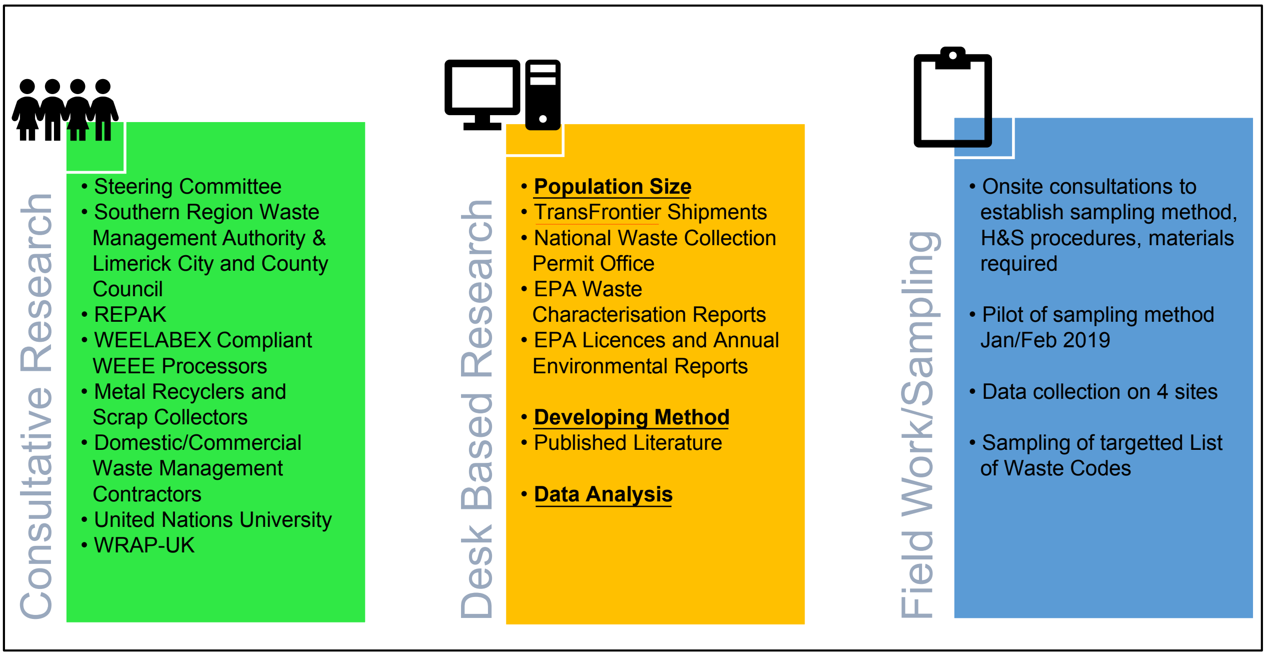

Figure 3.1. Overview of research methods employed.

report that margins are tight and space is minimal. Operators optimise processing, as each stage adds cost and depletes profit and the mantra that "every time you touch something it costs you money" is frequently repeated. Waste arrives on site, is weighed by weighbridge and assigned a European Waste Catalogue (EWC) code from the EWC List of Wastes (LoW). Sites are obliged under their waste permit conditions to keep a written record of all waste arriving on site, including (1) date of receipt, (2) the name and waste collection permit number of the company that transported the waste, (3) the location from which the waste originated and (4) a description of the waste, including LoW code. Depending on the source and LoW code, the load may be tipped and spread using a grab. On some sites, WEEE that is problematic (e.g. fridges, freezers) is removed, stored and subsequently diverted to a WEEE recycling facility. If single-material items are present, then these are sorted according to material type (e.g. copper cylinders, stainless steel items). Large (generally steel) objects may be set aside for shearing. Wastes that cannot be separated or determined as single metals become shredder or "frag" feed. After shredding or "fragmentisation" subsequent automated material separation occurs to add further value. The aim in scrap metal processing is to refine the scrap as far as possible to the end-of-waste standard so that the profit is maximised. Customers are paid for waste metal according to the grade; any off-specification materials are not rebated, and in some cases the costs of treatment are deducted from the overall payment to the customer. "Bad scrap", i.e. that which is bound to other materials such as wood, plastic or fibres, is sent to a shredding facility to release the metal components. Mechanical shredding facilities operated by scrap metal processors in Ireland are subject to Industrial Emissions Directive licensing by the EPA. All sites are permitted to accept WEEE; the licence conditions for shredding facilities state that "only WEEE that has been subject to selective treatment shall be treated in the shredder". Consultation with domestic/commercial waste contractors, WEEE recycling facilities and scrap metal processors as well as international research revealed that this is not the case and significant quantities of WEEE arise in metal scrap that are not separated for appropriate treatment.

At the time of project initiation, the UK was the only country to have completed a substantiated estimate of WEEE, specifically large domestic appliances arising in iron scrap (Smith *et al*., 2014). Their methodology consisted of segregating large domestic appliances from metal scrap arriving on site and using the sites' weighbridges to weigh materials. Consultations with scrap metal facilities in Ireland revealed that challenges with space and site turnover would render this method unworkable here, as the sites would need to be compensated for downtime incurred.

The research team was small and it was therefore necessary to devise a rapid assessment method that would be as minimally invasive as possible, reliable, replicable and low cost. This is also reflective of the constraints in which the EPA and local authority inspectorate operate.

Finally, pilot data collection and processing were conducted on two sites. The findings of the piloting were presented to the steering committee for approval before sampling officially commenced in March 2019.

3.2.2 Sampling

All researchers going on site completed Safe Pass training, manual handling training and a site-specific induction. A consultation meeting with each site was required in advance of sampling to ensure that the site accepts waste that is representative of the population. It was also necessary for the sites to operate as normal and not separate out WEEE that they would not have if the research team were not present. Clear communication with the grab operator was required to get the waste spread for observation and recording. The sampling method is outlined in Figure 3.2.

To ensure minimal disruption to the operations on site the research team counted the numbers of WEEE items, through observation and photography of items as they presented. To obtain the mass of the recorded items they were classified according to the United Nations University (UNU) classification system “UNU-keys” and assigned the according weight. There are 54 UNU-keys, which can then be grouped by EU-10 category or, more importantly, for current e-waste reporting and categorisation, EU-6 category. UNU-keys can be used to convert units to weights by applying average POM kg/unit weights

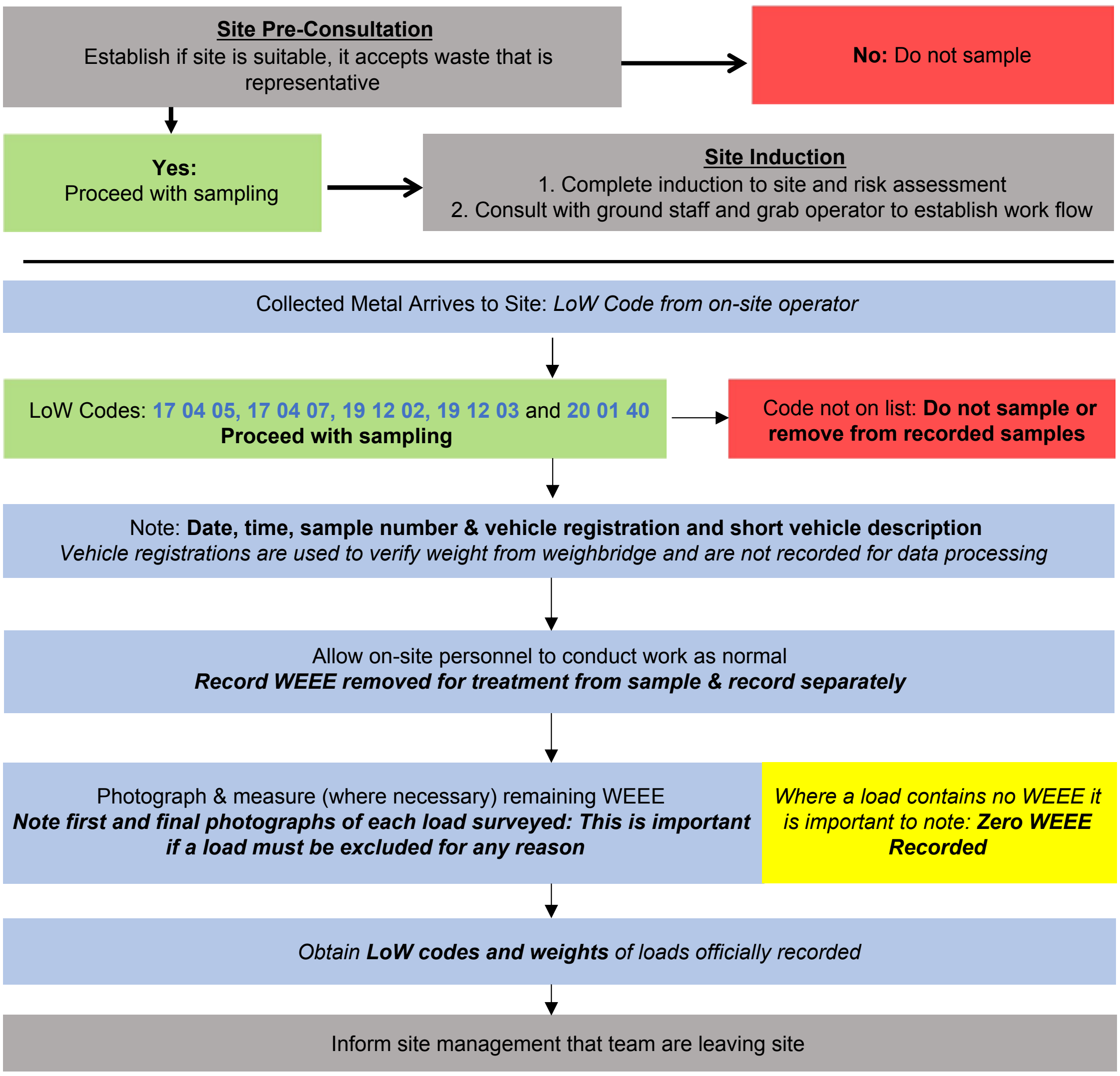

Figure 3.2. Site sampling decision and method flow chart.

from the EU-28 as described by Forti *et al.* (2018). The full list is presented in Appendix 1. The year 2000 was chosen as the average POM year for the WEEE arising in metal scrap. Previous studies on Irish WEEE arising (Johnson and Fitzpatrick, 2016) determined that in 2020 almost half of large WEEE items would be expected to be historical, i.e. pre-2005 POM. Twenty-nine categories did not change unit weight between 1995 and 2016; however, 12 categories decreased in weight and 13 categories increased. The degree of change was highest for the items increasing in weight. Appendix 2 provides details on the data entry method used to calculate weights of WEEE arising in scrap metal. A selection of photographs from the sampling is collated in Figure 3.3.

3.2.3 Establishing the population size

Initial consultations with scrap metal recyclers and the steering committee were used to compile the LoW codes (EPA, 2015), with potential for WEEE to be found incoming to scrap metal sites (Table 3.1).

