MATERIAL FOCUS

Research

Mapping UK waste electrical flows: key insights

July 2020

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An independent study on Waste Electrical and Electronic Equipment (WEEE) flows in the UK

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Executive summary

Anthesis and partners Lancaster University, Repic and Valpak were commissioned by the Material Focus, to investigate unreported flows of EEE and WEEE in the UK. Building on previous studies, the objective was to develop a robust inventory of the different routes by which EEE and WEEE flow through the UK economy, to relate to WEEE Directive target setting and as a basis for recommendations to improve recycling. The research team gathered data through primary research (e.g. surveys and sampling), stakeholder engagement, mathematical modelling and by reviewing the relevant literature.

The group investigated 21 different flows that influence the UK recycling rate for WEEE. The year 2017 was used as the baseline year for this assessment. Reporting for the WEEE Directive suggests that 1,615 Kt of EEE were sold in the UK in 2017, and 653 Kt of WEEE were collected for recycling. However, our findings suggest that this data set does not present the entire picture:

Stage 1

The inputs to Stage 1 are; producer reported EEE, free riders, misreporting EEE data, trends in product weight, and exports of sold products to other countries. These have a combined effect of adding 3% to the reported product weight sold. We estimate that 1,657 Kt were actually put on the UK market in 2017.

Stage 2

While we now have a better understanding of actual EEE sales, EEE does not come off the market on a like for like basis and consumers have more electrical products than before, and even multiples of the same electrical products in the home at any one time. Other factors resulting in EEE aggregation included in Stage 2; products that are embedded in street furniture or buildings (69 Kt), long life equipment (206 Kt), and patterns of product use (which can include retaining unwanted products as well as infrequently used products, practices often referred to as hoarding; 1499 Kt). This has a combined effect of discounting 21-23% (or 348 – 381 Kt) from the actual weight of products flowing into a reuse, recycling or disposal route, through growth in consumption and increased hoarding.

The estimate of the combined weight of used EEE moving on from use, storage and hoarding flows was between 1,393-1,425 Kt in 2017 (there is a range as we calculated this figure using both top down and bottom up analysis). The overall stock of EEE in use by UK households increased by 206 Kt in 2017.

Stage 3

Used EEE is not always collected for recycling as WEEE. Commercial reuse (90 Kt) and domestic reuse (82 Kt), the activities of ITAMs and other asset managers (90 Kt), warranty returns (102 Kt) and legal exports of used EEE (16 Kt), have a combined effect of discounting 17% (237 Kt) from the used EEE available for recycling. The estimate of the weight of collections for potential reuse is 364 Kt for 2017, though 127 Kt move on from here for further processing.

Stage 4

Some of the WEEE that is separately collected is recycled through AATFs, 653 Kt were reported in 2017 (this figure dropped by 90 Kt in 2018). However, there are other legal recycling routes that are not included in this figure. ATF facilities operating under T11 exemptions (5 Kt) and light iron recyclers (215 Kt) also process WEEE, adding a further 220 Kt for 2017 (not including legal exports).

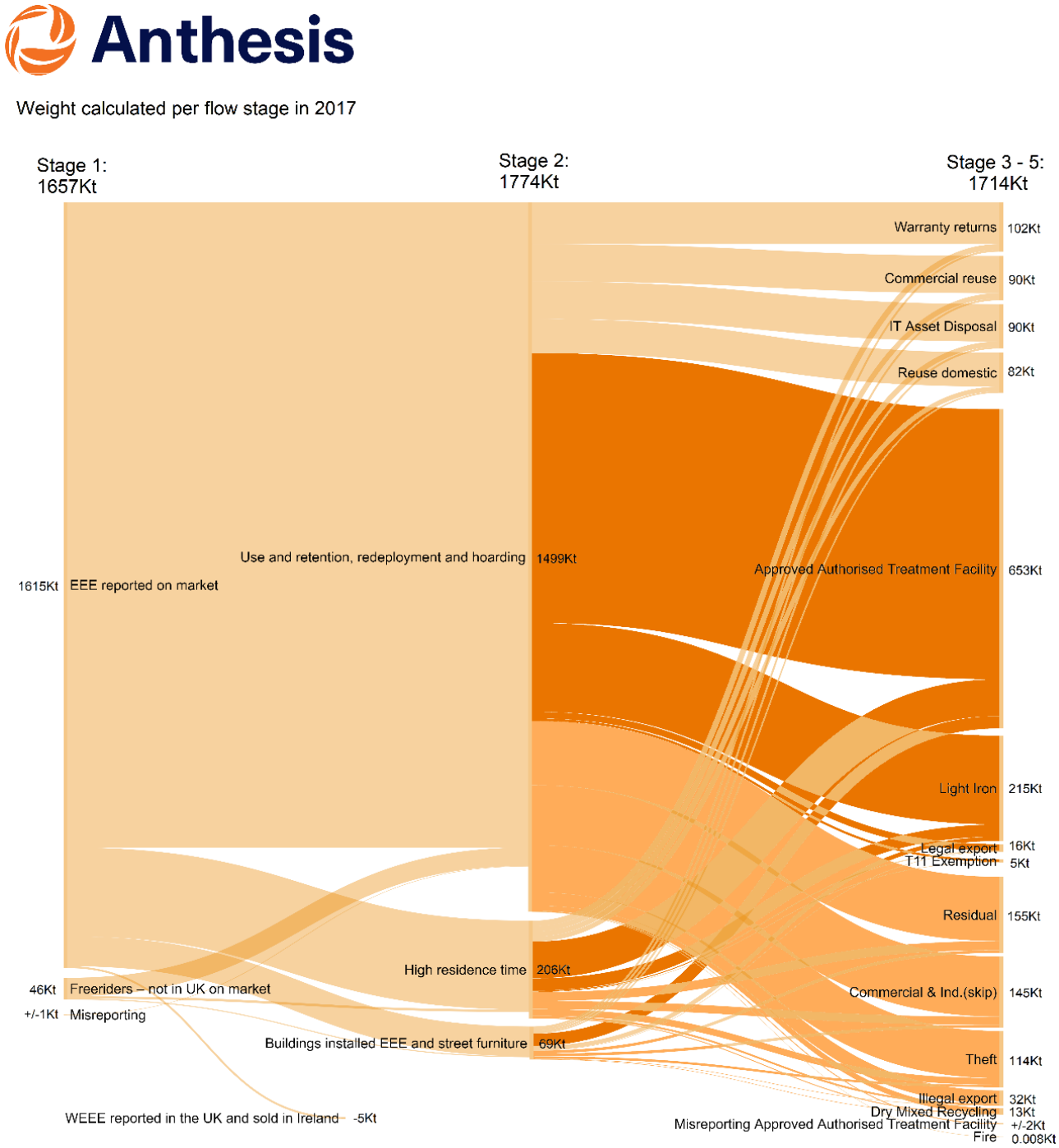
Stage 5

WEEE can be mixed into other waste streams, or otherwise collected and processed inappropriately. We estimate that 155 Kt of WEEE were collected in the residual waste and 145 Kt of WEEE were collected in the C&I waste in 2017. Furthermore, not all WEEE that goes to MRFs (13 Kt) is diverted to an AATF (though most of it does), WEEE can also be exported illegally (32K Kt) and a very small amount of WEEE is lost in fires. The estimate for the combined weight of WEEE collected and treated inappropriately is 461 Kt, 32% of the used EEE moving on from use, storage and hoarding to collection (or 28% of POM).

The research findings estimate that 300 Kt is collected in the residual and C&I waste, so we recommend that efforts to gather more WEEE for recycling focus here. There is also a considerable amount of hoarded EEE and WEEE (not used, and infrequently used products) in the UK. Our findings suggest that 348 – 381 Kt remains in use Stage 2 in 2017 and by gaining greater access to unwanted products, or changing purchase and use models, a better recycling rate could be achieved.

This report contains a detailed overview of our findings, the approach that was taken and an assessment of our confidence in the data sources, our analysis and recommendations. The charts that follow, in the key findings section, detail the weight of EEE or WEEE included in each flow and the types of equipment they contain.

The different routes by which EEE and WEEE flow through the UK economy have been plotted on the following Sankey Diagram:



For each EEE flow assessed in this study, we quantified the amount of material involved and then the amount that passed on to a different flow or stage. The following table summarises this:

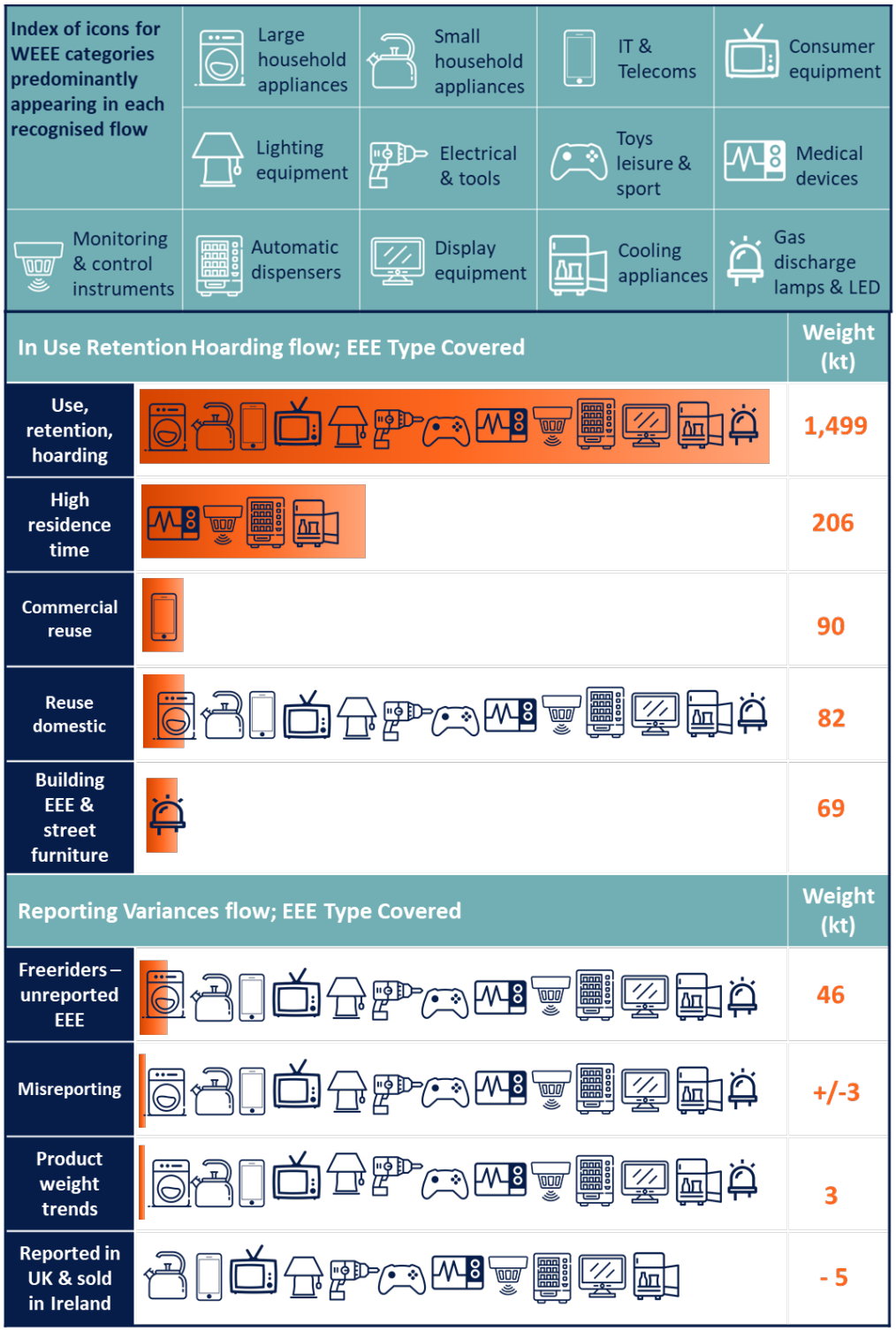
Stage 1		Stage 2			Stage 3			Stage 4			Stage 5		
Input	**Kt**	**Flow**	**Fate**	**Kt**	**Flow**	**Fate**	**Kt**	**Flow**	**Fate**	**Kt**	**Flow**	**Fate**	**Kt**
EEE reported POM (incl. +3Kt weight trend)	1615	**Use and retention, redeployment and hoarding**	Of POM remains in-use/ redeployment (88%), hoarding (12%)	277	**Commercial reuse**	remains in commercial use	59	**T11/ATFs**			**C&I (skip)**	ends in C&I (skip)	145
Freeriders – not in UK POM	46		moves on to reuse recycling or disposal	1222		moves on to recycling, disposal or legal export	31		ends in T11/ATF	5	**Fire**	ends in Fire	0
WEEE reported in the UK and sold in Ireland	-5	**Buildings**	remains in the building	34	**Reuse domestic**	remains in domestic use	53	**AATFs**			**DMR**	ends in DMR	13
Misreporting	1		moves on to reuse recycling or disposal	35		moves on to recycling, disposal or legal export	29		ends in AATF	653	**Residual**	ends in Residual	155
		High Residency	Remains in the home	38	**ITAMs**	remains in ITAM	59	**Light Iron**			**Theft**	ends in Theft	114
			moves on to reuse recycling or disposal	168		moves on to recycling, disposal or legal export	31		Ends in Light iron	215	**Misreporting AATF**	ends in Misreporting AATF	2
					Warranty returns	remains in returns	66	**Legal export**	ends in Legal export	16	**Use and retention, redeployment and hoarding**	ends in illegal export	32
						moves on to recycling, disposal or legal export	36						

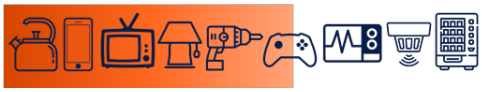
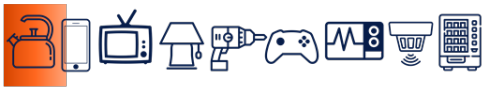
			Totals remain in stage	349		Totals remain in stage	237		Totals remain in stage	889		Totals remain in stage	461
Totals passed on	1657		Totals passed on	1425		Totals passed on	127		Totals passed on	-		Totals passed on	-

Key findings and data – Weight of EEE and WEEE in each flow by product type

The key findings graphic summarises each of the flows assessed in this study and the estimated annual tonnage that passes through each flow. These are grouped according to the source or location of the product, and the form it may be found: -

1. Use, retention and hoarding – still with a holder and not yet discarded.
2. Reporting variances – existing data sources that may not be a true representation of that source.
3. Recycled, destroyed and exported – products that have been discarded by the user.



Recycled Destroyed and Exported flows; EEE Type Covered		Weight (kt)
Approved Authorised Treatment Facility		653
Light iron		215
Residual		155
Commercial & Industrial (skip)		145
Theft		114
Warranty returns		102
IT Asset Managed		90
Illegal export		32
Legal export		16
Dry Mixed Recycling		13
T11/ATFs Permitted sites		5
Fire		0.008

Acknowledgments

We would like to express our gratitude to all persons providing valuable data, insights and feedback to this study.

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List of abbreviations

AATF - Authorised Approved Treatment Facility

ATF - Authorised Treatment Facility

B – Billion

BAN - Basel action network

B2B – Business to business

B2C – Business to consumer

C&I – Commercial and industrial

CRT - Cathode ray tube

C2C – Customer to customer

DCF - Designated collection facility

DMR – Dry mixed recycling

EEE - Electrical and electronic equipment

ELV – End of life

EPR – Extended producer responsibility

FPD - Flat panel display technologies

HMRC - HM revenue and customs

HWRC - Household waste recycling centres

ITAD - Information technology asset disposition

ITAM - Information technology asset management organisations

Kt – Kiloton (thousands of tonnes)

LACW - Local authority collected waste

LDA - Large domestic appliances

MRF - Material recycling facility

Mt – Megaton(millions of tonnes)

NTF - No trouble found

OEM - Original equipment manufacturer

Pa – Per annum

POM – Put on market

PCS – Producer compliance scheme

SDA – Small domestic appliance

SME – Small medium enterprise

SMW - Small mixed WEEE

UEEE - Used electrical and electronic equipment

UNU - Units in use

WEEE - Waste electrical and electronic equipment

WDA – Waste disposal authority

WDF - Waste data flow

WOT – Waste over time

See Appendix XV for full list of Definitions

1.0 Introduction

1.1 Project background

This study seeks to provide a robust and consolidated picture of unreported waste electrical and electronic equipment (WEEE) collection and processing activities in the UK. The research has been commissioned by the Material Focus and managed by Anthesis Group, with partners University of Lancaster, Repic and Valpak. The output of this work includes new and updated data on unreported WEEE activities, presenting a more accurate evidence base to support national recycling targets and prioritise policy initiatives that support a circular economy and encourage appropriate disposal when a product reaches end of life.

1.2 Broader context of the study

The UK WEEE Regulations aim to reduce the amount of WEEE in landfill. Since these regulations came into effect, it has been observed that a gap exists between the amount of electrical and electronic equipment (EEE) placed onto the UK market and the amount of WEEE being reported as collected and treated. One widely believed explanation for this, is that a significant amount of activity related to EEE is not currently being reported.

There is an opportunity to support the UK Government with achieving its collection targets, through research that quantifies unreported EEE and WEEE activities. Since 2019, the target WEEE collection rate has been 65% of EEE placed on market (based on average of the previous three years EEE sales). Unreported EEE and WEEE accounts for a significant proportion of WEEE in the UK, as seen in the Valpak UK EEE Flows Report 2016 which estimated that unreported EEE flows accounted for approximately 34 per cent[1] of WEEE generated in 2015. Some of this is collected and treated in a way that is acceptable and some is not. With WEEE collection target for the UK looking challenging, collection of novel data which provides data on unreported EEE, used-EEE and WEEE flows is pertinent.

1.3 Challenges of unreported WEEE

There are a number of reasons why WEEE waste streams are challenging to characterise, engage with and quantify including:

- WEEE is often mixed, and so collected and treated, in other metal waste streams.
- Authorised Treatment Facility (ATF) activities (which undertake WEEE treatment on behalf of producers) are not required to report treatment activity.
- The export of W/EEE for reuse or treatment is often difficult to track.
- There is little understanding on the amount of time a product is retained by its purchaser i.e. in use and retention, redeployment and hoarding.

[1] https://www.valpak.co.uk/more/material-flow-reports

- Consumer behaviour of improperly disposing of small WEEE equipment in residual waste, instead of being separately collected, results in the WEEE not being captured in recycling figures.
- WEEE items sold for reuse by the third sector and commercial operators are often not reported.
- Companies based abroad selling, their items in the UK are often not aware of regulations so do not report their data on EEE placed on the market.

All of these factors contribute to the aforementioned issue of unreported WEEE activity not being captured in the UK reported recycling figure. Therefore, there is a need to better understand the challenges that exist in gathering data on unreported WEEE activities.

1.4 Project objectives and deliverables

The aim of this study is to provide greater understanding on current unreported WEEE activities in the UK. Material Focus stakeholders identified more than twenty types of potential activity that is currently not being reported. There is limited information available on these topics with varying degrees of confidence. Thus, prioritising the collection of novel data is a key component of the project.

Objectives of this study include:

- Characterising the types of undocumented collection and treatment of WEEE.
- Quantifying the undocumented WEEE flows.
- Identifying the actors involved in unreported WEEE collection and treatment.
- Presenting the findings graphically, with a clear narrative on robustness, assumptions, approach and findings.

The intended applications of our findings include:

- Providing a robust and consolidated view of unreported WEEE flows.
- Highlighting good and bad practice in WEEE collection and treatment systems.
- Guiding policy makers and strategies on WEEE collection.
- Collecting data that will allow for more formal reporting on unreported WEEE flows.
- Providing data which can be used by compliance companies to target new sources of WEEE. Our research findings could be used towards further research into substantiated estimates for the UK WEEE collection targets.

2.0 WEEE Flows breakdown and research findings

This research identified three broad categories of EEE and WEEE flow:

1. Flows where EEE or WEEE is unavailable for further collection or processing in the UK, as it is recycled, destroyed or exported.
2. Flows where EEE or WEEE is currently unavailable for collection or processing, as it is in use or being retained, but could eventually be available in the future.
3. Flows where EEE or WEEE is subject to data anomalies, where reporting suggests that more or less product available than there actually is.

Section 2 documents more than 21 WEEE flows across these three broad categories, with a profile describing the flow and volume, types of EEE/WEEE covered, the source of the information or our approach to research, any potential duplication, our confidence in the data and any relevant links.

2.1 Flow category 1; Recycled, destroyed and exported

The first of the series of sub-divided flow categories draws together activities where the product and/or product is lost. This may be a loss in its original form, or a loss from the reach of the UK recycling systems.

Flows included here are both legal activities, and illegal activities performed by actors across the supply chain. Our focus has been upon understanding and quantifying the larger operations where we believe the majority of the volume to be handled.

As would be expected with a research project on waste, this section includes more than half of the WEEE flows scoped out within the project. Each flow should not be considered individually, but more so, one part of a complex interconnected entity that morphs its shape as a result of many socio economic factors which are pushing and pulling on the flows of products.

Data sources wherever possible reach out to primary or secondary research findings from recognised report authors and industry experts, cited research and other reputable authors all whom are referenced in this report. Further engagement activities have been made through stakeholder groups and individual representatives through 1 to 1 interviews.

2.1.1 AATF reported WEEE received

Flow description

WEEE can be received and treated by Authorised Approved Treatment Facilities (AATF). These licenced sites are Regulated and approved annually by the national Agencies. Data reports are made quarterly and annually of WEEE received and published by the Environment Agency. Product generally originates from the consumers (mostly collected via Local Authority services) and business end users, delivered via accredited waste carriers.

Estimated volume

Regular data returns made by the AATF to the Agencies quantify obligated and non-obligated, non household B2B and household B2C WEEE. The data sample taken in this study represents 2017 with 653

Kt of WEEE received for treatment (note 2018 was 563 Kt which shows a 90 Kt loss of treated WEEE through accredited processors from 2017 to 2018 compliance periods).

Types of W/EEE

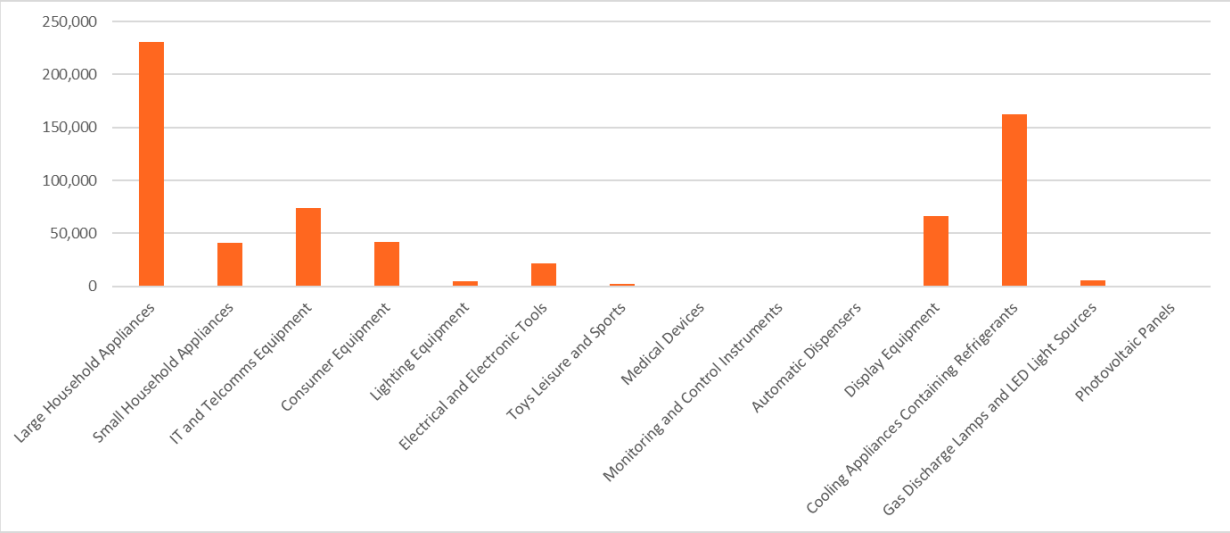


Figure 1; WEEE received at AATF 2017 by category.

The product categories illustrated in Figure 1 show the WEEE received at AATF. Categories for Small household and Consumer equipment will include a variety of actual products. Some products that fall into this category from consumer research suggest they are most likely to be disposed of correctly for recycling; small domestic appliances like kitchen items and tools, digital cameras, and media equipment. The products that fall into other categories of Large Household, Cooling and Display are much narrower by product type because of WEEE category scope.

Source and approach

Data submissions made by AATF are regulated and approved annually by the national Agencies. An aggregate of the tonnage of any B2B/B2C/non-obligated WEEE received and treated is included based on year 2017 across 68 large and 95 small site types (note; the number of AATF's are in decline which reduces the number of sites reporting WEEE treated).

Duplication

The tonnage reported by AATF is unlikely to appear in other flows to any material extent.

Confidence

There is a higher level of confidence in this data set because of the auditing, accrediting and robust processes that must be in place for the site to retain its AATF licence.

Links

AATF register; https://www.gov.uk/government/publications/waste-electrical-and-electronic-equipment-weee-public-registers

WEEE data; https://www.gov.uk/government/statistical-data-sets/waste-electrical-and-electronic-equipment-weee-in-the-uk

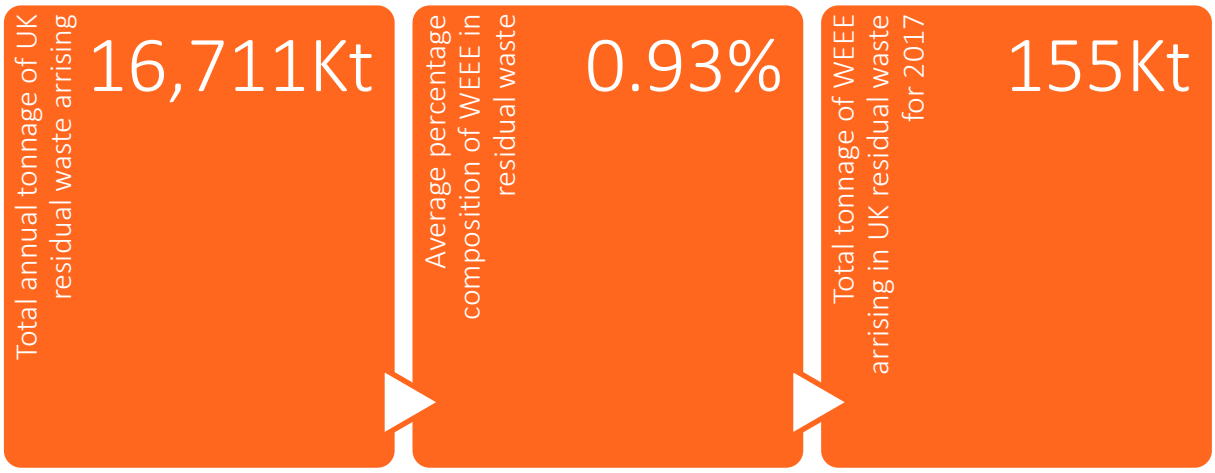
2.1.2 Residual waste stream

Flow description

Waste deposited by householders either at kerbside or local household waste recycling centres (HWRC), that has not been separated and is captured in the Local Authority collected household residual waste stream. Material, often referred to as 'black bag/black bin waste' is collected by waste contractors appointed by the Authority. This material is disposed through landfill or incineration. The aggregated authority data is reported on an annual basis via Waste Data Flow (WDF) and this has been used as basis for this study.

Estimated volume

Waste composition analysis of WEEE fractions is taken from household residual waste deposited through Local Authority networks across 135 councils/local authorities with over 15,000 waste samples from 2017 used in this study plus a further 10,000 used to indicate possible trends for 2018. The average for WEEE found in residual kerbside waste was 0.93%, resulting in a total WEEE in residual approximately 155 Kt in 2017. Adding in extra sample data for 2018 and estimates of residual arising in 2018, the WEEE in residual may increase to 164Kt.



Types of W/EEE

WEEE that escapes the recycling system and is discarded into the household residual waste stream is smaller by physical nature, and from a consumer perspective is too difficult to recycle, and/or they are unaware of the recycling options available in their local area. Research shows these items are lower value, smaller, frequently replaced items like media accessories, small kitchen as well as bathroom appliances and lamps. Higher perceived value items and those containing data, tend not to be discarded through this flow.

Source and approach

Annual reports from WDF are taken for each of the 135 councils/Local Authorities from years 2016/2017. This data represents the total household residual waste that is not recycled on an annual basis per authority. Another large set of data from composition analysis is gathered to extract the primary data composition analysis of WEEE in residual household waste. This is representative of 2.5M (2016) and 2.9M (2017) households across these authorities per year. The percentage of WEEE found in kerbside waste is applied to the residual tonnage per authority. The local tonnage is then extrapolated up from

local to national totals based on residual waste reported in the UK. This output represents total WEEE in residual waste stream for the UK.

Duplication

There is a very low likelihood of double counting through the WEEE in residual waste flow. WEEE products are taken from, or deposited by, the householder who is the waste owner directly. It is sent for treatment with little opportunity to be captured elsewhere because it is not separated from other waste material (unlike DMR for example). Materials have little or no treatment before being sent to landfill or incinerated through Local Authority contractors.

Confidence

There is a high degree of confidence in the sample of WEEE found during the assessment periods. Although not all authorities have carried out seasonal adjustment to average results, and the extrapolation of the sample is based upon the residual waste total for each area, the scope coverage and number of samples is the highest density of sampling published on WEEE composition analysis.

Links

Waste Data Flow https://www.wastedataflow.org/login.aspx?ReturnUrl=%2Fnews%2Fwelcome.aspx

https://melresearch.co.uk/service/waste-analysis

https://www.gov.uk/government/publications/quality-assurance-of-administrative-data-in-the-uk-house-price-index/acorn-consumer-classification-caci

2.1.3 Light Iron

Flow description

Material commonly called 'light iron', refers to steel scrap 5C loose old light domestic material. Light iron is a scrap metal that holds a positive value so despite the mixed nature of origins, there is reason to separate these metal rich materials. Material is often a mixed metal composition and is considered by industry to be the (non-product specific) waste stream where most WEEE may find itself, once it has been collected by waste contractors. Those treating the light iron may or may not be AATF, however the WEEE fraction is lost amongst the mixed scrap metals.

Estimated volume

The approximate annual amount of WEEE considered to be captured in light iron is 215 Kt for 2017. This will differ year to year based on other scrap metal flows and reported volumes but assumes a consistent 11% composition, but does not include an additional 1.2% of SDA from recent research.

Source	Detail	Tonnes (Kt)	Total LDA in Light Iron (Kt)
Total	Total light iron in-feed to a shredder 2015 (BMRA update not able)	4085	215
DCF mixed scrap stream	Waste Data Flow scrap metal minus LDA already evidenced via AATF	327	
WEEE from AATF	Household and Non-household IT and Display from AATF (2017)	104	

End of Life Vehicles (ELV)	stream does not include LDA (2017)	1470	
Separately collected LDA	All reported LDA at DCF	231	
Other sources	Remainder of the in-feed, of which will contain 11% LDA not accounted for above	1953	

Types of W/EEE

In relation to WEEE, those items damaged, unrepairable or perceived low value with high metal content such as white goods, or other metal rich WEEE products are most susceptible to enter this flow for their embedded scrap value. This is likely to feature large household appliances as the predominant type of WEEE, however since the initial WRAP[2] study, and as our stakeholder engagement found, industry now recognises around 1.2% may be small domestic appliances not counted.

Source and approach

An update of the original WRAP methodology into WEEE in the light iron stream has been re-calculated. This new calculation uses more recent 2017 data sets or estimates for; in-feed shredder, WDF scrap metal arising at designated collection facility (DCF) (minus 11.6% Large Domestic Appliances (LDA)), small mixed WEEE and Display from AATF data, latest ELV processing data, and separately collected LDA. However, the original study concluded at the time with an 11.6% presence of LDA, but in addition to this following a stakeholder engagement exercise, we understand 1.2% SDA estimate could be added to the total. The results are a more recent profile of scrap processing with greater presence per tonne processed that contains WEEE.

Duplication

The route into this flow can be legal and illegal, planned or opportunistic, and as a result may feature in other flows such as theft, DMR, C&I or AATF reported tonnage. As the final stage of treatment any possible duplication in flows will be repeated further up the supply chain.

Confidence

The methodology applied is based on a long-term industry accepted approach, however as a consequence the relevance to the current market (including market value and costs) the original calculation has become aged. Of particular importance is an update to the total tonnage in-feed to shredder across all scrap metal processors. However, with updates in other areas there is a satisfactory level of confidence in the net result.

Links

https://ec.europa.eu/environment/waste/weee/pdf/WEEE%20workshol%20february%202017/All%20WEEE%20flows_the%20case%20of%20UK.pdf

[2] WRAP WEEE Flows 2016/2018

2.1.4 Legal exports of EEE

Flow description

The products sold or supplied to customers outside the UK including new and used working items, would fall under this flow definition. Legal exports could be via; e-commerce, commercial wholesale or resale, and export or other specialist and high-tech product supply from the UK to the global market place, as well as borderline illegal activity. Supply of new EEE is fuelled by e-commerce (B2B and B2C). This is led by B2C transactions representing over 2/3rd of the market. Used and second hand continues to prove a challenge with grey areas of product testing, global growth of middle classes demanding more technology, alongside a legitimate asset management and remarketing business accessing more readily available global marketplace.

Estimated volume

The exports of all electronics represent £35B or 12% of all exports according to UK Government briefing papers[3] reports on electronics. Modelling is based upon HMRC customs code analysis for items that are recognisable as EEE categories; we estimate that 7% of the UK exports are second hand electricals equivalent to 16 Kt exported in 2017.

In addition to this there is an estimated 5 Kt of new EEE legally exported into Ireland from reported EEE.

Types of W/EEE

The analysis of data suggests that the physically smaller, more mobile, and higher value items of EEE are likely to be exported, rather than the dominance seen in UK EEE reported placed on market (by weight) of large household and cooling EEE categories and other low value items. As a result, more IT and consumer equipment and more specialist equipment (biased towards IT again) will feature more prominently.

In the second-hand and used markets; IT & Telecoms, Display, and Consumer Goods are most prominent categories of EEE leaving the UK for emerging markets like Western Africa, and Southern Asia.

Source and approach

A HMRC customs code analysis drawn from online data reports published annually, is expected to represent predominantly new EEE.

An approach has been developed to account for an estimate of the second-hand and used equipment exported. Following interviews with the asset management sector we have determined a export % and then tested this against prior research into illegal exports that has recognised working used equipment.

[3] Statistics on UK trade with Ireland – House of Commons Breifing Paper CBP 8173, 5 November 2019

Duplication

Legal exports are likely to be captured in IT asset management, warranty returns, commercial re-use, and producer mis-reporting of EEE data. The overlap here is led by a dynamic and market led movement of how used EEE is redistributed to meet market opportunity; exploited rapidly, by many smaller and agile players, and also those less reputable players blurring the lines between legal and illegal activity.

Confidence

The stand-alone data for HMRC is robust, however the overlap with reporting elsewhere in EEE placed on market, and how much this represents (non-classified EEE) lowers the confidence scoring of the data. The proportion that is represented by used EEE is also lacking confidence since it represents one sector and not all businesses commercially exporting used EEE. There is a reasonable amount of prior research on illegal exports.

Links

https://www.uktech.news/news/new-analysis-shows-online-marketplaces-set-to-exceed-%247-trillion-by-2024-20190929

https://www.parliament.uk/documents/commons-committees/Exiting-the-European-Union/17-19/Sectoral%20Analyses/13-Electronics-and-Machinery-Report.pdf

2.1.5 Theft

These flow reports are further broken down into the main product groups that are most susceptible to theft from the WEEE system. Each has its own unique factors that require individual consideration as part of the wider estimate on total amount lost from the system, so are presented under the following WEEE categories:

- Category 1: Large Domestic Appliances (LDA); see **Appendix III** for detailed approach
- Category 2 – 10: Small Mixed WEEE (SMW); see **Appendix IV** for detailed approach
- Category 11: Display Equipment; see **Appendix V** for detailed approach, and
- Category 12: (Cooling) Equipment containing refrigerants; see **Appendix VI** for detailed approach

2.1.5.1 Theft – Large Domestic Appliances (LDAs)

Flow description

This work focussed on the loss of large domestic appliances (LDAs) prior to them being collected from DCF sites. This was recognised as the least secure part of the supply chain, and therefore most likely to be prone to theft.

Estimated volume

There are 90 Kt of LDAs lost through theft that would have been expected to arise at DCFs. This represents 42% of the LDAs that would be expected to be collected in 2018.

Types of W/EEE

Large Domestic Appliances (LDAs) including washing machines, clothes dryers, dish washing machines, cookers, electric stoves and microwaves.

Source and approach

In order to estimate the quantity of LDAs lost through theft, the ratio of household LDAs to Cooling appliances placed on market (POM) was compared to the ratio of LDAs to Cooling appliances collected. It is assumed that the ratio collected should be the same as POM, taking into account the different average lifespans of each stream.

If the cooling appliances collection figure is assumed to be the true quantity that would be expected to be collected on site, adjusted for the effect of loss occurring through compressor and cable thefts, and then the Cooling/LDA ratio collected is applied, the quantity of LDAs that would be expected to be collected can be estimated. The difference between what is reported as collected and what is expected to be collected can then be identified as theft.

Duplication

There may be some duplication in other WEEE flows where the product becomes waste or is exported from the country.

Confidence

Analysis was conducted to sense check the 42% of LDAs figure lost through theft:

LDAs collected typically only account for 31% on average of LDAs POM. Research indicates that 83% of all new purchases are replacements, therefore with the purchase of a new appliance in the vast majority of cases there should be an equivalent WEEE item arising.

The greater the LDA scrap price the fewer LDAs are collected, which indicates that as their value rises so does the number of LDAs lost. Looking at the gap between the lowest and highest collection figures between 2008 and 2018, indicates there are potentially 82.345 Kt that can be affected by the LDA scrap price.

These analyses indicate LDA theft could be significant and that the 42% may be realistic.

Links

See Appendix III.

2.1.5.2 Theft – Small Mixed WEEE (SMW)

Flow description

This work focussed on the theft of Small Mixed WEEE (SMW) taking into account what is placed on the market, recycled, hoarded and lost in other waste streams.