Codes 16 02 14 and 20 01 36 are recorded as electronic waste, and weights etc. are reported to the NWCPO. Researchers informed sites that any waste coded 17 04 05, 17 04 07, 19 12 02, 19 12 03 and

Figure 3.3. Selected photographs of sampling conditions on scrap metal sites.

Table 3.1. LoW codes where WEEE typically is found incoming to scrap metal processors

LoW code	Waste description
16 02 14	Waste from electrical and electronic equipment not containing PCBs or hazardous components
17 04 05	Construction and demolition wastes: iron and steel
17 04 07	Construction and demolition wastes: mixed metals
19 12 02	Wastes from waste management facilities; wastes from the mechanical treatment of waste (e.g. sorting, crushing, compacting, pelletising): ferrous metals
19 12 03	Wastes from waste management facilities; wastes from the mechanical treatment of waste (e.g. sorting, crushing, compacting, pelletising): non-ferrous metals
20 01 36	Municipal wastes (household waste and similar commercial, industrial and institutional wastes): discarded electrical and electronic equipment not containing hazardous substances
20 01 40	Municipal wastes (household waste and similar commercial, industrial and institutional wastes): metals separated out from municipal, household, commercial and industrial waste

PCB, polychlorinated biphenyl.
Source: EPA (2015).

20 01 40 (construction and demolition waste, municipal waste and waste from waste management facilities containing metal) had been identified as potential for sampling on site. However, during the sampling period LoW codes 17 04 07, 19 12 02, and 19 12 03 were not encountered at all on any of the sites. The codes observed were 17 04 05 and 20 01 40 and therefore the sampling focused exclusively on these codes. The national total quantity of these codes from annual returns for 2018 was obtained from the NWCPO. The totals consist of waste collected by waste collection permit holders, plus waste brought by members of the public to waste collection permit holder sites. These are shown in Table 3.2.

Table 3.2. Population data for LoW codes of interest (2018)

LoW code	Waste description	Mass collected (tonnes)
17 04 05	Construction and demolition wastes: iron and steel	212,117
20 01 40	Municipal wastes (household waste and similar commercial, industrial and institutional wastes): metals separated out from municipal, household, commercial and industrial waste	67,945
		Total: 280,062

Source: EPA (2015).

A sample size calculator was used to establish a target sample of 384 tonnes, which would achieve a ±5% confidence interval and a confidence level of 95%. The sampling was undertaken over 15 days between March 2019 and March 2020 and spread across four sites, with a final sample of 415 tonnes recorded. The scrap metal market and steel prices have an impact on volume through sites. Particularly towards the latter half of the sampling period, the impact of the coronavirus disease 2019 (COVID-19) outbreak on sites could be seen, as volumes decreased. A small degree of seasonality exists. December is a busy month, as with the festive period it is a short month, and businesses do clear-outs, settle final bills and balance accounts before the end of the year; as a result January is particularly quiet. Otherwise volumes and composition remain relatively constant throughout the year.

3.3 Results

The headline figure for the study is that 3.91% ±1.88% of the scrap metal sampled was WEEE. This puts WEEE in the range of 2.03% to 5.79%, with a confidence level of 95%. Scaling this for the 2018 data for the LoW codes of interest gives a figure of 10,950 tonnes ±5265 tonnes, which translates to a range of 5685 tonnes to 16,215 tonnes with the same confidence level. In terms of mass per population, these figures equate to 2.28 kg/capita (±1.1 kg/capita). Figure 3.4 shows the most important contributors to the projected mass by UNU-key, and Figure 3.5 shows the most important contributors by count within the material sampled. A full list of UNU-keys is provided in Appendix 1.

To put these data in context for large household appliances, a comparison has been made between the POM “waste collected” for 2017 (most up-to-date data) and the combined figures in the scrap metal for washing machines and dryers, fridges, dishwashers and ovens (Table 3.3).

3.4 Discussion

The WEEE lost to metal scrap is a huge challenge in attaining the targets set out under the recast directive.

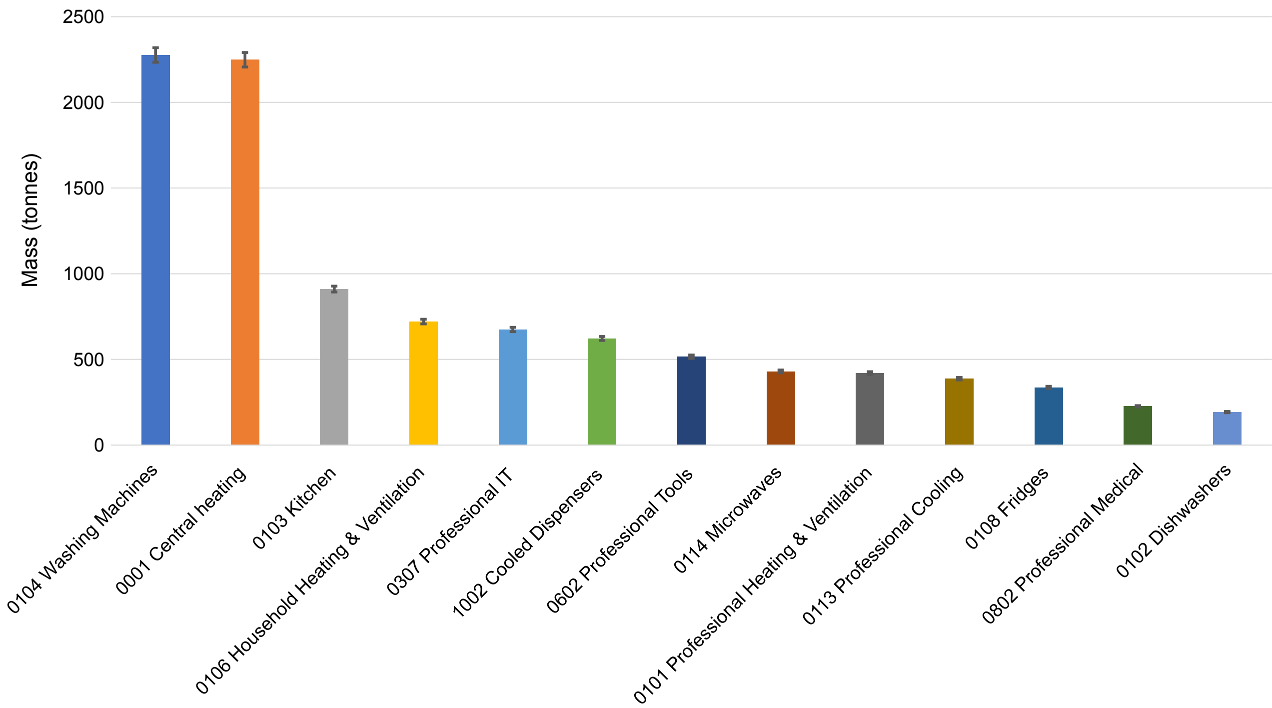

Figure 3.4. Most significant contributors by mass.

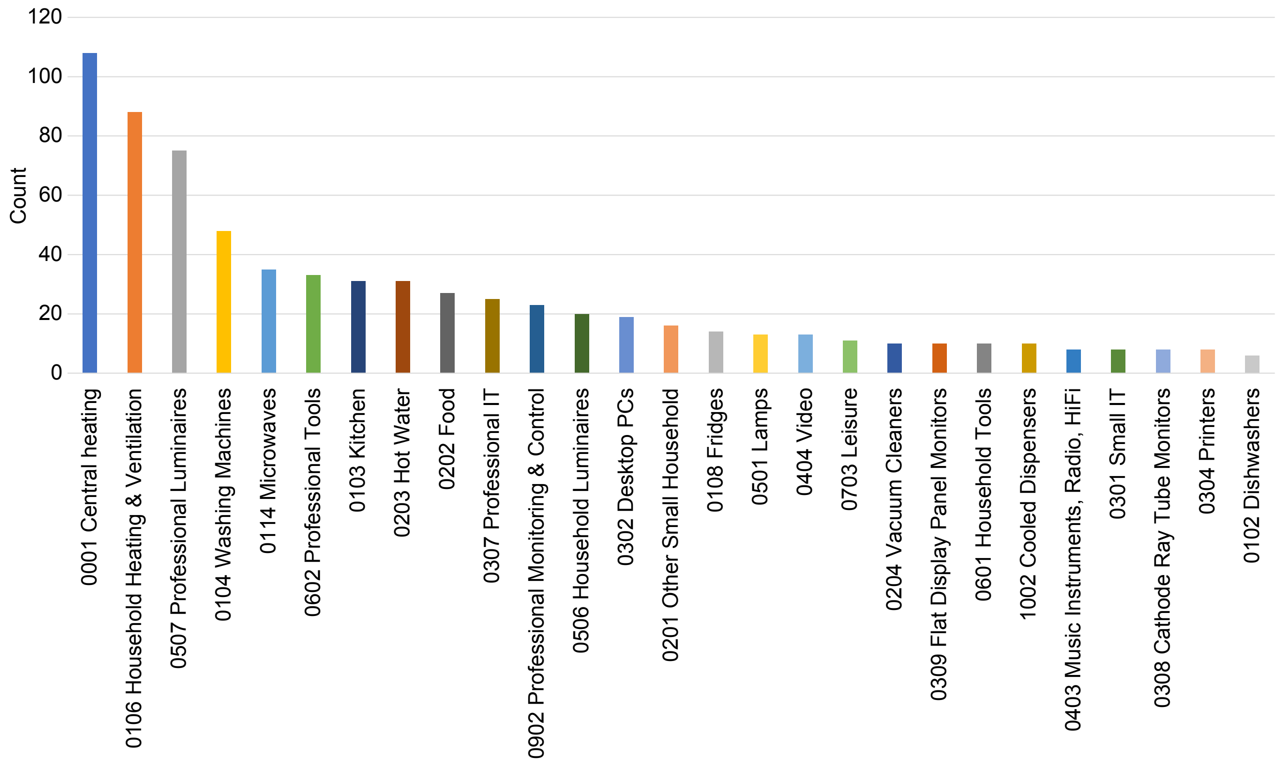

Figure 3.5. Most significant contributors by count.

Finding comparable studies is difficult, as methods to estimate these figures vary. The Countering WEEE Illegal Trade study (Huisman *et al.*, 2015) estimated that in the EU-28+2, 2.2 million tonnes of WEEE mixed with metal scrap in 2012. In the UK, the estimated large domestic appliance content of light iron scrap was found to be 10.87% ±2.4% (Smith *et al.*, 2014). The higher figure in the UK study points to a key

Table 3.3. Comparison of large household appliances in EEE POM and WEEE collected as reported to Eurostat and estimated quantities in scrap metal from this study

	2017		2018
Parameter	EEE POM (Eurostat)	WEEE collected (Eurostat)	Estimated in scrap metal
Large household appliances	53,839 tonnes	30,941 tonnes	3717 tonnes
Total of all (W)EEE categories	108,476 tonnes	52,312 tonnes	10,950 tonnes
Large household appliances as % of total	51%	59%	33%

difference in the structure of its compliance system, which lacks a mandatory retailer take-back scheme. Denmark has mapped unaccounted WEEE flows and estimates that 12,500 tonnes of WEEE is lost to unauthorised scrap dealers (Gilberg, 2017).

The composition of items observed in metal scrap (Figures 3.4 and 3.5) provides an insight into potential intervention areas. Skip hire associated with home renovations is a major source of WEEE in metal scrap and points to impulse decisions at “critical moments” (see section 3.2.1) on the part of the consumer, rather than a calculated scavenging of WEEE for its scrap metal value return.

Some limitations exist to this work; not all scrap metal sites were accessible for sampling purposes. In addition, not all loads could be sampled, as some brought by the public were too small to be weighed by the weighbridge.

Further research is required to fully account for all WEEE flows, particularly termination points, such as landfill, incineration and metals prepared for export.

4 WEEE Arising

4.1 The WEEE Calculation Tool

The recast Directive 2012/19/EU (EU, 2012) introduced a collection target of 45% of EEE POM applicable from 2016 and additionally stated that from 2019 "the minimum collection rate to be achieved annually shall be 65% of the average weight of EEE placed on the market in the three preceding years in the Member State concerned, or alternatively 85% of WEEE generated on the territory of that Member State" (EU, 2012). Member States will choose which way they wish to measure the target reported. It is anticipated that collection targets agreed would ensure that ~10 million tonnes, or ~20 kg/capita, will be separately collected from 2019 (EU, 2012).

To assist in the calculation of WEEE generated and to measure POM rates (where POM rates may not be readily available), the WEEE Calculation Tool was developed. The WEEE Calculation Tool enables countries to calculate WEEE arising using tonnes of EEE POM. The tool aims to provide a model of likely EoL of WEEE and therefore the expected WEEE generated per annum. There are separate versions of the tool (in Excel) for each EU Member State, prepopulated with historical sales data from 1980 to 2014, and a computer and web-based program has been provided to calculate years following on from the tool's development. It is important to note that the tool is not specified as the exclusive means by which WEEE generated can be calculated.

4.1.1 POM: apparent consumption methodology

The pre-filled data of EEE POM were calculated using the apparent consumption methodology, with trade data for each country extracted from PRODCOM. The *Manual for the Use of the WEEE Calculation Tool* (K. Baldé *et al*., 2017) states that users can edit the data in the POM sheet as well as the product lifespans. Users can enter EEE POM data from the national registers in the EU-6 or EU-10 format or use the UNU-keys (54) by using a program that extracts data from PRODCOM for the country in question.[2] Combined Nomenclature (CN) codes are used to identify goods in the economy; the creators of the WEEE Calculation Tool identified between 200 and 300 specific CN codes that correspond to EEE. Codes use different units (e.g. pieces, kilograms) so a conversion table was established with corresponding weights for each code over time. Import and export data include new and second-hand equipment, so the costs associated with each were used to differentiate new and used equipment. The annual quantity of POM is calculated as follows (Huisman *et al*., 2012):

$$\text{POM} = \text{Domestic Production} + \text{Import} - \text{Export} \quad (4.1)$$

4.1.2 WEEE generated: sales/lifespan distribution

To calculate the waste generated at the EU level a methodology called "sales/lifespan distribution" is employed by the tool. Two parameters are used for this: POM (see section 4.1.1) and lifespan distribution. In basic terms, the amount of WEEE generated in a given year is "calculated by a collective sum of discarded products that were POM in all historical years multiplied by the appropriate lifespan distribution" (Magalini *et al*., 2015). However, the route to calculating WEEE generated is more complex (Figure 4.1).

First, there must be an indication of POM from historical sales. In the tool, data reach back as far as 1980. Then, there needs to be an understanding of how the EEE resides in households and businesses, i.e. stocks. For this, results from a Dutch survey were used to measure stocks and gauge residence times, thereby informing two datasets for residence times: (1) age and number of appliances (including a second-hand loop) when discarded and (2) age of stock appliances not yet discarded. This helps to "fine tune lifespans independent of increasing or decreasing

2 The program can be downloaded for use. Alternatively, values can be obtained at: https://statistics-netherlands.shinyapps.io/sales_and_waste/ (accessed 30 November 2020).

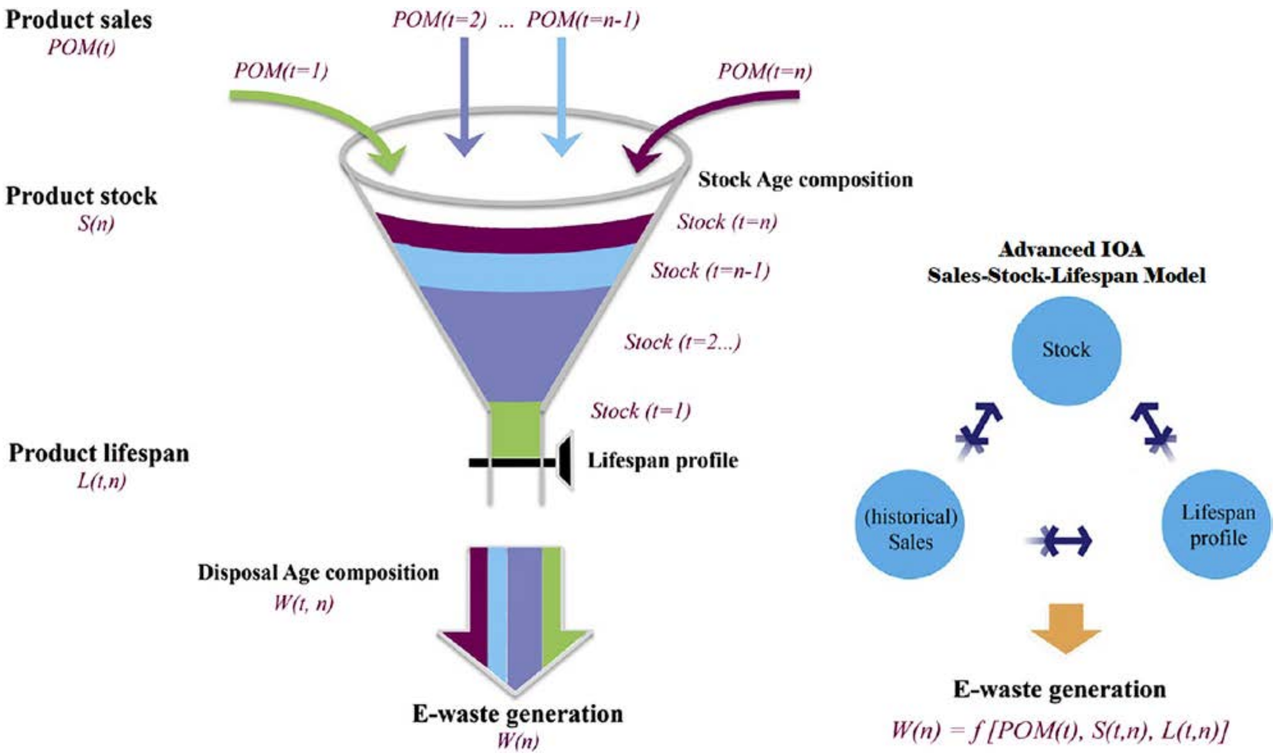

Figure 4.1. Sales, stock and lifespan model. Reproduced from Johnson *et al*. (2018), copyright 2018, with permission from Elsevier.

sales in the past" (Huisman *et al*., 2012). An added "first-year failure rate" is included in the calculations to account for electronics that do not work on arrival or are discarded quickly by consumers. These data are modelled as Weibull functions (Figure 4.2) to describe the movement of EEE from POM to retention to waste generated. In the WEEE Calculation Tool (Baldé *et al*., 2017), waste generated is defined as follows:

> WEEE generated in a Member State means the total weight of WEEE resulting from EEE within the scope of Directive 2012/19/EU that had been placed on the market of that Member State, prior to any activity such as collection, preparation for reuse, treatment, recovery, including recycling or export.

However, this means that the WEEE generated figure is an estimate of the likely amount of WEEE generated but it may not reflect the availability of this for collection (Magalini *et al*., 2020). The Weibull parameters have been generated for an extensive list of appliance types from the year 1990 onwards; an example is provided in Figure 4.2.

4.1.3 Placed on market analysis

The analysis in this section compares the POM calculated from the apparent consumption method in the WEEE Calculation Tool with Irish POM data reported to Eurostat. The POM is prepopulated in the WEEE Calculation Tool for Ireland with data ranging from 1980 to 2015. Figures for 2016 and 2017 using the apparent consumption methodology were obtained using the web-based program. These data were compared with the POM data for Ireland from Eurostat (2007–2017). Figure 4.3 graphically represents this analysis.

Data for 2008–2011 align because the available data from Eurostat for Ireland were used in designing the tool. The divergence from 2012 onwards is the difference between the POM calculated by the WEEE Calculation Tool (using apparent consumption method) and figures reported to Eurostat.

Table 4.1 provides a comparison of EEE POM totals and EU-10 category from the data submitted to Eurostat versus those generated by the apparent consumption method as used in the WEEE Calculation Tool (the years 2015–2017 are shown for comparison purposes). The difference (%) is the degree by which

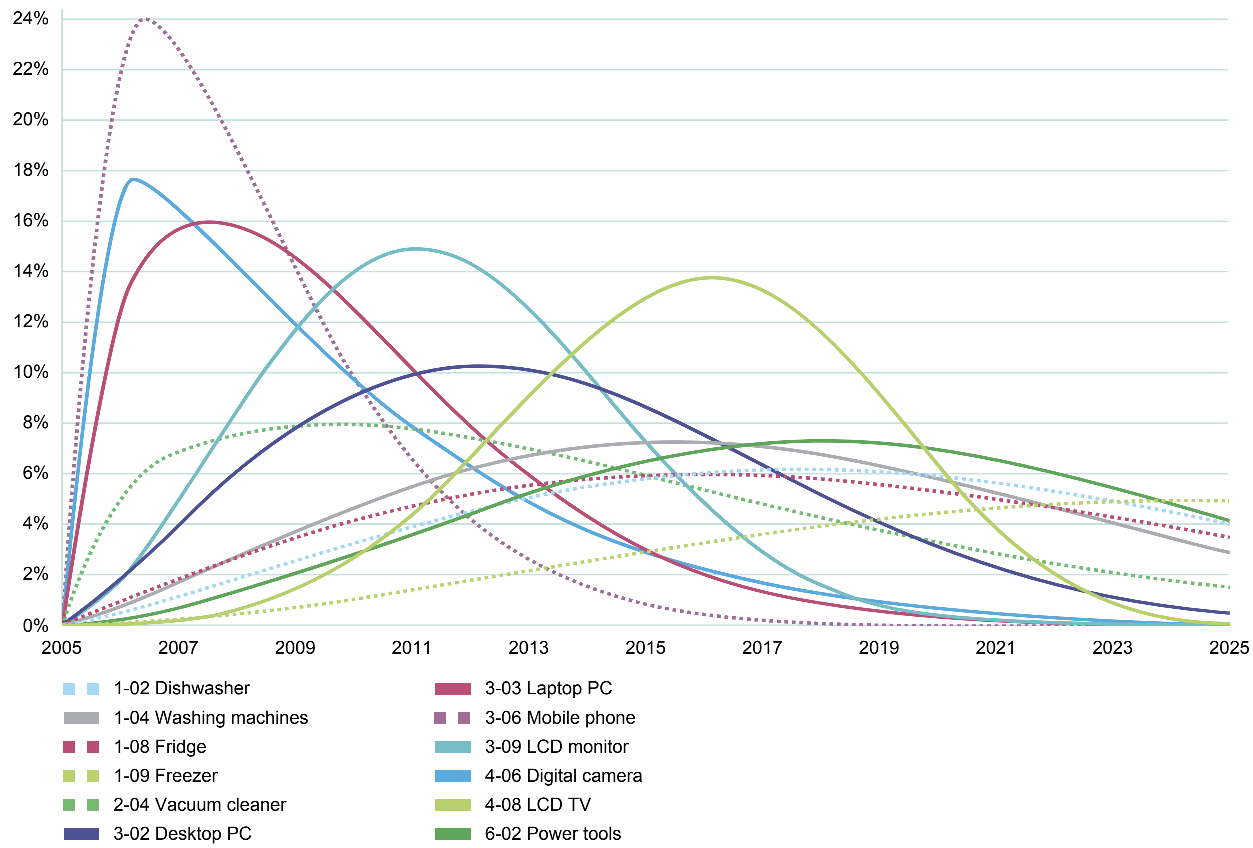

Figure 4.2. Residence times of EEE POM in 2005. Reproduced from Huisman *et al*. (2012) with permission.