Estimated volume

There are 91 Kt of SMW lost with some (3.201 to 5.335 Kt) lost as theft with the remainder ending up in the general waste bin.

Types of W/EEE

Small Mixed WEEE (SMW) includes all EEE categories 2 – 10. Common examples might be hair dryers, toasters and kettles, computers and media equipment, tools and toys.

Source and approach

In order to estimate the quantity of SMW lost through theft, a top down approach was used to determine from what is placed on the market, where the loss of SMW could be identified. Starting with EEE reported as put on market, deductions are made for each type of output – see Appendix IV Theft – Small Mixed WEEE (SMW) for details. This involved using data from reported recycling, recycling under exemption, protocolled recycling in other flows (LDAs), hoarding and theft. By estimating these flows the remainder that is likely consigned to the general waste bin can be identified.

Duplication

There may be some duplication in other WEEE flows where the product becomes waste or is exported from the country.

Confidence

Analysis was conducted to sense check the shortfall of SMW of 266.355 Kt that would be expected from DCF sites. This was sense-checked against an Anthesis estimate of losses from sites and indicated that the estimate seems sensible.

Links

See Appendix IV.

2.1.5.3 Theft – Display Equipment

Flow description

This work focussed on the quantifying theft of display equipment, taking into account the type of Displays which are likely and unlikely to be prone to theft. Theft of flat panel type displays hold a higher value and appeal in second-hand markets making them more susceptible to theft.

Estimated volume

This work concluded that losses from the official WEEE system totals approx. 1.15 million units (16%) of those placed on the market in 2018, which equates to 12 Kt per annum (assumes average display is 10kg).

Types of W/EEE

Display Equipment includes televisions and display monitors for computers.

Source and approach

Since the switchover of terrestrial television to digital signals, completed in 2012, cathode ray tube (CRT) televisions have ceased to be placed onto the UK domestic market in any meaningful quantities. The rapid development of flat panel display (FPD) technologies, meant that manufacturers have produced progressively lighter units. However, the recent customer preference for large-screen units appears to have arrested this decline.

The effect of these factors on the weight based WEEE system, since 2012, has been to show a broadly stable level of total weights reported as POM, whilst total weights received at AATFs have declined

significantly. This mismatch suggests that there is now a significant loss from the WEEE system. At the same time, old and heavier CRT units remain persistent in the WEEE stream, long after they were expected to decline to insignificant levels.

Due to the complexity of the various display technologies being POM, coupled with light-weighing, increase in their size and each having a different lifespan it is difficult to estimate the amount of theft occurring using weight-based methods, therefore in order to try and quantify display theft this project used a unit method.

Duplication

There may be some duplication in other WEEE flows where the product becomes waste or is exported from the country.

Confidence

The mismatch between the Displays POM and received for recycling suggest that there is a significant amount of theft. The findings of this work were reviewed by Valpak's AATF/ATF auditors and other project key industry stakeholders, who believe the display theft estimate seems sensible. Without other robust estimates this could not be verified further.

Links

See Appendix V.

2.1.5.4 Theft – Cooling Equipment

Flow description

To calculate the amount of Cooling Equipment lost through theft this project focussed on the valuable components of a fridge that are often missing when an item of cooling equipment is received for treatment by an AATF.

Estimated volume

This work estimates the loss to the official WEEE system of component theft from cooling equipment is approximately 7.7 Kt per annum.

Types of W/EEE

Cooling Equipment includes any equipment with for cooling with a refrigerant but mostly represents fridge and freezers.

Source and approach

The project focused on the incidents of compressor theft as the cause of losses from the WEEE system. By applying an average weight of the missing component, the total amount of theft can be estimated. The work was based on primary data for Cooling Equipment units received with missing components, and the average weight of complete cooling units, and those missing components.

Duplication

There may be some duplication in other WEEE flows where the product becomes waste or is exported from the country.

Confidence

The findings were reviewed by Valpak's AATF/ATF auditors and other project key industry stakeholders, who believe the estimate for cooling equipment theft seems sensible. Without other robust estimates this could not be verified further.

Links

See Appendix VI.

2.1.6 IT Asset Management & Destruction (ITAM/ITAD)

Flow description

Businesses hoping to recover asset value, or disposing of obsolete equipment of typically IT & Telecoms equipment, can do so via ITAM services. Coupled with data security laws, a service sector for asset recovery has grown during the last 20 years. In the UK the market is dominated by a small number of large companies including RDC-Computacenter, TES and SIMS Recycling ITAD. These organisations are involved in collection, recovery, repair and re-marketing of electronics and can achieve high levels of material recovery. When products are disposed of they may be working so suitable for re-sale, unless obsolete. Remarketing can be biased towards export markets where demand exceeds supply. Other non-working items can be stripped for parts or simply scrapped, either through AATF or other waste channels (scrap metal/plastics where EEE is not recognised).

Estimated volume

Based on the feedback from interviews with asset management sector, we have calculated the UK market is represented by approximately 15M products. This would represent approximately 90 Kt of predominantly IT & telecoms equipment flowing into ITAM organisations each year.

Types of W/EEE

Whole products entering ITAM are; display equipment, server equipment, laptop and desktop PCs, routing and transmission equipment, printer, media storage and other telecoms equipment. This will most often arise from a mid-size and upwards business setting for predominantly B2B, but also a considerable amount of dual use equipment. There may also be part complete products that have been salvaged or harvested for parts whilst with the original users.

Source and approach

Evidence has been collated from a prior B2B WEEE research project[4], plus a number of new stakeholder interviews from inside and outside of the ITAM sector. By estimating market size, and an average weight of equipment we have identified 2 different approaches to reach a similar total weight of EEE in the ITAM flow. The input to the ITAM estimate provided in this study is the total arriving into the ITAM sector, and does not distinguish that which is scrapped, or re-marketed.

Duplication

[4] B2B IT and asset management in UK and France (Anthesis, 2017)

Equipment arriving into ITAM organisations is understood to mostly be a direct transfer from end users or an intermediary, to the ITAM. As a result, any duplication may be downstream, potentially arising in; C&I, light iron, ATF/T11 sites and AATF, as well as export (legal and illegal). This will be as a result of products or material being passed down the chain for specialist material recovery, or alternative more localised markets and users. It is expected that only in re-marketing will the product remain in its original (or very near to) form to be recognisable as used-EEE.

Confidence

The basis of findings come from Anthesis' prior study, that included engagements across European network of contacts across UK and France. Subsequent interviews were carried out for this study with a number of stakeholders to re-visit the operations and latest market intelligence, to make updates to the calculation. We recognise there are many formal and informal players in the market but through analysis of earlier market coverage, the estimates presented in this study represents the greater majority of actors in the ITAM sector.

Links

https://ec.europa.eu/environment/waste/weee/pdf/WEEE%20workshol%20february%202017/All%20WEEE%20flows_R.Peagam.pdf

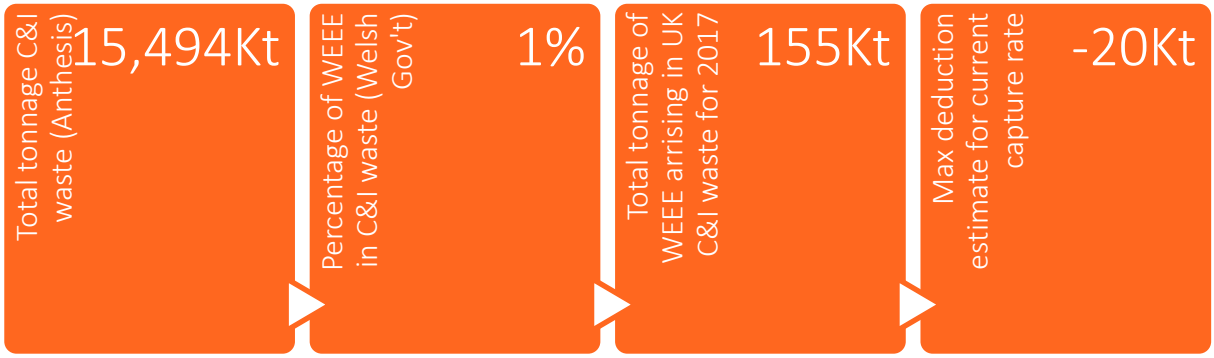
2.1.7 Commercial & Industrial

Flow description

This report includes flows of WEEE arising in municipal like C&I waste. Material is arising from businesses and industry in non-separated collections, however sampling studies have proven this contains a small proportion of WEEE. Example organisations include: generic industrial, accommodation and food service, education, health and social work, and generic commercial. WEEE items are typically damaged, obsolete and/or very low value, hence the intention to discard without recovering or recycling. Discarded C&I material will be deposited by business waste producers, transported by a waste management or haulage operator, then transported on via bulking to a transfer station, possibly for some separation, before ultimately being sent for treatment or disposal. WEEE product is lost in its original form unless extracted by waste management companies or processors during the transfer and handling stage, to be treated in a material specific process. These mixed waste streams, as the name suggests, contain many different products.

Estimated volume

The annualised amount of WEEE arising in C&I (municipal like) waste is estimated to be between 135 Kt and 155 Kt, from a baseline of 2017 data.



Types of W/EEE

The WEEE arising in C&I is likely to be similar to that of household residual, given the business and municipal waste like categorisation for the purpose of this study. This returns mostly small domestic appliance type items, that are easily discarded with other materials and without the need for specialist handling and treatment (assuming waste is being deposited correctly this rules out cooling and display) or consideration about physical size (ruling out most LDA).

Source and approach

Data used to calculate C&I waste has been modelled from DEFRA business survey results from 2009/10, then built from the bottom up using expertise from Anthesis colleagues in C&I waste futures modelling, and looking back at baselines from 2017. This provides a total C&I waste estimate for the UK. A C&I study commissioned by the Welsh Government as a regulatory impact assessment on the revision to business waste collections in Wales has determined a percentage of C&I that is WEEE. Bringing these 2 data sets together we have determined the total WEEE in C&I and measured this against feedback from stakeholder interviews across the waste sector.

Duplication

Waste materials arising from C&I may find their way into light iron waste stream, ATF/T11 licenced sites, and possibly AATF (as non-obligated), if this material is pre-treated with some degree of material or product separation after being deposited by the waste holder. The low proportion that WEEE represents makes it difficult for a stand-out separation of WEEE from C&I and further primary data work may be necessary to improve the robustness of the measure, and opportunity to extract more of this WEEE for recycling.

Confidence

There is a low to medium confidence in this data due to the lack of recent actual data from which the totals are determined. C&I has and continues to be a challenge to estimate total volumes arising, and this fraction used for the purpose of this study does not represent all C&I. Also, we have limited visibility of the approach taken in the study conducted for the Welsh Government, however this is a recent study and the results are considered to be reliable when cross referenced with stakeholder feedback.

Links

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/778779/CommercialandIndustrial_WasteArisings_Methodology_Revisions_Feb_2018_Oct_2018_rev2_update.pdf

https://gov.wales/sites/default/files/consultations/2019-10/regulatory-impact-of-options-to-increase-business-recycling-in-Wales.pdf

2.1.8 Illegal exports

Flow description

The export of WEEE (non-functioning) from the UK is illegal under the Basel Convention. However, the UK has been heavily criticised based on evidence from tracking research (examples from Basel Action Network (BAN) and Geeraerts et al. (2015)[5])into the shipments of hazardous and non-functioning WEEE to countries like Nigeria, Pakistan and Ghana. The Basel Action Network and Interpol activities have proven there are high volumes of EEE moving out of the UK, to these West African and South Asian developing countries. WEEE (and used EEE) appears to continue to be shipped abroad from small individual operators, to large organisations and organised crime gangs are believed to be involved.

From our research we found case studies and academic work that shows all scale of operations; from packed container loads of mixed WEEE and UEEE (used electrical and electronic equipment), through vehicles (cars, vans, HGV trailers) packed with mixed items, down to small scale, click to-order, and ad-hoc exporting of equipment. Equipment is most likely destined for these countries but may travel via other destinations e.g. 'port-hop' or via road freight, to avoid detection from authorities. Handling in the UK is minimal and volumes have to be large (tens of tonnes (Odeyingbo et al 2016[6])) for the export to be economically viable. Like legal export, growing economies and middle classes are demanding more technology, and their price point is such that a thriving second-hand market has developed. Volumes of untested equipment make their way overseas to meet this demand, this is resulting is a proportion that are illegally exported.

Estimated volume

Using a baseline of BAN research[7] from research published in 2019 and extrapolated from their research, we estimate the UK will represent approximately 32 Kt of WEEE illegally exported each year.

Types of W/EEE

The example list of products presented are from a study conducted in Nigeria that found UEEE and WEEE (mixed) entering the country misclassified or excluded from import documentation; LCD TVs, photocopiers, refrigerators, air conditioners, speakers, DVD, pressing irons, radios, microwaves, cookers and mobile phones.

[5] Geeraerts, K., Illes A. and J-P Schweizer (2015). Illegal shipment of e-waste from the EU: A case study on illegal e-waste export from the EU to China.

[6] Person in the port project - United Nations University (Odeyingbo, Nnorom, and Deubzer, 2015)

[7] Holes in the Circular Economy- WEEE Leakage from Europe (Basel Action Network 2019)

Other WEEE concluded from other studies will include IT & Telecoms, other flat screen TVs and monitors, small appliances and tools.

Source and approach

A review of secondary research was conducted, then key findings and insights extracted to formulate a view and quantify the amount of WEEE that represents the volumes leaving the UK as illegal exports was determined. The Basel Action Network research and estimate of the total volume of illegal exports from the EU was the main source of data for the study. We have also used Eurostat data to quantify the contribution the UK makes to exports. The secondary research relevant to the UK identified illegal exports mostly destined for West Africa, Southern Asia. Commentary (although unquantified results) are evident from shipments initially destined for a European port or moving via road haulage, that are not possible to specifically estimate weight volumes, other than as the extrapolation we have used from BAN totals leaving the EU.

Duplication

Illegal exports are quantified at the last point from the UK, so duplication will occur further up the supply chain, possibly through; theft, commercial and domestic re-sale, and ATF/T11 licenced operators. Obtaining these items can only be possible at lowest costs (or stolen) for the volumes to be viable to; bulk, resell to be ultimately exported. This is because of logistics and administrative costs.

Confidence

The basis for this estimate relies on the Basel Action Network and their extrapolation of primary data capture to total market supply. Other investigations and research show that UEEE /WEEE does find its way to these countries however the traceability is poor and the authorities hold intelligence confidentially. This approach is considered the best available information and is comparable to individual academic studies.

Links

https://www.ban.org/trash-transparency

https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nama_10_exi&lang=en

2.1.9 Unrecorded Treatment Under an Exemption

Flow description

The purpose of this section of the report is to estimate the quantity of WEEE that is refurbished and reused by organisations that operate under an exemption from environmental permitting but is not captured/reported within the official WEEE reporting system.

Estimated volume

It is estimated that 5.2 Kt of WEEE is reused by organisations that operate under an exemption. This is made up of 3.535 Kt of IT equipment, 0.853 Kt of small domestic appliances and 0.812 Kt of display equipment.

Types of W/EEE

Small Domestic Appliances / I.T. & Telecoms Equipment / Televisions and monitor displays for computers.

Source and approach

This project attempted to assess the extent of unreported WEEE treated under an exemption. This was done using Valpak intelligence to estimate the quantity of organisations operating in this way and then using assumptions for their likely scale (based on feedback through interviews from these companies operating at a scale that is worth taking the risk whist at a scale that does not draw the attention of regulators) identify the total quantity of unreported WEEE treated under an exemption.

Using Environment Agency data for reported WEEE treated under an exemption, coupled with an understanding of the end markets for various categories of WEE, the composition of WEEE treated under an exemption can be identified.

Duplication

Although not quantified in this section, any LDAs that are treated in this manner will likely be included in reported recycling or in estimates for LDAs in light iron calculations for substantiated estimates, which were used in section 2.1.5.1 Theft – Large Domestic Appliances (LDAs).

Confidence

The findings were reviewed by Valpak's AATF/ATF auditors and other project key industry stakeholders, who believe the estimate for unreported WEEE treated under an exemption seems sensible. Without other robust estimates this could not be verified further.

Links

See Appendix VII.

2.1.10 Warranty and returns

Flow description

The products handled via warranty and returns are rejected by the customer for functionality issues, as well as other colour, expectation or function rejection reasons. These items are typically handled by a retailer, and from survey responses, rarely find their way up the supply chain to importers and manufacturers. The product returns often reach the retailer who will process these under testing and/or inspection and remarketing (resale, auction or second-hand sales platforms) or disposal routes (waste management organisations). Returned products, once passed on by retailers, appear to disperse into many different smaller businesses, so visibility is lost as to the end destination where not disposed of as waste.

Estimated volume

Trends in return rates taken from existing survey data [8] [9] [10]shows both original equipment manufacturers (OEM) and retailers are experiencing an increase in returns in recent years. Using these findings, we estimate 102 Kt of EEE are being returned each year.

Types of W/EEE

All categories of products are likely to pass through the warranty and returns routes, because no product trend data has suggested one type of actual product is more susceptible to be rejected by the consumer, than another. We do believe the amount of product returned would reflect POM volumes.

Source and approach

To estimate the amount of warranty and returns we have surveyed producers, reviewed relevant existing research studies into returns, with specific profiles on electronics, and conducted interviews with retailers to hear of their own experiences. By compiling the findings and averaging results to demonstrate the most consistent feedback, we have calculated an 8% return rate in electronics, and applied this to the 2018 EEE POM (unadjusted for free riders) for the UK sales data.

Duplication

The likelihood of duplication is high in other non-reported EEE flows because the majority of returned products are shown to be classified as “no trouble found” (NTF) by the retailers. This can be remarketed by the original retailer or resold (commercial resale) in UK or possibly overseas. Even those that are faulty are likely to be processed in a WEEE specific product stream, so arising in AATF or T11 ATF sites.

Confidence

The data sources for returns rates have been triangulated against other sources to eliminate outliers. The studies are recent and reflect the e-commerce increases as well as higher consumption of electronics. The uniform return rate across product types can be challenged as this could be distorted by differing returns rates on LDA and Cooling Equipment, compared to other smaller items which are simply easier to handle (research shows ease of return is a significant factor when returning a product). This may suggest the estimate is slightly high, however no alternative data has been presented for this study. The calculation considers all returns from consumers because of the likely onward route of the product, rather than restocking with retailers.

Links

http://www.wrap.org.uk/sites/files/wrap/accenture-reducing-the-quantity-and-cost-of-customerreturns.pdf

https://www.ft.com/content/52d26de8-c0e6-11e5-846f-79b0e3d20eaf

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[8] WRAP switched on to value https://www.wrap.org.uk/sites/files/wrap/Switched%20on%20to%20value%20-%20Powering%20business%20change_0.pdf

[9] Navar Consumer Returns Survey 2017 https://see.narvar.com/rs/249-TEC-877/images/Narvar_Consumer_Survey_Returns_June2017.pdf

[10] KPMG Annual retail survey 2019 https://assets.kpmg/content/dam/kpmg/uk/pdf/2019/01/kpmg-annual-retail-survey-2019.pdf

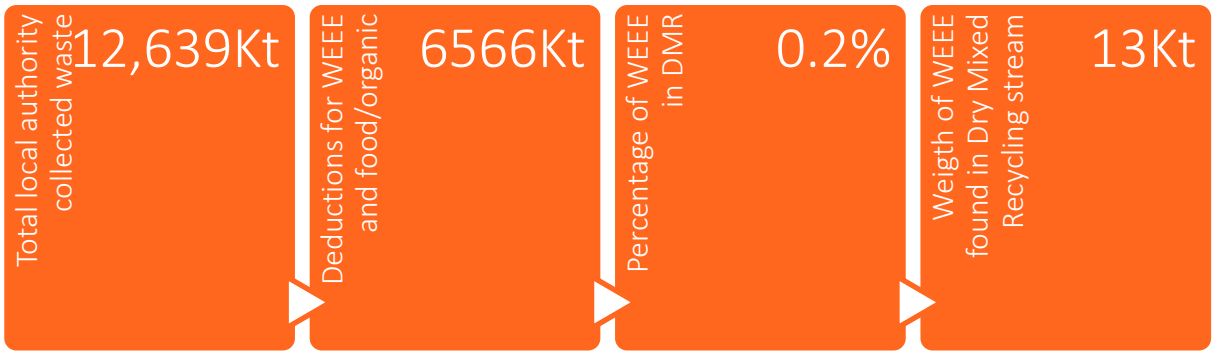
2.1.11 Dry Mixed Recycling (DMR)

Flow description

The report considers WEEE that has been deposited by end users in a DMR system and has then been removed in the material recycling facility (MRF) by either a manual or automated sorting processes. Typically, the operator of the facility will be discarding this material either back into the residual waste, or possibly in to the WEEE container for the Local Authority.

Estimated volume

This report estimates that annually there are 13 Kt of WEEE passing through the DMR materials flow, and onward into other flows within this study.



Types of W/EEE

The WEEE in DMR is typically small items that householders are trying to discard of through a recycling system, although this is not the intended route for that authority (or has become mixed at kerbside). Small items like kitchen appliances, consumer equipment and IT & Telecoms devices which are low value and small enough to fit inside a recycling box (<50cm maximum dimension) are the most common items. Accessories to these products are also commonplace as they easily become damaged and are more consumable than the device itself, although research suggests these are more probable to be discarded in residual.

Source and approach

Data used to estimate the amount of WEEE in the DMR stream is based on a small sample of stakeholder interviews and industry group feedback to indicate the proportion of WEEE seen in DMR. From this feedback, we have taken the total Local Authority collected waste for recycling, make several deductions for reporting elsewhere, then apply the WEEE composition to determine the total tonnage most likely to pass through a DMR.

Duplication

WEEE separated at this level of processing is likely to end up on one of 2 streams; residual waste, or, existing WEEE collections for the authority ultimately entering an AATF. This suggests that most of the products found in DMR will be counted in the larger flows elsewhere when discarded by the MRF operator into one of their output fractions.

Confidence

There is a medium to low level of confidence level in this calculation due to the limited sample of MRF operators, and the qualitative level of feedback provide through interviews and stakeholder group engagement. Although these sources are at the coal face of their respective activities, we have no sight of the type or approach to sampling data used. In the absence of other reports or analysis of waste fractions in MRFs this is deemed to be the best available data. The total local authority collected waste (LACW) tonnage is reliable however deductions for WEEE assume that no WEEE sent to AATF comes from the DMR, which could result in a double discount within the calculation.

2.1.12 WEEE lost in Fire incidents

Flow description

Coverage of fire related incidences involving waste have been very prominent within the waste industry and occasional national media. Whether this was a result of the more stringent Regulations imposed by the Environment Agency on Fire Prevention Planning, or, as a result of the more product and hazardous content is unclear. However, what we can see is that large scale fire events have involved different wastes and electronic and electrical devices have played a part in ignition. Those events measured are regardless of location, so include non-residential sites where electrics were recorded as an ignition source and could involve EEE being lost through fire damage.

Estimated volume

Using fire records, we have estimated that an average of 0.008 Kt per year of WEEE are lost to fire incidents.

Types of W/EEE

There is no information to suggest there are typical types of products that are more susceptible than others to loss through fire. Although statements suggest lithium batteries are an increasing cause of fires, the spread of fire can cause loss of both small battery-operated products, as well as larger items and other non-electrical waste materials.

Source and approach

The approach taken to estimate the weight volume of EEE and WEEE lost through fire incidents is based upon fire brigade reporting statistics that measure a number of reported incidences, with an average of relevant factors:

- Date; 2014/15, 2015/16, 2016/17;
- Faulty appliance or lead, misuse of appliance;
- Ignition source is electrical or other;
- Ignition in rubbish/waste.

With this selection from the data report the total damage extent per event is multiplied by the average weight of 10kg to determine the total. The average across the 3 years is then taken to return 0.008 Kt.

Duplication

Products that are lost to fire damage may not have been counted elsewhere. Products in waiting for treatment may be reported or estimated in licenced sites, and some hoarded products (commercial operations) may account for these products before they are processed. We have considered the items lost to all have been classified as waste already.

Confidence

The total tonnage calculated from this report is not material within the wider study. Despite this, fire events are high profile and dangerous. Our confidence in the data sources is low but despite this we do not believe the total tonnage of WEEE lost in fire incidents would be material, based on the data presented and stakeholder interviews with industry representatives.

2.2 Flow category 2; In-use and retention, redeployment and hoarding

The second of the series of sub-divided flow categories groups activities where product is still with the end user in the original form and is either in-use, or no longer in use and being hoarded, or being sold into a re-use application with a second end user.

Flows included here are significant by volume of units, but despite the size of the issue, very few holistic studies have been carried out to measure the full extent of products left in these settings.

Actors in this area will be all kinds of business and consumer end users. There is also a significant number of smaller re-selling businesses who are involved in commercial re-use of higher value products or retail returns.

Data sources reference primary and secondary research from recognised report authors and industry experts, cited research and other reputable authors all of whom are referenced in this report. Further engagement activities have been undertaken through key stakeholder interviews.

Overview of product fates

Product fates characterise the dominant pathways for disposing after use and, in some cases, after hoarding. Together with the times in use and in hoarding (both are components of the residence time), the fates determine detailed flows of used EEE through the reuse, recycling, general binning and other major routes by which WEEE is created.

The results for fates indicated that the common product destinations after use, in addition to hoarding, include reuse, second-hand sales, takeback schemes, recycling, general bin and unknown. We assumed that most of these fates also apply to the products discarded after hoarding. The results for the respective flows are based on the harmonised data for times in use, times in storage and fates, as well as the historic POM data for multiple product categories from Eurostat and Waste Over Time (WOT) v1.2 model, and are summarised in Appendix XIV. It is unsurprising that the heavy EEE products such as washing machines account for the bulk of the tonnage.

2.2.1 Use and retention, redeployment and hoarding

Flow description

Various types of household EEE could be used daily, regularly or occasionally, stored for a reason of possible future use, held for an emotional or sentimental value, or hoarded without an apparent intention of future use.

Depending on the EEE type, the regularity of use is likely going to affect the product's chances to be retained and/or redeployed in a household, which has obvious implications for the time it takes to arise as WEEE. However, we did not find quantitative data on the frequency/ regularity of use for EEE before it gets discarded or enters into hoarding in the peer-review literature, white papers, industry reports and surveys assessed.

The time a given EEE product spends in storage and is no longer used, before it gets discarded, is referred to as "in storage" or "hoarded". The reasons for hoarding EEE can be varied and include not knowing what to do with EEE in non-working condition, as well as intension of possible future use and sentimental

value. The most common factors affecting household hoarding relate to product type and size[11]; perceived economic value[12]; education and awareness of disposal pathways[13,14]; and socio demographics[13,14] such as low income, age (above 29) and/or gender (women). Other reasons for hoarding mentioned in the literature are:

- the desire to upgrade to the latest device[15]
- data security concerns[14]
- possible future use – either within the household or through donation[12,13]

The sources from which we retrieved hoarding data rarely provided the associated quantitative data for the reasons why EEE users/owners hoard the items. The most common extractable information found in the literature is whether discarded or stored appliances were in working condition or not. However, because the data is scarce and very heterogeneous, achieving acceptable confidence levels for each and all United Nations University Codes (UNU) categories reported becomes impossible when it comes to hoarding reasons. We found general evidence that the reasons behind hoarding vary by equipment, but the most common one appears to be lack of knowledge of what to do with an item that is broken/no longer needed[12,14]. Improving our understanding of how EEE hoarding affects WEEE flows would require additional consumer surveys on hoarding reasons across different EEE categories. This data would need to be further integrated into forecasting models.

Estimated volume

Our bottom-up analysis covered 73% of the Eurostat-derived POM in 2017 estimated from near-term forecasts in the Waste Over Time (WOT) model v1.2[16,17], amounting to 1,499.1 Kt.

We estimate that 1,293.0 Kt of household EEE stopped being used in 2017, entering various W/EEE streams (see Section 2.2 'Overview of product fates')

- The overall stock of EEE in use by UK households increased by 206.0 Kt in 2017
- Of the 1,293.0 Kt of household EEE no longer used, 175.4 Kt entered into hoarding in 2017
- We estimate that 171.4 Kt were discarded after hoarding, finding the way into multiple W/EEE streams
- The overall stock of EEE hoarded by UK households increased by 4.9 Kt in 2017

Based on the POM trends from WOT v1.2, we estimate that the 73% of POM analysed in this part of the study amounted to 1,547.8 Kt in 2019.

- We estimate that 1,343.1 Kt of household EEE stopped being used in 2017, entering various W/EEE streams (see Section 2.2 'Overview of product fates')
- The overall stock of EEE in use by UK households increased by 204.7 Kt in 2017

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[11] Hursthouse, A., Kelly S., McPherson, W., Menzies, B., Mirzaeian, M., Wood, D., Hendry, S and Q. Abbas (2018). WEEE collection and CRM recovery trials: piloting a holistic approach for Scotland. *Global NEST Journal*, 20(40), 712-718.

[12] Gutierrez, E., Adenso-Diaz, B., Lozano, S and P. Gonzalez-Torre (2010). A competing risks approach for time estimation of household WEEE disposal. *Waste Management,* 30(8-9, 1643-1652.

[13] Dataset GIN1772_Ginger_Comms (181).

[14] Dataset WEEE Fund.

[15] Dindarian, A., Gibson, A.A.P. and J. Quariguasi-Frota-Neto, (2012). Electronic product returns and potential reuse opportunities, a microwave case study in the United Kingdom. *Journal of Cleaner Production*, 32(September), 22-31.

[16] Van Straalen, V.M, Roskam, A.J., Baldé, C.P. (2016). Waste over Time [computer software]. The Hague: Statistics Netherlands (CBS). Information retrieved 10 August 2017. Available at: http://github.com/Statistics-Netherlands/ewaste.

[17] Stowell, A.F., Yumashev, D. et al. (2018). Setting robust and realistic PCS targets for WEEE to support the transition to a Circular Economy – an Industry White Paper. Available at: http://dynamicweeemodel.co.uk.

- Of the 1,343.1 Kt of household EEE no longer used, 181.8 Kt entered into hoarding in 2017
- We estimate that 176.2 Kt were discarded after hoarding, finding the way into multiple W/EEE streams
- The overall stock of EEE hoarded by UK households increased by 5.6 Kt in 2017

Types of W/EEE

We were able to extract data for products across 34 of the 54 aggregate UNU categories for the entire EEE sector (73% of total UK POM in 2017), covering 9 of the 14 UK WEEE categories. The product types that were estimated to be the biggest contributors to hoarding in 2017, as well as the products that had detailed data on hoarded stocks and storage times readily available, are summarised in Table 1.

Table 1 Biggest flows into hoarding, along with product types with detailed data on hoarded stocks and storage times. 2017 estimates.

WEEE Category (UK14)	UNU W/EEE Category (54 in total)	Estimated annual tonnage entering into hoarding (Kt/yr)	Number of units hoarded within a household (median [5% - 95%])	Estimated hoarding time in in years (median [5% - 95%])	Top EEE/WEEE disposal pathway after use	Estimated annual tonnage of top disposal pathway (kt/yr)[18]
01. Large domestic appliances	104 Washing Machines	19.555	NA	NA	General bin	67.705
	106 Heating	13.749	NA	NA	General bin	47.618
	114 Microwaves	20.072	NA	NA	Recycling	37.571
02. Small domestic appliances	201 Irons, fans, clocks, etc	14.054	NA	NA	General bin	35.316
	202 Food preparation	8.013	NA	NA	General bin	62.964
	204 Vacuum cleaners	3.921	NA	NA	General bin	30.825
03. IT and Telecommunications equipment	302 Desktop PC's	0	0 [0 - 4]	1.5 [0 – 10]	Recycling	33.591
	303 Laptops and Tablets	3.370	0 [0 – 5]	1.5 [0 – 7]	Recycling	3.713

[18] These figures include items disposed of both after being in use and hoarded.

	306 Mobile Telephones	0.871	3 [0 - 7]	2 [0 – 7.5]	Recycling	1.035
04. Consumer equipment	401 Consumer electronics	3.536	NA	2 [0 – 9.5]	Hoarding	3.536
	402 Portable Audio & Video	0	1 [0 – 2]	0 [0 -16.5]	General bin	0.697
	403 Musical Instruments	0	NA	NA	General bin	19.833
	404 Video & DVD	6.865	0 [0 - 2]	0.5 [0 – 13.5]	Recycling	15.528
	405 Speakers	9.249	NA	NA	Hoarding	9.249
	406 Cameras	0	3 [1 - 5]	NA	General bin	0.555
09. Monitoring and Control Instruments	901 Household Monitoring	5.561	NA	0 [0 – 24.5]	Hoarding	5.561
11. Display Equipment	407 CRT TVs	16.145	NA	1 [0 - 7]	Recycling	44.437
	408 FDP TVs	16.226	0 [0 – 3]	1 [0 - 19]	Recycling	19.951
12. Cooling equipment (with refrigerants)	108 Fridges	7.819	NA	NA	General bin	55.270
	109 Freezers	1.990	NA	NA	General bin	14.097

The results in Table 1 highlight the following:

- Based on annual tonnages, hoarding is a top destination for UNU401 'Consumer electronics' and UNU901 'Household monitoring and control equipment'. For the other major product categories, hoarding is behind recycling and put in the general bin.
- Category 3 'IT and Telecommunication equipment' and Category 4 'Consumer equipment' have the longest time in storage. Category 11 'Display Equipment and Category 9 'Monitoring and control equipment' have the shortest time in storage (see Section 6.3.1 in the appendices and supplementary datasets).

Recommendation

More quantitative data is needed to establish the reasons why EEE users/owners hoard the items. Attention should be paid to UK Category 1 'Large Household Appliances' and Category 12 'Cooling Equipment with Refrigerants' given that these products hold substantial weight and are more likely to enter an alternative flow outside of the official WEEE recycling system.

Source and approach

A quantitative desk-based research approach was adopted, involving:

- 10 reports and 81 academic research papers reviewed
- 5 datasets analysed and used

- 3 private sector experts consulted
- insights from the wider project team taken into account

The scope of this piece of work focused on hoarding, reuse, second-hand sales and commercial reuse. The research took a 4-phased approach. Phase 1 the "Gap analysis" examined existing EEE and WEEE data for refurbishment, e-waste, consumer behaviour, hoarding, second-hand and reuse products. The documents were reviewed for relevance by data availability and usability for the following variables: EEE time in use, EEE time in hoarding, EEE stock in use, EEE stock in hoarding and EEE fates (see Appendix XVII). This was followed by Phase 2 "Data extraction and harmonization", which we also refer to as "meta-analysis". The data was manually extracted from the useable sources identified in the gap analysis phase. This data was then classified into the parameters of interest (product age, stock in storage and fate) before harmonizing the data against the UNU categories using an automated script coded in the statistical software 'R'[19]. Given the limited UK data, other European studies were included and an additional 5 datasets were sourced from the wider project team and through the Lancaster University Research Teams network (see Appendix XVII and supplementary datasets available for publishing). Phase 3 "Second-hand flow analysis" focused on determining second-hand trends on major online marketplaces and will be introduced in Section 2.2.3. Phase 4 "Extending WOT model"[16,17] used the output from Phase 2, combined with the UNU-level POM data for the UK from Eurostat/WOT1.2 covering the period between 1980-2021, to estimate flows and stocks of EEE and WEEE over multiple destinations. The estimates were performed using a new automated script in MATLAB, and include stocks in use and in hoarding, the flows discarded after use and after hoarding, and the respective fates shares of the discarded product tonnages (see Appendix XIV and supplementary datasets and software).

Duplication

No observations could be extracted regarding possible sources of double counting.

Confidence

The confidence scoring methodology adopted in the desk-based study is presented in Appendix XVII. Broadly, the data confidence scoring was based on the following 5 criteria:

- Number of studies contributing to the data for each UNU category
- Granularity of the data samples relative to the given UNU
- Type of data in the studies feeding into a given UNU (raw numbers from household surveys VS results of statistical processing),
- Sample size of the datasets from which the data was extracted
- Age of studies

The overall confidence levels are ranked at 3.9 out of 5 for time and stock retention and hoarding for most of the UNU categories in Table 1. UK Category 4 (Consumer Equipment) has the lowest confidence scores, while Category 3 (IT and Telecommunications Equipment) has the highest confidence scores. This is mainly because UK Category 4 has a low number of sources and low granularity opposed to UK Category 3.

It is also important to note that despite confidence scores being relatively high, some data was sourced from research outside of the UK. The data was used in an attempt to fill the gaps and drawn from countries that adopt similar practices to the UK e.g. European countries.

Links

The following appendices provide in-depth insights into the research approach and findings:

[19] R Core Team (2018). R: A Language and Environment for Statistical Computing, Vienna: R Foundation for Statistical Computing.

- Appendix II – Definitions
- Appendix XVII – Gap analysis, data extraction and harmonization approach and results
- Appendix XVIII – Second-hand flow analysis
- Appendix XIV – Extending WOT model to estimate WEEE flows and stocks

2.2.2 Reuse Domestic

Flow description

We define "reuse" as 'a continued use of EEE or its components, for the same purpose for which it was conceived, beyond the point at which its specifications fail to meet the requirements of the current owner, and the owner has ceased use of the product'[20]. With the development of the internet, web-based auction and classified advertisement platforms have become a major selling channel for second-hand products – and in particular Gumtree and eBay[21,22]. Consumers who opt to reuse or purchase second-hand products attributed the following to their decision/s;

- product type – desktop computers and laptops are more likely to be donated to charity organisations[23] whereas mobile phones are more likely to be resold.
- purchase second-hand EEE is more likely for individuals under the age of 29, there is comprehensive production information and images available[24,25], the second-hand seller is perceived as trustworthy, easily accessible, and the onward second-hand EEE journeys are legitimate[26].
- barriers to reuse are attached to perceived social stigmatization of owning second-hand products and the quality standards attached with reuse[25], and in particular small mixed EEE[27].

Estimated volume

Across all UNU categories, the trend analysis results indicated that there has been a decline between 10-25% since 2016 (see Figure 1 below for indicators) of EEE available for resale in the second half of 2019. UK Category 4 'Consumer Equipment' showed the biggest decline of roughly 30%. The most stable UK categories were Category 11 'Display Equipment' and Category 6 'Electrical and Electronic Tools' (see Appendix XVIII for full details on Gumtree and Google Trends results).

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[20] UNU/Step (2009; 6). One global understanding of reuse – common definitions. Available at http://www.step-initiative.org/files/_documents/whitepapers/StEP_TF3_WPCommonDefinitions.pdf.