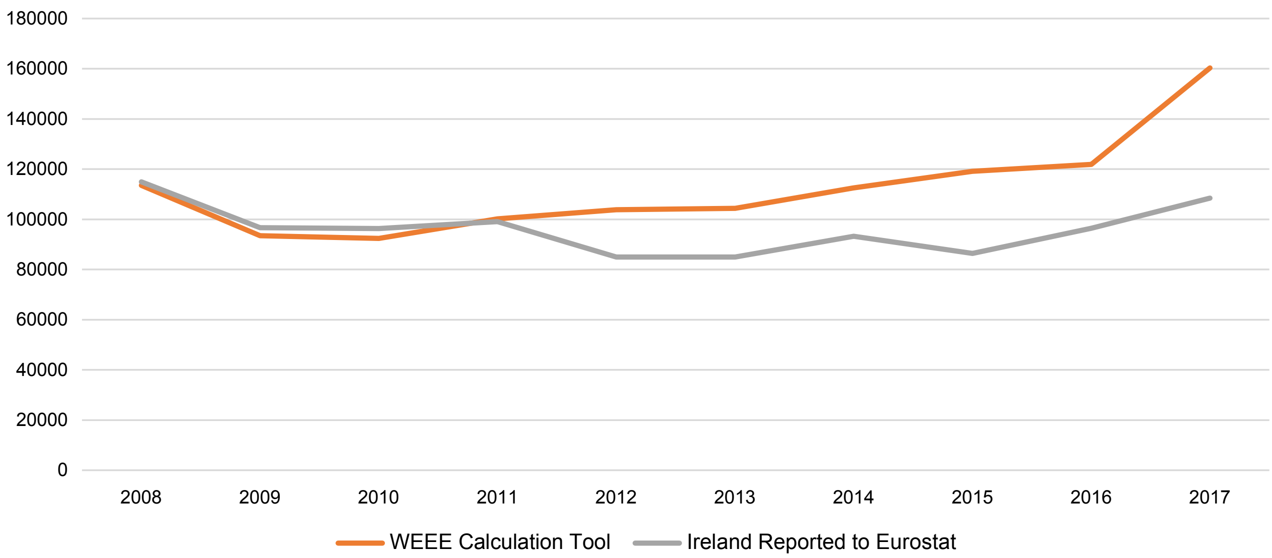

Figure 4.3. Comparison of POM data (tonnes per annum) reported to Eurostat and POM (tonnes per annum) generated by the WEEE Calculation Tool.

Table 4.1. EEE POM totals and EU-10 category breakdowns from data submitted to Eurostat versus those generated by the apparent consumption method used in the WEEE Calculation Tool

Category	Eurostat 2015	Tool 2015	Difference (tonnes)	Difference (%)	Eurostat 2016	Tool 2016	Difference (tonnes)	Difference (%)	Eurostat 2017	Tool 2017	Difference (tonnes)	Difference (%)
POM	86,357	119,149	32,792	38	96,463	121,881	25,418	26	108,476	160,312	51,836	48
EU-1: large household appliances	44,252	60,076	15,824	36	49,100	60,027	10,927	22	53,839	60,564	6725	12
EU-2: small household appliances	9545	17,428	7883	83	12,507	18,120	5,613	45	8,376	18,544	10,168	121
EU-3: IT and telecommunications equipment	12,752	13,475	723	6	11,994	13,344	1350	11	15,505	13,481	–2024	–13
EU-4: consumer equipment and photovoltaic panels	7266	8585	1319	18	7200	11,654	4454	62	9146	48,806	39,660	434
EU-5: lighting equipment	3854	11,279	7425	193	5066	11,150	6084	120	6514	11,190	4676	72
EU-6: electrical and electronic tools	3366	2291	–1,075	–32	4695	2310	–2385	–51	7070	2330	–4740	–67
EU-7: toys, leisure and sports equipment	2407	790	–1617	–67	2406	645	–1761	–73	2312	660	–1653	–71
EU-8: medical devices	1154	2074	920	80	884	2091	1207	137	3082	2109	–973	–32
EU-9: monitoring and control instruments	1110	2741	1631	147	1787	1918	131	7	2057	1974	–83	–4
EU-10: automatic dispensers	651	410	–241	–37	824	623	–201	–24	575	656	81	14

the tool over- or underestimates based on the Eurostat figures.

4.1.4 WEEE generated

The WEEE Calculation Tool was used to calculate WEEE generated using the prepopulated data and EEE POM data from Eurostat for 2015, 2016 and 2017. These figures were then compared with the figures for WEEE collected from Eurostat for which data are available from 2007 to 2017. The WEEE collected is falling well below EEE POM and WEEE generated as calculated by the tool (Figure 4.4).

4.1.5 Trends in WEEE generated

Large household appliances appear to account for the majority of WEEE generated (Figure 4.5).

In order to assess the trends envisaged for the remaining categories, EU-2 to EU-10 were plotted separately (Figure 4.6).

The WEEE generated predicts a decline in EU-4 consumer equipment (excluding photovoltaics). The section for photovoltaics predicts a very low WEEE generated for photovoltaics (single digits), yet apparent consumption demonstrates that photovoltaics are becoming a significant contributor to EEE POM.

4.1.6 Altering the POM data in the WEEE Calculation Tool

It was decided to test if altering the POM data in the WEEE Calculation Tool would influence the waste generated output. Using Eurostat data from 2007 onwards, the input POM function on the tool was used to generate a UNU-keys breakdown; this was repeated for all years and a new version of the tool was created where data from 2007 to 2014 were overwritten with Eurostat data as opposed to apparent consumption data. Additional Eurostat data were then input for 2015, 2016 and 2017 to calculate the WEEE generated (Figure 4.7).

It appears that the historical WEEE has a significant impact on WEEE generated predictions. Working backwards to convert EU-10 to UNU-keys is not reliable, as some products may be more plentiful in 2014 (the final year of the tool data available) than in 2007, e.g. photovoltaic panels.

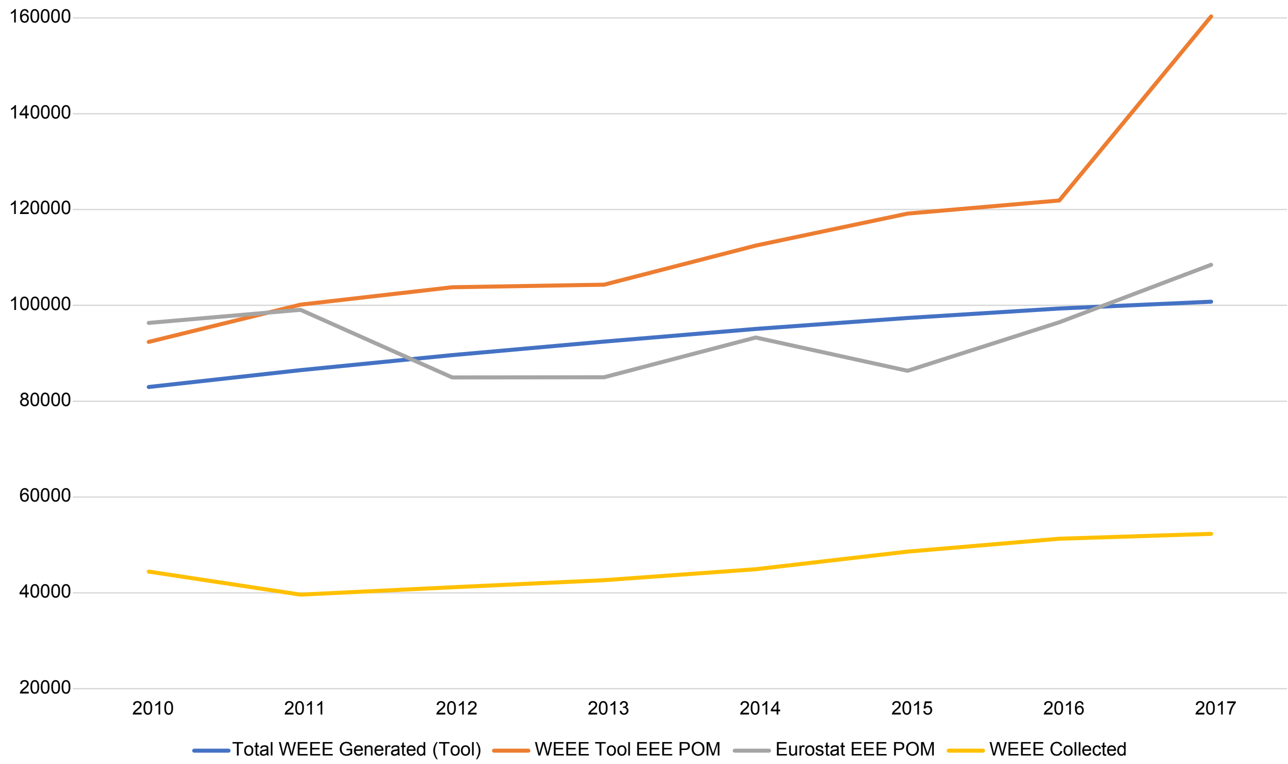

Figure 4.4. WEEE generated per annum (tonnes).