[21] GumTree and eBay are amongst the most popular shopping platforms in the UK see Statista, (2019a). Daily active users (DAU) of leading Google Play store shopping apps in Great Britain during August 2019. Available at: https://www.statista.com/statistics/881618/leading-google-play-shopping-apps-dau-great-britain/

[22] Statista, (2019b). Daily active users (DAU) of leading iPhone shopping apps in the United Kingdom. Available at: https://www.statista.com/statistics/878835/leading-iphone-shopping-apps-dau-the-united-kingdom/

[23] Hurthouse A., Kelly, S., McPherson, W., Menzies, B., Mirzaeian, M., Wood, D., Hendry, S and Q Abbas (2018). WEEE collection and CRM recovery trials: piloting a holistic approach for Scotland. *Global NEST Journal*, 20(4), 712-218

[24] Mugge, R., de Jong, W., Person, O and E. J. Hultink (2018). The influence of information about prior use on consumers' evaluation of refurbished electronics. *Research in Design Series*, 9: PLATE Product Lifetimes and the Environment e-book. Available at: http://ebooks.iospress.nl/publication/47886.

[25] Speak, J and L. N. Yangke (2015). "What do I do with my old mobile phone? I just put them in a drawer": Attitudes and perspectives towards the disposal of mobile phones in Liverpool, UK. Human Geographies, 9(12), 241-260

[26] Ongondo, F. O and I. D. Williams (2011). Green academia: Use and disposal of mobile phones among university studies. *Waste Management*, 31(7), 1617-1634.

[27] HatTrick PR_censuswide.

For the total pool of UNU categories (34 out of 54), an estimated 21.4 Kt were sold on second-hand markets in 2017, while 60.8 Kt donated or reused.

Types of W/EEE

The analysed data suggests that the top categories for second-hand sales in 2017 were:

- UNU202 Food preparation equipment – 3.599 Kt/yr
- UNU506 Household luminaries – 3.043 Kt/yr
- UNU408 FDP TV's – 3.174 Kt/yr

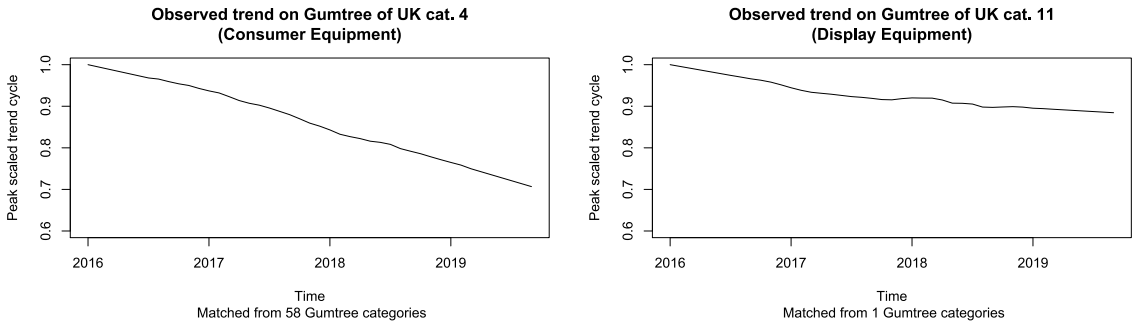

Figure 1 UK W/EEE Category 4 in decline and UK W/EEE Category 11 relatively stable.

A separate analysis into Flat Display Panel (FDP) TVs (UNU 408) being sold on of second-hand online platforms, which belong to UK Category 11 'Display Equipment', indicated that around 0.6 Kt per annum were sold in 2019[28] on eBay, and most of the used TVs being sold on eBay are older than 5-10 years, although this depends on the make (Figure 2). The full details of the eBay analysis are given in Appendix XVIII.

Recommendation

A broader and more longitudinal study at the listing level in needed, ideally covering multiple second-hand platforms and broader range of UNU categories for a longer period of time. The proposed text mining methodology in Appendix XVIII might allow one to identify potential unreported flows associated with 2nd-hand platforms.

[28] The weight is an estimation based upon 48% of the sample data for the 5 Television brands identified; 3 months' worth of data; 5 TV brands; and the assumption that all brands weighted the same.

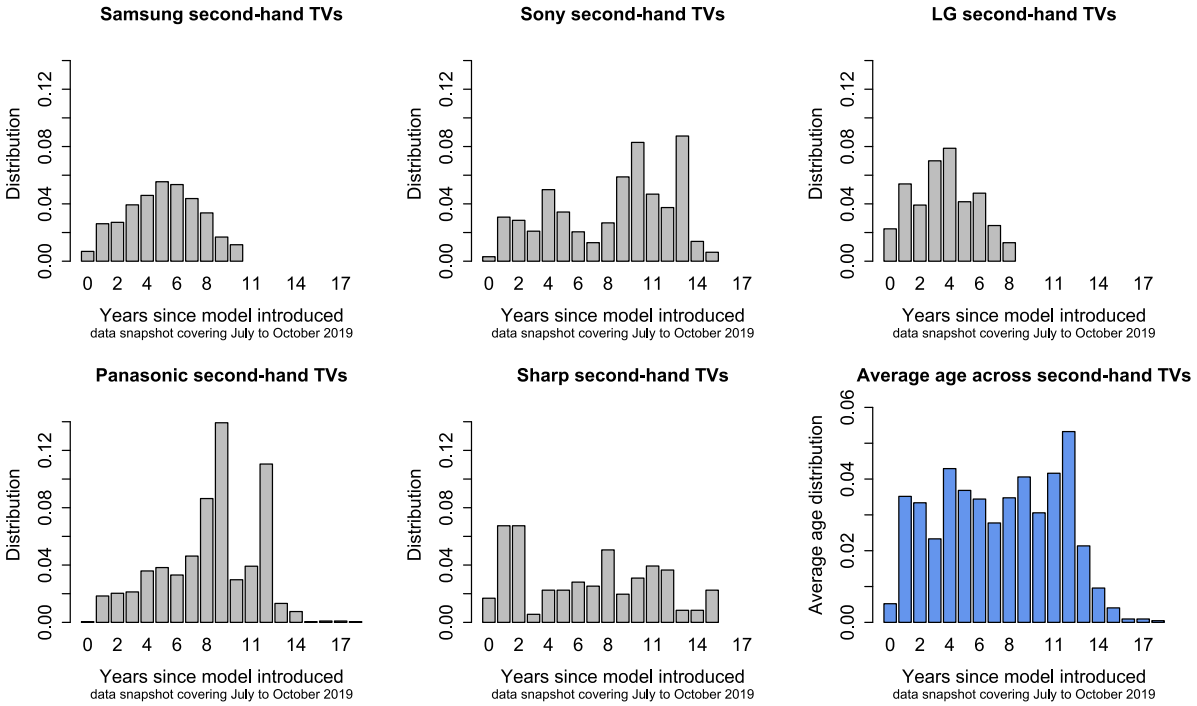

Figure 2 Age distribution of second-hand TVs listed on eBay.

Source and approach

This work from Phase 3 of the desk-based study (see Section 2.2.1 'Use and retention, redeployment and hoarding') focused on analysing the data from the classified advertisement website Gumtree to assess how EEE has evolved at a UK and UNU category level. In addition, an investigation was undertaken using Google Trends to get a sense of the popularity of second-hand platforms (e.g. Gumtree, eBay etc.). This Phase also included an analysis the product age distribution for five major brands of second-hand TV's investigating eBay listings. Finally, the total UK-wide second-hand sales, as well as the EEE flow through "donation and reuse", were estimated as part of the meta-analysis and WOT model extension (Phases 2 and 4).

Duplication

The data collection itself was carried out at the listing level which prevents double counting. However, there is the possibility that the seller listed the same item again after the advertisement elapsed (Gumtree and eBay after one month).

Confidence

Same scoring methodology was adopted for second-hand sales as in Section 2.2.1 'Use and retention, redeployment and hoarding', but using the following criteria for each individual data source (see confidence_score_reuse_domestic.xlsx for details):

eBay data

- Data collection methodology;
- Robustness of extracting TV model information;
- Precision of mapping TV model number with year;
- Sample weight estimation confidence;
- Scaling methodology.

Gumtree data

- Data collection methodology;
- Robustness of UNU and UK category mapping;
- Trend estimation.

Google Trends data
- Data quality;
- Robustness of Keyword selection.

The Gumtree data processing has confidence score of 4 out of 5. The main uncertainty part is the manual Gumtree category matching with UK WEEE and UNU categories. Some categories might also contain a mix of EEE and none EEE products. More details on the listing level would be required to make a more granular selection.

We score eBay data with a 3 out of 5. The dictionary and rule-based identification of TV models will not provide a 100% identification rate. Especially older models might not be detected due to changes in model naming convention. The main drawback is that eBay only dates back up to 3 months. For the weight estimation, this adds substantial uncertainty since we have no information about seasonal changes in numbers of listings which we would expect.

Similarly, we score Google Trends information with 3 out of 5. Depending on keywords selected the curve of second-hand interest changes substantially. Without any reference data, it is challenging to verify the correctness of the shown trend. Similarly, the interest in Gumtree and eBay would be more useful if there would be a verification with a different data source.

Links

See Section 2.2.1 ‘Use and retention, redeployment and hoarding’ for the list of supplementary datasets.

2.2.3 Household residence times

Flow description

Household residence time is defined as combined time from the moment of EEE sale until the product is discarded[29]. This includes the time the EEE product is used and, for some products, the subsequent time in storage (hoarding). The common explanations for the time duration are the same as in Section 2.2.1 ‘Use and retention, redeployment and hoarding’.

Estimated volume

The effect of long residence times on the amount of used EEE and WEEE generated proved difficult to isolate from the available data since the latter represents present-day behaviour, while changes in residence times and the associated EEE flows occur over longer time periods. However, we estimate that in 2017, 206.0 Kt were added to the stock of EEE currently in use by UK households, and 4.9 Kt were added to the hoarded household stock. Longer residence times for some products are likely to have contributed to these figures, although there are other drivers behind the growth in the stock numbers, namely households gaining multiple units of the same product and changes in product weights. The

[29] We used the oldest EEE products reported in the available household surveys as a proxy to determine the time duration.

overall growth in the number of UK households at a rate of just under 1% per year is another contributing factor.

Types of W/EEE

The results for times in use and times in storage indicated the following (see Appendix section XVIII for the full set of plots):

1. UK WEEE Category 1 'Large Household appliances' and Category 11 'Display Equipment', were more likely to be used for longer times than other products.
2. UK WEEE Category 3 'IT and Telecommunication equipment' and Category 4 'Consumer electronics' presented the shortest time in use and the longest time in stored.
3. UK WEEE Category 4 'Consumer equipment' and UK WEEE Category 9 'Monitoring and Control Instruments' were hoarded for the least amount of time.

Recommendation

Future EEE flow assessments using models should attempt to account for both the time in use and time in hoarding explicitly, whenever suitable EEE Flows data is available, rather than combine everything into a single residence time. This would improve the level of detail and confidence for the multiple EEE flows. At present, the lack of quantitative data on time in storage (infrequent use and hoarding) represents one of the biggest challenges for improving future assessments.

Source and approach

The source and approach are the same as in Section 2.2.1 'Use and retention, redeployment and hoarding'.

Duplication

No observations could be extracted regarding possible sources of double counting.

Confidence

The confidence level methodology is the same as in Section 2.2.1 'Use and retention, redeployment and hoarding'.

For the time in use data, the overall confidence is 3.5 out of 5 for the 24 mapped UNU categories where datasets were extracted and harmonized. The UNU categories Small Consumer Electronics, Video Equipment and Speakers had the least confidence scores, while Mobile phones, Laptops, Portable Audio and Video, Vacuum Cleaners and Cameras had the highest scores.

UK Categories 1 (Large Household Appliances), 2 (Small Household Appliances) and 4 (Consumer Equipment) have the lowest confidence scores for the times in use due to data availability, while UK Category 3 (IT and Telecommunications Equipment) has the highest confidence levels.

For the time in hoarding data, the overall confidence is 3.9 out of 5 for the 11 mapped UNU categories where datasets were extracted and harmonized. The UNU categories Small Household Equipment, Small Consumer Electronics, Fridges and Freezers had the least confidence scores, while Laptops and Mobile Phones had the highest confidence scores.

Links

See Section 2.2.1 'Use and retention, redeployment and hoarding' for the list of supplementary datasets.

2.2.4 Commercial Reuse

Flow description

Commercial reuse is defined as 'Business to Business (B2B) electronic and electrical equipment (EEE) that includes products used by large organisations, public sector and small to medium enterprises, providing coordination of collection and treatment following the initial business use is independent from municipal authorities'[30].

Discarded EEE is channelled through brokers such as Asset Recovery companies, waste recyclers or the products are donated by from businesses to a charity or social enterprise[31]. One study indicated that there were over 400 organisations operating within the reuse space and were typically SMEs[30]. The brokers offered different services depending on their client's needs, including:

- Collection services
- Data eradication (both on and off client sites) – for data bearing devices[32]
- Refurbishment for resale
- Repair for resale and/or training[33,34]
- Component resale
- Recycling and/or training[32,33,34]

Depending on the contractual obligations between the company and the broker would depend on whether the clients were financially remunerated minus a service fee[32], or the income for the resale of the products could be donated to a charitable cause[31]. Outlets for resale included auction sites, company-specific websites, charities and charity shops both in the UK and overseas.

Estimated volume and types of W/EEE

Quantitative data was limited on commercial EEE reuse. One study indicated that in 2009, around 300 Kt of B2B reused EEE was placed on the UK market and nearly half was ICT equipment[30]. In order to estimate the volume of EEE passing via commercial reuse we have assumed the same products will flow through the asset management sector, with 90 Kt of mainly B2B IT equipment.

Recommendation

It is necessary to conduct stakeholder interviews and run stakeholder workshops to better understand the concerns surrounding access to EEE information and broaden understandings of wider UK EEE categories. These need to include representation from a public sector, private sector and charitable organisations operating in different sector spaces e.g. retail, consultancy, manufacturing and recycling.

Source and approach

The insights on commercial reuse are derived from the 'Gap Analysis' Phase of the study. See Section 2.2.1 'Use and retention, redeployment and hoarding' for further details.

Duplication

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[30] Peagam, R. et al. (2014; 178). Business to business end of life IT industrial networks. *Waste and Resource Management*, 167 (WR4), 178-192.

[31] Stowell, A.F and Brigham, M. P (2018). Extractivism, Value and Waste: Organizational mining of e-waste in the United Kingdom. *Etnografia e Ricerca Qualitativa*, 2018 (1), 75-95.

[32] Dataset Organizing e-Waste. Lancaster University. 10.17635/Lancaster/researchdata/78.

[33] Bozkurt, O. and Stowell, A.F. (2016). Skills in the green economy: recycling promises in the UK e-waste management sector. *New Technology, Work and Employment*, 31(2), 146-`60.

[34] Training relates to skill development typically working with charities, examples include working with unemployed, young offenders etc.

Depending on how the reuse goods enter the second-hand markets could pose a potential source for double counting. For example, if marked as recycling but upon assessment the device comes back into reuse stream. However, no observations could be extracted regarding possible sources of double counting.

Confidence

The confidence level is 1 and low as the results are not representative of the sector due to the research sample size, and the age of the data (1985-2012). The lack of primary data availability was due to perceived commercial sensitivity common among the survey respondents, longer times that are often needed to secure non-disclosure agreements, and limited time available for this project. However, the sources identified are robust and draw upon both primary and secondary data.

Links

See Section 2.2.1 'Use and retention, redeployment and hoarding' for the list of supplementary datasets.

2.2.5 Buildings installed EEE and street furniture

Flow description

Products that have been installed into buildings are often specialist items, and often large by size and weight. These are questionable in the definition of EEE (i.e. if the product is EEE or the building itself) but less so since the introduction of open scope in 2019, that aims to cover end of life treatment of all electrical devices. Both products installed into buildings and as street furniture will most often be installed (and deinstalled) by buildings engineers, contractors and maintenance firms operating in a B2B setting. Product removed from buildings will be disposed of by these operators and discarded through their waste management channels for the site. These materials traditionally will be handled through light iron or C&I waste systems and will have a simple material separation.

Estimated volume

This report estimates that 69 Kt of products are flowing into these buildings and street furniture applications each year.

Types of W/EEE

Using expertise from within the business on the EEE sector, we have considered the higher level EEE categories as the indicator for products arising in this flow. Typical equipment into buildings will be electrical distribution, controls, meters, and systems installed or retrofitted into the commercial and industrial buildings, on the basis they are declared as B2B products.

In a similar approach, we consider street furniture to be most easily recognisable as street lighting (excluding the lamp itself) for the purposes of quantifying the amount of product supplied and disposed of each year.

Source and approach

The report takes a simplistic look at quantifying the number of products in the absence of any other identified data sources.

The data source is the EEE producer data reports for 2017 and includes all Category 5 and Category 9 B2B EEE. Examples of products reported into these categories are most closely associated with the buildings and street furniture settings.

Duplication

On the basis the product sales are replacing discarded equivalent items in most cases, and the professional install / deinstall requirements for these specialist items, the waste products will most likely arise in the C&I waste streams through contractors' waste management firms. The products are deposited by the contractors from the waste holder so any duplication will be from waste management operator onwards. Possible pre-treatment of the C&I waste may cause products to be added to the light iron stream and therefore both exempt ATF/T11 and AATF sites.

Confidence

This approach is simple and absence of waste related data, therefore a low level of confidence in the material that may become waste on annual basis. The product identified may be representative of those in this flow, however the approach relies on growth in use which would suggest a lower estimated tonnage discarded annually, with an accrual of EEE in use.

2.3 Flow category 3; Data anomalies

The third and final series of sub-divided flow categories draw together activities where the current measurement systems data reports are distorting the reality of product flows and business activities. These will be both intentional and unintentional, or simply a result of the design of products placed on the market from one year to the next, as technology rapidly changes and uptake varies.

Data sources, wherever possible, reach out to secondary research findings from recognised report authors and industry experts, cited research and other reputable authors all whom are referenced in this report. Further engagement activities have been made through research partners in-house experiences and data records.

2.3.1 Free riders

Flow description

Free riders are businesses who are non-compliant with the WEEE Regulations. These businesses are typically unaware of, or avoiding, compliance through the EPR system; as a result they are non-compliant, they do not report EEE POM, take a share of the end of life costs of the products they sell into the UK, or possibly elsewhere. Prominent coverage on free riders is directed to global e-commerce businesses, either those with marketplaces or those operating from outside the UK, whereby there is no UK presence for the person or business making the product available to end users in the UK.

There is no distinction about the end users in this report as households or businesses, and we believe that both are susceptible to sourcing product from non-compliant retailers. In defining a producer, we have considered the products being placed on the UK market by free riders as businesses who are selling direct to end users, and not wholesale operations.

Estimated volume

Estimates of product placed on the market each year are between 5 and 10% of all EEE. This is equivalent to 77-155 Kt. The figure we have used is based on an updated approach to the original study by WRAP[35] (2016); and Valpak[36] (2018) estimates giving 3% of the EEE placed on the UK market, but our estimate is updated to reflect the latest product profile. Our report uses 2018 POM data and estimates 46 Kt of EEE are placed on the market by free riders each year. As the move to open scope that will capture more products with an electrical function, this figure is likely to increase, however data for the end of 2019 (at time of writing) has not been published, but we estimate this could add 10%, presenting a grand total of approx. 50 Kt of EEE per year unreported. See Appendix XX: Free riders calculation for source data.

Types of W/EEE

Our findings and conclusions suggest the product types are most often higher value items that are more readily transported based on size and weight. We believe that small household appliances, IT & telecoms equipment, consumer equipment, toys and tools will be the greatest contributors by volume, but all small

[35] UK EEE Flows Report, WRAP 2016 https://www.valpak.co.uk/docs/default-source/environmental-consulting/eee530-uk-weee-flows-final_publish.pdf

[36] UK EEEFlow 2018 , Valpak 2018

domestic appliance are susceptible. Feedback from recent work assessing an online sales channel suggests that large domestic appliances can feature in free riding[37] despite the size and weight challenges for logistics, but that there is less evidence for display and cooling equipment feature in any material volumes.

Source and approach

In the research for this flow we have consulted industry experts and carried out a secondary research review of existing methodologies and assessments into the issue of free riders to the WEEE Directive. From a variety of sources including OECD, WRAP and WEEE Scheme Forum, similar results and trends are identified on the scale of the issue, allowing us to benchmark the totals we have determined in this WEEE Flows study. From these sources we have selected the most relevant research piece from WRAP and Valpak, and re-applied the approach to a more recent data set on EEE. The research has been validated against several other key research pieces from the UK and Europe.

Duplication

The flow of product from free riders is new EEE that is not reported in the UK national data. As a result, we cannot see if a displacement effect generates WEEE on a 1 for 1 basis when new EEE is sold and may distort results suggesting more WEEE being generated as a ratio against the reported (registered producers) EEE. There is likely little duplication of the EEE in other flows until it is discarded by the end user.

Confidence

The best available information has been used to estimate the tonnage from free riders, where increased visibility of the approach used, and where new data is available to replicate but update. To validate this approach, we have looked at the overall percentage of WEEE that this study represents and benchmarked it against other recent studies from OECD and WEEE Scheme Forum. These are comparable and with access to an updated dataset we have revised the estimate to reflect 2018 sources.

Links

http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=ENV/WKP(2019)1&docLanguage=En

2.3.2 Product weight trends

Flow description

This calculation into product weight trends observes the shift in technology relating to the average weight of particular products. Advancements in product design and features, combined with high consumer consumption rates, brings new technology onto the market at a rapid rate. As these products change, the ratio between EEE and WEEE diverges, as we see in display EEE (average product weight of EEE decreasing from WEEE) and cooling appliances (average product weight EEE increasing from WEEE). We have consulted with producers, compliance schemes and surveyed industry on this subject to present an

[37] Online sales of non-compliant product, EucoLight 2019

https://www.oecd.org/environment/waste/policy-highlights-extended-producer-responsibility-and-the-impact-of-online-sales.pdf

estimate on the total weight shift on an annualised basis. The impact of these changes is seen initially by the producers in the annual datasets and market share (by weight), the retailers supplying the latest technology, and users of new purchases in swap out or addition to the older item.

Estimated volume

The report estimates a small growth in tonnage annually based on market trends in; EEE POM reported, product design and average product weights equivalent to 3 Kt annualised, despite reductions in weights for IT & Telecoms and Consumer Equipment.

Types of W/EEE

For the purpose of this report we have only considered EEE categories; Large Household Appliances, Small Household Appliances, IT and Telecoms Equipment, Consumer Equipment, Toys Leisure and Sports, Display Equipment, and Cooling Appliances. These have been selected as the remaining categorises without outliers in annual POM changes. The categories which featured in industry feedback and surveys were LDA, IT, Consumer equipment, display and cooling.

Source and approach

The most recent sources, and therefore we believe the most representative in the electronics sector, has come from survey feedback, interview responses, and compliance scheme profiles of data reports. Taking this anecdotal feedback from a small number of larger producers, we have used industry feedback to moderate the POM derived estimates, that are based on trends from the last 4 years. Previous flow studies from WRAP (2011, 2016 and 2018) have indicated some similar trends in technology weights and size, especially IT, consumer equipment and display but not quantified this sufficiently to measure annualise flow.

Duplication

There is a low likelihood of this weight being duplicated in the other subsequent flows reported in this study. Increased weight of products will however be captured in reported EEE POM.

Confidence

We have a medium level of confidence in these estimates, because the refences to changes are based on latest producer feedback, thereby reflecting the rapidly evolving electrical technologies, whilst supported by whole market producer EEE data reporting to quantify these changes. Although the sample size is small for industry feedback, these are large producers, and it is acknowledged more widely across electronics industry (producers, schemes and WEEE recyclers) these products are experiencing change in design and resulting in a movement in weight per product. Further improvements can be made if more weight and quantity data were presented as part of EEE reporting or producer information, to distinguish and further strengthen the evidence of sales decreases versus average weight decreases.

2.3.3 Misreporting

2.3.3.1 Misreporting – Producers Misreporting Data Returns

Flow description

Producers are required to file initial details with their compliance scheme of the products they placed on the market in the previous year, or file these directly with their regulator. Thereafter, the data submissions are subject to review by the producer itself, its compliance scheme via its internal audit and technical teams, and by the regulator.

Errors and omissions will be identified during these review processes, however some may not. This section of the work aimed to identify the scope and extent of misreporting.

Estimated volume

Errors in reporting can be overestimates as well as underestimates, so our calculation reflects this variance. It is estimated that there are ±2.005 Kt of loss of EEE by unresolved misreporting. This is made up of ±1.937 Kt from producer compliance scheme members and ±0.068 Kt from directly registered producers.

Types of W/EEE

All categories (excluding Lighting and Automatic Dispensers).

Source and approach

This work was based on primary data made available to this project by Valpak in house records, regarding misreporting over the past five years. Based on this, a series of assumptions were made to estimate to amount of misreporting that is not identified/rectified.

Duplication

There is a very low likelihood of duplication of this mis reporting in other EEE or WEEE flows.

Confidence

The findings were reviewed by Valpak's AATF/ATF auditors and other project key industry stakeholders, who believe the estimate seems sensible. However, without other robust estimates this could not be verified further.

Links

See Appendix VIII.

2.3.3.2 Misreporting – AATFs Misreporting

Flow description

The reporting of WEEE received for treatment by AATFs is the source of the collection data that underpins the WEEE system. Compliance schemes rely on regular reports and any validating data received from DCFs to report in turn to their contracted collection counterparties (WDAs, DCF operators, etc.), as well as to the regulators.

Errors and omissions may occur in these AATF reports. They are identified by the receiving PCS by sense-checking and verification against any validating data from other sources, such as the records of DCF operators and hazardous waste consignment returns.

This section of the report aimed to identify the extent to which AATF misreporting can impact the overall recycling figures reported in the UK.

Estimated volume

Errors in reporting can be over estimates as well as under estimates, so our calculation reflects this variance. It is estimated that there are < ±1.063 Kt (0.2% of WEEE received) that will be erroneously reported by AATFs and not subsequently identified by their contracted compliance schemes.

Types of W/EEE

All categories (excluding Automatic Dispensers).

Source and approach

This work was based on primary data made available to the project by Valpak regarding three large AATFs misreporting over a twelve-month period. Then based on this a series of assumptions were made to estimate to amount of misreporting that is not identified/rectified.

Duplication

NA

Confidence

The findings were reviewed by Valpak's AATF/ATF auditors and other project key industry stakeholders, who believe the estimate seems sensible. However, without other robust estimates this could not be verified further.

Links

See Appendix IX.

2.3.4 WEEE reported in the UK and sold in Ireland

Flow description

Products imported to the UK as the first stage of this supply may attract a producer responsibility to report the EEE imported into the UK, however, these products may be subsequently exported to Republic of Ireland, thus the product never will end its lifespan in UK. The interpretation of 'placed on market' made by the UK producer, therefore would report this product in their quarterly EEE returns. These imports and subsequent sales to Republic of Ireland (an export) can be a wholesale or retailer level supply chain businesses, and likely to be a greater impact to household products.

Guidance issued by the Environment Agency in 2015 allows for producers who can demonstrate the export within the compliance year, to nett off the sales to non-UK customers. However, industry feedback suggests these guidelines only practically works for Q1-Q3 EEE reported, and the sales in Q4 and for the Q4 EEE data reports, it is often not possible to nett off in-year. Stakeholder feedback from producer compliance schemes has suggested this can be a significant impact on some businesses annual reporting. The inclusion of these sales in UK reported EEE data can be prevalent where peak season sales falls in Q4 and the supply of goods.

Estimated volume

An estimate of the total weight of electrical products shipped to Ireland that have not been netted off is 5 Kt.

Types of W/EEE

All products are likely to fall into this flow.

Source and approach

To estimate the amount of product exported to Ireland that producers are unable to nett off (deduct from EEE reporting), we have started with several market research reports that quantify the trade between UK and Ireland. These suggest around 3% of exports to Ireland are electronics and equivalent to almost £1.5B. In calculating the tonnage of products that cannot be netted off, we have drawn a 4-digit classification customs code report from HMRC data reports for each of the calendar years 2017, 2018 and part of 2019. These are for items that could be EEE (it is not possible to directly map HS customs code to the same degree of granularity as the EEE categories). These totals are very close to the market research reports so we consider the scope of Harmonized Commodity Description and Coding System (HS codes) as sufficient for this flow research. We have analysed the value and mass reported as exported in December and considered this to most likely be reported in UK EEE data even though it has been exported (i.e. not netted off EEE POM data). This is equivalent to 0.3% of EEE placed on UK market.

Duplication

This tonnage is duplicated in legal exports and UK EEE placed on market.

Confidence

There is a medium level of confidence in this data report and we recognise it is a high estimate of the EEE exported but not netted off by producers within year. This assumes the interpretation of the guidance on netting off is adopted by all producers, and that all producers report EEE placed on market based on a common ‘placed on market’ definition (i.e. when product arrives in UK and not just sales data where a lag in time between imported and sold to a non-UK customer).

3.0 WEEE Flows consolidated analysis and key findings

3.1 Flows Analysis

To consolidate our results, we have mapped out the most prominent movements and connections in the UK WEEE system. This follows product and material from importers and producers introducing EEE to the UK market, through to the product and material changing state through a recycling or destruction process or by leaving the UK. This exercise gives a clearer picture of how WEEE is most likely to find its way into these flows, so that those of greatest importance and volume can be identified and better understood.

Our findings in the report have been presented under three broad categories of flow:

1. WEEE being recycled, destroyed or exported.
2. EEE in use or being retained.
3. Reporting variances or anomalies.

This characterisation has been useful in understanding how much EEE or WEEE is handled where, and by whom, and the materiality of the volumes involved. However, as we move to tracing the movement of used EEE and WEEE through the wider system, the interdependencies between different collectors, processors and disposers becomes more important. A key challenge in measuring EEE and WEEE flows is avoiding double counting. As a result, for our analysis we moved from characterizing flows in three groups based on product form, to five (not necessarily sequential) stages of handling:

1 Influences on products entering the UK system.

2 Influences on availability for collection.

3 Collections for processing where EEE or WEEE is temporarily made unavailable but could potentially (but not always) be made available again.

4 Collections for processing where EEE or WEEE is no longer available, as it is processed in a way that is authorised.

5 Collections for processing where EEE or WEEE is no longer available, as it is processed in a way that is unauthorised.

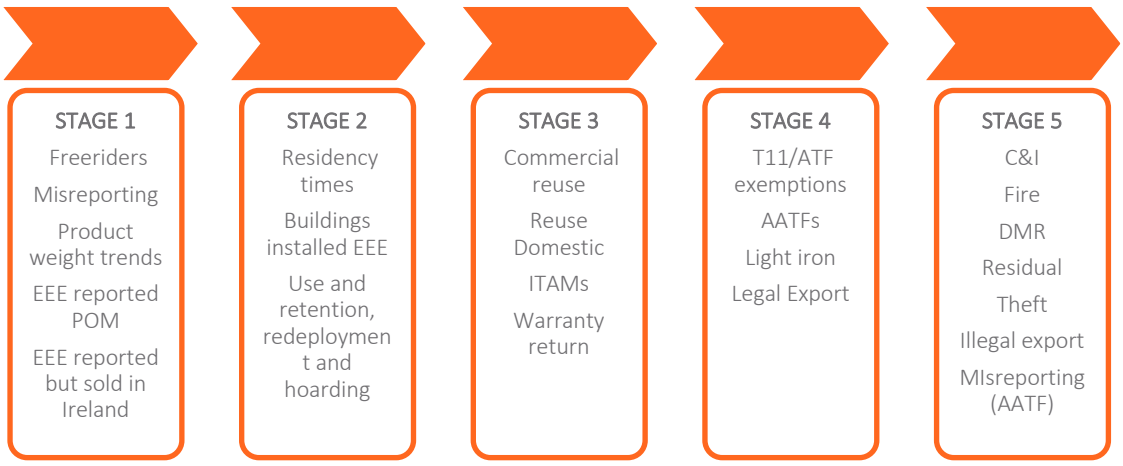
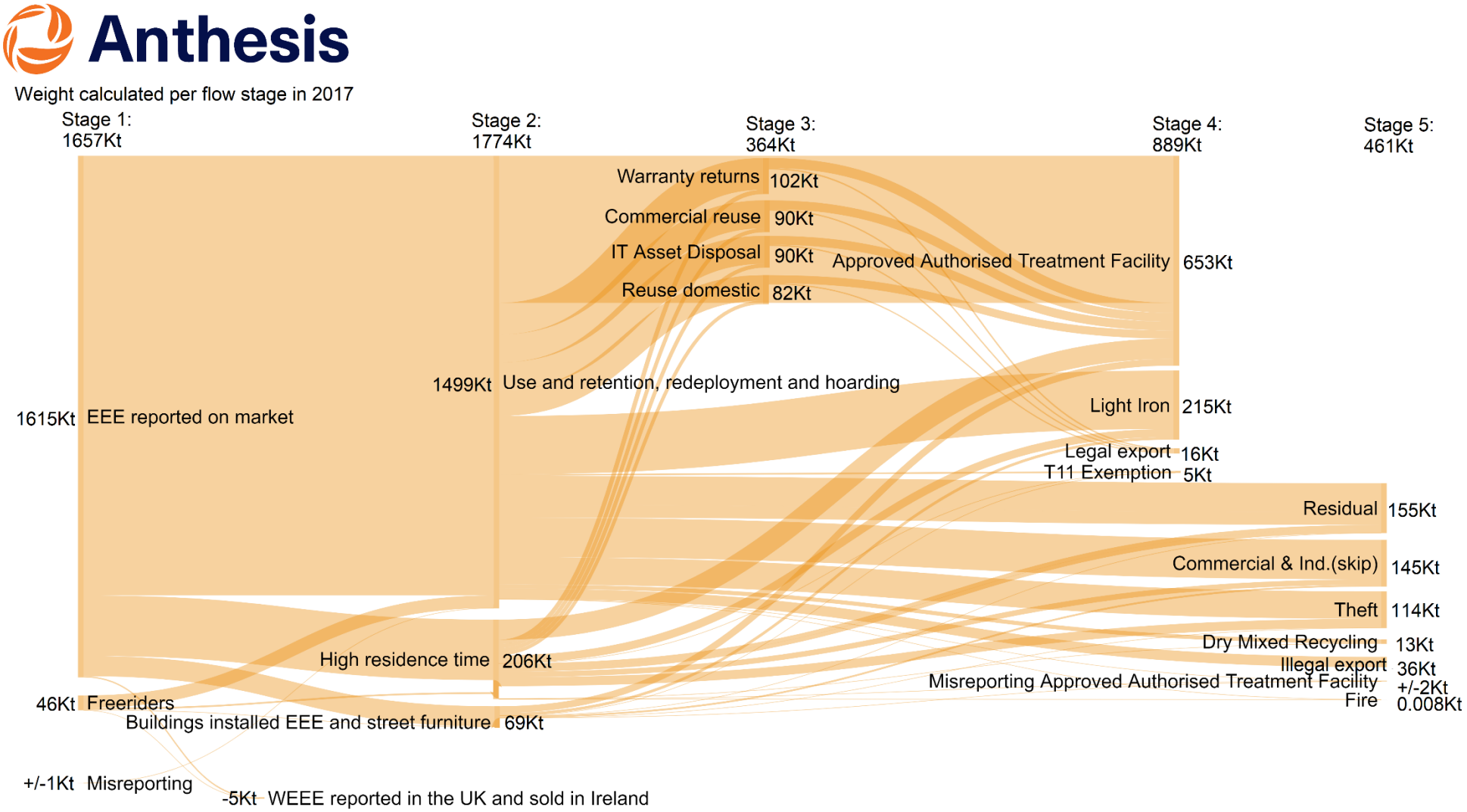


Figure 4; Anthesis 5 stages of WEEE illustration.

The following Sankey Diagram shows our consolidated view of how much and how EEE flows through the UK, the following graphics show the weight and product types involved in each flow. (note: Theft is most likely to occur at the pre-DCF and DCF stages).



For each EEE flow assessed in this study, the research has quantified the total then tracked what tonnage passed on as annualised total, or, the tonnage that remained and accumulated in that flow. The follow table summarises these totals;

Stage 1		Stage 2			Stage 3			Stage 4			Stage 5		
Input	**Kt**	**Flow**	**Fate**	**Kt**	**Flow**	**Fate**	**Kt**	**Flow**	**Fate**	**Kt**	**Flow**	**Fate**	**Kt**
EEE reported POM (incl. +3Kt weight trend)	1615	**Use and retention, redeployment and hoarding**	Of POM remains in-use/ redeployment (88%), hoarding (12%)	277	**Commercial reuse**	remains in commercial use	59	**T11/ATFs**			**C&I (skip)**	ends in C&I (skip)	145
Freeriders – not in UK POM	46		moves on to reuse recycling or disposal	1222		moves on to recycling, disposal or legal export	31		ends in T11/ATF	5	**Fire**	ends in Fire	0
WEEE reported in the UK and sold in Ireland	-5	**Buildings**	remains in the building	34	**Reuse domestic**	remains in domestic use	53	**AATFs**			**DMR**	ends in DMR	13
Misreporting	1		moves on to reuse recycling or disposal	35		moves on to recycling, disposal or legal export	29		ends in AATF	653	**Residual**	ends in Residual	155
		High Residency	Remains in the home	38	**ITAMs**	remains in ITAM	59	**Light Iron**			**Theft**	ends in Theft	114
			moves on to reuse recycling or disposal	168		moves on to recycling, disposal or legal export	31		Ends in Light iron	215	**Misreporting AATF**	ends in Misreporting AATF	2
					Warranty returns	remains in returns	66	**Legal export**	ends in Legal export	16	**Use and retention, redeployment and hoarding**	ends in illegal export	32
						moves on to recycling, disposal or legal export	36						
			Totals remain in stage	349		Totals remain in stage	237		Totals remain in stage	889		Totals remain in stage	461
Totals passed on	1657		Totals passed on	1425		Totals passed on	127		Totals passed on	-		Totals passed on	-

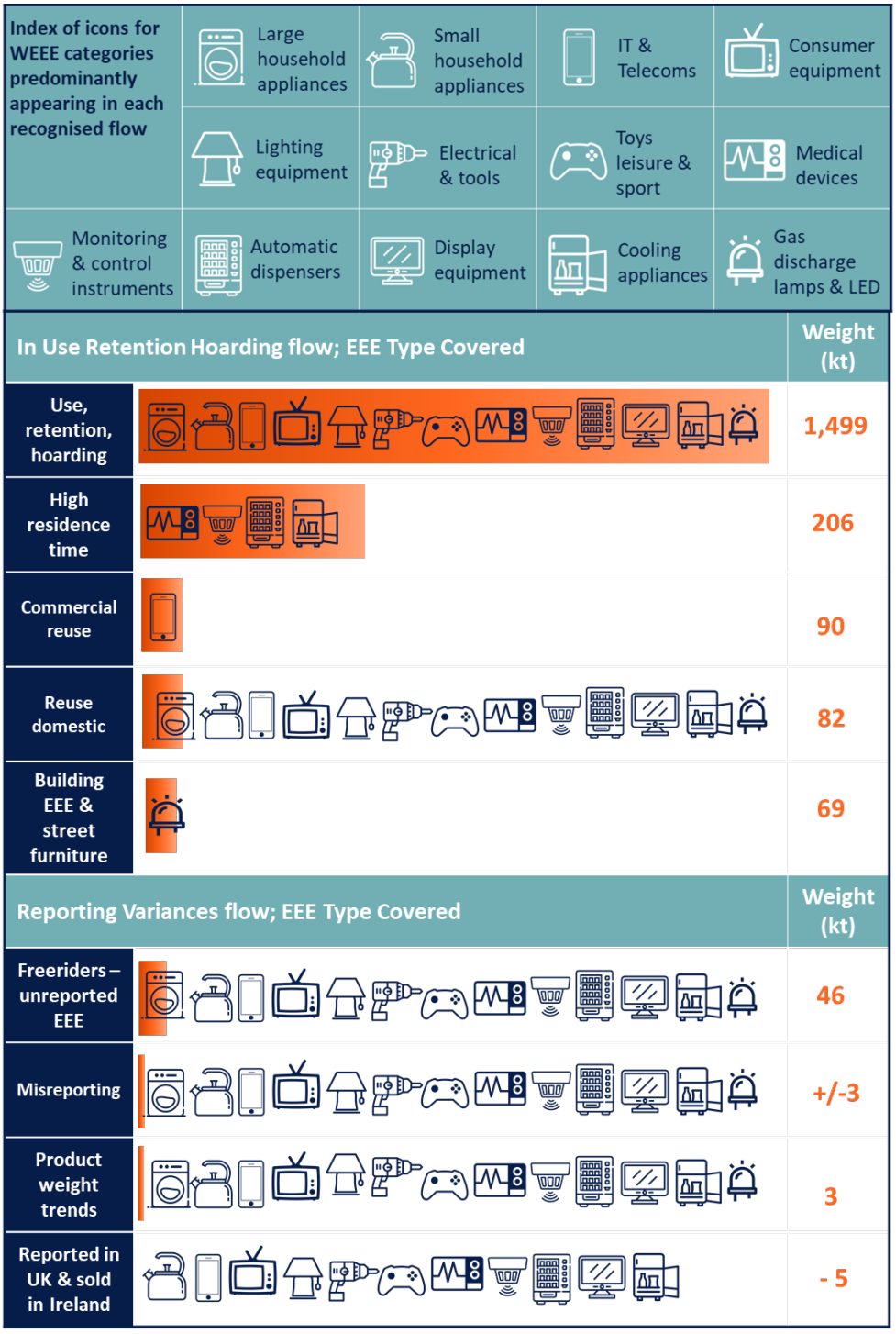
Key findings and data – Weight of EEE and WEEE in each flow by product type

The key findings graphic summarises each of the flows assessed in this study and the estimated annual tonnage that passes through each flow. These are grouped according to the source or location of the product, and the form it may be found:-

Use, retention and hoarding – still with a holder and not yet discarded.

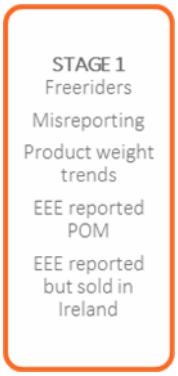
Reporting variances – existing data sources that may not be a true representation of that source.

Recycled, destroyed and exported – products that have been discarded by the user.



Recycled Destroyed and Exported flows; EEE Type Covered	Weight (kt)
Approved Authorised Treatment Facility	653
Light iron	215
Residual	155
Commercial & Industrial (skip)	145
Theft	114
Warranty returns	102
IT Asset Managed	90
Illegal export	32
Legal export	16
Dry Mixed Recycling	13
T11/ATFs Permitted sites	5
Fire	0.008

3.1.1 STAGE 1



Stage 1 covers the ways that products are produced, imported and supplied into the UK. The base data for this is the EEE reported as POM for WEEE Directive reporting. This has been relatively stable, at 1.5-1.7Mt pa, for the last five years. 2017 is used as the base year in this analysis as there is the most available comparable data.

Some EEE is put on the market in the UK without being included in this data, particularly that sold by free riders i.e. producers who choose not to register, report and pay fees for end of life treatment of WEEE. Our research and analysis suggests that free riders add about 46 Kt EEE to the UK market each year, this is lower than previous estimates as fewer Photovoltaic panels are being installed since the change in the Government incentive scheme.

The tonnage we have calculated as placed on market by free riders is 46 Kt. The impact and comparison to earlier studies reduces the overall tonnage placed on market through freeriding by nearly half previous study from WEEE Flows 2018 (Valpak, 2018) was 71 Kt.

In our modelling based on 2017 baseline data of the EEE placed on market, we have recalculated the tonnage of EEE placed on market by free riders using the same approach but new data. PV holds a unique calculation based on Feed-in Tariff reports. As a result of the recent decline in PV connected to the grid, with a reduction over 60%, this reduced the tonnage likely to be placed on the market by freeriding PV producers.

The overall reduction in total weight volume placed on the market by free riders (from 4% to 3% unregistered) hides the PV specific reduction. In future research, we suggest considering the new open-scoping definitions of WEEE within published data analysis that was not available at time of writing this report. Interim reporting in 2019 suggests that there is little change in B2C EEE reported with the exception of Category 5 lighting. This 'new' EEE tonnage is in line with estimates previously made by Lumicom as part of the Valpak 2018 WEEE Flows report. B2B EEE reporting is yet to be tested because of the timing data is published for end of 2019 reporting.

Product weight trends also impact the weight of EEE entering the UK system from one year to the next. Variances in like for like product weight over time, hide the changes in the number of units supplied. By simply comparing EEE vs WEEE, distortion is caused; increasing non-replacement activities by consumers (multiples in the home or appliance purchases with new build homes), and product average weight changes.

A summary of average product weight changes by product category is as follows:

Category	Annual increase	Annual decrease	Negligible change	Variable change
Large Household Appliances				✔
IT and Telcomms Equipment		✔		
Consumer Equipment		✔		
Display Equipment	✔			
Cooling Appliances Containing Refrigerants			✔	

Table 3; Summary of reported change in weight in categories over the past 4 years.

The results from our producer survey demonstrates a considerable variation in product weight over the last 2- 5 years. Factors for change include:

- Premium vs budget brands; more products sold at lower prices.
- Physical size versus total unit weight; feedback suggests some products like Cooling and Consumer Equipment are changing in size but the weight per unit may not follow the same trend.
- Light weighting; including the move in technology to flat panel LED display equipment, as well as lighter smaller consumer equipment.
- Market demand change; producer feedback as well as previous research including an EC study on Study on collection rates of WEEE[38] shows a move in consumer opting for Laptops over heavier desktop PCs, but contra to this they have more devices per household.

Our survey yielded inputs from a wide range of brands. We combined the results with market research to estimate that a 3 Kt increase included in the reported put on market figure, primarily from LDA getting heavier and IT getting lighter.

The impact of producer misreporting is thought to be minor. Extrapolation of resubmission data from producers, sourced from compliance scheme partners, suggest the impact is +/- 1 Kt annually.

The final factor that could be distorting the actual weight volume of EEE placed on market, is EEE that has been reported as sold but is then subsequently exported. HMRC data suggests that 5 Kt of EEE is reported as sold, but not deducted from EPR reporting.

The combined impact of Stage 1 influences is that 42 Kt more EEE is put into the UK market than the EEE reported might suggest.

[38] Study on collection rates of WEEEE (UNU, 2014)

3.1.2 STAGE 2

STAGE 2
Residency times
Buildings installed EEE
Use and retention, redeployment and hoarding

The second stage of flow covers situations where EEE has been supplied to the first user and remains there, either being used or retained. Our analysis uses a top down and bottom up approach for stage 2 resulting is a small variance in the outputs.

There is a large aggregation of 'high residence time' equipment. We calculated that items with high residence times, growth in EEE in the home and number of households are effectively adding 206 Kt each year as part of the 1499 Kt calculated through a bottom up calculation of UNU code analysis, compared to 1657 Kt calculated through the aggregated top down results from EEE reported, misreporting, product trends and free riders. Our results indicate a time lag between 10 to 15 years after sale, before some products arise as WEEE. In future by analysing residence time by more UNU product types, rather than using broader product groups, a more accurate estimate could be calculated.

Figure 5; Time in use .

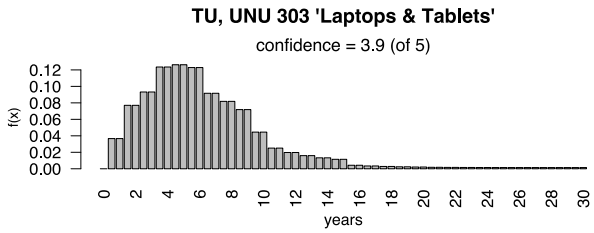
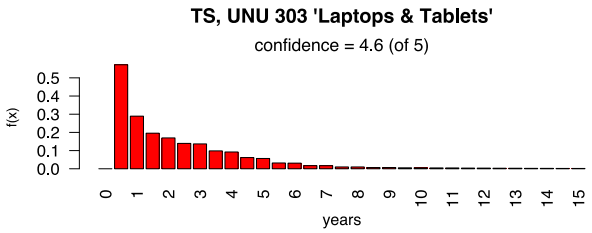


Figure 6; Time in storage (hoarding).



There are also particular items that remain in situ and in-use, as buildings installed EEE. Typical examples of these products used to estimate the total weight in this category, are drawn from sales data for B2B Lighting and Monitoring & Control equipment. Recent data suggests that 69 Kt of EEE were placed on the market in 2018. Although difficult to track to specific products, the EEE categories selected are sufficiently specific to capture those products measured in this flow calculation.

The biggest volume of product and material in this stage are used EEE products being hoarded by end users. The accumulation behaviour here prevents the product from being collected for reuse or recycling. We considered the results from surveys by Ipsos Mori[39], WRAP[40] and REPIC[41] about why these items remain in the home (or business) for longer than might be expected. Value, security, age, awareness of disposal pathways, reuse or replacement all feature as influencing factors on how long these products are hoarded for. Our project team has assessed considerable list of literature, market information and our own mathematical modelling and calculated using a bottom up approach to an annualised growth of EEE

[39] Ipsos Mori consumer behaviour study on disposal of WEEE (unpublished)

[40] Switched on to value, Powering business change (WRAP, 2014)

[41] REPIC annual survey results (unpublished)

is based on 1499 Kt entering the use and retention, redeployment and hoarding flow each year with annualised in hoarding of this 175.4 Kt, as detailed in section 2.2.1. these bottom up results compare to an equivalent 1657 Kt entering the use stage from total calculated on market.

The early stage flows on the UK WEEE system contain the most product. As a result, the visibility of the use phase is very important in understanding the likely outputs, as well as developing information and infrastructure to better support helping end of life products to reach the desired recycling systems. While we now have a better understanding of actual EEE sales, the research shows that because of use and retention behaviour, WEEE does not come off the market on a like for like basis. EEE types that are embedded into street furniture or buildings, long life equipment like vending machines and consumer hoarding behaviour, have a combined effect of discounting 21% from the used EEE being moving on from use, storage and hoarding, for collection. We estimate the combined weight of used EEE available for collection to be 1393 - 1425 Kt for 2017.

3.1.3 STAGE 3

The third stage of the WEEE flows includes a number of market led efforts, generally driven by the opportunity to create value through further use of a product. This type of activity is preferable to recycling and disposal, as products are used for longer. Key actors at this stage include the IT asset management sector (ITAM), mobile phone buy-back schemes, online auction sites and classified listings.

Commercial reuse covers businesses reselling second-hand goods to other businesses. One study indicated that there were over 400 organisations operating within the reuse space in the UK, which were typically SMEs. To calculate weight handled at this stage, we carried out a literature review and engaged resellers for feedback on the market. While market data is limited for commercial reuse, it is clear that there are a lot of businesses active in this space (though some are very small). The best available estimate for this segment of the market is 90 Kt, as taken from the asset management sector calculation.

Domestic reuse in general involves the public donating and reselling items to other members of the public, covering most general household type products. Based on analysis of the metadata from eBay and Gumtree, we estimate that 82 Kt pass through domestic reuse channels each year.

The IT asset management sector (ITAM and ITAD) is another prominent flow at this Stage. This activity involves the refurbishment and redistribution of (primarily) IT & telecoms equipment. Led by a small number of large global operators like RDC-Computacenter, TES and SIMS, these organisations recover and maximise value from business assets by repairing or refurbishing products, then reselling to new markets, both in the UK and internationally.

These businesses operate to high treatment standards and we estimate that this segment handles 90 Kt each year, though there is some duplication in this data as some items might be resold to a broker and unsaleable and broken items will be diverted to an AATF.

The final recognized flow within the market led reuse stage of the flow analysis is warranty and returns. Engagement with producers and retailers suggest that returns are increasing. There is scope for duplication from this flow, as items can be resold via asset managers or brokers, online auction sites or recycled via AATFs. Our analysis suggests that 102 Kt of items are returned under warranty each year.

The flows in this stage can be very positive from a sustainability standpoint, but particular interest should be taken into how significant the export market is in driving the activity sector, as the outcomes are less easy to guarantee.

Commercial and domestic reuse, the activities of ITAMs and other asset managers, warranty and returns and legal exports of used EEE, have a combined effect of discounting 14% of EEE on the market from used EEE available for recycling. We estimate the weight of products collected for potential reuse, to be 237 Kt for 2017.

3.1.4 STAGE 4

The stage 4 group of activities predominantly cover recycling. These operators collect electrical products through various channels and in different conditions, to process and extract value. After processing, the product no longer holds its original form and is considered out of the scope of our analysis.

The sites operating under exemptions T11 (Para 47 Scotland) and ATF permits, allow processing activities to be carried out without consistent formal reporting. The feedback from industry representatives including producers, recyclers and producer compliance schemes, from the outset suggested that this was an area of concern. Through access to Environment Agency and auditing data, we estimate the following weight of product being handled at these sites in the UK:

Category	Kt
Small Domestic Appliances	0.853 Kt
IT and Telcoms Equipment	3.535 Kt
Display Equipment	0.812 Kt
Total of categories assessed	**5.200 Kt**

Table 4; Estimated weight products by WEEE category being handled at sites and not formally reported.

The primary source of data on WEEE recycling in the UK is AATF reporting to the Environment Agency on B2C (household), B2B (professional) and non-obligated WEEE. The 2017 data published shows that 653 Kt were processed at AATFs, from multiple sources but Local Authority collected WEEE makes up the bulk of the product. There could be double counts in this data, with ATF sites and the light iron feeding into AATFs (it is not clear how product this is).

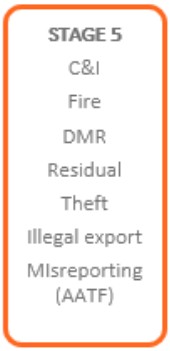
The light iron flow was calculated in the WEEE Flows study published by WRAP in 2016, with a refresh by Valpak in 2018. Since then, new market data has become available to recalculate the weight and we estimate that 215 Kt of LDA were processed in the light iron waste stream. Some stakeholders suggested the working assumption that 11% of the LDA was light iron was too high, but equally we received feedback that non-LDA WEEE was processed via this route too which to some extent could counterbalance this (there is an unpublished study which it is claimed supports Small WEEE in Light Iron stream adding a further 1.2% WEEE in LDA that is not included in the 215 Kt estimate). The materiality of the WEEE composition in the light iron could be revisited over time, though it was widely agreed that LDA is still collected in this manner.

AATFs reportedly recycled 653 Kt WEEE, however there are the other legal recycling routes above that are not included in this figure and some AATF handled product is diverted. The total calculation of unrecorded treatment under an exemption, adds a further 220 Kt for 2017 and taking UK to an estimated 61% of WEEE available or 52% of EEE put on market for 2017.

Products leaving the UK cannot justifiably be returned for recycling, unless returned by the competent authorities of another country as seen recently from Malaysia, but this is rare. To consider legal exports, we looked at customs codes for specific product types (with a focus on LDA, Small appliances, IT, and cooling) and a standard reuse rate of 7% (Zero Waste Scotland Scottish re-use mapping and sector analysis, Resource Futures). We estimate that 16 Kt of functional used EEE as exported and we assume that this was not captured in other producer EEE reporting.

The WEEE recycling treatment standards in Stage 4 vary, but are all legal and represent legitimate routes to recycling. Stage 5 profiles routes that do not fall into this category.

3.1.5 STAGE 5



This stage covers processing activities that mean that WEEE is lost from systems for recycling and reuse, through being channelled to undesirable outcomes.

An impact assessment for the Welsh Government by Eunomia[42] suggests that the WEEE is a minority constituent of Commercial and Industrial waste but given the high volume of such waste produced in the UK, we estimate that 145 Kt of WEEE is lost via this channel. Measures are being considered in Wales for the mandatory separation of WEEE from C&I, which will act as a case study for how much could be diverted. A wider sampling base across England, with support from more waste collectors, would be a logical step in validating this opportunity, but we found this sector difficult to engage.

Fires at waste sites attract considerable attention, so are often cited as a cause of product loss. However, our research showed that the weights in question were minor (8 tonnes per year). Stakeholder engagement suggested that there were more fires, up to 500 each year, but many were too small to count towards official figures. Most fires caused by batteries were said to be in non-WEEE waste streams like Dry Mixed Recyclables (DMR), rather than processors who expect to find batteries in WEEE.

There is some unintended collection of WEEE with DMR from the kerbside, likely driven by householder misunderstanding. Through engaging with MRF operators and Local Authority waste contractors, we estimate that 13 Kt of WEEE arises at MRFs. Opinion was split on how much of this was diverted to an AATF, as opposed to a metal's processor. All of the MRFs we spoke to worked with an AATF though.

WEEE disposed of by consumers in the household residual waste stream is lost to landfill or incineration. The products susceptible to this are small enough to fit in a household bid. Our research gathered data from across 135 local authorities with over 15,000 bin samples, with a further 10,000 bin samples used to indicate possible trend for 2018. Our dataset is one of the most significant collective studies of WEEE in the residual waste, suggesting an average of 0.93% UK residual waste is WEEE. The modelling indicates

[42] Regulatory Impact of Statutory Instruments (Part 4 Environment (Wales) Act 2016 Articles 9-11 Waste (Wales) Measures 2010) Eunomia, 2019

155 Kt of WEEE was lost in the household residual waste stream in 2017, and this may increase in 2018 to 1.02%.

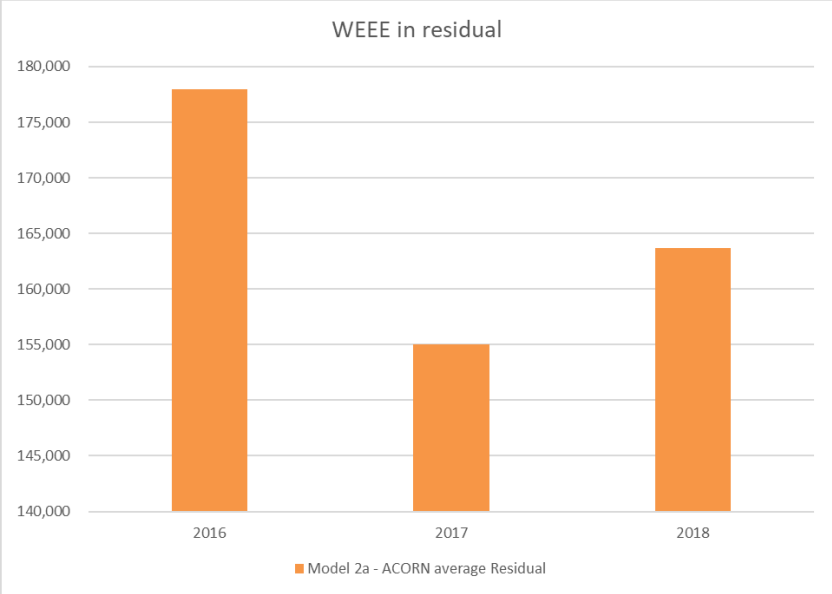


Figure 7; Average WEEE in residual waste 2016-2018 derived from ACORN profile waste sampling.

There is low likelihood of duplication in this estimate and the data holds a high level of confidence because of the UK wide coverage, demographics and housing types (flats are included in studies albeit smaller sample by comparison to housing).

We have included theft, legal and illegal export in this stage of the analysis, however, the volumes involved are an aggregate which can be fed from multiple points along the supply chain.

The most significant loss of product to theft was in the LDA category, theft activity tracks commodity prices closely, and we estimated that 90 Kt were lost.

Through a review of multiple sources, we concluded that 91 Kt of SMW were lost with some 3-5 Kt lost through theft (the remainder going through other routes explored in Appendix IV).

The weights associated with display equipment are highly dynamic, with the switch in prevailing technologies. Display equipment arising at AATFs is decreasing, but heavier CRTs still present, and per the analysis in Appendix V of this document, the decline in display weight at AATFs is likely exacerbated by hoarding and theft. We estimated that 12 Kt of display equipment are stolen each year, much of which is likely to re-enter the UK market or export for reuse.

The biggest challenge for cooling equipment is compressor theft, as these components have a high material value. The subject challenges waste companies, who lose up to 10kg of valuable material when a compressor is stolen. There are also environmental impacts with cooling gases lost to the atmosphere when compressors are improperly removed. A combined effect is 8 Kt lost to theft for cooling equipment.

Our literature review suggested that legal and illegal activities can be mixed – i.e. exports contain mixes of functional and non-functioning products. This creates further ambiguity when trying to calculate illegal exports, it isn't clear whether this makes the whole shipment illegal or just the non-functioning products. Further data would be needed to determine a true UK specific figure for exported second-hand products, but this would require a lot of work and there are larger unreported flows identified elsewhere in this report.

Our method for determining the weight volume of illegal WEEE exports is based upon research from the Basel Action Network, whose primary sampling and tracking of non-functioning WEEE was the basis of analysis that factored other studies and we estimate that 32 Kt left the UK this way. There is little reporting on this subject, so quantification is taken from studies, interviews with UK Regulators, industry commentary and experiences with loss of products and coverage of legal cases.

We evaluated the potential for data distortions at this stage of processing through AATF misreporting, looking at compliance scheme audit and resolution frequencies. Given the commercials involved in evidence production, the level of scrutiny is high. Our analysis determined that 0.2% of WEEE received will be erroneously reported by AATF and not subsequently identified for correction. The sample size across sites and schemes is high and the resulting margin is low, and presents little or no evidence that reporting errors are contributing materially to the reported and unreported EEE flows.

These final stages of handling are when WEEE is entirely lost from the system. In practical terms, products have avoided correct disposal and handling routes if they reach this stage and should be the focus of policy intervention. We estimate that the combined weight of WEEE collected and treated inappropriately to be 461 Kt, 32% of the used EEE moving on from use, storage and hoarding for collection or 28% of calculated EEE put on market.

4.0 Project conclusions

Following our analysis, we have the following reflections on options for the UK WEEE sector, moving forward.

4.1 Key issues for the future of UK used EEE and WEEE flows

More EEE is put on the market than is reported, through freeriding and prevailing trends in product weight, but these volumes are offset by sales to Ireland from the UK and producer misreporting, making the combined impact on reporting minimal. We do not recommend this as a priority area for further work or policymaking.

More used EEE and WEEE is collected and treated for recycling and reuse than is apparent in reporting, but the governance around this activity is unclear. Similarly, there is an opaque overlap between legal and illegal exports. Minimum standards, voluntary reporting and greater enforcement activity could all contribute to building a greater understanding and more confidence in these offtake markets for used EEE and WEEE, which have arisen spontaneously. We recommend outreach to key actors in these areas to discuss potential options.

Product use patterns, including hoarding behaviour, have an impact on the amount of WEEE available for recycling, the upcoming communications campaign could focus on building awareness and greater confidence in collection and reuse and recycling networks and encourage uptake. Furthermore, Material Focus could continue allocating funding to help make it more convenient for the general public to access proper reuse and recycling routes. Greater scope for retailer takeback could also be a consideration.

Domestic reuse, including that enabled by online C2C platforms, means that useful products stay in circulation for longer. This is a greater priority than recycling under the Waste Hierarchy and in building a more Circular Economy. This type of activity should be promoted, so while initiatives to recycle more WEEE should factor the impact of domestic reuse, it should also not seek to challenge it.

A considerable weight of WEEE is disposed in household residual waste bins and with Commercial and Industrial waste. Given that this is not an appropriate treatment route for WEEE, and that there is a shortfall in UK recycling targets for WEEE, these two collection and treatment routes should be a priority. The demographic data that we gathered in the residual waste sampling could help steer upcoming campaigns, targeting the proper disposal of electricals. Furthermore, engagement with the C&I waste sector to better understand practice, monitoring and awareness of WEEE should be a priority.

4.2 Impacts on future EPR targets

The UK target for WEEE recycling is 65% of sales, and the current reported recycling rate is 40% for 2017. Our analysis shows that the current recycling rate is 53% of actual EEE put on the market. An additional 14% of the EEE put on the market is diverted for potential reuse. There is therefore an 12% shortfall on the recycling and 204 Kt more WEEE would need to be collected for recycling, to close this gap.

Given that we estimate that 300 Kt are collected in the residual and C&I waste, we recommend that efforts to gather more WEEE for recycling focus here. There is also a considerable stock of hoarded and infrequently used EEE in the UK, we estimate that 348 – 381 Kt was added to this in 2017 and could also be an area of focus when looking to improve the UK WEEE recycling rate.

At this stage, we do not believe that there are any further avenues for gathering substantiated estimates to support UK WEEE reporting. This is because no flows qualify as being appropriate for WEEE treatment,

beyond light iron for non-cooling LDA (though the data here is under question, see below) and the B2B IT equipment handled by ITAM's, which is already under consideration.

4.3 Future development and opportunities

We recommend that the Light Iron research is re-visited. Stakeholders have suggested that the substantiated estimate is overstated, as it did not consider WEEE flowing from light iron shredders to AATFs, though it was not made clear how common this phenomenon actually was. Furthermore, other stakeholders pointed out that other types of WEEE made their way into the light iron, beyond LDA which is currently permitted, which would go some way to mitigating a double count here.

Building on from this, researchers found it difficult to engage with the C&I sector and the best available research suggests that a considerable volume of WEEE is mixed into this waste stream. Targeted engagement, perhaps supported with enforcement bodies, could improve understanding of what actually happens here and where the WEEE comes from.

The researchers factored reporting anomalies and provided robust analysis of hoarding and the impact of WEEE availability of long product life. More quantitative data is needed to establish the reasons why EEE users/owners hoard the items. Future modelling should attempt to account for both the time in use and time in hoarding explicitly, rather than combining everything into a single residence time. This analysis is useful, as it helps to prioritise other areas for activity where more WEEE can be collected and recycled, particularly in areas where WEEE is being treated inappropriately.

Longer residence times for some products are likely to have contributed to the observed growth in household stock of EEE, although there are other drivers behind the growth in the stock numbers, namely households gaining multiple units of the same product, changes in product weights and the overall growth in the number of UK households.

The view of the research team is that the next steps should focus on measures to prevent consumer and business WEEE disposal in the residual and C&I waste and also to discourage hoarding of unwanted products, but also that this shouldn't discourage reuse or repair.

5.0 Appendices

Appendix I About Anthesis Consulting Group

Anthesis is a specialist global sustainability services and solutions provider founded on the belief that sustainable business practices are at the heart of long-term commercial success.

Our Activator Approach is our three-stage methodology for delivering sustainable performance. Whether corporate strategy or specific operational problem solving, the Activator Approach flexibly combines the right expertise and tools for the job, across a proven, end-to-end logic of change.

Analytics

The Analytics phase develops insightful diagnostics of business and sustainability issues, builds engagement, and identifies opportunities and risks. Our methods combine primary research and data collection, big data analytics, scenario modelling and multi-stakeholder qualitative research.

Solution

Sustainability poses new challenges and presents extraordinary new opportunities for organisations. But the very newness of these factors can make them difficult to address: they require new tools, methods and approaches. Rooted in robust evidence and analytics, we work with clients to identify and design high impact strategies and solutions that unlock sustainable performance.

Implementation

The future is what actually happens. From energy generation to public engagement campaigns, and from programme management through delivery on the ground: where clients need implementation support, our specialist teams help to make plans into reality and results.

The company was founded for this moment, on a combined conviction in the power of human ingenuity and the potential of practical action to solve the problems of the decisive decade, and make sustainability happen.

We believe that productivity and resilience will be the master values of these coming years: the ability, through creativity and innovation, to realise more of what we value from what we have, and to avoid, or recover strongly from the shocks and challenges that lie ahead.

From complete strategic transformation to the first steps, we are dedicated to serving leaders, in the practical work of shaping a more productive and resilient world.

Appendix II Definitions

Authorised Approved Treatment Facility (AATF) – a licenced site where WEEE is treated. These sites are regulated and approved annually by national agencies.

Authorised Treatment Facility (ATF) – a facility that has been licensed by the Environment Agency that treats WEEE.

Business to business (B2B) - quantities of EEE where the end user is a business rather than a consumer.

Business to consumer (B2C) - supplies of EEE where the end user is a member of the public.

Commercial reuse - commercial reuse is understood as 'Business to Business (B2B) electronic and electrical equipment (EEE) that includes products used by large organisations, public sector and small to medium enterprises. Coordination of collection and treatment following business use is independent from municipal authorities'.

Designated collection facility (DCF) - places where WEEE is collected before being sent for treatment, reuse and recycling.

Domestic reuse - the public donating and reselling items to other members of the public.

Dry mixed recycling system (DMR) – method of treating clean, uncontaminated recyclable material.

Electrical and Electronic Equipment (EEE) - equipment which is dependent on electric currents or electromagnetic fields in order to work properly and equipment for the generation, transfer and measurement of such currents and fields and designed for use with a voltage rating not exceeding 1,000 volts for alternating current and 1,500 volts for direct current (Directive 2012/19/EU).

End user - the person or business/public institution that uses EEE when it becomes waste.

Extended producer responsibility (EPR) – an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle.

Fates – the destination pathways for discarded EEE

Flow discarded after hoarding

Flow recycling – EEE taken or collected for recycling

Flow general bin – EEE put on general bin and going to landfill sites

Flow donation or reuse – EEE donated to charities or others for reuse

Flow discarded after use

Flow sold – EEE sold as second-hand

Flow – take-back scheme – EEE taken to take-back service provided by retailers to their costumers

Flow other – other flow that is not in the present flow categories

Flow unknown – the fate given to the discarded EEE is unknown

Free riders - businesses who are non-compliance with WEEE regulations

General bin - WEEE put in the waste bin and not separately collected for recycling but typically landfilled or incinerated includes household waste and mixed bulky waste.

Hoarding - Hoarding is defined as the time in storage when an EEE device stops being used and before it is discarded, referred to as 'in storage' or 'hoarded'.

Household waste recycling centre (HWRC) - a facility where the public can dispose of household waste, these sites also often have recycling points.

Information technology asset disposal (ITAD) - business built around disposing of obsolete or unwanted IT equipment in a safe and ecologically-responsible manner.

Information technology asset management (ITAM) - a set of business practices that combines financial, inventory and contractual functions to optimise spending and support lifecycle management and strategic decision making of IT equipment.

Listing (Gumtree / eBay) – EEE product that is listed as an auction or classified ad for sale.

MATLAB - a high-level programming language developed by the MathWorks computer software company. It is used extensively in industry and academia to perform a wide range of computer model simulations and data analytics. URL: https://uk.mathworks.com/products/matlab.html

Material recycling facility (MRF) – a processing plant for recyclable material.

Non-obligated WEEE – any WEEE collected and treated which is not received by an authorised approved treatment facility or on behalf of a producer compliance scheme.

Obligated WEEE - WEEE received by an authorised approved treatment facility or on behalf of a producer compliance scheme.

Put on the market (POM) - put on the market means the first time a product is sold, or available, on the market within the territory of the UK on a professional basis (Directive 2012/19/EU) and as defined in the UK by The WEEE Regulations 2013 (SI 2013/3113).

Product fates – various ways an EEE product is disposed of after being used or hoarded.

R programming language v. 3.5.1 (R Core Team, 2018) - a high-level open source programming language popular both in academia and industry allowing users to perform a wide range of statistical calculations involving data.

Residence time - household residence time is defined as combined time from the moment of EEE sale until the product is discarded. This includes the time the EEE product is used and, for some products, the subsequent time in storage.

Residual waste - non-hazardous waste material that cannot be re-used or recycled and needs to be sent to energy recovery or disposal.

Reuse – reuse of electrical and electronic equipment or its components is defined as a continued use of it (for the same purpose for which it was conceived) beyond the point at which its specifications fail to meet the requirements of the current owner and the owner has ceased use of the product.

Stock - number of items stored in households, regardless of whether they're still functioning or in use.

Time in Storage (TS) - time in storage (hoarding) between the moment when the device stops being used and until it is discarded (as before, the age of the oldest device serves as a proxy if no direct figures for the end of hoarding age are available).

Time in Use (TU) - time in use from the moment of purchase, until the device is discarded/stored (the oldest device in use serves as a proxy if no direct end of use age is available).

T11 waste exemption - the T11 exemption allows you to repair, refurbish or dismantle various types of WEEE so that the whole WEEE item or any parts can be reused for their original purpose or recovered.

Units in storage (US) - number of units of a given EEE product or products within a category under use in the household.

Units in use (UU) – number of units of a given EEE product or products within a category which is not under use, but kept in storage (hoarding) in the household.

UNU codes – a set of 54 aggregate EEE and WEEE categories with sufficient granularity to define individual product parameters such as household residence times and average unit weights.

Waste stream - flows of specific waste from its source through to recovery, recycling or disposal.

WOT model – waste over time model which is used by the European Union to estimate electrical products placed on the market and WEEE generated.[16,17.]

Appendix III Theft – Large Domestic Appliances (LDAs)

Methodology

This work focussed on the theft of large domestic appliances (LDAs) prior to them being collected from DCF sites as this was recognised as the least secure part of the supply chain and therefore most likely prone to theft.

In order to estimate the quantity of LDAs lost through theft, the ratio of household LDAs to cooling appliances placed on market (POM) was compared to their ratio collected. It is assumed that the ratio collected should be the same as POM, taking into account their respective average lifespans of each stream.

If the cooling appliances collection figure is assumed to be the true quantity that would be expected to be collected on site, adjusted for the effect of theft occurring through compressor and cable thefts, and then the Cooling/LDA ratio collected is applied, the quantity of LDAs that would be expected to be collected can be estimated. The difference between what is reported as collected and what is expected to be collected can then be identified as theft.

This method of identifying LDAs lost as theft assumes that:

- Both types of item are often replaced on a like-for-like basis
- Due to the size and shape of these items any hoarding of these appliances is minimal
- The average life of LDAs is 11 years and cooling appliances is 16 years
- The ratio of household LDAs to cooling appliances POM remains relatively stable over time
- Theft of cooling appliances is generally limited to compressors and cables. Therefore, if the cooling equipment reported collected figure is uplifted to take this into account then this should always represent the quantity of fridges that are legitimately expected to arise as WEEE
- Due to LDAs and cooling appliances being similar types of appliances in terms of size and shape the public are likely to dispose of items in the same way. Therefore, it should be expected that the ratio between LDAs to cooling appliances POM should be the same when collected from DCF sites

Analysis

UK Household POM Ratio of LDAs to Cooling Equipment

The table below shows the quantity of LDAs and cooling equipment POM from 2008 to 2018. This shows that the ratio between them has remained relatively constant.

Quantity of LDAs to Cooling Equipment POM[43]

Category	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Av.
LDAs	508,721	468,936	476,168	462,795	473,363	495,959	519,036	556,801	594,751	566,170	549,422	
Cooling Appl.	187,395	170,772	173,039	171,101	175,269	188,546	201,816	216,836	225,032	219,071	204,090	
LDAs	73.1%	73.3%	73.3%	73.0%	73.0%	72.5%	72.0%	72.0%	72.5%	72.1%	72.9%	**72.7%**
Cooling Appl.	26.9%	26.7%	26.7%	27.0%	27.0%	27.5%	28.0%	28.0%	27.5%	27.9%	27.1%	**27.3%**

However, there is a difference in the lifespans of these items, with LDAs typically lasting 11 years compared to cooling equipment which can last 16 years on average. Therefore, for cooling equipment to arise at a DCF site it will have been placed on the market five years before the LDA.

The table below shows cooling equipment POM staggered back by five years to show the ratio of LDAs to cooling that would be expected to arise on site at a DCF site at the same time. Although the data is not available to go back 16 years to identify the POM data for cooling equipment that would be expected to arise as WEEE in 2018 it does show the ratio between the categories between 2008 and 2013.

Quantity of LDAs to Cooling Equipment (Staggered Back Five Years) POM

Category	2008	2009	2010	2011	2012	2013	2014		2015	2016	2017	2018	Av.
LDAs	508,721	468,936	476,168	462,795	473,363	495,959	519,036		556,801	594,751	566,170	549,422	
Cooling Appl.	188,546	201,816	216,836	225,032	219,071	204,090							
LDAs	73.0%	69.9%	68.7%	67.3%	68.4%	70.8%							**69.7%**
Cooling Appl.	27.0%	30.1%	31.3%	32.7%	31.6%	29.2%							**30.3%**

[43] https://www.gov.uk/government/statistical-data-sets/waste-electrical-and-electronic-equipment-weee-in-the-uk

This shows that the average ratio between the two categories is 69.7% LDAs and 30.3% cooling equipment. It also shows that this ratio does not change significantly over the period. Therefore, if it is assumed the public would dispose of these items in the same way then this is the ratio of LDAs to cooling equipment that would be expected to arise at DCFs.

To validate these proportions the EA statistics under the direct PCS and distributor collection regulations were reviewed to compare the relevant data from 2012 to 2018 (Appendix XIV). The ratio of LDA to Cooling using the average weights collected per year is (66.44:33.56), so broadly in proportion which is in line with POM ratios above.