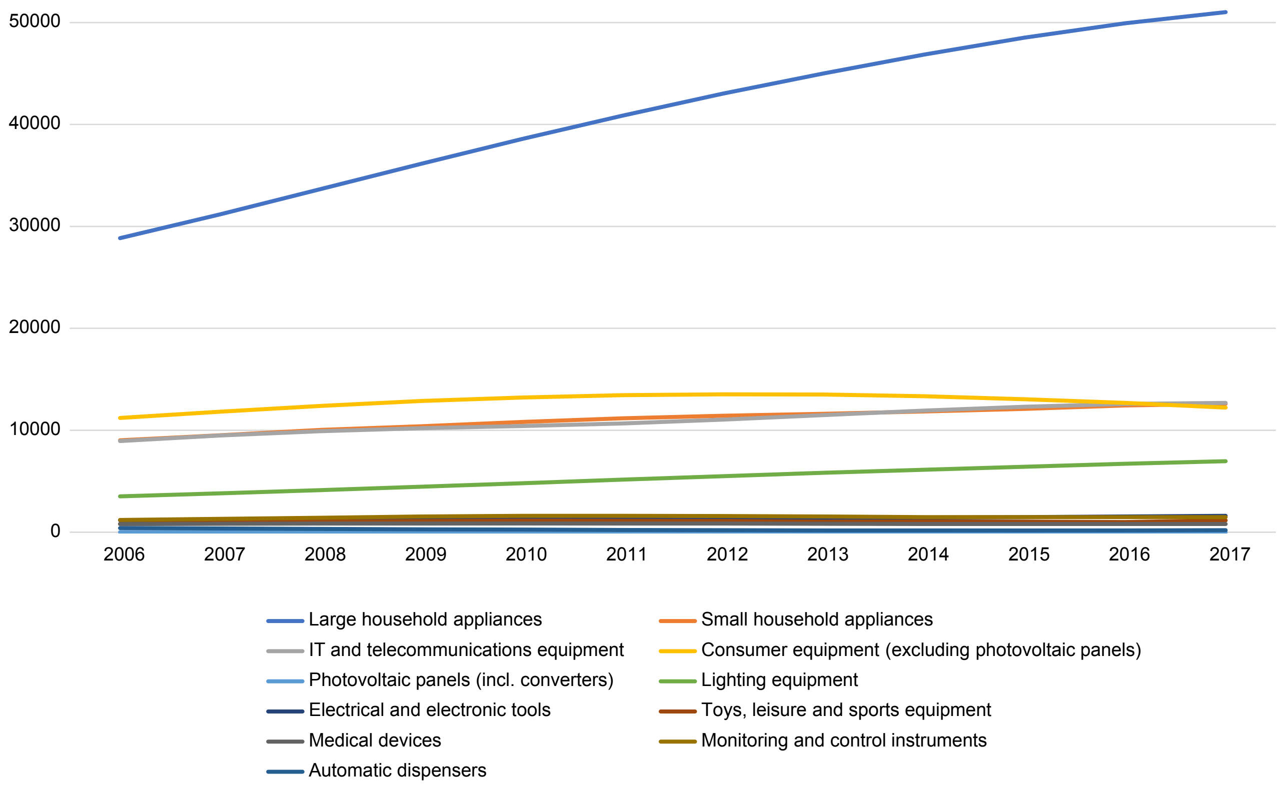

Figure 4.5. WEEE generated EU-10 classifications from the WEEE Calculation Tool.

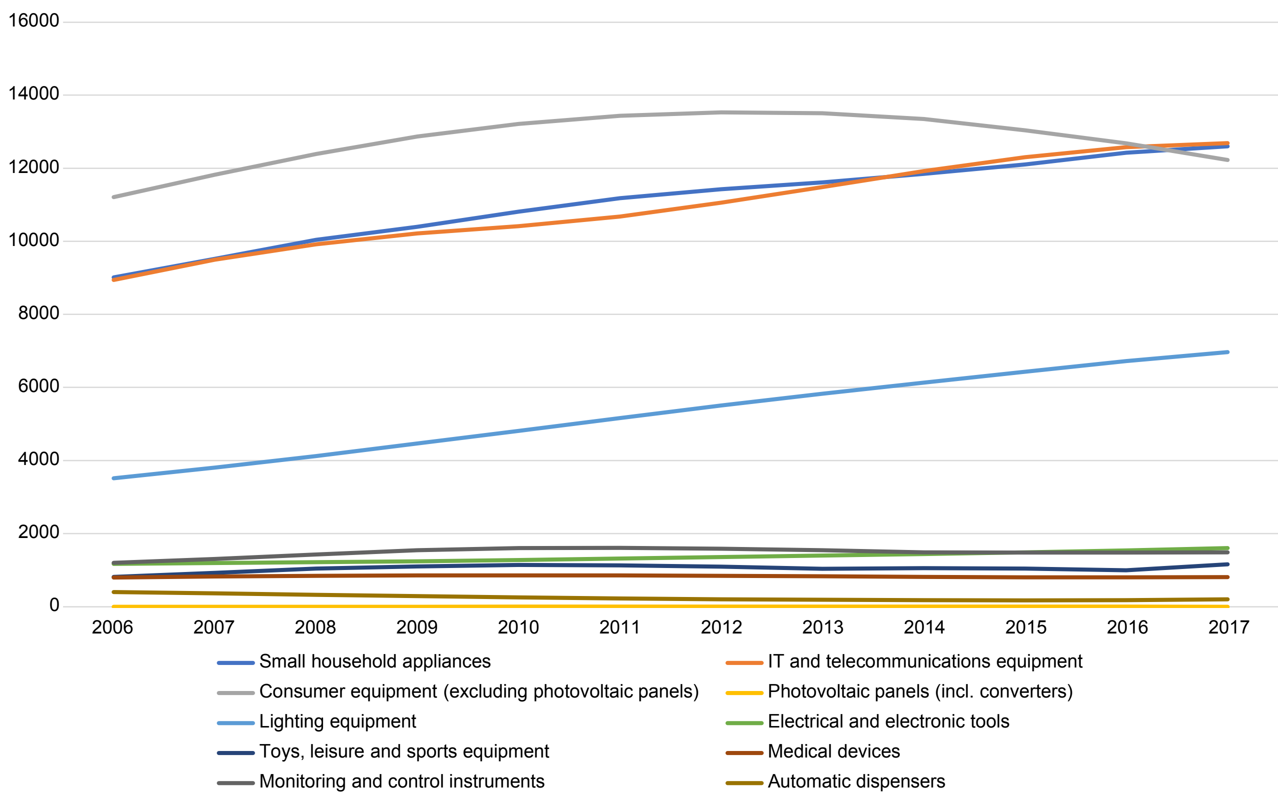

Figure 4.6. Categories EU-2 to EU-10 (large household appliances excluded) of WEEE generated (tonnes).

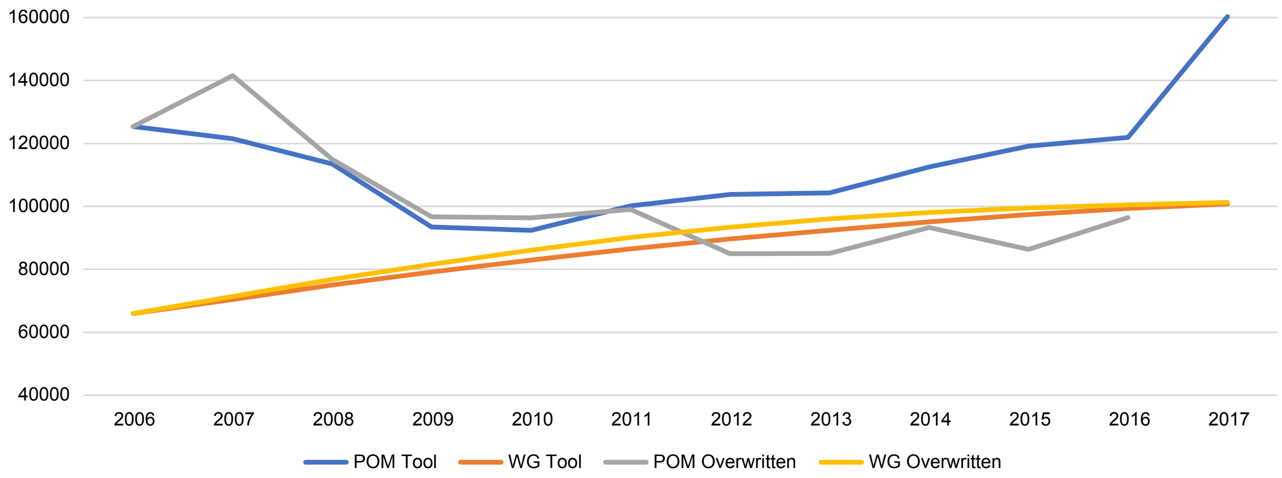

Figure 4.7. Results of altering POM data in WEEE Calculation Tool to match Eurostat data (tonnes).

4.1.7 *Target setting*

Table 4.2 reflects the reported WEEE collected as percentages of the average of 3 years' previous POM as calculated by the WEEE Calculation Tool, the average of 3 years' previous POM reported to Eurostat, and the reported WEEE collected as WEEE generated (calculated using the WEEE Calculation Tool).

4.2 Findings and Discussion

Both Romania (Magalini *et al*., 2020) and the UK (Stowell *et al*., 2018) have conducted research on target setting using the WEEE Calculation Tool. Both concluded that they are facing significant challenges in meeting POM or waste generated targets.

4.2.1 *Placed on the market analysis*

Figure 4.3 raises the following questions. (1) What are the causes of divergence between the POM data in the WEEE Calculation Tool and Eurostat-reported POM figures? (2) The apparent consumption method shows a spike between 2016 and 2017; can reasons for this be identified?

It is important to examine both the percentage and weight differences between the two figures. A large percentage difference does not necessarily equate to a large contribution to the overall differences in totals. For example, from 2012 to 2016, category EU-1, large household appliances, provides the bulk weight of the EEE POM Eurostat data and were calculated at an average of 47% and 53% of total POM using Eurostat and the WEEE Calculation Tool, respectively. In the case of category EU-5, lighting equipment, there is an average 107% increase in tonnes calculated by the WEEE Calculation Tool, but because the average weights are lower, the magnitude does not appear as large in comparison with moderate increases in large household appliances. The more significant numbers derived from the apparent consumption method may point to free riders or underreporting of EEE POM

Table 4.2. WEEE collected as a percentage of WEEE POM (Calculation Tool and Eurostat data) and WEEE generated

WEEE collected analysis	2010	2011	2012	2013	2014	2015	2016	2017	2017 + WEEE in metal scrap
WEEE collected as a percentage of average of previous 3 years' POM from Tool (target 65%)	41	40	43	43	44	46	46	44	53
WEEE collected as a percentage of average of previous 3 years' POM from Eurostat (target 65%)	46	40	48	50	48	56	53	57	68
WEEE collected as a percentage of WEEE generated (target 85%)	54	46	46	46	47	50	52	52	62

to the producer register. Certain categories, such as category EU-5, lighting equipment, may prove to be products where improved B2B EEE POM reporting resolves accounting issues. However, this is not a complete interpretation; the source of divergence is not consistent with underreporting from the national register, since many of the EU-10 categories at some points over the years analysed had larger Eurostat tonnage values than those produced by the WEEE Calculation Tool. These were EU-3 – IT and telecommunications equipment; EU-6 – electrical and electronic tools; EU-7 – toys, leisure and sports equipment; EU-8 – medical devices; EU-9 – monitoring and control instruments; and EU-10 – automatic dispensers. There are no discernible patterns with respect to the differences between figures derived from the WEEE Calculation Tool and those reported as POM. Possible explanations for this may lie in the method by which apparent consumption works. Producer registers work based on actual weights provided by sellers and producers, whereas apparent consumption is reliant on the application of average weights to categories of materials. It is also possible that there are anomalies between coding and classification of products in the two methods. PRODCOM contains only the data on foreign trade corresponding to production data and necessary for the calculation of markets. Therefore, only trade relating to sold production is included and not that relating to total production. PRODCOM data are not reliable pre-1995 and do not exist pre-1992/1993 (Eurostat, 2017c).