This supports the adjusted POM rates where the appliance seller takes back the old appliance or where a third-party collector is engaged to remove it, meaning that these WEEE collections are neutral to the issue of leaked LDA. It also supports the principal of the method that the ratio of cooling to LDAs going on the market should be approximately the same as the ratio coming off the market.

UK Household DCF Collected 2018

The table below shows the quantity of LDAs and cooling equipment reported as collected at DCFs in 2018. The LDA figure has been updated based on the recently revised default protocol for separately collected LDA from DCFs, effective from January 2020, which identified an increase of 10.64% of the LDA content when compared to the previous protocol used to calculate the 2018 collections. The cooling equipment figure has also been updated to include the estimate for missing components that should have arisen on site with the remainder of the units.

Category	DCF Collected (Kt)	Ratio (%)
LDAs		
LDAs Reported Collected from DCFs	78.754[44]	
Adjusted for revision to non-WEEE in separate LDA collections protocol. Non-WEEE collected in separate LDA collections has reduced (Source: revised protocols project). This will increase LDAs at DCF sites by ~10.64%.	9.377	
LDAs Collected Total	88.132	48.7%
Cooling Equipment		
Cooling Equipment Reported Collected	85.281	
Adjusted for Cooling Theft*	7.700	
Cooling Equipment Total	**92.951**	**51.3%**

*See section 2.6 for cooling theft calculation

[44] https://www.gov.uk/government/statistical-data-sets/waste-electrical-and-electronic-equipment-weee-in-the-uk

This table shows that the ratio for adjusted DCF collections varies considerably from the lifespan average POM ratio (69.7:30.3).

Adjusted Household Collected 2018

By using the cooling equipment figure as a measure for what is expected to be collected and that it represents 30.3%, then this means that 213.817 Kt of LDAs should have been collected as shown in the table below.

Category	DCF Collected (Kt)	Ratio (%)
LDAs Expected	213.817	**69.7%**
Cooling Equipment	92.951	**30.3%**

If the adjusted LDAs collected figure of 88,132 is deducted from the expected LDAs figure of 213.817 Kt, then it means that there are 125.686 Kt missing from DCF sites.

However, WRAP estimates that 11% of light iron is made up of LDAs[45], therefore if the 2016/17 Waste Data Flow (WDF) estimate of 327.404 Kt[46] of 'other scrap metal' arising on Household Waste Recycling Centres (HWRCs) is used and apply the 11% it indicates that 36.014 Kt of LDAs end up in the light iron container.

Internal estimates by Valpak believe that up to 20% of light iron could be LDAs. Using this would indicate that there were 65.481 Kt of LDAs collected in the light iron container, rather than in the separately collected WEEE steam.

Results

The analysis above indicates that there are 89.671 Kt (125,686 – 36,014) of LDAs lost through theft that would have been expected to arise at DCFs. This represents 42% of the LDAs that would be expected to be collected. If the total of LDAs in light iron is higher (20%) it would mean that 65.481 Kt (28%) of LDAs are lost through theft. It also highlights that the estimate for total LDA theft is sensitive to the estimate for LDAs in light iron.

Analysis was conducted to sense check the 42% of LDAs figure lost through theft. Appendix XV shows the historic POM and collected data for LDAs as well as the LDA scrap price from 2008 to 2018. This highlights two key points:

- The LDAs collected over this period only account for 31% on average of LDAs POM in the same year, with few outliers outside the range of 30-32%. This highlights a significant gap between POM and collected. Research of the UK major domestic appliances market indicates that 83% of all new purchases are replacements[47], therefore with the purchase of a new appliance in most

[45] WRAP, Evidence of Large Domestic Appliances recovered in the UK light iron stream (2014)

[46] This was the latest cleansed WDF data available to the project team at the time of writing

[47] The Association of Manufacturers of Domestic Appliances (AMDEA), "The market is now focused on replacement products (83% of all new purchases are replacements – of this, 53% are due to appliance breakdown). This is largely driven by buyers moving home. Other reasons may be changing needs, for example having children; a desire to change the look of the kitchen; the

cases there should be an equivalent total of units arising as WEEE (if due to the size and nature of these items, they are unlikely to be withheld through hoarding)

- That there is an inverse correlation (-0.75) between the LDA scrap price and the quantity of LDAs collected i.e. the greater the LDA scrap price the less LDAs are collected, which indicates that as their value rises so does the number of LDAs that are lost to the official collection system. By looking at the gap between the lowest and highest collection figures between 2008 and 2018 it indicates that there are potentially 82.345 Kt that can be affected by the LDA scrap price (based on available data)

This analysis supports the theory that a significant number of LDAs are being disposed/recycled outside the official reported WEEE system. This theft is likely to occur at the pre-DCF and DCF stages through kerbside totters, theft from site and hoarding (although this is expected to be minimal for LDAs).

arrival of innovations; or increasingly concerns about energy and water efficiency", https://www.amdea.org.uk/industry-information/market-information/

Appendix IV Theft – Small Mixed WEEE (SMW)

Methodology

In order to estimate the quantity of Small Mixed WEEE (SMW) lost through theft the following activities were conducted:

- A literature review was used to identify publicly available information on the theft of WEEE
- The WEEE Protocols Revision project team was engaged to gain an understanding of where SMW can end up on site
- Valpak internal review by AATF/ATF auditors and other internal specialists involved in the management of DCF WEEE contracts
- Analysis using Environment Agency WEEE data and diversion rates
- Peer review by the project team consisting of Anthesis, Repic and Lancaster University

Analysis

The literature review identified that losses, the difference between the totals POM and collected arise from hoarding, theft, incorrect segregation for recycling, recycled under an exemption and disposal in the general waste. However, there was no single report that included all these potential flows.

Following the literature review the project team which had recently completed the review of default WEEE protocols for the LDA and SMW steams were then engaged. This work involved the manual analysis and classification of sampled LDA and SMW loads arising from DCFs in two phases during 2018-19. The purpose of the work was to refresh the default protocols applied by AATFs in the reporting and evidence issuing of these WEEE streams where bespoke, site-specific protocols had not been previously agreed.

The results, which will be adopted for the 2020 compliance period, showed that 1.2% of SMW collected at a DCF site ends up in the LDA container. The previous LDA protocol did not recognise this content.

Results from a survey of the public conducted by Valpak in the North East of England during 2016-17 were reviewed to quantify the well-understood phenomenon of domestic hoarding of old EEE items as they are replaced. It is understood that members of the public will retain items that have been subsequently replaced with more current items, especially with IT and telecommunications equipment. Often older items are retained as spares if the replacement item fails. Over time the hoarded items become obsolete and are discarded.

Once diversion rates were identified an internal workshop was held with key Valpak staff involved in the management of DCF WEEE contracts to sense check the datasets used and estimate for theft.

Results

Categories 2-10		2018 (Kt)
Total Placed on Market		411.717
Total Collected from DCFs		-113.292
Total Collected under Reg43		-1.737
Total Collected under Reg50		-24.590

Net		272.097
Cat 2 Handled but not reported under Exemptions		-0.853
Cat 3 Handled but not reported under Exemptions		-3.535
Total Category 1 - LDA Collected from DCFs	78,754	
Lost at site - SMW in LDA separately collected from DCFs (2020 Protocols project)	**1.21%**	-0.953
Shortfall (at DCFs)		266.756
Hoarding (Valpak STWWMP Survey 2016-17)	**42%**	-172.921
Purchased for new GB housing stock (10 Kgs/dwelling)		-2.410
Purchased for new NI housing stock (10 Kgs/dwelling)		-0.086
Lost to general waste and theft		91.339
Theft - 360 Environmental estimate based on Shortfall	**1.20%**	3.201
Theft - Valpak estimate based on Shortfall	**2.00%**	5.335

This shows that there is a shortfall of 266.756 Kt that would be expected from DCF sites. This was sense-checked against an Anthesis estimate of 287.700[48] Kt, and as such, indicates that the estimate seems sensible.

After factoring in hoarding and theft estimates there are between 86.004 and 88.138 Kt per annum is likely to be lost in general domestic waste. Assuming 28 million households in Great Britain[49] and 798,000 in Northern Ireland[50], this equates to approximately 3 kgs/UK household.

[48] Anthesis, Unreported WEEE Flows in the UK, 2018

[49] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/803934/LT_102.xls

[50] https://www.opendatani.gov.uk/dataset/e4397d4b-db1e-43cd-9acf-4e84ee85cb42/resource/46a79515-e6c4-4602-82a5-252e160021ad/download/ni-housing-stock-april-2019.csv

Appendix V Theft – Display Equipment

Methodology

Since the switchover of terrestrial television to digital signals, completed in 2012, cathode ray tube (CRT) televisions have ceased to be placed onto the UK domestic market in any meaningful quantities.

The rapid development of flat panel display (FPD) technologies, from Thin Film Transistor (TFT) to Plasma, Liquid Crystal Display (LCD), Light Emitting Diodes (LED) and Organic Light Emitting Diodes (OLED), meant that manufacturers produced progressively lighter units. However, the recent customer preference for large-screen units appears to have arrested this decline.

The effect of these factors on the weight-based WEEE system since 2012 has been to show a broadly stable level of total weights reported as POM, however the total weights received at AATFs have declined significantly, even though older and heavier CRT units are still arising in the WEEE stream, long after they were expected to decline to insignificant levels. This mismatch suggests that there is now a significant loss from the WEEE system.

Due to the complexity of the various display technologies being POM, coupled with light-weighing, increases in their size and each having a different lifespan it is difficult to estimate the amount of theft occurring using weight-based methods, therefore in order to try and quantify display theft this project used a unit approach. This has been done by converting both the weight-based POM and collection data to the number of units using estimates of average unit weights for each:

- Converting the POM data based on average weights reported by producers
- Converting the WEEE received at an AATF data based on average weights by displays types reported by AATFs

This allows valid comparisons between these datasets, reflecting unit types of different weights to be made. The estimated unit equivalent becomes the common metric.

Once this is done the following calculation was used to estimate the quantity of display units that are lost to theft.

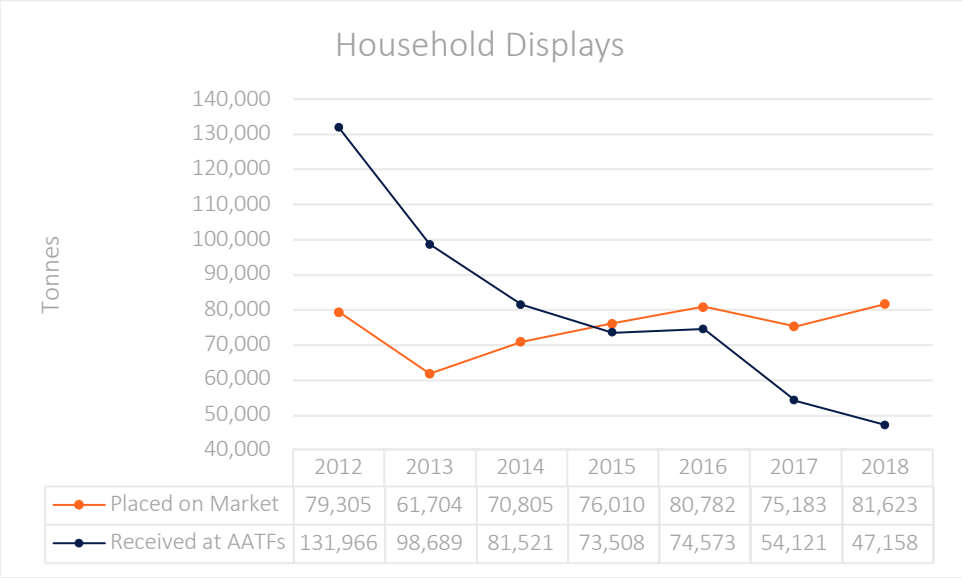
Display theft	=	Displays Placed on the Market	-	Received at an AATF	-	Purchased for New Homes	-	Hoarding

Then, using the average weights the total weight of display equipment lost through theft can be estimated.

It should be noted that the Environment Agency's published data for household WEEE Received for Treatment at AATFs, was used rather than Total separately collected household WEEE, as these reflect what was made available in each year for treatment within the official WEEE system. The standard deviation between these annual totals of 2% over the period 2012 to 2018.

Analysis

The following graph plots the EA full-year totals for household Displays (Category 11) placed on market since 2012 against those received for treatment at AATFs[51]:



	2012	2013	2014	2015	2016	2017	2018
Placed on Market	79,305	61,704	70,805	76,010	80,782	75,183	81,623
Received at AATFs	131,966	98,689	81,521	73,508	74,573	54,121	47,158

Notwithstanding some variations in macro-economic conditions in the period, the total tonnes POM has remained broadly stable at around 80 ktpa.

The decline in total tonnes received at AATFs om 2018 is at a level far below that of the POM total, even though, AATFs are still receiving a significant proportion of CRT units in the Displays WEEE stream. As discussed below, it is believed this is in the region of one third of the units arising. This suggests that the mismatch is more pronounced than is suggested by the Received at AATFs total and is a result of both hoarding and a high level of theft.

Converting POM Data to Units

Using placed-on-market data reported by Valpak scheme members for the 2019 compliance period the average weight per unit placed-on-market has been calculated:

Average weight of Displays placed on the market in 2019	
Household (B2C)	11 Kgs/unit

It is believed that this weight can be considered as broadly representative of the UK as Valpak's total market share in this category for 2019, when compared to the 2018 full-year UK placed-on-market totals, is >20%.

[51] https://www.gov.uk/government/statistical-data-sets/waste-electrical-and-electronic-equipment-weee-in-the-uk

Applying this average to the 2018 reported POM data[52], the latest available, the following unit equivalent can be implied:

Display Equipment POM	Kt	Units
Household	81.623	7,420,273

Non-household equipment is excluded due to its specialist nature (e.g. oscilloscopes and aviation instrumentation displays), it is unlikely to be misdirected from the official WEEE system. Also, any displays which are similar to those that would be in a household, due to dual-use, will already be included in the household figures.

Converting WEEE Received at AATF Data to Units

In 2012 it was anticipated that most CRT units would be discarded in favour of FPD replacements, and as such, would quickly work their way through to the Displays WEEE stream. It was initially estimated they would only arise in the WEEE stream in negligible numbers after five years.

However, CRT arisings have persisted. It is believed that large numbers of CRT units were hoarded by households immediately following the digital switchover. Over time as newer FPD technologies replaced older ones a domino effect occurred in hoarding behaviour, leading to the eventual discarding of the by-then older and less popular CRT units.

The proportion of CRTs in the current WEEE stream is exacerbated by the theft of lighter FPD units. These have a value in the legitimate and illicit second-hand markets, which CRT units do not.

Data received from AATFs in three regions serviced by the Valpak Schemes over periods between Jan 2018 and April 2019 was analysed. These covered collections received by each AATF from DCF collections. In all cases, the AATF was able to provide a breakdown of the units received for treatment by display type. These were used to calculate the weight of each type in all regions.

The following are the total number of units and proportions aggregated for the three regions:

	Cathode Ray Tube	Flat Panel	Monitors	Total
Total Units Received by AATFs in Regions	42,633	77,933	5,061	125,627
	34%	62%	4%	100%

52 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/828199/Electrical_and_electronic_equipment_placed_on_the_UK_market.ods

No separate weighing of Monitors occurred at any of the AATFs, so it was assumed that those arising as waste are FPD units. It is therefore assumed that the arisings of CRT monitors in the WEEE stream is minimal due to their size and limited functionality i.e. they have not been subject to the same level of hoarding as CRT televisions.

The AATF data from one of the regions, covering a fifteen-month period, included weights by Displays type. The average weights per unit collected were:

Display Type	Average Weight (Kgs/unit)
Cathode Ray Tubes	18.60
Flat Panel Displays and Monitors	10.54

To sense-check these results they have been compared to the Furniture Resource Network average weights, to which Valpak subscribes. These data are copyrighted so cannot be disclosed in this report.

The FRN Average weights are quoted over a range of screen sizes, from <14" to 36" for CRTs and 15" to 70" for FPDs. Using a simple average of the FRN weights across the range weights, so with no weighting possible by screen size, the results vary by respectively, 23%, 14% and 16%.

Applying Valpak average weights and proportions by type to the EA statistics for WEEE Received at AATFs in the UK for 2018[53], the following unit counts can be implied:

Household	Kt	Collected	Kgs/Unit	Units
Cathode RayTubes	16.034	34%	18.60	862,028
Flat Panel Displays	31.124	66%	10.54	2,952,968
Totals	47.158			3,814,996

Results

In order to assist in quantifying display theft, the following practical assumptions were made:

- CRT units are no longer placed on the market

53 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/828196/WEEE_collected_in_the_UK.ods

- CRT units arising in the waste stream are not subject to misdirection from WEEE treatment facilities as they have no resale or other residual value.

Also, in order to identify hoarding, a survey of the public conducted by Valpak in the North-East of England in 2016-7 was used that showed that that 327 of 1,265 respondents (26%) having purchased a new displays unit, hoarded their existing appliance for two years or longer.

Data issued by ONS in May 2019 shows an increase in housing stock in Great Britain of 241,000[54] dwellings between 2016 and 2017, the latest available figures. The housing stock dataset for Northern Ireland shows an additional 8,643 dwellings added in the financial year 2018/19[55].

It has been assumed that:

- The GB increase was replicated in 2018 [56]
- That 1.8 new Displays units are purchased for each new dwelling

The estimate of Displays exported illegally under exemption from Section 1 of this report, 0.812 Kt per annum, has been converted to units at 10.54kgs/unit from Valpak AATF Data above, the average weight of FPD units arising in the waste stream.

Applying these factors to the analysis results, it can be concluded that theft from the official WEEE system totals approx. 1.2 million units (16%) of those placed on the market in 2018.

	Estimated Units
Placed on Market in 2018	7,420,273
Purchased for new GB housing stock (1.8 units/dwelling)	-433,800
Purchased for new NI housing stock (1.8 units/dwelling)	-15,480
POM available for disposal as WEEE	6,970,993
Received at AATFs	
Cathode Ray Tube	862,028
Flat Panel Displays	2,952,968
Total	3,814,996
FPDs Hoarded by public (26% of POM)	-1,929,271

[54] Office for National Statistics, National Records of Scotland, Northern Ireland Statistics and Research Agency – Population Estimates

[55] https://www.finance-ni.gov.uk/publications/annual-housing-stock-statistics

[56] https://www.finder.com/uk/tv-statistics

Illegally exported under Exemption	-77,040
Theft	1,149,686

If 1,149,686 leaked units are taken to weigh 10.54 kgs each (from the Valpak AATF Data above), then they are equivalent to 12.118 Kt per annum.

Appendix VI Theft – Cooling Equipment

Methodology

To calculate the amount of cooling equipment lost through theft this project focussed on the removal of valuable components of a fridge, which are principally compressors. These are typically removed from the unit rather than the whole unit being lost to theft as this is the most valuable components. Cooling equipment as whole units are a costly to treat/dispose.

In order to estimate the quantity of cooling appliances lost through theft the following was conducted:

- A literature review was used to identify publicly available information on the loss of WEEE
- Internal Valpak review of AATF reports and the amount of cooling appliances damaged with items missing
- Review of Valpak internal data relating to the average weight of a cooling appliance
- Internal review by Valpak staff involved in the management of DCF WEEE contracts
- Analysis using Environment Agency WEEE data and diversion rates
- Peer review by the project team consisting of Anthesis, Repic and Lancaster University

Analysis

The project focused on the incidents of compressor theft as the cause of losses from the WEEE system. It is believed that both the domestic and export markets for functioning units are adequately served by AATFs and that this activity is captured within the WEEE system.

Where functioning units are sold for reuse by resellers that are not AATF-accredited the nature of this stream mitigates against them being collected speculatively, out with the WEEE system. The units are most likely to be acquired by resellers via sales or auctions by the first receiving AATFs. These companies will have access to collections in volume and the means to dispose of those items that are unsuitable for reuse. This will be captures and recorded in the official WEEE system.

In addition, it has been assumed:

- Beyond the compressor, there is little residual value in a cooling unit. It contains a small quantity of metal by mass, being mostly comprised of plastic in the form of internal fittings and insulation foam
- There is little additional financial incentive to export functioning units illegally. Due to their low density, the transport cost per unit is high
- To transport non-functioning units for disposal is not cost-effective given their low residual value

Collections made on behalf of the Valpak compliance schemes in four geographically diverse regions over differing twelve-month periods between January 2018 and June 2019 were analysed. The following table represents more than 3.6 Kt and 91,800 units collected. The weight of a missing compressor is assumed at 10kg/unit throughout.

	Missing Compressors (% of units collected)	Avg Kgs/unit Collected	Avg Kgs/unit Collected if whole
Semi-rural with urban areas	11.7%	40.98	42.15
Major urban area	72.6%	35.39	42.65
Rural with urban areas	14.1%	40.71	42.12
	23.3%	**39.90**	**42.31**

Results

The datasets published by the Environment Agency for the full year 2018 show the total tonnes for Category 12 – Cooling Appliances Containing Refrigerants (included in the table below). This has been converted to a unit count using the average of 39.90 kgs/unit above:

	Household	
	Kt	Units
Received at an AATF	132.149	3,312,005

Applying 42.31 kgs/unit, the average weight had compressors not been missing, to the household unit count at AATFs gives a total of 139.907 Kt. The loss to the official WEEE system of component theft from Cooling is therefore estimated at approximately 7.7 Kt per annum.

Appendix VII Unrecorded Treatment Under an Exemption

Introduction

The purpose of this section of the report is to estimate the quantity of Waste Electrical and Electronic Equipment (WEEE) that is refurbished and reused by organisations that operate under an exemption from environmental permitting but is not captured/reported within the official WEEE reporting system.

In England, the T11 exemption allows an organisation to repair, refurbish or dismantle various types of WEEE so that the whole WEEE item or any parts can be reused for their original purpose or recovered[57]. In Scotland, the Paragraph 47 exemption allows "the repair and/or refurbishment of Waste Electrical and Electronic Equipment (WEEE)"[58].

Both exemptions allow the holders to conduct these activities without the need for full environmental permitting. These exemptions are typically granted to smaller organisations, including charities, which manage small amounts of WEEE within the limitations and conditions specified by the exemption.

Those that are granted accreditation as Approved Authorised Treatment Facilities (AATFs) will report their activities to government and the regulators directly within the WEEE regime.

However, it should be noted that the granting of such an exemption does not oblige the organization to seek AATF status, and as such. the activities of exempted organisations which handle WEEE may go unreported in official statistics. Some, such as social enterprises or local charities, may deal in such small quantities as to make an AATF application financially unviable, and as such, provision of data to the regulator is not guaranteed.

In addition to these repair and refurbishment exemptions, others may be granted for the temporary storage of waste before transportation to another site for recovery are available in England (S2) and Scotland (Paragraph 48). Typically, these are granted to distributors offering customer takeback where they are obliged to temporarily store the returned units prior to on-carriage for treatment at an AATF.

It has been acknowledged by at least one of the regulators that some organisations may seek an exemption in order to undertake illegal activity on the pretext of refurbishment and reuse, in the expectation that they will not be subject to regular regulatory scrutiny. Such activities would include:

- The export of components, such as fridge compressors, and fractions derived from WEEE for disposal in contravention of trans-frontier shipment (TFS) obligations
- The on-trading within the UK of whole WEEE items without pre-treatment or assessment, ostensibly for refurbishment and reuse
- The on-trading or direct export of WEEE items with the expectation of reuse and/or disposal in non-OECD countries:
    - The export of loads containing both functioning and non-functioning items circumvents TFS requirements and burdens the destination country with the consequences of disposing of the latter, where environmental standards may be lower than those in the EU.

Methodology

[57] https://www.gov.uk/guidance/waste-exemption-t11-repairing-or-refurbishing-waste-electrical-and-electronic-equipment-weee

[58] https://www.sepa.org.uk/media/105287/wmx-tg47.pdf

In order to quantify the amount of WEEE treated by exempt organisations the following stages were conducted:

- The Register of Exempt Activities held under Schedule 2 of the Environmental Permitting (England and Wales) Regulations 2010[59] was reviewed to identify organisations operating under S2 and T11 exemptions and then this was compared to the public registers of AATFs
- Reuse data on the categories and quantities of WEEE reused in the UK was collected
- The categories of WEEE permitted under an exemption were cross checked with the categories reused in the UK to provide a profile of WEEE categories likely reused under exemptions
- Regulatory bodies including the Environment Agency (EA) and Scottish Environment Protection Agency (SEPA) were engaged to establish if they collected data on the category and quantity of WEEE treated by exempt organisations, and whether this could be made available
- Internal audits of Authorised Treatment Facilities (ATFs) that Valpak use were reviewed to identify the category and quantity of WEEE they treat
- An internal workshop was conducted with AATF/ATF auditors and other internal specialists to estimate the proportion of WEEE treated but not reported by organisations working under an exemption
- Using the data/processes described above the quantity of UK WEEE treated but not reported by organisations working under an exemption was quantified

Analysis

This project attempted to assess the extent of WEEE treated by AATFs under exemption.

Summaries of the exemption terms in respect to WEEE are summarised in Appendices 1 and 2. In general, they cover typically collected WEEE (excluding items containing asbestos and polychlorinated biphenyls).

England

The T11 exemption permits up to 1 Kt of WEEE to be stored or treated in any 12-month period. The S2 exemption permits the storage of up to 400m³ of WEEE for up to 6 months.

For context, 400m³ represents approximately:

[59] https://environment.data.gov.uk/public-register/view/search-waste-exemptions

Item	Dimensions (m)	Volume (m^3)	No of Items	Assumed Weight per item (Kgs)	Total Weight (Kt)
Washing Machine/Dish Washer/Tumble Dryer	0.60 x 0.85 x 0.60	0.31	1,290	40	0.052
Fridge Freezer	0.55 x 0.65 x 1.75	0.63	635	60	0.068
Fridge	0.55 x 0.65 x 0.85	0.30	1,333	30	0.040
Displays	0.75 x 0.25 x 0.30	0.06	6,667	11	0.733
Mixed WEEE	40 yd^3 RoRo	30.58	N/A	N/A	0.026

Large appliances are manufactured to standard dimensions. Displays and other Mixed WEEE categories are non-standard and often irregular in shape.

It has assumed an average Displays unit to have the maximum external dimensions and weight indicated.

A 40yd^3 RoRo containing un-compacted mixed WEEE has been assumed to contain two tonnes.

The following exemptions were held by AATFs listed in the June 2019 update of the EA public register for England[60]:

[60] https://environment.data.gov.uk/public-register/view/index

	Small Tier (Able to issue Total WEEE evidence < = 400tpa)	Large Tier (>400tpa)
Total AATFs	65	60
Holding T11	35	4
Holding S2	12	7

Data provided by the Environment Agency for the 2017 and 2018 compliance periods (Appendix XII) show that the proportion of both English household and non-household WEEE received by AATFs operating under a T11 exemption to the total received by all UK AATFs has declined significantly:

Category		2008		2009		
	Total received by all UK AATFs	Total received by EA T11 AATFs	EA T11 / Total Rec'd	Total received by all UK AATFs	Total received by EA T11 AATFs	EA T11 / Total Rec'd
Total B2C	525,197	13,970	2.66%	493,759	3,881	0.79%
Total B2B	9,385	490	5.22%	8,203	61	0.74%
Total Both	534,582	14,460	2.70%	501,962	3,942	0.79%

Wales

Of 11 Small-tier AATFs registered with National Resources Wales[61], none were identified as registered with S2 or T11 exemptions, suggesting that they were all permitted for the storage, treatment and refurbishment of WEEE. No register of exemption holders in Wales is publicly available.

Scotland

In Scotland the Paragraph 47 exemption sets volumetric storage (50 and 80m^3) and daily treatment limits (2, 3 and 5 tonnes/day as detailed in Appendix XII). Again, for context these volume limits represent approximately:

[61] https://nrwregulatory.naturalresources.wales/Exemptions/PublicRegister/Search

Item	No of Items	Total Weight (Kt)	No of Items	Total Weight (Kt)
	50m³		80m³	
Washing Machine/Dish Washer/Tumble Dryer	161	0.0064	258	0.0103
Fridge Freezer	79	0.0047	126	0.0075
Fridge	167	0.0050	267	0.0080
Displays	833	0.0092	1,333	0.0146
Mixed WEEE	N/A	0.0032	N/A	0.0052

Of 23 Small-tier AATFs registered with SEPA, three were known by Valpak to be operating under a Paragraph 47 exemption. No publicly available register was available.

Northern Ireland

Although basic information regarding WEEE and available exemptions is available at the Department of Agriculture, Environment and Rural Affairs (DAERA) for Northern Ireland website, no public register of exemption holders is available.

Eight AATFs and six AEs are shown as accredited in the small tier. As no WEEE exports have been reported for the UK in the past year, the estimate in the following section of three AATFs in NI refurbishing under exemption would appear reasonable, based on population distribution (see below).

Results

The analysis suggests that the risk of losses to the WEEE system from the non-reporting of collection, reuse and subsequent on-treatment by legitimate, non-AATF exempted operators in Scotland is small. These organisations would consider applying for the permitting of their activities in the event that the exemption limits were reached. They could then be persuaded to seek AATF status by the attendant financial advantage of being able to contract with a producer compliance scheme.

However, the potential for losses from questionable operators using exemptions is considerable. As the exemption limits in Scotland are low when compared to those in England, exceeding them would not be a material consideration as their main intention is to avoid regulatory scrutiny of their activities.

In England, the disparity between the limits in the refurbishment (T11 – 1,000tpa) and storage (S2 - < 100t for up to six months) exemptions suggests that holding an S2 exemption is not a relevant consideration for the any organisation already holding a T11 exemption.

The English AATFs in the small tier, legitimately refurbishing and reusing under a T11 exemption are likely to operating at a rate of less than 400tpa, despite the higher T11 limit. From the experience of the Valpak WEEE producer compliance scheme, it is highly unlikely that any single exempted site of a reuse AATF will attempt to refurbish more than 400tpa (the equivalent of 10,000 washing machines at approximately 40kgs each), even those operated by the major national charities.

It is notable that seven of the Large tier AATFs hold the S2 storage exemption. This appears to be inconsistent with their decision to seek and pay for the upper tier AATF accreditation. In the absence of evidence to the contrary this can be assumed to be a legacy situation, and so not relevant to this analysis.

In the absence of any equivalent data from Natural Resources Wales (NRW), NIEA and SEPA to that provided by the EA in respect of exempted tonnage reported in to the WEEE system, using pro-rating based on population the quantity of WEEE legitimately collected for refurbishment and reuse under an exemption across the UK can be estimated:

	Population 2018	Share of UK population	2018 Received by Exempted AATFs (Kt)	AATFs operating under Exemption
England	55,977,000	84.26%	3.942	39
Wales	3,139,000	4.72%	0.221	0 (est)
Scotland	5,438,000	8.19%	0.383	10 (est)
Northern Ireland	1,882,000	2.83%	0.133	3 (est)
UK	**66,436,000**	**100.00%**	**4.679**	**52**

Valpak has contracts with twelve out of thirty-one local authorities in Scotland and is aware of three reuse operators working under an exemption. Using Valpak's market share it is estimated there are ten across the country.

Based on population distribution and the Scottish total, it is estimated there are five operating in Wales and three in Northern Ireland.

This would indicate that there were 4.7 Kt of WEEE legitimately treated and reported from the estimated fifty-two exemption holders in the UK.

An internal workshop with Valpak AATF/ATF auditors and other internal specialists was held to estimate the proportion of WEEE treated but not reported by organisations working under an exemption. This identified that approximately 15% (8) of these operators are potentially operating illegally.

It is believed that nearly all of the English exempt operators are nevertheless AATF-accredited, primarily because the T11 exemption limit is so high at 1 Kt per annum. This may not be such a convenient option for Scottish exemption holders, where the treatment and storage limits are lower.

There will be some AATFs that are nevertheless operating illegally, using the legitimacy of being an AATF and the T11 limit to minimise unwanted regulatory interest. In order to justify the risks in doing so, they are likely to deal in quantities larger than the 400tpa Small Tier AATF limit.

If it is assumed that each illegal operator is either on-selling or exporting one or two Forty Foot Equivalent Units (FEUs) per week, with a payload of eight tonnes per FEU, it would handle between 400 and 900tpa of WEEE.

The estimate of a payload for a FEU is based on experience of working with 40ft curtain-side trailers within the UK. These have approximately the same capacity as a FEU and can be loaded with up to six tonnes of Cooling units in normal circumstances. It is assumed that payloads are likely to comprise a combination of larger less dense units, possibly functioning fridges, and irregularly shaped Displays and smaller, denser items to fill any available spaces and voids. Given the density of most electrical items, it is

believed there is little chance of a filled FEU breaching the axle limit (c30tonnes, 44t gross for a vehicle) required to transport it for shipment.

A site regularly receiving more than two FEUs per week would be likely to attract attention from the shipping line, its agents and therefore Her Majesty's Revenue and Customs (HMRC). Given the high value of these items when compared to that of other commodities that might be exported in contravention of Transfrontier Shipment of Waste (TFS) Regulations, such as plastic wastes, illegal operators may not be incentivised to over-trade, thereby risking unwanted attention to their activities.

It is therefore estimated that the loss from illegal activity by exemption holders to be 8 x 650 (The midpoint of 400 and 900tpa) = approximately 5,200tpa.

Both the Environment Agency and SEPA now have a dedicated group to specifically investigate and prevent illegal exports of WEEE and WEEE-related product. These initiatives are warranted by both the likely extent of the problem, clearly objectively unquantifiable, and the detrimental environmental consequences arising from this activity.

The data provided by the EA in Appendix XII show that the collection of household (B2C) WEEE under exemption by weight in 2018 was skewed towards Large (20.05%) and small (9.59%) domestic appliances, IT & Telecoms equipment (39.75%), Displays (9.13%) and Cooling equipment (18.24%). This would suggest that these categories are the most likely to be exported illegally.

However, large domestic appliances (LDAs) and Cooling units are not cost-effective to transport internationally. LDAs are attractive for disposal locally due to their high metal content and there is enough domestic demand for reused Cooling appliances to believe that nearly all the reported exempted activity is legitimate. Discounting the LDA and Cooling streams and using the proportions by weight in the Environment Agency data, the breakdown of the 5.2 Kt estimate of unrecorded activity would be:

Category		Proportions in EA Data	% of estimated Unrecorded activity	Qty (Kt)
2	Small Domestic	9.59%	16.40%	0.853
3	IT & Telecoms	39.75%	67.98%	3.535
11	Displays	9.13%	15.61%	0.812
		58.47%	**100.00%**	**5.2**

Appendix VIII Misreporting – Producers Misreporting Data Returns

Methodology

Producers are required to file initial details with their compliance scheme of the products they placed on the market in the previous year, or file these directly with their regulator if the total is <5tpa. The scheme will then register the information with the regulator by the deadlines for the compliance period.

Thereafter, the data submissions are subject to review by the producer itself, its compliance scheme via its internal audit and technical teams, and by the regulator.

Many errors and omissions will be identified during these review processes, however not all errors may be identified. Not all producers' submissions will be reviewed by their regulator in a given year. The thoroughness of data validation and audit processes may vary between compliance schemes. In practice, it is not possible for any scheme to verify all submissions by all producers in a given compliance period.

An initial desk-top research exercise identified that there was no publicly available information on the accuracy of reporting of producer obligations. Therefore, to estimate the effect of misreporting by producers, the differences between the initial and final declarations of reported POM EEE by Valpak scheme members were analysed. These were then used with a series of assumptions to estimate the effect of total producer misreporting in the UK.

The 28 compliance scheme operators registered for 2019 were grouped for their probable ability to identify member reporting errors. This is based on a subjective assessment of their operator's abilities and resources to be able to conduct checks on its members. Following this, the possible errors per category nationally were estimated.

Analysis

In the five-year period 2014-2018 incl., the variations by category in POM totals initially and finally reported by Valpak on behalf of its members were:

		Valpak Differences - Initial against Final Obligations				
	Category	2014	2015	2016	2017	2018
1	Large household	-0.77%	0.35%	1.49%	2.84%	2.02%
2	Small household	0.23%	1.48%	0.80%	9.62%	-0.04%
3	IT and telecoms	1.67%	-1.85%	-6.42%	9.79%	2.08%
4	Consumer	3.49%	29.09%	3.76%	1.66%	-5.77%
5	Lighting	0.00%	0.00%	0.00%	0.00%	0.00%
6	Electrical and electronic tools	-3.22%	-2.56%	-3.48%	-0.19%	-1.01%
7	Toys, leisure and sports	-0.21%	0.64%	5.09%	3.10%	-4.73%
8	Medical devices	-0.31%	28.20%	-2.08%	0.00%	-13.85%

9	Monitoring and control	-3.76%	-10.37%	-18.04%	4.37%	19.53%
10	Automatic dispensers	0.00%	-1.80%	-0.85%	0.00%	0.00%
11	Displays	-0.39%	0.22%	3.26%	0.28%	-0.02%
12	Cooling	-1.04%	-0.90%	0.03%	-0.47%	0.59%
13	Lamps	-0.44%	-7.41%	-10.10%	-1.41%	-10.74%
14	PV Panels	0.00%	5.31%	-6.49%	-0.02%	-21.14%
	Valpak Total Variation Reported	-0.14%	3.65%	0.45%	2.80%	0.18%

From the compliance schemes registered for the 2019 compliance period (one scheme was delisted in 2018), it was estimated that six operators running nine schemes and responsible for 70% of the total UK targeted household tonnage (PCS Group 1) are most likely to have the resources necessary to verify 80% their members' data submissions, identifying and correcting errors before the end of the compliance period. This means that 20% of the member errors remain unresolved and so remain misreported to the regulators and DEFRA.

Of the remainder (PCS Group 2) it was assumed that they are able to verify 60% of their total obligation. i.e. 40% of member errors are therefore misreported.

Working assumptions about the effectiveness of schemes' and regulators' auditing and checking processes in general were made:

- Out of 4,860[62] producers registered with compliance schemes for household obligations in 2018, 74% (being 70% of obligation with 80% resolution plus 30% of obligation with 60% resolution) would be subject to data review by their schemes during the compliance period
- The regulating agencies will check and audit 20% of registered producers. Any discrepancies will then be resolved by their compliance schemes, so the results are included in the scheme estimates
- 904 producers directly registered in 2018 for household or unknown obligations are subject to the PCS Group 2 levels of misreporting

Results

Using the assumptions above the following are the results in respect of producer compliance scheme members:

[62] https://www.gov.uk/government/publications/waste-electrical-and-electronic-equipment-weee-public-registers

	Category	Valpak - Variations 2014-18			Total UK PCS Obligation 2018 (tonnes)			PCS Group 1	PCS Group 2	
		Mean	Min	Max	Obligation Distribution			70%	30%	
						Error resolution		80%	60%	
						Error Risk		Missed Errors using Mean (tonnes)		Total Errors (tonnes)
1	Large household	1.18%	-0.77%	2.84%	190,171	6,857	3.61%	315	270	586
2	Small household	2.42%	-0.04%	9.62%	37,589	3,633	9.67%	127	109	236
3	IT and telecoms	1.05%	-6.42%	9.79%	51,239	8,306	16.21%	76	65	140
4	Consumer	6.45%	-5.77%	29.09%	41,308	14,398	34.85%	373	320	692
5	Lighting	0.00%	0.00%	0.00%	-	0	0.00%	0	0	0
6	Electrical and electronic tools	-2.09%	-3.48%	-0.19%	19,337	636	3.29%	-57	-49	-105
7	Toys, leisure and sports	0.78%	-4.73%	5.09%	2,377	233	9.82%	3	2	5
8	Medical devices	2.39%	-13.85%	28.20%	26	11	42.05%	0	0	0
9	Monitoring and control	-1.65%	-18.04%	19.53%	184	69	37.57%	-0	-0	-1
10	Automatic dispensers	-0.53%	-1.80%	0.00%	-	0	0.00%	0	0	0
11	Displays	0.67%	-0.39%	3.26%	50,350	1,836	3.65%	47	40	88

12	Cooling	-0.36%	-1.04%	0.59%	138,891	2,267	1.63%	-69	-59	-128
13	Lamps	-6.02%	-10.74%	-0.44%	5,517	568	10.30%	-46	-40	-86
14	PV Panels	-4.47%	-21.14%	5.31%	76	20	26.45%	-0	-0	-1
	Total	**1.39%**	**-0.14%**	**3.65%**	**537,065**	**20,350**	**3.79%**	**1,043**	**894**	**1,937**

An error risk has been calculated by applying the spread between the Valpak minimum and maximum variations and applying it to the total UK schemes obligation. On the assumption that the Valpak results are typical of the absolute of variations across the reminder of UK schemes, this shows that the risk of errors occurring in a given compliance period is ±3.79%. Of this, the proportions assumed above in each PCS group will be picked up and corrected, leaving < ±1,937 tonnes unresolved.

Within these estimates, category-specific errors will vary greatly. In the Valpak data, the largest percentage variations occur in those categories with the smallest obligations.

Of the 904 directly registered producers, their maximum total obligation would be 5t (the upper limit for direct registration) x 904 = 4,520 tonnes. Assuming an error risk of 3.79% and a resolution rate of 60% (so 40% unresolved) the total of unresolved errors would total ±68 tonnes, so insignificant in comparison to the schemes total.

On these assumptions, the UK's total reported producer obligation is subject to losses by unresolved misreporting of up to 2,005 tonnes ((1,937 + 68) / (537,065 + 4,520)) or approx. 3.5%

Appendix IX Misreporting – AATFs Misreporting

Methodology

This section of the report aimed to identify the extent to which AATF misreporting can impact the overall recycling figures reported in the UK.

The reporting of WEEE received for treatment by AATFs is the source of the collection data that underpins the WEEE system. Compliance schemes rely on regular reports and any validating data received from DCFs to report in turn to their contracted collection counterparties (WDAs, DCF operators, etc.), as well as to the regulators.

Errors and omissions may occur in these AATF reports. They are identified by the receiving PCS by sense-checking and verification against any validating data from other sources, such as the records of DCF operators and hazardous waste consignment returns.

To assess the probable effect of these mistakes on the WEEE system, the reporting errors identified in the twelve-month period from October 2018 to September 2019 were reviewed from three of Valpak's larger AATFs. These were selected because of the high number of collection transactions they handled in each month.

There is no reason to believe that these larger organisations are any more prone to making errors or omissions than smaller ones. Indeed, it could be argued that smaller AATFs may be more likely to misreport, however the effect of their errors on the WEEE system is likely to be reduced because of the small quantities they collect and treat.

The results have then been applied to the UK's Scheme targets for 2018.

Analysis

All of the selected AATFs were collecting in more than one WEEE stream, but none collected in categories 13 (Lamp) or 14 (PV Panels). Both these streams are treated in low quantities by a limited number of specialised AATF operators.

Producer compliance schemes were again grouped by a subjective assessment of their operator's organisation and resources in order to estimate their abilities to identify and correct AATF reporting errors. As these reports are the basis for issuing WEEE evidence notes and the payment of monies, it can be assumed that the schemes' level of scrutiny is going to be high. The assumptions for this exercise are:

	PCS Group 1	PCS Group 2
Obligation Distribution	70%	30%
Error resolution	95%	90%

The results are based on the following assumptions:

- Valpak has been able to identify 95% of AATF reporting errors
- Schemes responsible for 70% of the WEEE Received for Treatment at AATFs in 2018 are similarly able to identify this proportion of reporting errors

- Schemes responsible for 30% of the WEEE received for treatment can identify and resolve 90% of reporting errors
- The error and resolution rates are extrapolated to the totals of WEEE Received for Treatment at AATFs in 2018
- The Received for Treatment at AATFs totals in the table below include weights allocated by protocols applicable to LDA and SDA stream collections. For example, the Cat 1 total will comprise 83% separately collected LDAs, 12.67% of the total mixed WEEE collected plus an unspecified element of LDA collected under site-specific, bespoke protocols
- The Mixed WEEE stream E comprises categories 2-10 only
- It should be noted that changes in default protocols for separately collected LDA and SDA loads from DCFs, applicable from 2020, will affect a similar analysis in future.

The relevant changes are:

LDA Loads

- The Category 1 Large Domestic content will increase from 87% to 97.64%
- 1.21% will be assumed to be SDA (Stream E)
- 0.17% will be assumed to be Cooling (Category 12)

SDA Loads

- The Category 1 content will increase from 12.6% to 15.88%
- The Displays content (Category 11) will reduce from 0.95% to 0.915%
- The Cooling content will increase from 0.19% to 0.241%

It is anticipated these revisions will have minimal impact on the overall estimate for misreporting

Results

The table below suggests that there is a likelihood of < ±1.063 Kt (0.2% of WEEE received) that will be erroneously reported by AATFs and not subsequently identified by their contracted compliance schemes.

Stream		Category	Received for Treatment at AATFs 2018 (Kt)		Valpak AATF Error Results					PCS Group 1	PCS Group 2	
								Obligation Distribution		70%	30%	
									Error resolution	95%	90%	
			By Category	By Stream	Mean	Min	Max	Months with Errors	Error Risk (Kt)	Missed Errors using Error Risk (Kt)		Total Errors (Kt)
A	1	Large household	169.586	169.586	20.29%	-14.37%	251.38%	5	14.337	0.502	0.430	0.932
B	12	Cooling	132.149	132.149	-1.45%	-37.91%	8.78%	10	1.601	0.056	0.048	0.104
C	11	Displays	47.158	47.158	0.32%	0.00%	3.10%	2	0.025	0.001	0.001	0.002
D	13	Lamps	4.759	4.759								
E	2	Small household	38.023									
	3	IT and telecoms	45.161									
	4	Consumer	36.576									

	5	Lighting	0.003									
	6	Electrical and electronic tools	17.901									
	7	Toys, leisure and sports	2.201									
	8	Medical devices	0.008									
	9	Monitoring and control	0.149									
	10	Automatic dispensers	0									
				140.021	-0.42%	-8.26%	7.24%	8	0.390	0.014	0.012	0.025
F	14	PV Panels	0.086	0.086								
		Total	**493.759**	**493.759**					**16.353**	**0.572**	**0.491**	**1.063**

The Error Risk has been calculated by multiplying the Mean by the total received for treatment, weighted by the number of months in which errors occurred. It is an absolute value. The Min-Max range was not used as these included the effects of what were considered to be manifest clerical errors. Where these occur they should be easily identified and corrected.

These results suggest that the high volume of LDA arisings and the possible presence of non-WEEE material leads to misunderstandings and misclassification in the reporting of the loads.

The Cooling results seem to reflect the fact that these units are loose-collected and can vary considerably in dimensions and weight. This adds points of potential confusion and opportunities for misreporting. However, they are collected as a hazardous waste and so checks and verifications are likely to be more robust than for LDAs.

The results for Mixed WEEE are a probable reflection of the misunderstanding of what items constitute this stream. An example is in the case of microwave ovens, which should be classified as LDA. If this reclassification occurs at the AATF and is then reported as a separate LDA collection rather than as part of a mixed WEEE load, a discrepancy will arise.

Obligated/Non-obligated Data

WEEE that is obligated is received by an AATF or AE for or on behalf of a PCS. Anything else is deemed to be non-obligated.

There is some doubt that even larger AATFs fully apply the distinction, especially in respect of household and dual-use items received out with pre-existing arrangements with compliance schemes.

Where an AATF operator acquires such WEEE from sources that are not contracted to a PCS, such as from a final holder under a bilateral commercial arrangement, misreporting may occur. In the event that the WEEE is erroneously reported to a scheme, it is highly likely that the error identified: The scheme is unlikely to accept evidence on, or pay for WEEE that it has not previously contracted to accept.

Similarly, where arrangements are made to on-sell the evidence arising to a scheme, any failure to report the collection because it has been erroneously reported as non-obligated WEEE would be quickly identified.

For the purpose of this project it is assumed that any misclassification in the reporting of these collections has no effect on the validity of the totals collected. This is on the premise that although the collection is misreported, it is nevertheless within the official WEEE system.

Appendix X Summary of Exemptions Relating to Waste Electrical and Electronic Equipment in England and Wales

			S2		T11
EWC Code	Description	Occurrence	Storage Limit	Max Duration	Treatment Limit
080318, 150102, 160216, 200139	printer cartridges only		5,000 units	6 months	
080318, 150102, 160216, 200139	printer cartridges only		5,000 units	6 months	
16 02 14	General WEEE without hazardous components		400m³	6 months	1,000tpa
WEEE other than those mentioned in:					
16 02 09	Transformers and capacitors containing PCBs	Most likely to occur in Stream A - LDA	Not permitted		
16 02 10	discarded equipment containing or contaminated by PCBs other than those mentioned in 16 02 09	Most likely to occur in Stream A - LDA	Not permitted		
16 02 11	discarded equipment containing	ODS Coolants occurring in older	400m³	6 months	1,000tpa

	chlorofluorocarbons, HCFC, HFC	fridges and freezers Stream B - Cooling			
16 02 12	discarded equipment containing free asbestos	Old heating equipment (stand-alone radiators) Stream A – LDA	Not permitted		
16 02 13	discarded equipment containing hazardous components other than those mentioned in 16 02 09 to 16 02 12	All	400m³	6 months	1,000tpa
16 02 16	Non hazardous components removed from discarded equipment		400m³	6 months	1,000tpa
20 01 36	discarded electrical and electronic equipment other than those mentioned in:		400m³	6 months	1,000tpa
20 01 21	fluorescent tubes and other mercury-containing waste	Stream D – Lamps Older items in Stream E – Other WEEE	400m³	6 months	
20 01 23	discarded equipment containing chlorofluorocarbons	Stream B – Cooling	400m³	6 months	1,000tpa

20 01 35	discarded electrical and electronic equipment other than those mentioned in 20 01 21 and 20 01 23 containing hazardous components	All	400m³	6 months	1,000tpa

Appendix XI Summary of Exemptions Relating to Waste Electrical and Electronic Equipment in Scotland

			Paragraph 47 _Repair/Refurbishment		Paragraph 48 - Storage	
EWC Code	Description	Occurrence	Storage Limit	Treatment Limit	Max Quantity	Max Duration
16 02 14	General WEEE without hazardous components		50m³	2 tonnes/day	80m³	3 months
WEEE other than those mentioned in:						
16 02 09	Transformers and capacitors containing PCBs	Most likely to occur in Stream A - LDA	Prohibited		Prohibited	
16 02 10	discarded equipment containing or contaminated by PCBs other than those mentioned in 16 02 09	Most likely to occur in Stream A - LDA	Prohibited		Prohibited	

16 02 11	discarded equipment containing chlorofluorocarbons, HCFC, HFC	ODS Coolants occurring in older fridges and freezers Stream B - Cooling	80m³	5 tonnes/day	80m³	3 months
16 02 12	discarded equipment containing free asbestos	Old heating equipment (stand-alone radiators) Stream A - LDA	Prohibited		Prohibited	
16 02 13	discarded equipment containing hazardous components other than those mentioned in 16 02 09 to 16 02 12	All	80m³	5 tonnes/day	80m³	3 months
16 02 14	WEEE other than those mentioned in 16 02 09 to 16 02 12	All	Prohibited		80m³	3 months
20 01 36	discarded electrical and electronic equipment other than those mentioned in:		50m³	2 tonnes/day		
20 01 21	fluorescent tubes and other mercury-containing waste	Stream D – Lamps	Prohibited		50m³	3 months

		Older items in Stream E – Other WEEE				
20 01 23	discarded equipment containing chlorofluorocarbons	Stream B - Cooling	Prohibited		80m³	3 months
20 01 35	discarded electrical and electronic equipment other than those mentioned in 20 01 21 and 20 01 23 containing hazardous components	All	80m³	5 tonnes/day	80m³	3 months
20 01 36	WEEE other than those mentioned in 20 01 21, 20 01 23 and 20 01 35	All	Prohibited		80m³	3 months

Appendix XII WEEE Reported to the EA as Received by AATFs Under T11 Exemption

	2018					2017			
B2C	Total received by all UK AATFs	Total received by EA T11 AATFs	Total reuse by EA T11 AATFs	% of Total received by EA T11 AATFs	EA T11 / Total Rec'd	Total received by all UK AATFs	Total received by EA T11 AATFs	Total reuse by EA T11 AATFs	EA T11 / Total Rec'd
1. Large household appliances	169,585.988	778.230	501.422	20.05%	0.46%	183,589.095	3,680.471	689.031	2.00%
2. Small household appliances	38,022.979	372.215	297.586	9.59%	0.98%	36,744.866	1,359.577	230.081	3.70%
3. IT and telecommunications equipment	45,160.964	1,542.682	597.535	39.75%	3.42%	48,706.905	2,289.688	325.139	4.70%
4. Consumer equipment	36,575.659	93.927	64.782	2.42%	0.26%	39,542.255	1,007.996	83.922	2.55%
5. Lighting equipment	2.557	0.019	0.000	0.00%	0.74%	1.028	0.000	0.000	0.00%
6. Electrical and electronic tools	17,900.784	17.809	8.647	0.46%	0.10%	18,758.894	625.660	56.278	3.34%
7. Toys, leisure and sports equipment	2,200.509	11.017	9.687	0.28%	0.50%	2,331.037	78.014	12.410	3.35%
8. Medical devices	8.358	0.226	0.000	0.01%	2.70%	25.404	0.652	0.000	2.57%
9. Monitoring and control instruments	149.154	1.173	0.000	0.03%	0.79%	150.560	9.583	0.306	6.36%
10. Automatic dispensers	0.153	0.000	0.000	0.00%	0.00%	3.051	0.048	0.000	1.57%

11. Display equipment	47,157.683	354.454	190.200	9.13%	0.75%	54,121.892	2,026.507	356.431	3.74%
12. Appliances containing refrigerants	132,149.345	707.986	188.879	18.24%	0.54%	135,731.797	2,887.177	228.044	2.13%
13. Gas discharge lamps and LED light sources	4,758.782	1.611	0.000	0.04%	0.03%	5,383.564	4.592	0.000	0.09%
14. Photovoltaic panels	86.241	0.000	0.000	0.00%	0.00%	106.407	0.000	0.000	0.00%
Total	**493,759.156**	**3,881.349**	**1,858.738**	**100.00%**	**0.79%**	**525,196.755**	**13,969.965**	**1,981.642**	**2.66%**

	2018					2017			
B2B	Total received by all UK AATFs	Total received by EA T11 AATFs	Total reuse by EA T11 AATFs	% of Total received by EA T11 AATFs	EA T11 / Total Rec'd	Total received by all UK AATFs	Total received by EA T11 AATFs	Total reuse by EA T11 AATFs	EA T11 / Total Rec'd
1. Large household appliances	521.328	0.000	0.000	0.00%	0.00%	769.581	0.024	0.000	0.00%
2. Small household appliances	31.595	0.000	0.000	0.00%	0.00%	55.587	0.002	0.000	0.00%
3. IT and telecommunications equipment	1,159.755	4.850	0.275	7.99%	0.42%	1,075.547	1.907	0.301	0.18%
4. Consumer equipment	32.370	0.000	0.000	0.00%	0.00%	13.269	0.666	0.000	5.02%
5. Lighting equipment	3,274.704	0.000	0.000	0.00%	0.00%	3,465.921	0.000	0.000	0.00%

6. Electrical and electronic tools	172.821	0.000	0.000	0.00%	0.00%	434.748	197.299	152.952	45.38%
7. Toys, leisure and sports equipment	3.570	0.000	0.000	0.00%	0.00%	2.674	0.000	0.000	0.00%
8. Medical devices	180.105	0.468	0.337	0.77%	0.26%	137.127	2.709	0.000	1.98%
9. Monitoring and control instruments	88.583	0.000	0.000	0.00%	0.00%	105.689	0.163	0.000	0.15%
10. Automatic dispensers	120.998	0.000	0.000	0.00%	0.00%	97.532	0.000	0.000	0.00%
11. Display equipment	24.056	0.000	0.000	0.00%	0.00%	67.464	0.034	0.000	0.05%
12. Appliances containing refrigerants	2,591.426	55.377	49.800	91.24%	2.14%	3,156.075	286.876	1.327	9.09%
13. Gas discharge lamps and LED light sources	1.548	0.000	0.000	0.00%	0.00%	4.065	0.012	0.000	0.30%
14. Photovoltaic panels	0.000	0.000	0.000	0.00%	0.00%	0.000	0.000	0.000	0.00%
Total	**8,202.859**	**60.695**	**50.412**	**100.00%**	**0.74%**	**9,385.279**	**489.692**	**154.580**	**5.22%**

	2018					2017			
TOTAL (B2C and B2B)	Total received by all UK AATFs	Total received by EA T11 AATFs	Total reuse by EA T11 AATFs	% of Total received by EA T11 AATFs	EA T11 / Total Rec'd	Total received by all UK AATFs	Total received by EA T11 AATFs	Total reuse by EA T11 AATFs	EA T11 / Total Rec'd
1. Large household appliances	170,107.316	778.230	501.422	19.74%	0.46%	184,358.676	3,680.495	689.031	2.00%
2. Small household appliances	38,054.574	372.215	297.586	9.44%	0.98%	36,800.453	1,359.579	230.081	3.69%
3. IT and telecommunications equipment	46,320.719	1,547.532	597.810	39.26%	3.34%	49,782.452	2,291.595	325.440	4.60%
4. Consumer equipment	36,608.029	93.927	64.782	2.38%	0.26%	39,555.524	1,008.662	83.922	2.55%
5. Lighting equipment	3,277.261	0.019	0.000	0.00%	0.00%	3,466.949	0.000	0.000	0.00%
6. Electrical and electronic tools	18,073.605	17.809	8.647	0.45%	0.10%	19,193.642	822.959	209.230	4.29%
7. Toys, leisure and sports equipment	2,204.079	11.017	9.687	0.28%	0.50%	2,333.711	78.014	12.410	3.34%
8. Medical devices	188.463	0.694	0.337	0.02%	0.37%	162.531	3.361	0.000	2.07%
9. Monitoring and control instruments	237.737	1.173	0.000	0.03%	0.49%	256.249	9.746	0.306	3.80%
10. Automatic dispensers	121.151	0.000	0.000	0.00%	0.00%	100.583	0.048	0.000	0.05%
11. Display equipment	47,181.739	354.454	190.200	8.99%	0.75%	54,189.356	2,026.541	356.431	3.74%
12. Appliances containing refrigerants	134,740.771	763.363	238.679	19.36%	0.57%	138,887.872	3,174.053	229.371	2.29%

13. Gas discharge lamps and LED light sources	4,760.330	1.611	0.000	0.04%	0.03%	5,387.629	4.604	0.000	0.09%
14. Photovoltaic panels	86.241	0.000	0.000	0.00%	0.00%	106.407	0.000	0.000	0.00%
Total	501,962.015	3,942.044	1,909.150	100.00%	0.79%	534,582.034	14,459.657	2,136.222	2.70%

Appendix XIII Household WEEE Received at AATFs by Source

		Household WEEE							
		Returned under Reg43	Returned under Reg50	Received from DCFs	Total Received for Treatment at AATFs		Total Separately Collected	Difference Recd at AATF less Collected	
1	Large Household Appliances	79,784	11,039	78,763	169,586		169,577	9	0.01%
2	Small Household Appliances	692	5,393	31,939	38,023		38,046	-23	-0.06%
3	IT and Telcomms Equipment	603	12,192	32,366	45,161		45,013	148	0.33%
4	Consumer Equipment	212	5,744	30,620	36,576		36,529	46	0.13%
5	Lighting Equipment	-	-	3	3		-	3	100.00%
6	Electrical and Electronic Tools	205	960	16,735	17,901		17,901	-1	-0.00%
7	Toys Leisure and Sports	21	189	1,991	2,201		2,194	7	0.31%
8	Medical Devices	1	4	3	8		6	3	31.36%
9	Monitoring and Control	3	108	38	149		146	3	2.28%
10	Automatic Dispensers	0	0	-	0		0	-0	-31.37%
11	Display Equipment	1,218	4,767	41,172	47,158		47,066	91	0.19%
12	Cooling Appliances	38,196	8,481	85,472	132,149		131,939	211	0.16%
13	Lamps	258	3,518	983	4,759		4,819	-60	-1.27%
14	Photovoltaic Panels	71	9	7	86		87	-1	-0.78%
	Totals	121,264	52,404	320,091	493,759		493,323	436	0.09%
2-10	Mixed WEEE Categories	1,737	24,590	113,694	140,021		139,835	187	0.13%

Appendix XIV Household WEEE Collected under Distributor and Direct Collection Regulations 2012-18

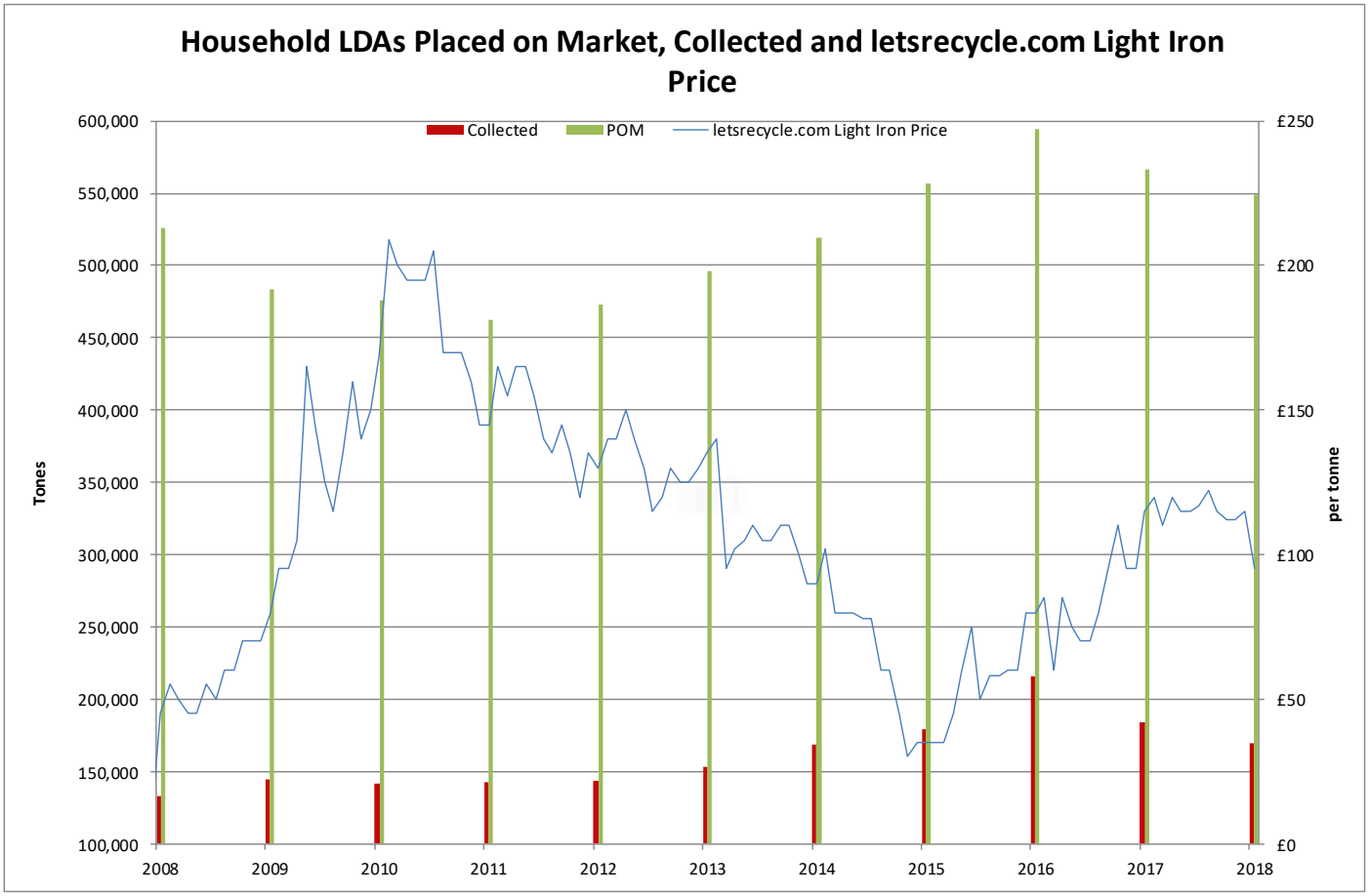
		2012		2013		2014		2015		2016		2017		2018			
	Category Name	R32	R39	R32	R39	R43	R50	R43	R50	R43	R50	R43	R50	R43	R50	Average	
1	Large Household Appliances	20,307	27,091	26,607	14,832	67,410	13,030	62,783	14,116	67,116	32,735	59,550	17,144	79,784	11,039	36,682	66.44%
2	Small Household Appliances	2,682	3,154	1,456	3,894	790	3,048	435	3,852	431	4,632	594	4,443	692	5,393		
3	IT and Telcomms Equipment	1,594	5,219	929	2,691	621	5,572	437	14,200	1,034	16,726	695	14,431	603	12,192		
4	Consumer Equipment	545	4,498	380	3,932	394	5,237	361	6,272	261	7,594	166	7,972	212	5,744		
5	Lighting Equipment	0	0	1	4	0	1	-	1	-	-	-	-	-	-		
6	Electrical and Electronic Tools	1,111	842	814	691	776	950	372	1,405	420	1,078	240	1,359	205	960		
7	Toys Leisure and Sports	127	337	57	301	57	183	43	264	28	257	18	256	21	189		
8	Medical Devices	0	7	0	9	0	6	-	32	-	15	0	19	1	4		
9	Monitoring and Control	9	9	6	8	7	13	1	61	65	72	39	67	3	108		
10	Automatic Dispensers	0	0	-	1	0	6	-	1	0	9	0	0	0	0		
11	Display Equipment	6,639	16,563	4,580	7,342	3,728	4,397	3,134	7,298	1,747	10,727	1,320	5,224	1,218	4,767		
12	Cooling Appliances	14,701	18,571	20,692	10,836	32,621	6,522	28,110	7,156	28,890	6,991	28,408	9,232	38,196	8,481	18,529	33.56%
13	Lamps	47	152	39	112	96	1,076	123	4,262	253	4,532	284	3,791	258	3,518		
14	Photovoltaic Panels					-	-	92	-	-	77	10	69	71	9		
		47,763	76,443	55,560	44,652	106,502	40,041	95,891	58,921	100,244	85,443	91,324	64,007	121,264	52,404	55,211	100.00%

NB

Regulation 32, then 43 - Distributor's right to return HH WEEE to a compliance scheme's (collection and treatment) system

Regulation 43, then 50 - Compliance scheme's arrangements to take back HH WEEE directly into its system

Appendix XV Household LDAs Placed on Market, Collected and Letsrecycle Light Iron Price



Appendix XVI Flows summary table

Recycled, destroyed, exported

Flow	Weight (Kt)	EEE Type Covered	Source	Double count?	Confidence
AATFs	653	All	EA published data (2017) B2B B2C and Non-obligated	No	High
Residual	155	Small Mixed WEEE	Curb side and HWRC sampling by ACORN and MOSAIC profiles, with over 15,000 households assessments (2019)	No	High
Light Iron	215	LDA	Substantiated estimate methodology updated with most recent published records where available (2015/16/17).	No	Medium, representative but dated. Excludes recent research of SDA results.
Legal export	16	Small household, IT & Telecoms, Tools,	DExEU Electronics and Machinery Sector Report (2019) and mapping HMRC	Likely, ITAMS and T11/ATFs	Low, high estimate for Ireland but not including other non-UK markets for EEE

		Medical, Consumer equipment	customs codes to EEE categories (2017)		imported then exported.
Theft	114	Large domestic (90 Kt), categories 2-10 (2 Kt -5 Kt), Cooling (8 Kt), Display (12 Kt).	Modelling LDA & cooling expected to arise in DCF network, but removed or parts stripped before/at DCF (2019). SMW estimates from aggregate of prior studies.	Yes, most in light iron stream, others include; exported or re-use.	Medium, part evidence based assumptions in modelling
ITAMs	90	Mostly B2B IT & telecoms	Market studies (2015) and Stakeholder interviews (2019)	This is split 70% as re-use (back on market UK or overseas) and 30% via AATF	High, representative of greater market share but partly dated market study
C&I (skip)	145	Primarily B2B: Cooling, Toys sports and leisure, Monitoring and control	Anthesis modelling C&I wastes (2017), Welsh Gov't impact assessment for mandatory separation of C&I waste (2018) and stakeholder feedback (2019)	Likely light iron and ITAM	Medium - strong baseline for total C&I and recent study into % of WEEE (modelled on businesses in Wales)
Illegal export	32	All	Basel Action Network (2018) study with proportion attributed to UK. Estimates to Africa 20-25 Kt from	No	Medium, robustness tested by cross reference sources.

			Eurostat & Nigeria e-waste research (2016). (whole item)		
T11/ATFs	5.2	Small Domestic 853T IT & Telecoms 3,535T Displays 812T	New modelling based on data records and interviews with experts (2019)	Unlikely, some possible in-feed to AATF Light iron	Medium, multiple expert inputs to modelling
Warranty returns	102	All	Stakeholder interviews and producer survey responses (2019) and Accenture Returns in Consumer Electronics (2011) WRAP Switched on to Value survey (2016)	Potentially via AATF, but also export and resale	Medium, some anecdotal some aged
DMR	13	Small mixed WEEE	Stakeholder interviews (2019) for average % appearing in larger MRF operators applied to	Yes	Medium, most accounted for in AATF data

Storage and UK reuse

Flow	Weight (Kt)	EEE Type Covered	Source	Double count?	Confidence
Hoarding, retention, redeployment	1,499	All	Scheme surveys, Ipsos Mori research, academic and industry research	Likely, some will be disposed eventually	Medium
Reuse domestic	82	All	Scheme surveys, Ipsos Mori research, academic and industry research	Likely, some will be disposed eventually, double count with hoarding	Medium
Residence time	206	Medical devices, automatic dispensers, AC, monitoring and control	Scheme surveys, Ipsos Mori research, academic and industry research	Likely, some will be disposed eventually	Medium
Commercial reuse	90	All	Industry research	Likely, some will be disposed eventually	Low, not representative
Buildings installed EEE and street furniture	69	B2B; Lighting, Monitoring & controls	Based on all Cat 9 B2B EEE POM	Likely, some will be disposed eventually. Waste into C&I	Low, not representative

Influences on reported volumes

Flow	Weight (Kt)	EEE Type Covered	Source	Double count?	Confidence
Free riders – not in UK POM	46	All	WRAP and Valpak studies 2016 and 2018, OECD 2019	Likely, some will be disposed eventually	Medium, representative category assessments but dated Total POM based on 2012 UNU mapping
Product weight trends	3	Large domestic, small domestic, IT & Telecoms, Consumer equipment, Display and Cooling,	Producer surveys and Stakeholder interview and registered POM modelling (2019)	No	Medium, representative category assessments but low producer representation
Misreporting	+/-3	All	Producer AATF & PCS feedback	No	Medium, adequate sample size and intelligence from large PCS
WEEE reported in the UK and sold in Ireland	- 5	All	HMRC export data Nov & Dec 2017 and 2018	No	Low, likely to be a high estimate assuming all netting off follows EA guidance

Appendix XVII – Gap analysis, data extraction and data harmonisation

17.0 Gap analysis

Phase 1 of the research was the identification and examination of existing data, the parameters and approaches. Keywords were utilised to source relevant research, for example, consumer electronics, electronic and electrical equipment (EEE), Waste of Electronic and Electrical Equipment (WEEE), refurbishment, e-waste, consumer behaviour, hoarding, second-hand and reuse products. Scientific databases and the google search engine were used to interrogate and extract academic articles, white papers and government reports[63]. In addition, the wider project team were consulted for additional information.

The pre-selected documents were reviewed and split into three categories according to the following meanings:

- Relevant = articles that indicate that there are quantitative insights and/or extractable data and/or provide anecdotal insights into flows of second-hand EEE and WEEE flows – the focus was on quantitative insights.
- Useful = articles provide anecdotal insights into EEE and WEEE Flows, quantitative insights are not forthcoming.
- Not relevant = the article does not directly discuss second-hand and/or the parameters are not what we are investigating for this piece of research.

A total of 91 documents were assessed (58 relevant, 24 useful and 9 non-relevant)[64], detailed notes can be found in ***Reuse_Secondhand_WEEE_Gap_Analysis.xlsx***.

17.1 Acquisition of WOT model inputs

UNU-level data for POM was obtained from the WOT1.2 model and can be traced to trade and manufacturing statistics reported via Eurostat as a much more granular level. UNU categories provide sufficient granularity to combine various datasets while retaining individual feature of distinct products such as times in use and fates.

17.2 Data extraction and harmonization

Phase 2 focused on data extraction and harmonization – this process was executed in two parts: **Manual steps** involved systematic literature review, selection of data sources with extractable data, manual data extraction and data classification into our three variables of interest for feeding the WOT model (Residence time, Stock and Fates – definitions in Appendix II); and **Automated step** involved data harmonization across sources, mapping datasets according to granularity and UNU categories level, averaging datasets to UNU level and definition and assignment of confidence scores.

[63] Repositories included are: Emerald Business and Management Journals, Jstor, Science Direct, Scopus, Sage journals, Wiley online.

[64] The documents were published between 2000-2019, covering 40 countries and research dating from 1985 to 2016.

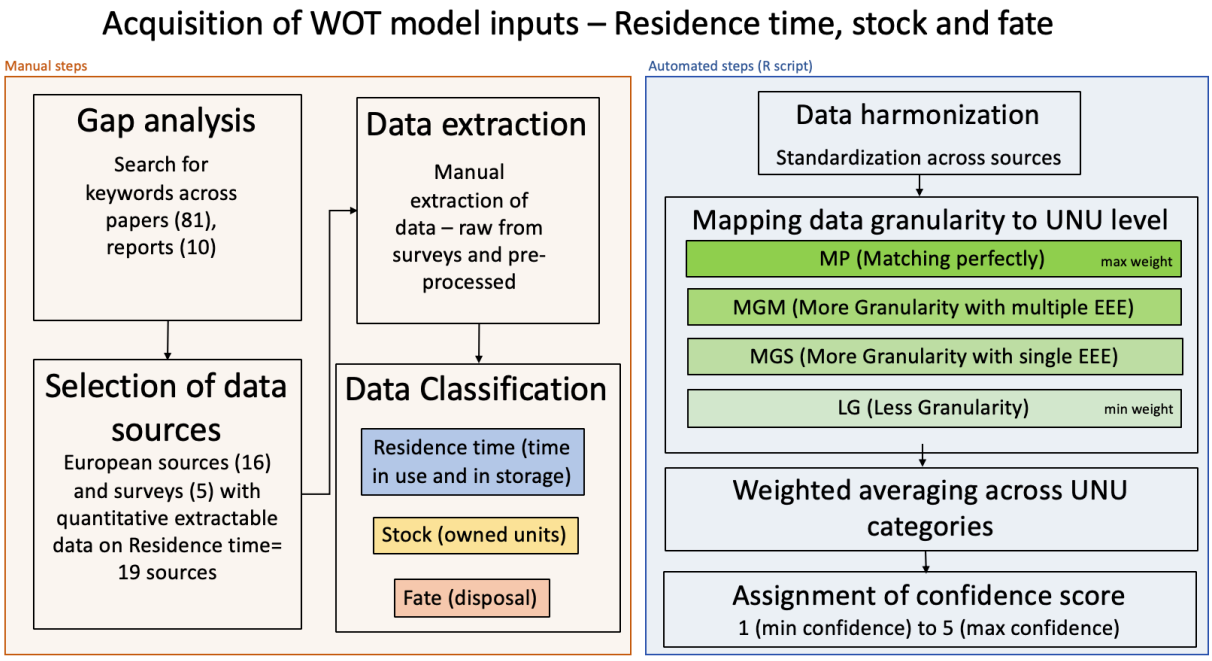


Figure 3 Phase 2 Data extraction and Harmonization

17.2.1 Manual Data Extraction

The manual date extraction began with interrogating the gap analysis for extractable quantitative data sources on products residence time, stocks and fate (Figure 3). Given the limited UK specific quantitative research the data extraction was broadened to include insights from European (16 sources)[65]. To supplement the data, 5 UK wide consumer surveys[66] were sourced on second-hand unreported flows. The detailed notes can be found in ***Data extracted sources.xls***.

All numeric data including raw and pre-processed data was manually extracted from sources. All data reported as frequencies (e.g. counts of TVs per 'time in use' classes as found in Gutiérrez et al. 2010) were considered as raw data; and the data considered as pre-processed are those which summary statistics (e.g. mean, standard deviation, percentiles as found in Pérez-Belis et al. , 2017 and Thiebaud et al. , 2017) or distribution parameters (e.g. Weibull parameters for residence time distributions as found in Gloser-Chahoud et al. 2019) were reported.