Finally, the spike between 2016 and 2017 needs to be addressed. This is where the tool could prove useful, as it can detect changes in PRODCOM data that may translate into a warning system for POM accounting purposes. If certain categories display uncharacteristic spiking, thereby significantly increasing tonnes of EEE POM, there may be a need to re-examine reported POM data. The spike in 2017 POM data generated by the WEEE Calculation Tool results from an 81% increase in the calculated value of category EU-4, consumer equipment and photovoltaic panels, above what was reported in the Eurostat figures. This increase then relegates category EU-1, large household appliances, to 38% of the total calculated WEEE. Further work needs to address whether this reflects economic conditions, e.g. increased demand for photovoltaics as a result of an increase in homebuilding and renovations, or increased free riders in this category, or both. Consideration would need to be given to what impact this may have on recovery rates and targets. Research on the UK EEE flows in 2016 concluded that "registered POM accounts for 88% of total POM" (Vickery, 2017); this includes estimates of exemptions from regulations in force at that time and POM from unregistered companies. In 2015 it was estimated that 7% of EEE POM was accounted for by unregistered companies (Vickery, 2017).

4.2.2 Waste generated

Sale/lifespan distribution is contingent on having reliable data available. Weibull curves should look different across Member States. Although some have speculated that the sale/lifespan distribution model used to calculate WEEE generated has a "high potential of harmonization/compatibility across different countries" (Magalini *et al*., 2015), our and others' research suggests otherwise. Altering the POM for recent years had little to no impact on the WEEE generated output; this is because the WEEE generated is largely affected by EEE POM in previous years (Magalini *et al*., 2020).

The WEEE generated and EEE POM may deviate from the expected sale/lifespan distribution given specific events in a Member State, e.g. the Saorview switchover in Ireland, which led to the buying of newer models of televisions. This may lead to WEEE being generated in a year much earlier than anticipated and then missing from an expected peak year.

Considering EEE POM related to WEEE generation, photovoltaic POM spiked between 2016 and 2017. An understanding of how and when these photovoltaics will become WEEE will be critical to target setting, particularly in preparing appropriate collection, reuse and recycling approaches.

4.2.3 Target setting

The tool itself and methodology has inherent issues. Stowell *et al*. (2018) criticised it for relying on "relatively simple statistical algorithms", such as design life as opposed to actual life, not accounting for future innovations, adding open scope to items without accurate masses, and the accounting of historical WEEE in calculating current WEEE generated.

The analysis of the POM results generated by the WEEE Calculation Tool reveals that caution should be exercised when considering a target based on POM. Targets based on POM in an expanding market could prove difficult to achieve, as not every new EEE item results in disposal of an old one (Magalini *et al*., 2020). This is borne out by our findings in section 2.3.1; Irish consumers practise waste avoidance even when old EEE items have been replaced in use by newer stock. The analysis of POM showed that spikes – through the incentivisation and accessibility of new technologies, e.g. photovoltaics and heat pumps – can occur and these will have a knock-on impact on target setting.

At present the WEEE Calculation Tool contains too many uncertainties to be considered for use in setting a target for WEEE collection based on WEEE generated. Data entered from 2014 onwards may become increasingly unreliable as the user inputs EU-10 or EU-6 codes, which the tool then breaks proportionately into UNU-keys. The category split over time may well change, and these market dynamics may not be reflected by the tool. Additionally, new EEE is assigned a UNU-key that may not necessarily be reflective of its weight, leading to further errors (Stowell *et al*., 2018; Magalini *et al*., 2020).

As the Calculation Tool calculates WEEE available for collection, it may not consider that certain used EEE is donated to family members or sold. Research from Romania estimates this to be around 34% of WEEE (Magalini *et al*., 2020). The research team have also identified events by which EEE is rendered immediately obsolete, thereby approaching EoL faster than anticipated by the Weibull distributions.

Many studies (Huisman *et al*., 2015, 2017; Bigum *et al*., 2017; European Commission, 2017) acknowledge the magnitude of WEEE that is lost to inappropriate disposal, scavenging, illegal trade and export. Magalini *et al*. (2020) report that 25% of WEEE generated is discarded through alternative channels, i.e. waste disposal and metal scrap, which are not accessible to compliant treatment. In addition, this trend is dependent on scrap metal pricing and so quantities vary accordingly (Stowell *et al*., 2018).

Our research on WEEE arising in metal scrap collections estimated a figure of 3.91%, accounting for a further 10,055 tonnes of WEEE in 2017. This is 19% of the WEEE collected in 2017 and if recovered would have raised the percentage collected as the average of 3 years' previous POM from 53% to 68%.

4.3 Summary and Conclusions

- Congruent with similar studies to this (Stowell *et al*., 2018; Magalini *et al*., 2020), the importance of reliable data is highlighted by our analysis, particularly the importance of reliable and credible POM data. The role of the producer register in gathering and cross-checking data is paramount to this process. The issue of free riders and emergent free riders needs to be taken seriously, and greater resourcing of the producer register to address these matters needs to be considered.
- In predicting WEEE generated, consumer surveys and policy analysis play an important role, especially at national level, where cultural events, governmental policies and emergencies could have implications for EEE and WEEE flows.
- The tool is useful as a check on which types of EEE are trending in POM and as a mechanism to verify and cross-reference data. The apparent consumption methodology may also prove useful in preparing systems for future treatment and collection mechanisms for certain categories of products.

5 Synthesis

The recast of the WEEE Directive, with ambitious consumption-based targets, has given EU Member States cause to re-examine their WEEE collection systems with a view to understanding why the targets are proving to be so challenging to meet. In this work we have participated in part of this examination for the Irish WEEE collection system to provide insight into some key dimensions that are affecting collection rates.

Specifically, we explore how consumer and business behaviours regarding EoL electronics are leading to complementary flows outside the formal WEEE collection channels. The study then advances this exploration by undertaking a quantitative analysis of a very significant complementary flow, namely the materials which present at scrap metal collection sites, leading to a quantification and characterisation of this fugitive WEEE. Finally, we have done some work to examine the target-setting mechanisms to see how they can be employed in the best interests of a sustainable WEEE management system for Ireland.

The consumer survey confirmed in a quantitative manner several of the qualitative findings from the ColectWEEE project. Frugality and waste avoidance are overwhelming drivers for consumers to continue to store used electrical and electronic equipment that they have stopped using. Combining this with the general lack of connection between long-term storage and extra pressure on virgin raw material extraction means that this is likely to persist. The accumulation of items in this manner, combined with a significant number of people finding recycling inconvenient, is leading to substantial quantities of items ultimately being disposed of at “critical moments”, with a high potential for this material to enter a complementary stream if disposed of via skip hire or casual waste collectors during clear-outs or indeed through their own waste bins.

The organisational research also unearthed some interesting themes. WEEE is typically a very small stream of waste for many organisations and therefore does not command much attention from those responsible for its management and disposal. Trust is placed in waste contractors to collect and dispose of ICT WEEE appropriately, including data destruction, but other items of WEEE are not given much attention beyond having it removed by a waste contractor once it accumulates.

These findings from consumers and organisations relating to potential sources of WEEE in complementary flows are borne out in the sampling that took place at scrap metal facilities. This work revealed that an estimated 3.91% of scrap metal received at sites is made up of WEEE. This equates to 10,950 tonnes based on 2018 returns to the NWCPO, which is very significant in national terms, representing over 20% of compliant WEEE collected (based on 2017 data from Eurostat for waste collected). One noteworthy finding from this sampling is the prevalence of central heating boilers, which is indicative of waste from home renovations. Another finding of interest is the sheer quantity of small appliances, which is indicative of domestic clear-outs. Large household appliances are also very significant by weight. The arising of a non-trivial quantity of data-bearing devices is slightly worrying from a data protection perspective as well as from the perspective of the resource loss from circuit boards on account of inappropriate treatment. Although the quantities are low enough to suggest that the IT asset disposition (ITAD) services are largely working well, the SME sector should be targeted for improvement.

Finally, the work has explored the WEEE generated method for target setting and found that, although the method makes logical sense, it is highly dependent on having high-quality data for the quantities of equipment POM and product lifetimes. The work revealed several concerns in both areas. Nonetheless, it is not advisable to discard it entirely. In particular, the likely widespread sales of photovoltaic panels in coming years (with lifespans well in excess of 3 years) will create unreachable targets according to the 65% of the average POM in the previous 3 years method.

6 Policy Recommendations

The findings of this research are the basis of the following recommendations aimed at supporting Ireland in reaching the collection targets dictated by the WEEE Directive.

Increase the convenience and visibility of WEEE recycling

Although consumers are positively disposed towards the recycling of WEEE, it is largely invisible as part of normalised behaviours, even where WEEE collection points are technically available in larger retailers. Making such collection points more visible within these larger retailers would help to normalise the practice. Incorporating small WEEE collections in the delivery of new appliances would also make compliant recycling convenient for consumers. Likewise, collection rates would be improved by the establishment of more collection options, for example bring banks in frequently visited locations such as shopping centres. More frequent special collection events within the community can also trigger critical moments that promote compliant recycling.

To prevent waste hoarding, provide more options for consumers, including preparation for reuse services

Waste aversion is causing hoarding of used items, which in turn are often being disposed of incorrectly during critical moments. The availability of “preparation for reuse” and altruistic donation schemes and options can help to overcome this tendency to resist the recycling of items that are still functional, and registered charity shops in conjunction with “approved preparation for reuse of WEEE organisations” could play a role in these collections. Regardless as to whether the bulk of items end up being reused, it provides a channel for items to enter the formal WEEE system via organisations approved to prepare WEEE for reuse.

Develop incentives and deterrents for skip hire companies, waste collectors and scrap metal facilities to direct WEEE into the formal recycling system

Without regularising this flow, the attainment of targets will be very difficult to achieve. It also places recyclers who undertake pre-treatment of WEEE in a compliant fashion at a disadvantage because of the extra processing and reporting costs that are borne by them in de-pollution and other actions. However, a significant push factor from consumers through skip hire companies and casual waste collectors through this channel is likely to persist. The potential separation and storage of WEEE by skip hire companies, waste collectors and scrap metal sites would add complexity and cost to their operations. An enforcement-led approach is likely to be very costly and adversarial with uncertain outcomes in terms of the additional WEEE that would end up in the formal system. We recommend a negotiated solution between scrap metal sites, the EPA and compliance schemes that addresses the concerns of all parties and recognises and adequately compensates parties for the collection, separation and storage of all WEEE that presents to them. However, it is important that this would not create an incentive to channel WEEE from already functioning collection channels.

Recommend that the European Commission explores a hybrid approach to target setting

The blanket adoption of the WEEE arising approach to target setting would require very significant work in developing Ireland-specific Weibull parameters based on the sales–stock–lifespan modelling approach. Likewise, the reliance on the apparent consumption data for the period preceding the creation of the blackbox is problematic with no obvious solution. However, a target based on 65% of POM in the previous 3 years will create difficulties in the case of new long-lived products coming on the market, with photovoltaic solar panels being an immediate concern in this area. We recommend that a hybrid approach to target setting is explored, with the WEEE arising method being pursued for photovoltaics only at this time.