Finally, as a last manual task, we separated the products datasets for each source into variable groups: Residence time (time in use and time in storage), Stock (units in use and units in storage) and Fate categories (Donation, General bin, Other, Recycling, Sold, Storage, Take-back scheme, Unknown). At this stage, we assigned to reported products the United Nations University (UNU) product key codes (54).

[65] The countries chosen were deemed to have similar EEE and WEEE practices.

[66] Survey datasets were sourced from Repic Ltd, WEEE Fund and Lancaster University network.

17.2.2 Data harmonization

The next steps were automated into an R code (This is an open source software language for statistical computing and graphics http://www.r-project.org), starting with data harmonization across sources. This involved the data standardization within each data entry group - frequencies, summary statistics, percentiles and Weibull parameters (only for residence time). Next we defined four granularity levels for the UNU categories assigned to the products datasets:

- Matching Perfectly (MP) – when the UNU assigned to a product matched perfectly with UNU definition (e.g. mobile phones in UNU 306)
- More Granularity with multiple products (MGM) – when the UNU assigned to multiple products meaning more granularity than UNU definition (e.g. coffee makers, juicers and kettles in UNU 203)
- More Granularity with Single Product (MGS) – when the UNU assigned to a single product meaning more granularity than UNU definition but other products were missing (e.g. Iron in UNU 201)
- Lower Granularity (LG) – when the UNU assigned to a product with broad definition meaning lower granularity than UNU definition (e.g. Refrigerator in UNU 108 and 109)

17.2.3 UNU level datasets

We averaged MGM datasets (multiple products) within each given UNU category in order to have the datasets at UNU level. We also determined weight values for the granularity levels (MP = 1, MGM = 0.75, MGS = 0.5, LG = 0.5) which were later used in the averaging process across sources for each UNU category. By doing this, within each given UNU category the MP and MGM datasets had more contribution when averaged with MGS and LG. All datasets were transformed into probability distribution functions, which is the required data format to be used as the WOT model input. The probability distribution functions can be found in ***PDFs datasets.xlsx***.

For each and all UNU categories we calculated a confidence score ranging from 1, minimum confidence, to 5, maximum confidence. The scores were calculated based on the following criteria described in Table 2; the original scores were awarded out of 10 and then rescaled to 5:

Table 2 Confidence scores determination.

Criteria	Class	Description	Scores
granularity	MGM_source	More granularity than UNU classification with multiple products within a given UNU category	7.5
	MGS_source	More granularity than UNU classification with single product within a given UNU category	5
	MP_source	Matching perfectly with UNU classification	10

	LG_source	Less granularity than UNU classification	5
data processing level	raw	Data is not pre-processed (frequencies are reported)	10
	pre-processed	Data is pre-processed (statistical parameters are reported)	7.5
number of sources	max	Maximum value for number of data sources	10
	min	Minimum value for number of data sources	1
sample size	max	Maximum value for sample size	10
	min	Minimum value for sample size	1
source age	before 2010	Data source was published before 2010	3
	2010 - 2015	Data source was published between 2010 - 2015	6
	after 2015	Data source was published after 2015	10

A summary of the dataset sources by UNU category, variable group, and their respective confidence scores can be found in ***UNU mapping scores.xlsx***[67].

17.3. Key findings and outputs

The gap analysis results showed that there was limited available research into unreported flows in the UK, especially in regard to commercial reuse. Out of the 'relevant' 3 studies explored commercial reuse and 56 covered households.

17.3.1 Quantitative results

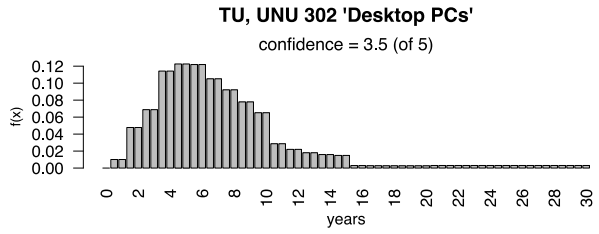
Residence time (time in use and storage) at the UNU categories level

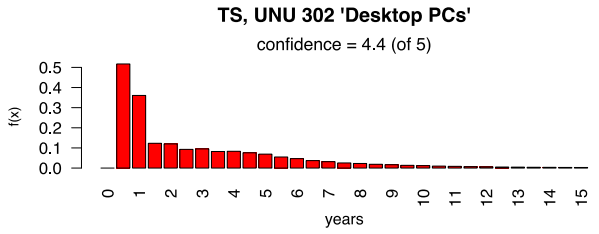
[67] UNU mapping scores do not cover all UNU categories as some of the datasets were not in the required format.

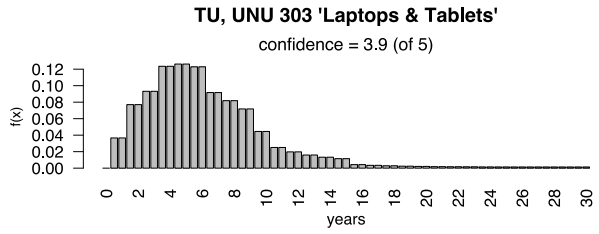
The harmonized probability distributions for time in use and time in storage varied across UNU categories (Figure 4, Figure 5). The TVs (UNU 407 and 408), washing machines (UNU 104), fridges and freezers (UNU 108 & 109) are more likely to be used for longer times than the other products included in the analysis.

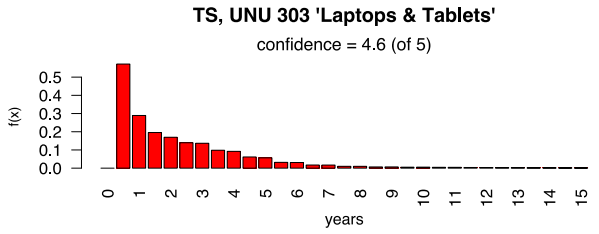
Despite this relevant finding, confidence for fridges and freezers are the lowest, which indicates these products should be prioritized in future research and consumer surveys. Mobile phones (306) and consumer electronics (401) such as headphones and remote controls presented the shortest time in use and longest time in storage, while laptops and tablets (303) are likely to be used and stored for longer periods. The products categories likely to be stored for the least time included Portable Audio & Video (402), Video and projectors (404) and Household Monitoring & Control equipment (901).

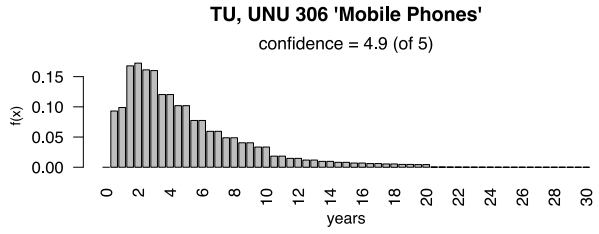
The overall confidence for time in use and storage distributions are 3.5 and 3.9 (of 5) for the 24 and 11 mapped categories respectively, which datasets were extracted and harmonized. For time in use, the categories Small Consumer Electronics, Video and Speakers had the least confidence scores, while Mobile phones, Laptops, Portable Audio & Video, Vacuum Cleaners and Cameras had the highest scores. For time in storage, the categories Small household equipment's, Small Consumer Electronics, Fridges and Freezers had the least confidence scores, while laptops and mobile phones had the highest confidence scores.

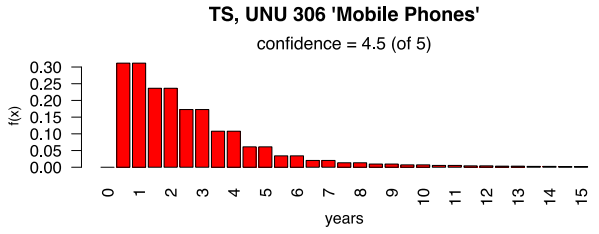


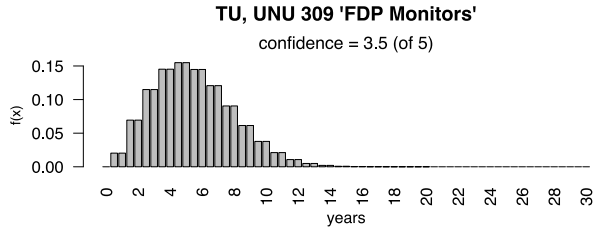


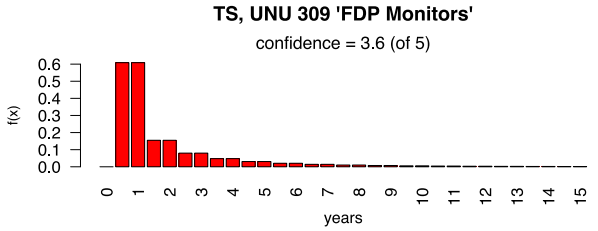









TU, UNU 309 'FDP Monitors'
confidence = 3.5 (of 5)
f(x)
0.15
0.10
0.05
0.00
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
years


TS, UNU 309 'FDP Monitors'
confidence = 3.6 (of 5)
f(x)
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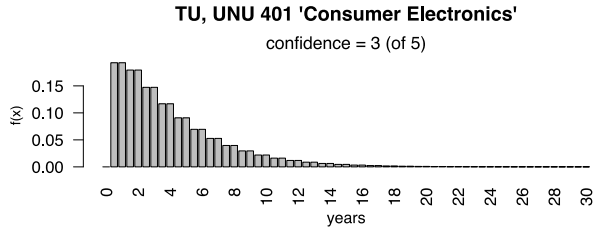
0.5
0.4
0.3
0.2
0.1
0.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
years


TU, UNU 401 'Consumer Electronics'
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0.10
0.05
0.00
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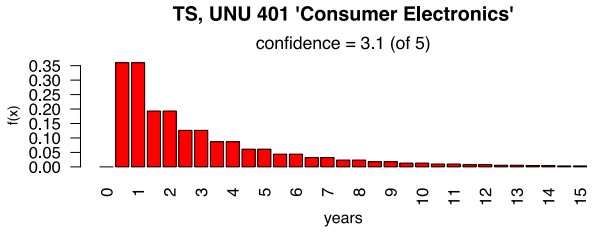
years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0.20
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0.10
0.05
0.00
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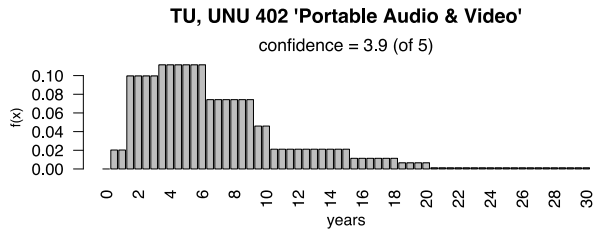
years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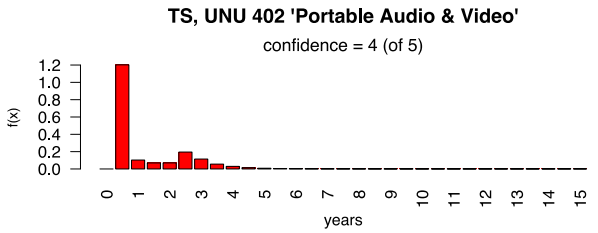
0.08
0.06
0.04
0.02
0.00
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
years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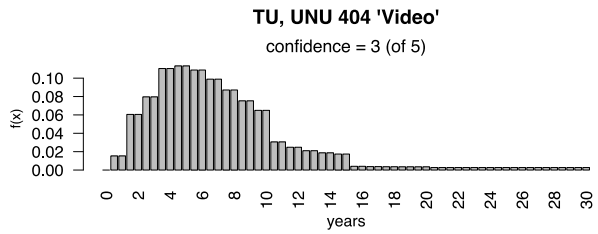
0.6
0.4
0.2
0.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
years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0.06
0.04
0.02
0.00
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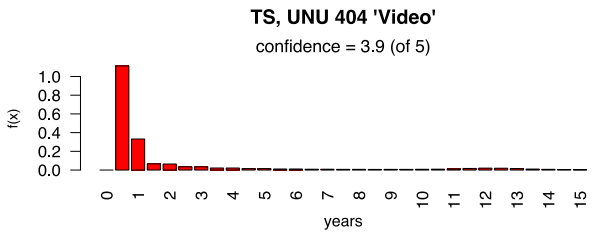
years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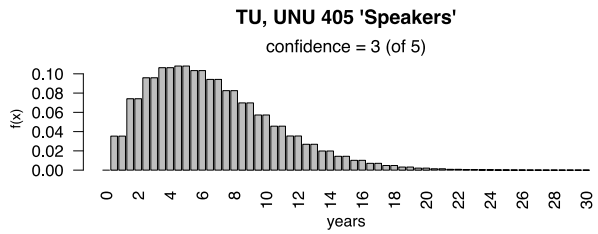
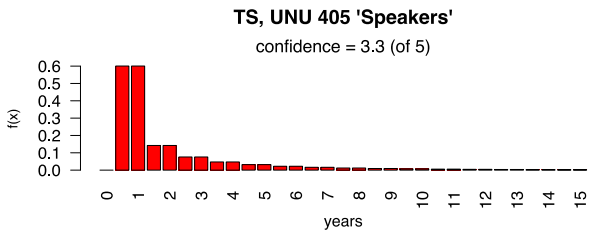
0.8
0.6
0.4
0.2
0.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
years


TU, UNU 405 'Speakers'
confidence = 3 (of 5)
f(x)
0.10
0.08
0.06
0.04
0.02
0.00
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
years


TS, UNU 405 'Speakers'
confidence = 3.3 (of 5)
f(x)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
years

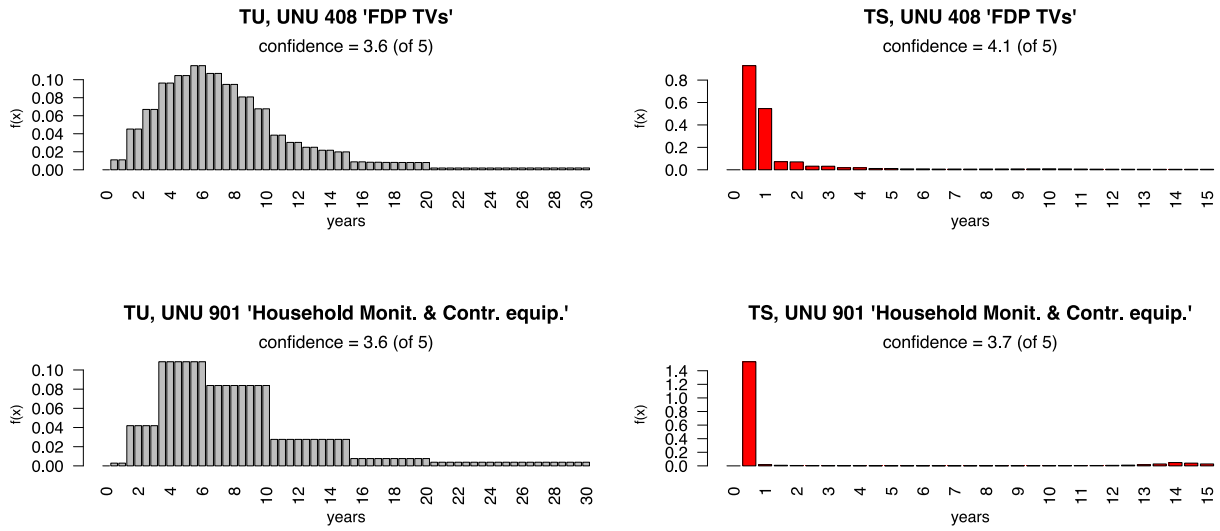
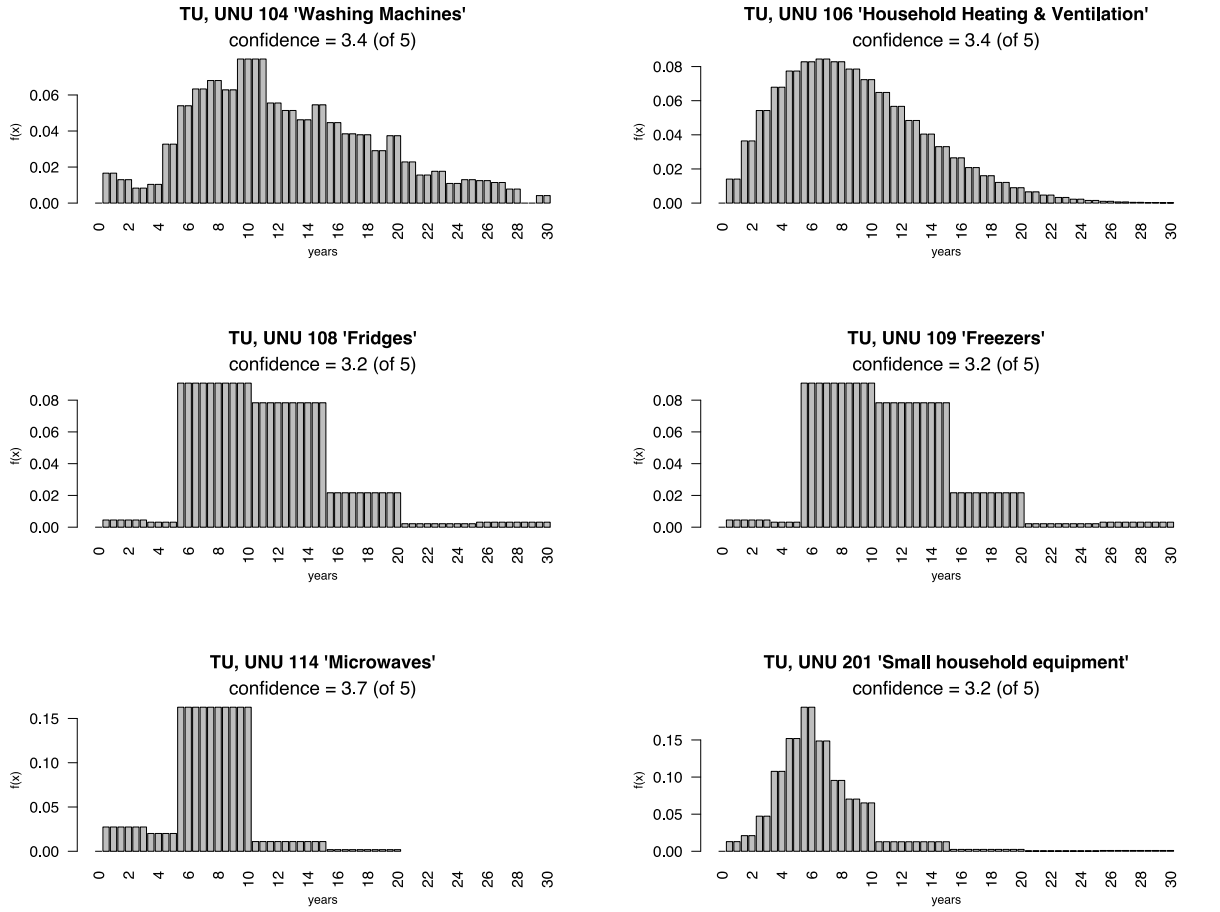


Figure 4 Residence time distributions - time in use (TU) and in storage (TS)



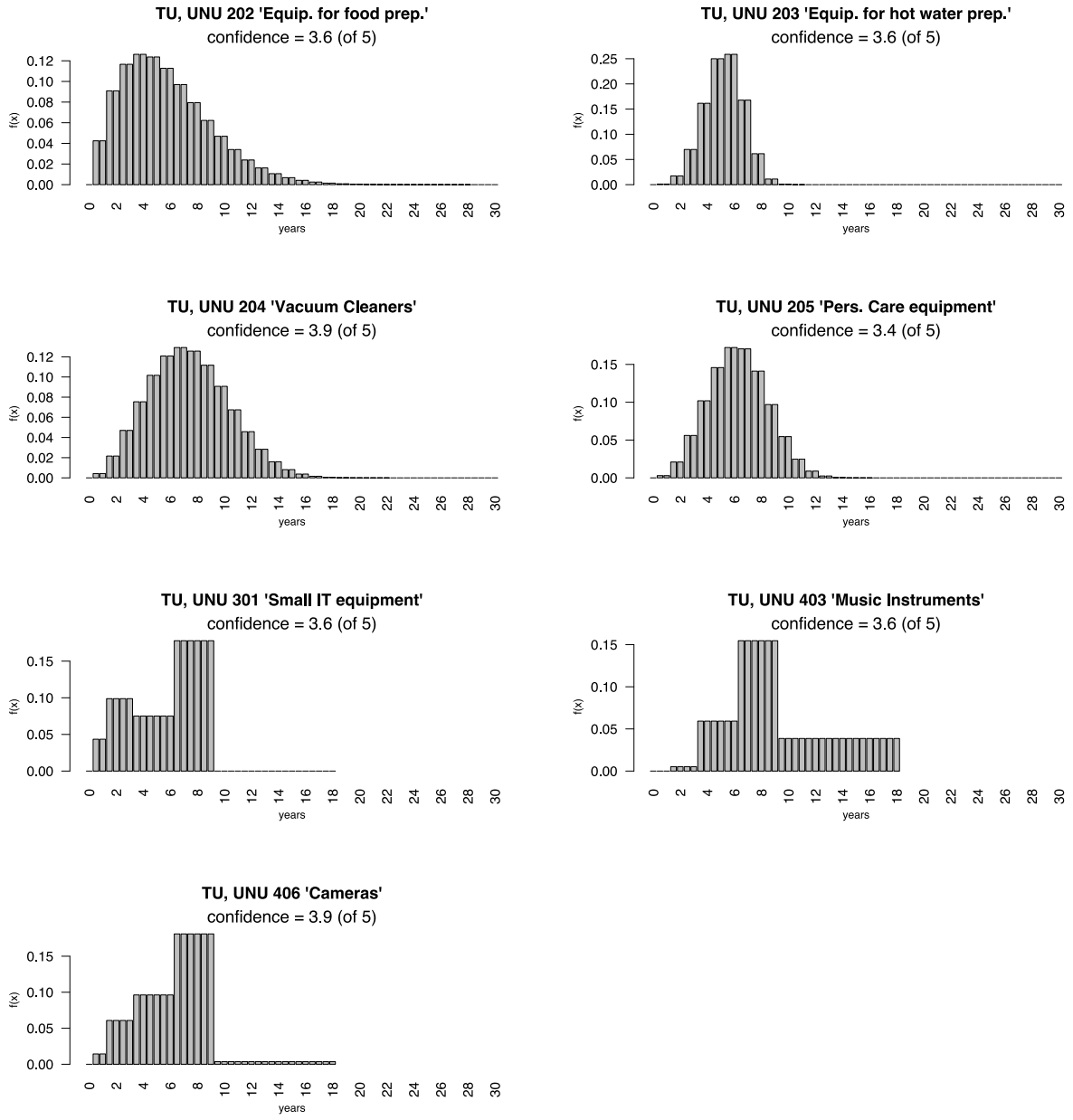
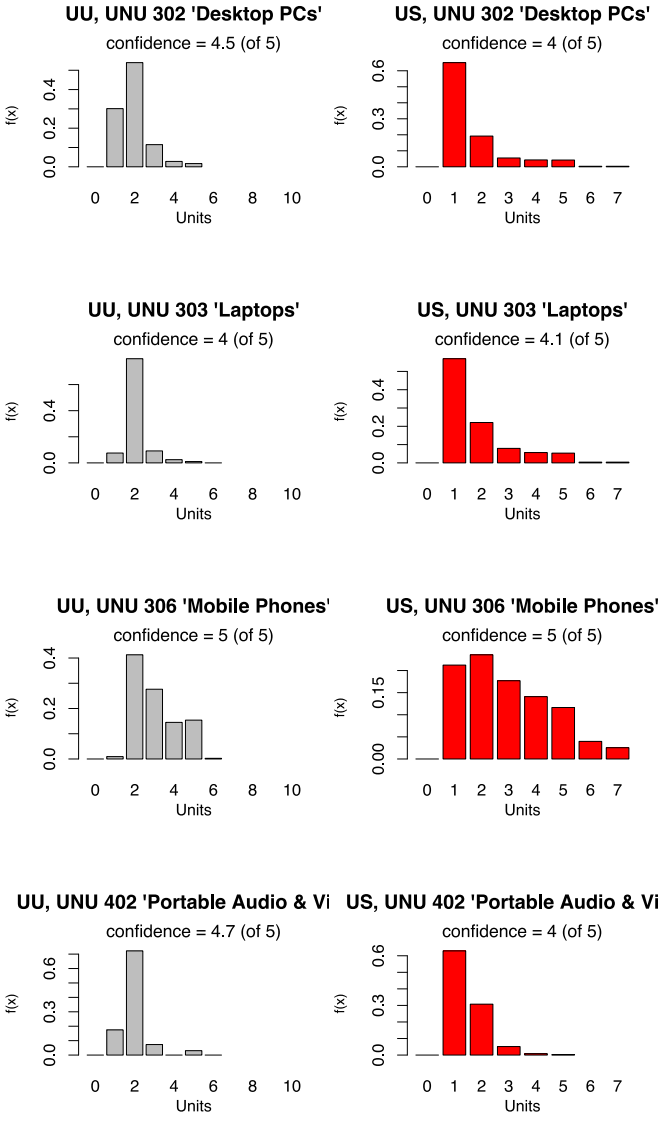


Figure 5 Time in use distributions for UNU categories with no data available for "time in storage"

Stock (Number of units in use and in storage) at the UNU category level

The stock distributions are reported for the number of product units in use (UU) and number of product units in storage (US) in the household. We obtained harmonized stock distributions for 16 UNU categories, from which 7 have data on both, stock in use and stock in storage. For 3 UNU categories there is data only for stock in use, and for other 6 UNU categories only data on stock in storage are available. Overall, the number of **product units in use or in storage is likely to be less than or equal to 2**. However, the stocks distributions varied across UNU categories – for example for video (404) and desktop PCs (302) is less likely that consumers have more than 1 unit in storage than for mobile phones (306) (Figure 6, Figure 7, Figure

8). Our confidence in the harmonized stocks distributions for stock in use is 4.4 and 3.9 for stock in storage. For stock in use, the categories Video, Household Monitoring & Control equipment had the least confidence scores, while mobile phones, laptops and Portable Audio & Video had the highest confidence scores. For stock in storage, the category Video had the least confidence scores, while mobile phones and laptops had the highest confidence scores.



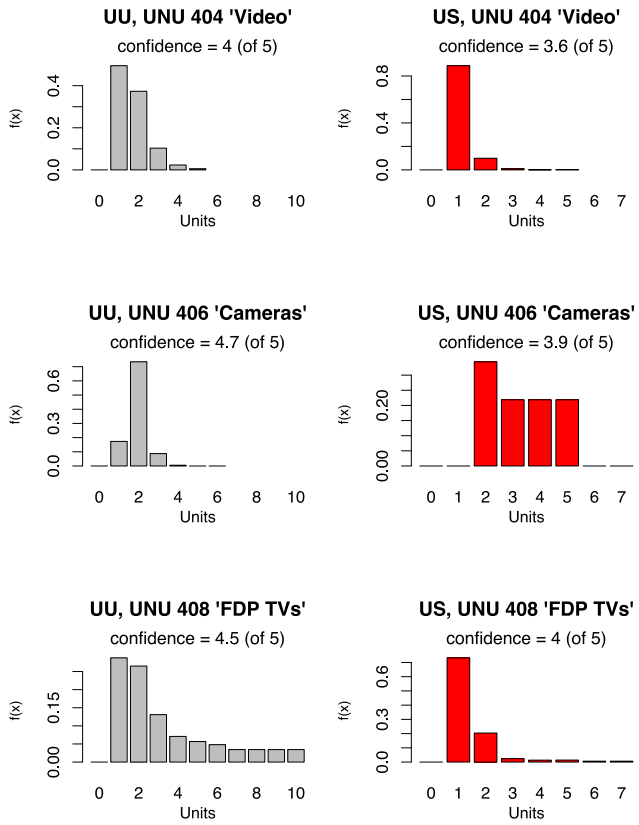
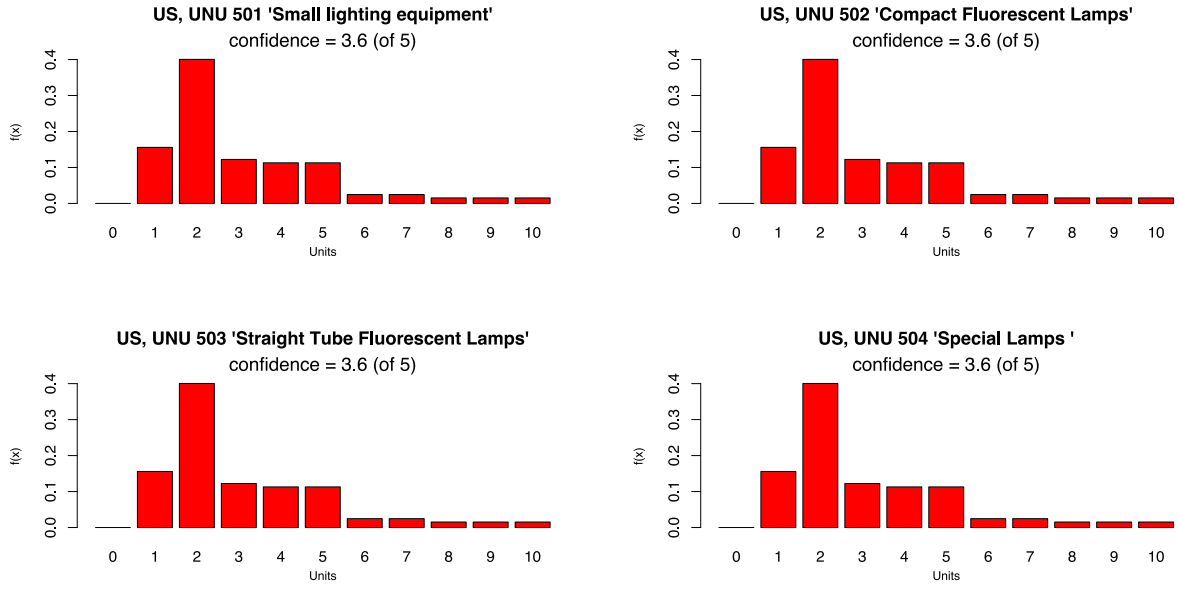
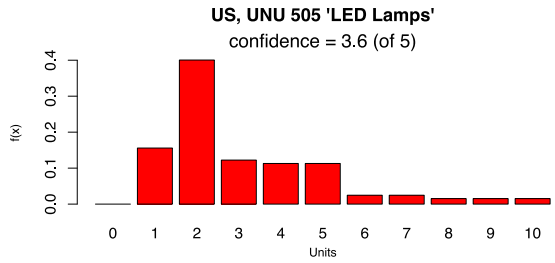


Figure 6 Stock distributions - units in use (UU) and in storage (US)





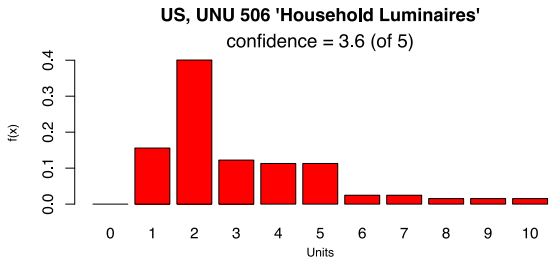
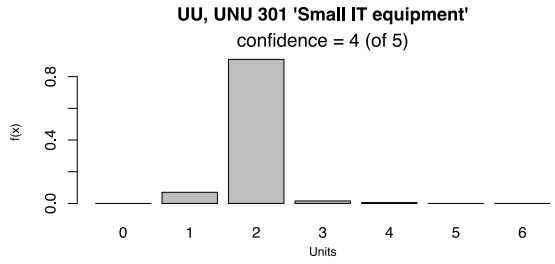
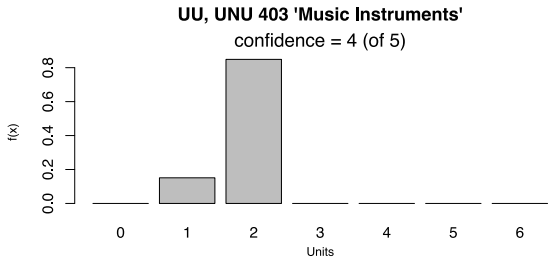


Figure 7 Stock in storage (Units in Storage) distributions for UNU categories with no data available for 'stock in use'.





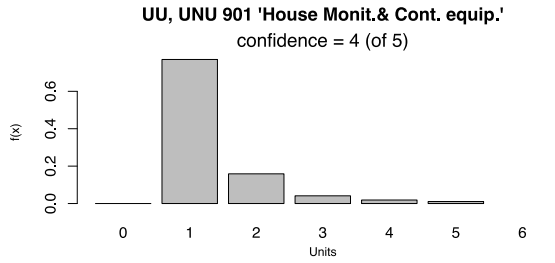
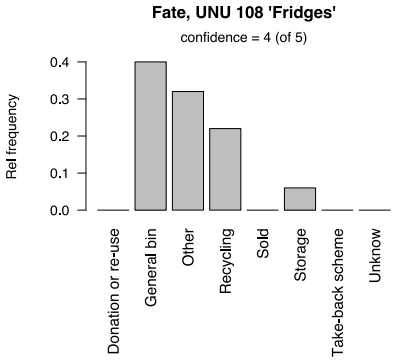
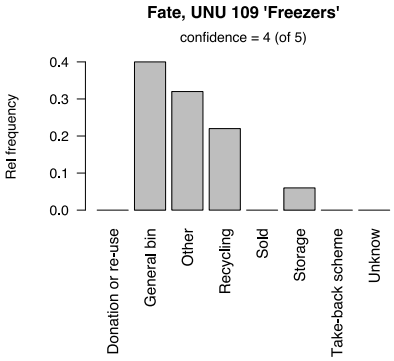


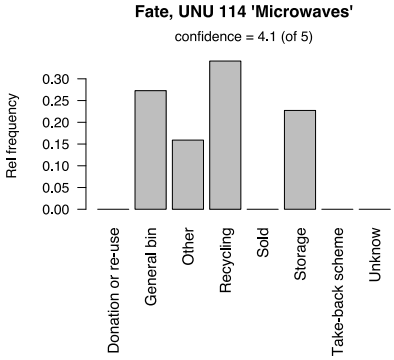
Figure 8 Stock in use (Units in use) distributions for UNU categories with no data available for "stock in storage".

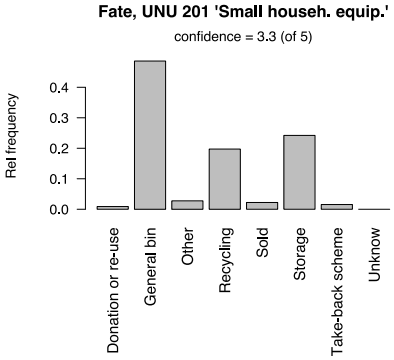
Fate

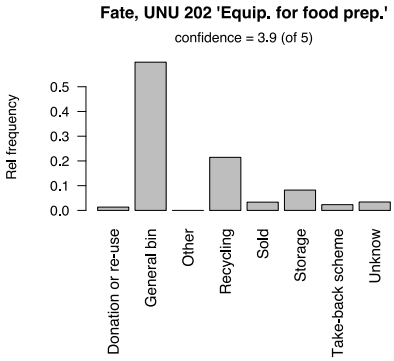
We obtained harmonized relative contribution of 5 fate classes (WEEE disposal destination) selected by consumers for 27 UNU categories (Figure 9). The preferred fate for WEEE disposal greatly varied across the UNU categories – e.g. while 88% of consumers recycle desktop PC's, only 21% recycle vacuum cleaner with 60% of these going to general bin (landfill). The confidence scores varied across UNU categories - Small Consumer Electronics (401) and small household equipment (201) had the least confidence scores, while mobile phones (306) and laptops (303) had the highest confidence scores.