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Abbreviations

B2B	Business to business
B2C	Business to consumer
EEE	Electrical and electronic equipment
EoL	End of life
EoU	End of use
EPA	Environmental Protection Agency
EU	European Union
ICT	Information and communications technology
IT	Information technology
LoW	List of Waste
NWCPO	National Waste Collection Permit Office
POM	Placed on the market
SME	Small to medium-sized enterprise
UNU-keys	United Nations University – keys (EEE classification)
WEEE	Waste electrical and electronic equipment
WSR	Waste Shipment Regulation

Appendix 1 Average Unit Weights UNU-Keys Placed on the Market EU-28

UNU-Key	Description	1995	2000	2005	2010	2015	2016	2016–1995
0001	Central heating (household installed)	30.85	30.85	30.85	30.85	30.85	30.85	0.00
0002	Photovoltaic panels (including converters)	17.00	17.00	17.00	17.00	17.00	17.00	0.00
0101	Professional heating and ventilation (excluding cooling equipment)	124.61	124.61	124.61	124.61	124.61	124.61	0.00
0102	Dishwashers	49.35	47.62	45.46	43.30	43.30	43.30	–6.05
0103	Kitchen (e.g. large furnaces, ovens, cooking equipment)	41.86	43.52	45.59	47.66	47.66	47.66	5.80
0104	Washing machines (including combined dryers)	69.36	70.27	71.40	72.54	72.54	72.54	3.18
0105	Dryers (wash dryers, centrifuges)	38.27	40.47	43.23	45.98	45.98	45.98	7.71
0106	Household heating and ventilation (e.g. hoods, ventilators, space heaters)	12.14	12.14	12.14	12.14	12.14	12.14	0.00
0108	Fridges (including combi-fridges)	33.59	35.65	38.22	40.79	40.79	40.79	7.20
0109	Freezers	43.45	43.73	43.91	44.09	44.09	44.09	0.64
0111	Air conditioners (household installed and portable)	26.70	26.70	26.70	26.70	26.70	26.70	0.00
0112	Other cooling (e.g. dehumidifiers, heat pump dryers)	41.70	41.70	41.70	41.70	41.70	41.70	0.00
0113	Professional cooling (e.g. large air conditioners, cooling displays)	90.00	95.74	102.92	110.10	110.10	110.10	20.10
0114	Microwaves (including combined, excluding grills)	16.34	18.21	20.56	22.90	22.90	22.90	6.56
0201	Other small household (e.g. small ventilators, irons, clocks, adapters)	1.30	1.21	1.10	0.99	0.99	0.99	–0.31
0202	Food (e.g. toaster, grills, food processing, frying pans)	3.27	3.27	3.27	3.27	3.27	3.27	0.00
0203	Hot water (e.g. coffee, tea, water cookers)	1.89	1.89	1.89	1.89	1.89	1.89	0.00
0204	Vacuum cleaners (excluding professional)	4.88	5.17	5.52	5.88	5.88	5.88	1.00
0205	Personal care (e.g. toothbrushes, hair dryers, razors)	0.55	0.55	0.55	0.55	0.55	0.55	0.00
0301	Small IT (e.g. routers, mice, keyboards, external drives and accessories)	0.65	0.58	0.49	0.40	0.40	0.40	–0.25
0302	Desktop PCs (excluding monitors, accessories)	10.31	9.87	9.32	8.77	8.77	8.77	–1.54
0303	Laptops (including tablets)	4.50	4.14	3.68	2.13	1.26	1.26	–3.24
0304	Printers (e.g. scanners, multifunctional, faxes)	7.00	7.95	9.13	10.32	10.32	10.32	3.32
0305	Telecom (e.g. phones – including cordless ones –, answering machines)	0.82	0.71	0.58	0.45	0.45	0.45	–0.37
0306	Mobile phones (including smartphones, pagers)	0.12	0.11	0.10	0.09	0.09	0.09	–0.03
0307	Professional IT (e.g. servers, routers, data storage, copiers)	40.00	40.00	40.00	40.00	40.00	40.00	0.00
0308	Cathode-ray tube monitors	14.60	19.71	19.36	22.00	22.00	22.00	7.40
0309	Flat display panel monitors (LCD, LED)	5.00	5.14	5.32	5.50	5.50	5.50	0.50
0401	Small consumer electronics (e.g. headphones, remote controls)	0.39	0.39	0.39	0.39	0.39	0.39	0.00
0402	Portable audio and video (e.g. MP3, e-readers, car navigation)	0.40	0.35	0.29	0.23	0.23	0.23	–0.17

UNU-Key	Description	1995	2000	2005	2010	2015	2016	2016–1995
0403	Music instruments, radio, HiFi (including audio sets)	4.15	4.03	3.88	3.73	3.73	3.73	–0.42
0404	Video (e.g. video recorders, DVD, blue ray, set-top boxes)	3.51	3.51	3.51	3.51	3.51	3.51	0.00
0405	Speakers	3.00	2.75	2.45	2.14	2.14	2.14	–0.86
0406	Cameras (e.g. camcorders, photo and digital still cameras)	1.00	0.80	0.54	0.29	0.29	0.29	–0.71
0407	Cathode-ray tube TVs	25.00	27.34	30.27	33.20	33.20	33.20	8.20
0408	Flat display panel TVs (LCD, LED, plasma)	7.00	9.20	11.95	14.70	10.20	10.20	3.20
0501	Lamps (e.g. pocket, Christmas, excluding LED and incandescent)	0.09	0.09	0.09	0.09	0.09	0.09	0.00
0502	Compact fluorescent lamps (including retrofit and non-retrofit)	0.08	0.08	0.08	0.08	0.08	0.08	0.00
0503	Straight tube fluorescent lamps	0.11	0.11	0.11	0.11	0.11	0.11	0.00
0504	Special lamps (e.g. professional mercury, high- and low-pressure sodium)	0.08	0.08	0.08	0.08	0.08	0.08	0.00
0505	LED lamps (including retrofit LED lamps and household LED luminaires)	0.08	0.08	0.08	0.08	0.08	0.08	0.00
0506	Household luminaires (including household incandescent fittings)	0.45	0.45	0.45	0.45	0.45	0.45	0.00
0507	Professional luminaires (offices, public space, industry)	2.67	2.67	2.67	2.67	2.67	2.67	0.00
0601	Household tools (e.g. drills, saws, high-pressure cleaners, lawn mowers)	2.60	2.57	2.53	2.49	2.49	2.49	–0.11
0602	Professional tools (e.g. for welding, soldering, milling)	23.17	23.17	23.17	23.17	23.17	23.17	0.00
0701	Toys (e.g. car racing sets, electric trains, music toys, biking computers)	0.45	0.45	0.45	0.45	0.45	0.45	0.00
0702	Game consoles	0.48	0.48	0.48	0.48	0.48	0.48	0.00
0703	Leisure (e.g. large exercise, sports equipment)	7.37	7.37	7.37	7.37	7.37	7.37	0.00
0801	Household medical (e.g. thermometers, blood pressure meters)	0.18	0.18	0.18	0.18	0.18	0.18	0.00
0802	Professional medical (e.g. hospital, dentist, diagnostics)	67.04	67.04	67.04	67.04	67.04	67.04	0.00
0901	Household monitoring and control (alarm, heat, smoke, excluding screens)	0.24	0.24	0.24	0.24	0.24	0.24	0.00
0902	Professional monitoring and control (e.g. laboratory, control panels)	5.51	5.51	5.51	5.51	5.51	5.51	0.00
1001	Non-cooled dispensers (e.g. for vending, hot drinks, tickets, money)	44.00	44.00	44.00	44.00	44.00	44.00	0.00
1002	Cooled dispensers (e.g. for vending, cold drinks)	92.22	92.22	92.22	92.22	92.22	92.22	0.00

DVD, digital versatile disc; HiFi, high fidelity; LCD, liquid-crystal display; LED, light-emitting diode; PC, personal computer; TV, television.

Appendix 2 Data Processing and Analysis

A2.1 Data Pre-processing

1. Download and sort photos from sampling and create a folder using the site acronym, e.g. Site A; create sub folders for each date of sampling. Save photos according to the site, date (11 March 2019 = 11032019) and sample number e.g. \WEEE in Scrap Sampling\Site A 13032019\SiteA_AS37 (1), the second photo of Sample 37 from Site A becomes \WEEE in Scrap Sampling\Site A 13032019\SiteA_AS37 (2). This ensures that sample photos are searchable, by site and sample number.
2. Remove photos of loads that may have been excluded from analysis.
3. Identify WEEE from downloaded pictures or notes taken on site (for some samples it might not be possible to get close to take pictures because of the number of loads arriving simultaneously).
4. Group and count identical items together, e.g. if a load had three microwaves, note these as one entry in the load.
5. Ensure that all loads containing zero WEEE are noted and prepared for data entry.

A2.2 Data Entry

1. Open Excel file “WEEE in Metal Scrap Data Entry.ods”.
2. Open Sheet “Data Entry” The following table lists the information to be entered and the values returned by the spreadsheet.

Column	Column description	Data to be entered/description
A	Location	Each site location is given a unique code: e.g. Site A, Site B
B	Date	Date of data collection
C	Time	Time of sampling (used to match to photographs of WEEE and obtain weights from weighbridge)
D	Sample number	Number of load sampled labelled as Letter of site, S (for sample), then number of sample, e.g. AS21 is Site A, Sample 21
E	Load weight	Weight of total load as taken from weighbridge at end of sampling **(must be in kg)**
F	LoW code	LoW code recorded for reporting by the site
G	Item description	Type in item description e.g. LCD TV 42”, microwave, commercial hob
H	Number of items	Aggregate similar items per load, e.g. two washing machines
I	Drop down list of UNU-keys	Use the drop-down lists to assign a UNU-key to the item.
		If unsure of classification, consult sheet “Directory of UNU-Keys”
J	EEE category under EU-6	**None**: sheet returns EU-6 category based on UNU-key assigned
K	Approximate weight (kg/unit)	**None**: sheet returns value of UNU-key assigned weight
L	Weight of items	**None**: sheet returns value of approximate weight multiplied by number of units
M	Total sampled (tonnes)	**None**: sheet returns value of total weight sampled (sum of column E divided by 1000)
N	Total WEEE (tonnes)	**None**: sheet returns value of total WEEE (sum of column L divided by 1000)
O	% WEEE arising	**None**: sheet returns value of total WEEE as a percentage of total sampled

AN GHNÍOMHAIREACHT UM CHAOMHNÚ COMHSHAOIL
Tá an Ghníomhaireacht um Chaomhnú Comhshaoil (GCC) freagrach as an gcomhshaol a chaomhnú agus a fheabhsú mar shócmhainn luachmhar do mhuintir na hÉireann. Táimid tiomanta do dhaoine agus don chomhshaol a chosaint ó éifeachtaí díobhálacha na radaíochta agus an truaillithe.

Is féidir obair na Gníomhaireachta a roinnt ina trí phríomhréimse:

Rialú: *Déanaimid córais éifeachtacha rialaithe agus comhlíonta comhshaoil a chur i bhfeidhm chun torthaí maithe comhshaoil a sholáthar agus chun díriú orthu siúd nach gcloíonn leis na córais sin.*

Eolas: *Soláthraímid sonraí, faisnéis agus measúnú comhshaoil atá ar ardchaighdeán, spriocdhírithe agus tráthúil chun bonn eolais a chur faoin gcinnteoireacht ar gach leibhéal.*

Tacaíocht: *Bímid ag saothrú i gcomhar le grúpaí eile chun tacú le comhshaol atá glan, táirgiúil agus cosanta go maith, agus le hiompar a chuirfidh le comhshaol inbhuanaithe.*

Ár bhFreagrachtaí

Ceadúnú
Déanaimid na gníomhaíochtaí seo a leanas a rialú ionas nach ndéanann siad dochar do shláinte an phobail ná don chomhshaol:
- saoráidí dramhaíola *(m.sh. láithreáin líonta talún, loisceoirí, stáisiúin aistrithe dramhaíola)*;
- gníomhaíochtaí tionsclaíocha ar scála mór *(m.sh. déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta)*;
- an diantalmhaíocht *(m.sh. muca, éanlaith)*;
- úsáid shrianta agus scaoileadh rialaithe Orgánach Géinmhodhnaithe *(OGM)*;
- foinsí radaíochta ianúcháin *(m.sh. trealamh x-gha agus radaiteiripe, foinsí tionsclaíocha)*;
- áiseanna móra stórála peitril;
- scardadh dramhuisce;
- gníomhaíochtaí dumpála ar farraige.

Forfheidhmiú Náisiúnta i leith Cúrsaí Comhshaoil
- Clár náisiúnta iniúchtaí agus cigireachtaí a dhéanamh gach bliain ar shaoráidí a bhfuil ceadúnas ón nGníomhaireacht acu.
- Maoirseacht a dhéanamh ar fhreagrachtaí cosanta comhshaoil na n-údarás áitiúil.
- Caighdeán an uisce óil, arna sholáthar ag soláthraithe uisce phoiblí, a mhaoirsiú.
- Obair le húdaráis áitiúla agus le gníomhaireachtaí eile chun dul i ngleic le coireanna comhshaoil trí chomhordú a dhéanamh ar líonra forfheidhmiúcháin náisiúnta, trí dhíriú ar chiontóirí, agus trí mhaoirsiú a dhéanamh ar leasúchán.
- Cur i bhfeidhm rialachán ar nós na Rialachán um Dhramhthrealamh Leictreach agus Leictreonach (DTLL), um Shrian ar Shubstaintí Guaiseacha agus na Rialachán um rialú ar shubstaintí a ídíonn an ciseal ózóin.
- An dlí a chur orthu siúd a bhriseann dlí an chomhshaoil agus a dhéanann dochar don chomhshaol.

Bainistíocht Uisce
- Monatóireacht agus tuairisciú a dhéanamh ar cháilíocht aibhneacha, lochanna, uiscí idirchriosacha agus cósta na hÉireann, agus screamhuiscí; leibhéil uisce agus sruthanna aibhneacha a thomhas.
- Comhordú náisiúnta agus maoirsiú a dhéanamh ar an gCreat-Treoir Uisce.
- Monatóireacht agus tuairisciú a dhéanamh ar Cháilíocht an Uisce Snámha.

Monatóireacht, Anailís agus Tuairisciú ar an gComhshaol
- Monatóireacht a dhéanamh ar cháilíocht an aeir agus Treoir an AE maidir le hAer Glan don Eoraip (CAFÉ) a chur chun feidhme.
- Tuairisciú neamhspleách le cabhrú le cinnteoireacht an rialtais náisiúnta agus na n-údarás áitiúil *(m.sh. tuairisciú tréimhsiúil ar staid Chomhshaol na hÉireann agus Tuarascálacha ar Tháscairí)*.

Rialú Astaíochtaí na nGás Ceaptha Teasa in Éirinn
- Fardail agus réamh-mheastacháin na hÉireann maidir le gáis cheaptha teasa a ullmhú.
- An Treoir maidir le Trádáil Astaíochtaí a chur chun feidhme i gcomhair breis agus 100 de na táirgeoirí dé-ocsaíde carbóin is mó in Éirinn.

Taighde agus Forbairt Comhshaoil
- Taighde comhshaoil a chistiú chun brúnna a shainaithint, bonn eolais a chur faoi bheartais, agus réitigh a sholáthar i réimsí na haeráide, an uisce agus na hinbhuanaitheachta.

Measúnacht Straitéiseach Timpeallachta
- Measúnacht a dhéanamh ar thionchar pleananna agus clár beartaithe ar an gcomhshaol in Éirinn *(m.sh. mórphleananna forbartha)*.

Cosaint Raideolaíoch
- Monatóireacht a dhéanamh ar leibhéil radaíochta, measúnacht a dhéanamh ar nochtadh mhuintir na hÉireann don radaíocht ianúcháin.
- Cabhrú le pleananna náisiúnta a fhorbairt le haghaidh éigeandálaí ag eascairt as taismí núicléacha.
- Monatóireacht a dhéanamh ar fhorbairtí thar lear a bhaineann le saoráidí núicléacha agus leis an tsábháilteacht raideolaíochta.
- Sainseirbhísí cosanta ar an radaíocht a sholáthar, nó maoirsiú a dhéanamh ar sholáthar na seirbhísí sin.

Treoir, Faisnéis Inrochtana agus Oideachas
- Comhairle agus treoir a chur ar fáil d'earnáil na tionsclaíochta agus don phobal maidir le hábhair a bhaineann le caomhnú an chomhshaoil agus leis an gcosaint raideolaíoch.
- Faisnéis thráthúil ar an gcomhshaol ar a bhfuil fáil éasca a chur ar fáil chun rannpháirtíocht an phobail a spreagadh sa chinnteoireacht i ndáil leis an gcomhshaol *(m.sh. Timpeall an Tí, léarscáileanna radóin)*.
- Comhairle a chur ar fáil don Rialtas maidir le hábhair a bhaineann leis an tsábháilteacht raideolaíoch agus le cúrsaí práinnfhreagartha.
- Plean Náisiúnta Bainistíochta Dramhaíola Guaisí a fhorbairt chun dramhaíl ghuaiseach a chosc agus a bhainistiú.

Múscailt Feasachta agus Athrú Iompraíochta
- Feasacht chomhshaoil níos fearr a ghiniúint agus dul i bhfeidhm ar athrú iompraíochta dearfach trí thacú le gnóthais, le pobail agus le teaghlaigh a bheith níos éifeachtúla ar acmhainní.
- Tástáil le haghaidh radóin a chur chun cinn i dtithe agus in ionaid oibre, agus gníomhartha leasúcháin a spreagadh nuair is gá.

Bainistíocht agus struchtúr na Gníomhaireachta um Chaomhnú Comhshaoil
Tá an ghníomhaíocht á bainistiú ag Bord lánaimseartha, ar a bhfuil Ard-Stiúrthóir agus cúigear Stiúrthóirí. Déantar an obair ar fud cúig cinn d'Oifigí:
- An Oifig um Inmharthanacht Comhshaoil
- An Oifig Forfheidhmithe i leith cúrsaí Comhshaoil
- An Oifig um Fianaise is Measúnú
- Oifig um Chosaint Radaíochta agus Monatóireachta Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáideacha

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag comhaltaí air agus tagann siad le chéile go rialta le plé a dhéanamh ar ábhair imní agus le comhairle a chur ar an mBord.

EPA Research Report 366

An Investigation into WEEE Arising and Not Arising in Ireland (EEE2WEEE)

epaResearch
Climate - Water - Sustainability
Identifying pressures • Informing policy • Developing solutions

Authors: Yvonne Ryan-Fogarty, Katherine Casey, Damian Coughlan, Maria Lichrou, Lisa O'Malley and Colin Fitzpatrick

Identifying Pressures

Waste electrical and electronic equipment (WEEE) is the fastest growing waste stream in Europe. The recast WEEE Directive (2012/19/EU) laid down new collection targets of either 65% of the average weight of electrical and electronic equipment (EEE) placed on the market in the previous 3 years or 85% of WEEE arising. This represents challenges for all stakeholders in the WEEE domain. Across Europe it is recognised that collection rates through official channels remain low. This research provides insight into consumer and business behaviours towards WEEE, particularly regarding how key decisions are made around WEEE disposal. Consumer and business behaviours contribute to WEEE arising in complementary flows outside compliant WEEE collection and treatment. Scrap metal sites were surveyed and a substantiated estimate of WEEE arising was calculated. Combining consumer and business survey findings with the substantiated estimate of WEEE arising in scrap metal pointed to key intervention points by which complementary flows could be eliminated, reduced or regularised.

Informing Policy

Frugality and waste avoidance are overwhelming drivers for consumers to store EEE that is no longer in use. A lack of connection between long-term storage and pressure on virgin raw material extraction means this is likely to persist. The accumulation of items combined with finding recycling inconvenient leads to items being disposed of at "critical moments" with a high "push factor" for materials to enter complementary streams.

WEEE accounts for a tiny proportion of waste in organisations and therefore does not command much attention. Trust is placed in waste contractors to dispose of information and communications technology (ICT) WEEE appropriately, but other items of WEEE are not considered.

In total, 415 tonnes of scrap iron, steel and mixed metals from construction and demolition and municipal waste were sampled. An estimated 3.91% ± 1.88% of the sample contained WEEE, equating to 10,950 tonnes or 2.28 kg/capita (± 1.1 kg/capita) based on 2018 data. Home renovations are critical moments in the disposal of WEEE. Professional WEEE accounted for almost 30% of WEEE observed in metal scrap.

The WEEE Calculation Tool's functionality depends on high-quality data. Its importance may lie as a cross-reference tool for identification of free riders as well as new emergent technologies and their likely impact on target achievement.

Developing Solutions

The convenience and visibility of WEEE recycling needs to be increased. Consumers are positively disposed towards recycling of WEEE, but it needs to normalised and made easier. Small WEEE collections could be included in the delivery of large EEE and additional visible collection opportunities should be provided in frequently visited locations.

More repair, "preparation for reuse" and reuse opportunities for consumers would assist consumers and businesses to make connections to appropriate treatment rather than waste avoidance through storage, which is current practice. This would provide channels for WEEE to enter the formal accounting systems.

Another key recommendation is to explore incentives and penalties to facilitate mandatory handover and the direction of WEEE to appropriate recycling systems from skip hire companies, waste collectors and scrap metal facilities. This would aid in removing WEEE from complementary flows when consumers and organisations act inappropriately at "critical moments".

Further work is necessary to support greater collection rates of business to business WEEE, in particular from small to medium-sized enterprises, for which appropriate disposition of WEEE, with the exception of data-bearing devices, is often not a priority. The further work should target greater awareness of the appropriate means of disposal and should also focus on waste collectors.

Finally, a hybrid approach to WEEE target setting should be explored, using data available to Ireland and using aspects of the WEEE Calculation Tool.

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