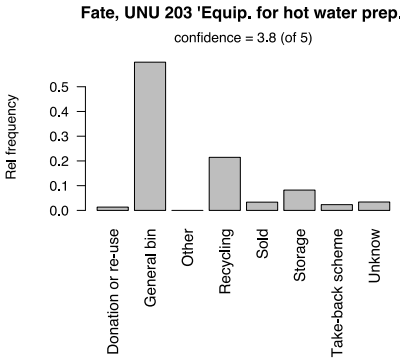

Fate, UNU 108 'Fridges'
confidence = 4 (of 5)
Rel frequency
0.0
0.1
0.2
0.3
0.4
Donation or re-use
General bin
Other
Recycling
Sold
Storage
Take-back scheme
Unknow

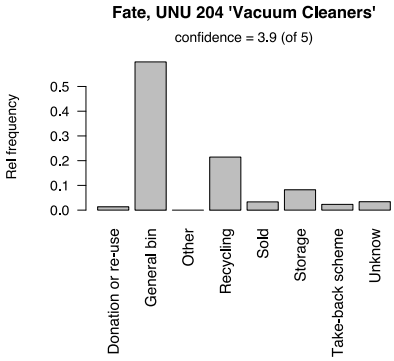

Fate, UNU 109 'Freezers'
confidence = 4 (of 5)
Rel frequency
0.0
0.1
0.2
0.3
0.4
Donation or re-use
General bin
Other
Recycling
Sold
Storage
Take-back scheme
Unknow

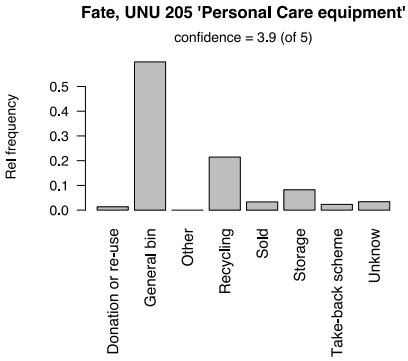

Fate, UNU 114 'Microwaves'
confidence = 4.1 (of 5)
Rel frequency
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Donation or re-use
General bin
Other
Recycling
Sold
Storage
Take-back scheme
Unknow

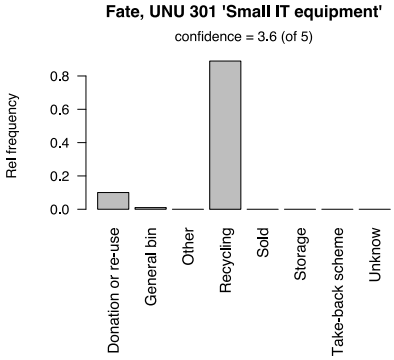

Fate, UNU 201 'Small househ. equip.'
confidence = 3.3 (of 5)
Rel frequency
0.0
0.1
0.2
0.3
0.4
Donation or re-use
General bin
Other
Recycling
Sold
Storage
Take-back scheme
Unknow

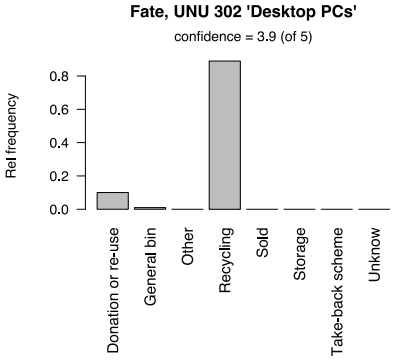

Fate, UNU 202 'Equip. for food prep.'
confidence = 3.9 (of 5)
Rel frequency
0.0
0.1
0.2
0.3
0.4
0.5
Donation or re-use
General bin
Other
Recycling
Sold
Storage
Take-back scheme
Unknow

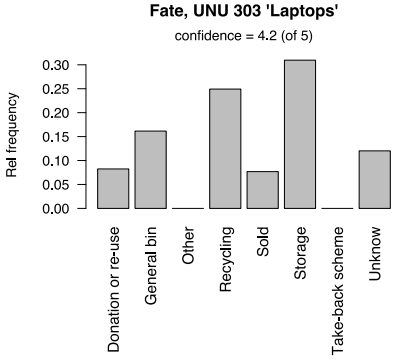

Fate, UNU 203 'Equip. for hot water prep.'
confidence = 3.8 (of 5)
Rel frequency
0.0
0.1
0.2
0.3
0.4
0.5
Donation or re-use
General bin
Other
Recycling
Sold
Storage
Take-back scheme
Unknow

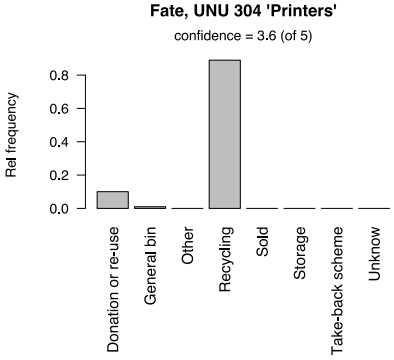

Fate, UNU 204 'Vacuum Cleaners'
confidence = 3.9 (of 5)
Rel frequency
0.0
0.1
0.2
0.3
0.4
0.5
Donation or re-use
General bin
Other
Recycling
Sold
Storage
Take-back scheme
Unknow

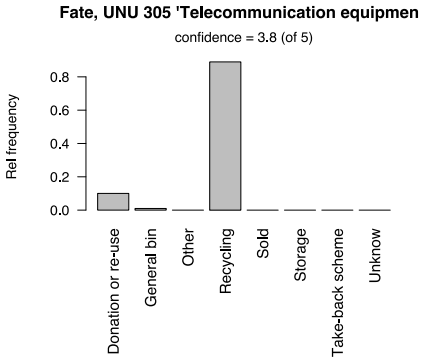

Fate, UNU 205 'Personal Care equipment'
confidence = 3.9 (of 5)
Rel frequency
0.0
0.1
0.2
0.3
0.4
0.5
Donation or re-use
General bin
Other
Recycling
Sold
Storage
Take-back scheme
Unknow

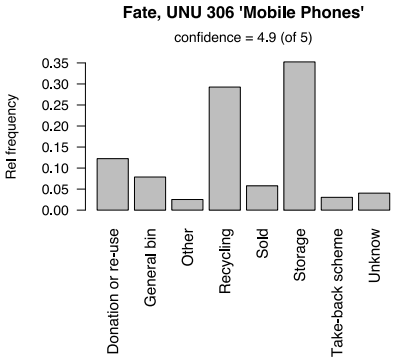

Fate, UNU 301 'Small IT equipment'
confidence = 3.6 (of 5)
Rel frequency
0.0
0.2
0.4
0.6
0.8
Donation or re-use
General bin
Other
Recycling
Sold
Storage
Take-back scheme
Unknow

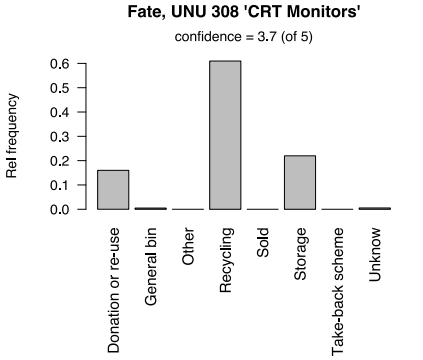

Fate, UNU 302 'Desktop PCs'
confidence = 3.9 (of 5)
Rel frequency
0.0
0.2
0.4
0.6
0.8
Donation or re-use
General bin
Other
Recycling
Sold
Storage
Take-back scheme
Unknow

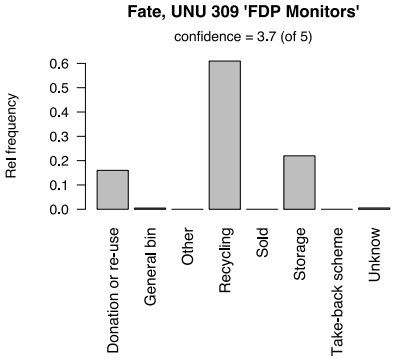

Fate, UNU 303 'Laptops'
confidence = 4.2 (of 5)
Rel frequency
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Donation or re-use
General bin
Other
Recycling
Sold
Storage
Take-back scheme
Unknow

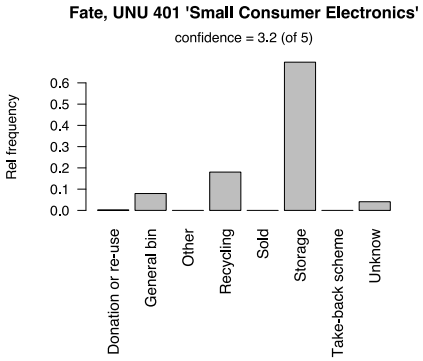

Fate, UNU 304 'Printers'
confidence = 3.6 (of 5)
Rel frequency
0.0
0.2
0.4
0.6
0.8
Donation or re-use
General bin
Other
Recycling
Sold
Storage
Take-back scheme
Unknow

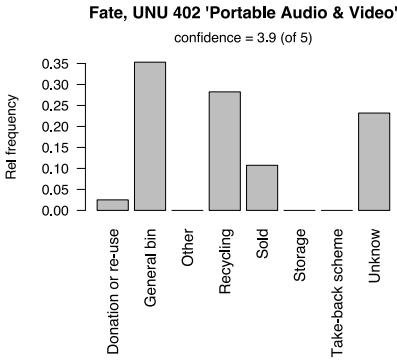

Fate, UNU 305 'Telecommunication equipmen
confidence = 3.8 (of 5)
Rel frequency
0.0
0.2
0.4
0.6
0.8
Donation or re-use
General bin
Other
Recycling
Sold
Storage
Take-back scheme
Unknow

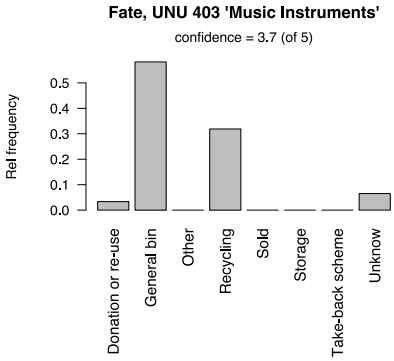

Fate, UNU 306 'Mobile Phones'
confidence = 4.9 (of 5)
Rel frequency
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Donation or re-use
General bin
Other
Recycling
Sold
Storage
Take-back scheme
Unknow

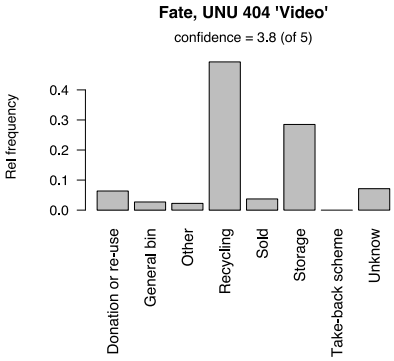

Fate, UNU 308 'CRT Monitors'
confidence = 3.7 (of 5)
Rel frequency
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Donation or re-use
General bin
Other
Recycling
Sold
Storage
Take-back scheme
Unknow

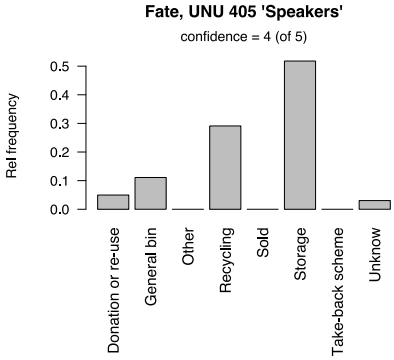

Fate, UNU 309 'FDP Monitors'
confidence = 3.7 (of 5)
Rel frequency
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Donation or re-use
General bin
Other
Recycling
Sold
Storage
Take-back scheme
Unknow

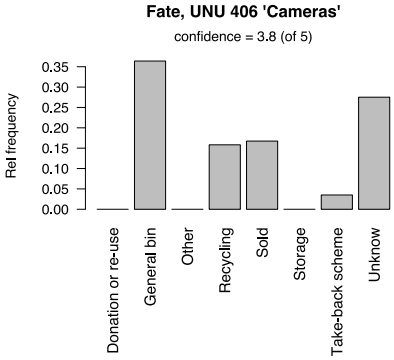

Fate, UNU 401 'Small Consumer Electronics'
confidence = 3.2 (of 5)
Rel frequency
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Donation or re-use
General bin
Other
Recycling
Sold
Storage
Take-back scheme
Unknow

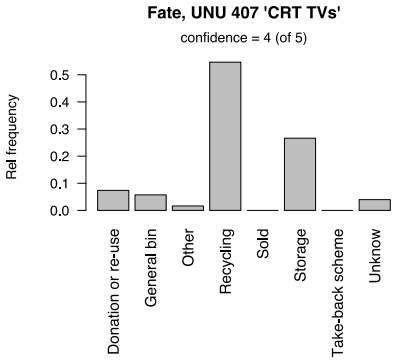

Fate, UNU 402 'Portable Audio & Video'
confidence = 3.9 (of 5)
Rel frequency
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Donation or re-use
General bin
Other
Recycling
Sold
Storage
Take-back scheme
Unknow

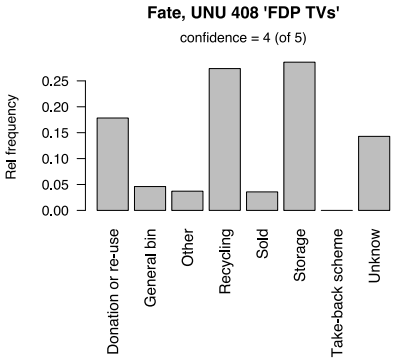

Fate, UNU 403 'Music Instruments'
confidence = 3.7 (of 5)
Rel frequency
0.0
0.1
0.2
0.3
0.4
0.5
Donation or re-use
General bin
Other
Recycling
Sold
Storage
Take-back scheme
Unknow


Fate, UNU 404 'Video'
confidence = 3.8 (of 5)
Rel frequency
0.0
0.1
0.2
0.3
0.4
Donation or re-use
General bin
Other
Recycling
Sold
Storage
Take-back scheme
Unknow


Fate, UNU 405 'Speakers'
confidence = 4 (of 5)
Rel frequency
0.0
0.1
0.2
0.3
0.4
0.5
Donation or re-use
General bin
Other
Recycling
Sold
Storage
Take-back scheme
Unknow


Fate, UNU 406 'Cameras'
confidence = 3.8 (of 5)
Rel frequency
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Donation or re-use
General bin
Other
Recycling
Sold
Storage
Take-back scheme
Unknow


Fate, UNU 407 'CRT TVs'
confidence = 4 (of 5)
Rel frequency
0.0
0.1
0.2
0.3
0.4
0.5
Donation or re-use
General bin
Other
Recycling
Sold
Storage
Take-back scheme
Unknow


Fate, UNU 408 'FDP TVs'
confidence = 4 (of 5)
Rel frequency
0.00
0.05
0.10
0.15
0.20
0.25
Donation or re-use
General bin
Other
Recycling
Sold
Storage
Take-back scheme
Unknow

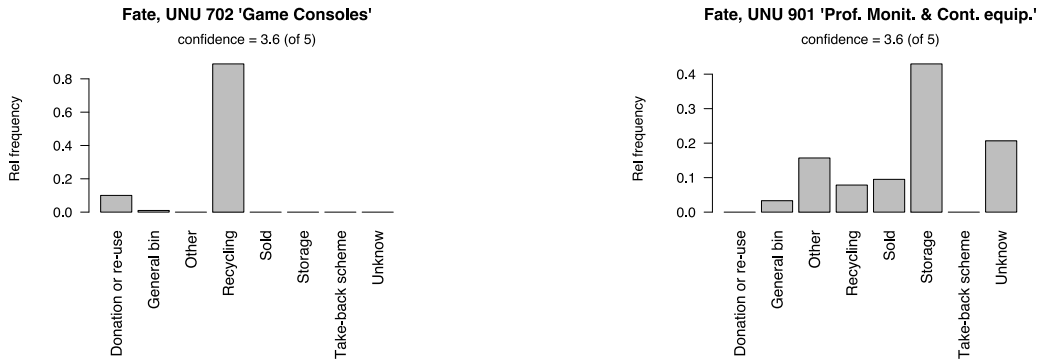


Figure 9 Relative contribution of WEEE disposal fates selected by consumers.

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Gloser-Chahoud S., Adenso-Díaz, B., Lozano, S., González-Torre, P. (2019) Simulating the service lifetimes and storage phases of consumer electronics in Europe with a cascade stock and flow model. Journal of Cleaner Production (213) 1313-1321.

Appendix XVIII: Second-hand flow analysis

18.0 Introduction

The literature on WEEE and second-hand use often relied on household surveys and estimates from producers (***Reuse_Secondhand_WEEE_Gap Analysis Spreadsheet.xlsx***). With the development of the internet, web-based auction and classified advertisement platforms have become a major selling channel for second-hand products. Despite allowing individuals to easily reach a large audience and sell their used EEE products, the platforms provide opportunities to gain insights about the flow and product properties of second-hand products. This report provides insights into the flow of second-hand EEE products in the

UK by looking into the platforms Gumtree and eBay.[68] While eBay is an auction-based platform (with the option to also sell items for a fixed price), Gumtree on the other hand, hosts classified ads where individuals can sell their personal goods. Both platforms are amongst the most popular shopping platforms in the UK (Statista, 2019a; 2019b). In the following, we focus on two research questions.

- How can insights into the product age distribution of second-hand TVs can be gathered?[69] And what does that tell us?
- How does the supply of second-hand product/s evolve at a UK and UNU W/EEE category level?

18.1 Methodology

18.1.1 Product age distribution

eBay sales listing data for LCD models of Samsung, LG, Sony, Panasonic and Sharp were obtained to gather insights into product ages of second-hand TV's (***ebay_dataset.csv***). In 2018, globally those five brands had a combined LCD TV market share of more than 36% (Statista, 2019c), and accounted for more than 60% of TV listings on the 20/12/2019 on eBay UK. The official application programming interface of eBay ('Finding API') offers access to detailed listing information such as text description, price and view count (eBay, 2019). The API allows to track back on completed items for up to three months, i.e. listings that ended with or without sales. In total we obtained 11,614 listings for the five TV brands that ended between the 26/07/19 and 24/10/19. Table 3 shows the brand level listing count as well as the percentage of those listings that ended in sales and the average numbers of bids per listing. The last two columns indicate the number of listings which contained the word "spare parts" and "retro models" and were subsequently removed since the focus is on whole products. This leaves us with a sample of 10,973 listings.

Table 3 Overview of collected completed eBay items between July and October 2019.

	# Listings	Ended with sales	Avg. # bids	# Spare parts	# Retro models
Samsung	4308	88%	7.9	193	22
Sony	2404	87%	6.5	80	86
LG	2328	86%	7.6	151	9
Panasonic	2197	83%	6.1	51	28
Sharp	377	88%	7.3	17	4

Typically, sellers do not directly indicate the product age, nor is there any specific output available in the eBay 'Finding API'. To determine the age of the LCD TV either a model number dictionary or rule-based pattern matching was undertaken using the named-entity recognition of the TV model number. Both the product listing title and the description text to detect any model number match were analysed. With the

[68] Note that Gumtree is also part of the eBay group (FAME, 2019)

[69] The proposed methodology on collecting product age information can readily be expanded to other products if production years are linked to model numbers.

lack of availability of TV model data, and their respective release date, other sources off data were sourced (Table 4). The most reliable way of obtaining the manufacturing year is to decode the model number. In the case of Samsung for example, the 5th digit of the model number UE55F8000AFXZ indicates the production year of 2017 (Samsung, 2019). However, not all producers provide year information in their model numbering or have used inconsistent labelling over the years which makes rule-based pattern matching challenging. To overcome the challenges a in this a dictionary-based approach was adopted where, when possible, a full list of released TV models was obtained. For example, for Panasonic, the model introduction year was scrapped using 'RSelenium' from their online manual library (Harrison & Kim 2019; Panasonic, 2019). In all other cases, model lists were sourced from online review portals and took the review publication date as an age indicator (PRAD, 2019). The column "detection rate" in Table 4 indicates the percentage of identified product age across all listings for each brand, i.e. the sample further analysis is carried out on. Thus, listings with no year identified either had no model number mentioned or not been recognised by the algorithm. To further increase the detection rate, TV models were manually added to the dictionary when there was a high number of similar unidentified model numbers. For example, some TVs sold on eBay seemed to originate from the Asian or US production line and were not reflected on the PRAD review list. In these cases, the corresponding US or Asia model number using the same release date as the European version was manually added.

Table 4 Overview of age identification methodology and classification rate.

	Sample Size	Age data source	Algorithm	Detection rate	Avg. age
Samsung	4093	Model number	rule-based	37%	5.1
Sony	2238	PRAD reviews	dictionary-based	58%	8.4
LG	2168	Model number	rule-based	43%	3.7
Panasonic	2118	Manual library	dictionary-based	67%	8.4
Sharp	356	PRAD reviews	dictionary-based	51%	6.8

To calculate the weight of the observed and identified sample of eBay listings, the screen size was first extracted from the model number and then multiplied with a weight/inch ratio of the TV from data sourced from one of the TV brands products weights. The weight of an LCD screen has changed substantially over the years as shown in Figure 10. As the obtained TV weight data only covers the year from 2006 and 2017. With the limited data available, an assumption had to be made where it was assumed the weight was

unchanged before and after our observed weight ratio. All analysis and calculations are done using R programming language v. 3.5.1 (R Core Team, 2018).

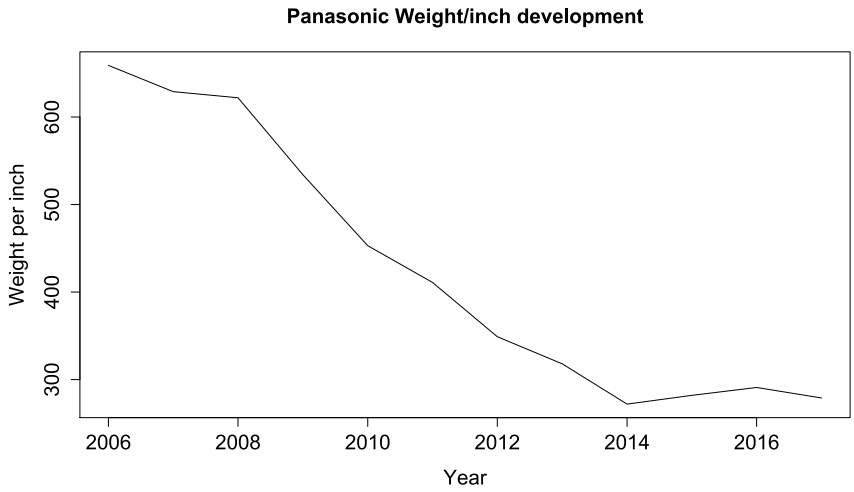


Figure 10 Weight development of LCD TVs.

18.1.2 Trend analysis of second-hand platforms

Two data sources were used to gain insights into the second-hand market. The first data source came from Gumtree that included daily listings data for all available Gumtree categories from 01/01/2016 through 17/09/2019 (***Gumtree_dataset.csv***). The second data source used was from Google Trends, a service by Google, that reports the popularity of search keywords.

The first step was to allocate and aggregated all relevant Gumtree categories to the investigated UK WEEE categories (1, 3, 4, 6, 11 & 12) and UNU category numbers (in brackets) as shown in Table 5. To visualise the trend development for each of the UNU and UK categories over time, classical time series decomposition (Ord et al., 2017), as implemented in the R package "tsutils" (Kourentzes, 2019), was used. To make the trends for the different categories comparable, a re-scaling of values between 0 to 100, relative to their own maximum observed value.

Table 5 Mapped Gumtree categories into the UK (UNU) categories.

UK Category 1
blenders (103); bread makers (103); cookers (103); dishwashers (102); hobs (103); microwave & ovens (114); home appliances (103); ovens, hobs & cookers (103); rice cookers (103); slow cookers (103); tumble dryers (105); washer dryers (105); washing machines (104)
UK Category 3
answering machines (305); atari (302); blackberry (306); cables & connnectors (301); calculators (301); memory cards readers (301); copiers (307); desktop & workstation pcs (302); electric keyboards (301); faxes (304); hard drives & external drives (301); home phone, cables & adapters (305); home phone sockets (305); htc (306); iphone (306); keyboards, webcams & mice (301);

label markers (304); laptops (303); macs (302); memory, motherboards & processors (302); mobile phone cables & adapters (306); mobile phone chargers & docks (306); mobile phone headsets (305); modems, broadband & networking (307); motorola (306); nokia (306); home phone accessories (305); mobile phones (306); printers (304); printers & scanners (304); routers (307); samsung (306); scanners (304); server (307); shredders (307); siemens (306); sony ericsson (306); tablets, ebooks & ereaders (303); tablets, ebooks & ereaders accessories (301); video & sound cards (301); walkie talkies (305)
UK Category 4
amplifiers (403); dj-equipment parts & accessories (403); dj-mixers (403); midi controllers (403); midi-interfaces (403); blu-ray-films& tv (404); blu-ray players & recorders (404); camcorders & video cameras (406); camera cables & adapters (406); camera replacement parts & tools (406); cb & radios (403); compact stereos (403); digital camera accessories (406); digital cameras (406); dvd players (404); guitar & bass amplifiers (403); guitar & basse effects (403); ham amatuer radios (403); headphones (403); hi-fi-separates (403); ipods (403); karaoke-equipment (403); minidisc-discman (403); mobile phone audio docks-speakers (405); mobile phone car speakerphones (405); monitors & projectors (404); mp3 players (403); multimedia projectors (404); non-digital cameras (406); dj-equipment accessories (403); radio-equipment (403); stereo audio (403); stereos accessories (403); studio equipment (403); tv & dvd cameras (404); tv, dvd & vcr accessories (404); pdas handhelds (402); portable dvd & blu-ray-players (404); radio parts accessories (403); record players turntables (403); recorders (403); satellite cable equipment (404); security surveillance systems (404); sega (404); speakers (405); speakers monitors (405); microphones (403); radios (403); stereo-systems (403); studio parts & accessories (403); surveillance cameras (404); synthesizers (403); tv projectors (404); tv reception & set-top boxes (404); vhs films & tv (404); video game motion sensors cameras (404); video games controllers (404); video recorders (404)
UK Category 6
chainsaws (601); garden-shredders (601); generators (601); grass-trimmers (601); grinders (601); hedge-trimmers (601); lawn-mowers (601); lawnmowers-trimmers (601); leaf-blowers-vacuums (601); other-garden-power-tools (601); other-power-tools (601); polishers (601); power-saws (601); power-screwdrivers (601); power-tool-combo-kits (601); power-tool-drills (601); power-tool-sets (601); pressure-washers (601); rotary-hammers (601); screwdrivers-nut-drivers (601); soldering (602); welding-equipment (602)
UK Category 11
televisions, plasma & lcd tvs (408)
UK Category 12
air-conditioners (111); air-purifiers-dehumidifiers (112); freezers (109); fridges-freezers (108)

Google Trends has been widely used to explain economic and social behaviour that allows results to be filtered on a regional level and allow direct comparison between and up to 5 keywords. To make queries more robust, it is also possible to combine multiple keywords or use topic search which automatically takes into account several related keywords (Schaer et al., 2019). Two types of queries were conducted. The first query combines the keywords "refurbished + second-hand + preloved" to estimate the interest in potential second-hand products. The second query looks into the comparison of the search interest into identified second-hand platforms. These include eBay, Gumtree, eBid, preLoved, Cash Converters and Vivastreet. The result Google Trends returns the relative interest into a keyword. It is peak scaled to its own maximum value (scale 0 to 100). If multiple keywords are included, all queries will be scaled relative to the highest value amongst all queries.

18.3 Results

18.3.1 TV product age distribution on eBay

Figure 11 and Figure 12 presents the observed age distribution amongst the five investigated TV brands on eBay according to the corresponding annual numbers of units and tonnages. In addition, the histograms in blue illustrates the average age distribution amongst all five TV brands. We can see that the age of second-hand TVs advertised on eBay is relatively consistent between 1 and 12 years old. It is significantly less before and after. The availability of the LCD technology could also account for the sharp decline for older devices. There were some observable differences between the brands. Despite, being the largest and third-largest producer, LG and Samsung have a substantial younger product age represented on eBay. Panasonic, on the other hand, has some particularly strong years. Again, those might be some of the last remaining plasma TV models.

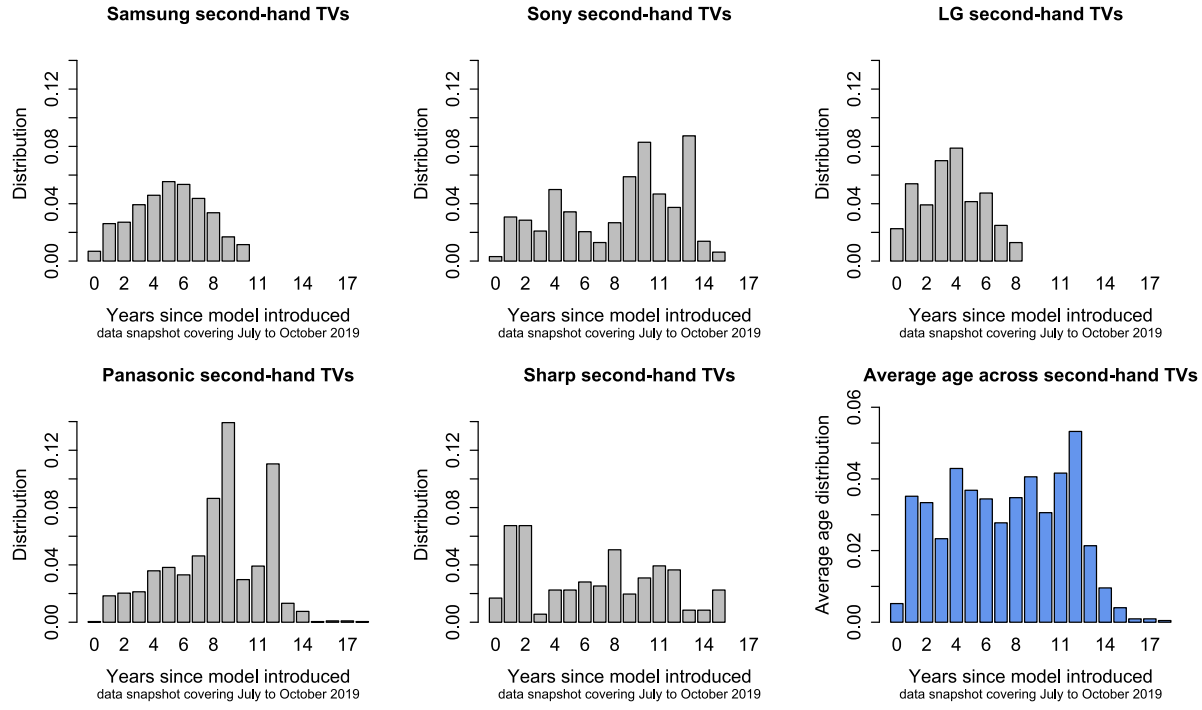


Figure 11 Age distribution of second-hand TVs listed on eBay.

As indicated in the methodology Section, investigations into the associated weight of each models was undertaken. Using the weight by screen size and age, the total weight from all our identified and classified TVs is around 74 tons. The overall distribution by age is highlighted in the blue histogram in Figure 11. The remaining plots show the individual brands. Our identified sample accounts for 48% of the listings of the full sample retrieved from eBay (Table 3). Assuming a similar weight distribution for the remaining sample indicates that the five brands account for about 150 tons listed on eBay over 3 months. On a yearly basis, this would total around 600 tons. However, since we do not have any insights about potential seasonal changes during the year, this figure is surrounded by high levels of uncertainty. Our suggestion is to undertake a broader and more longitudinal study at the listing level. Ideally, covering multiple second-hand platforms and broader range of UNU categories for a longer period of time.

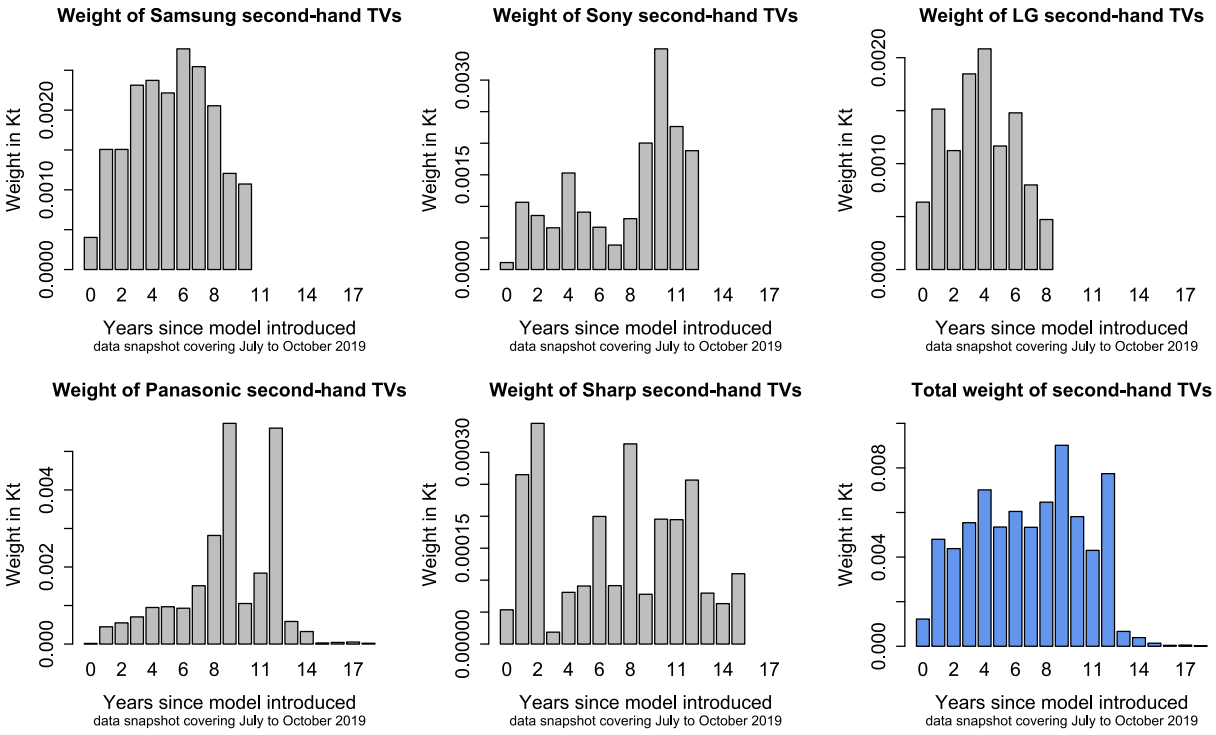


Figure 12 Weight distribution of second-hand TVs on eBay (units: Kt/yr).

Trend analysis of second-hand platforms

When looking into the search popularity from Google Trends on the combined second-hand keywords, a decline in interest since 2014 was observed (Figure 13, left). A similar pattern can be seen when comparing second-hand platforms (Figure 13, right). eBay and Gumtree are dominating the search popularity that even the combined search interest of all other identified platforms is neglectable. In relative terms, between 2016 and 2019, eBay and Gumtree lost 25% and 50%, respectively. However, one has to keep in mind that this kind of information might be subject to other forces that change the Google search behaviour not taken into consideration such as the popularity of Google itself or change in user behaviour.

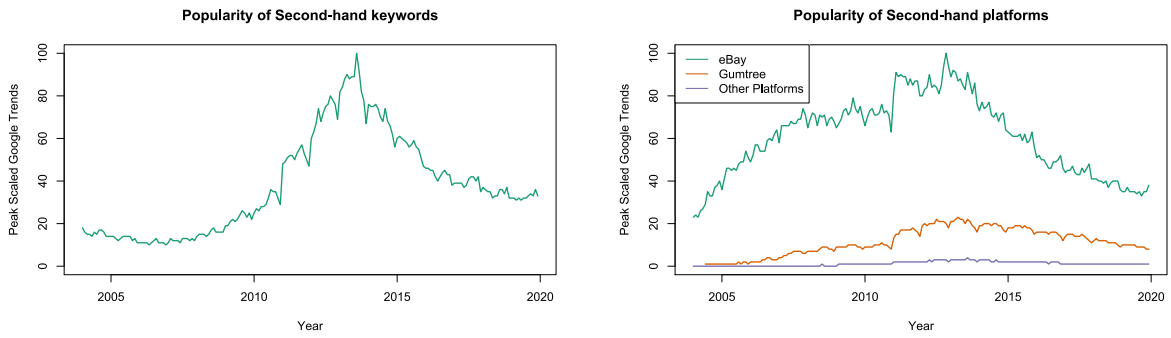
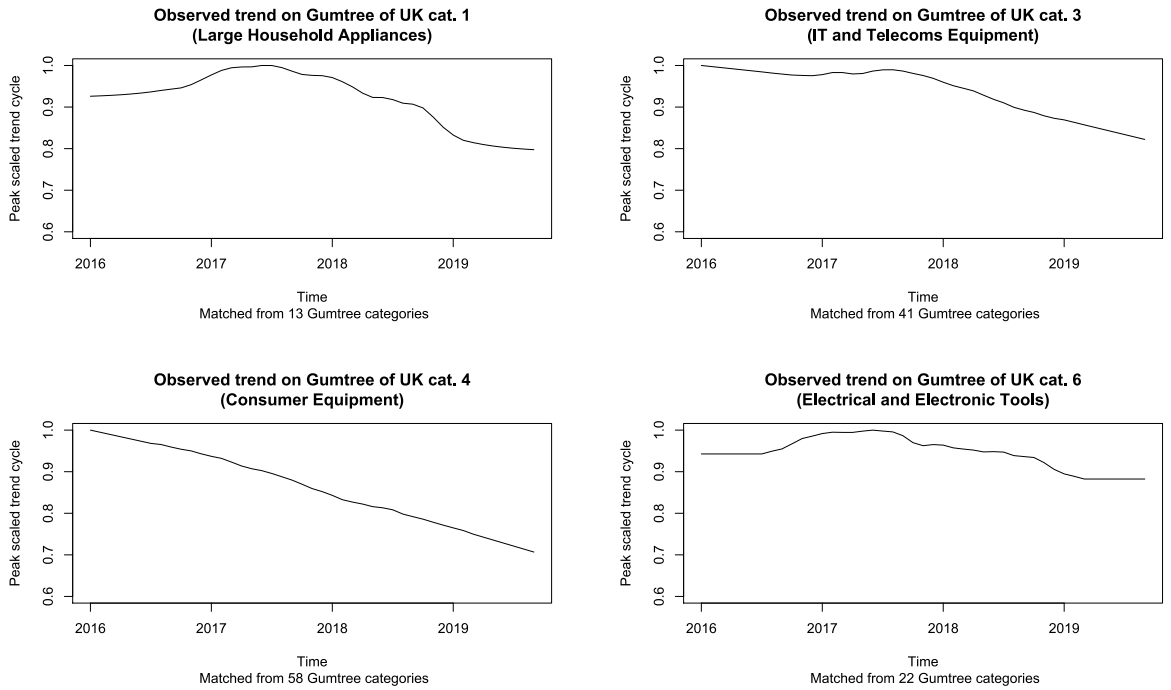


Figure 13 Google Trends popularity of second-hand and second hand-platforms.

Figure 14 shows the observed trend from the aggregated Gumtree categories on the UK level. The number of Gumtree categories used for each UK category is indicated below each graph. Similar to the Google Trend data, the trend value was peak scaled to have a simpler comparison. In this comparison, they show a relative change over time, e.g. a value of 0.6 corresponds to 60% of the maximum observed value. The results show that since 2016, all categories have observed a decline in numbers of listings at Gumtree. The biggest decline came in the consumer equipment category, where the relative number of listings declined by roughly 30%. The most stable categories are display (UK Category 11) and electronic tools (UK Category 6). **Error! Reference source not found.** shows the absolute numbers of listings that our data observed for both the UK and UNU categories.



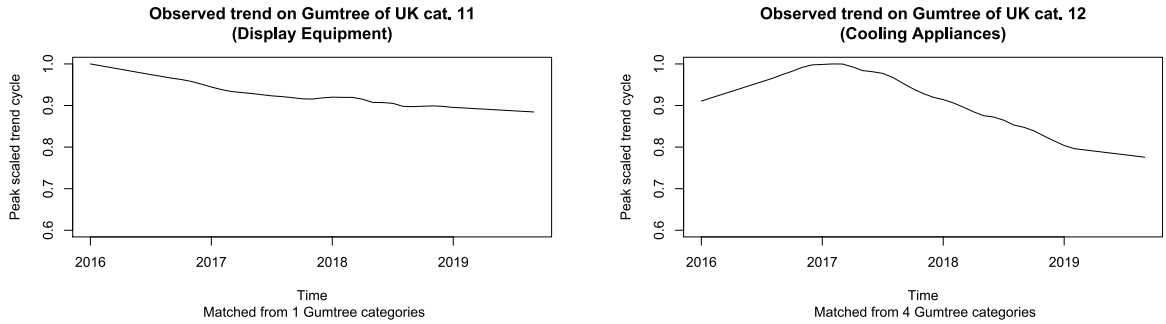
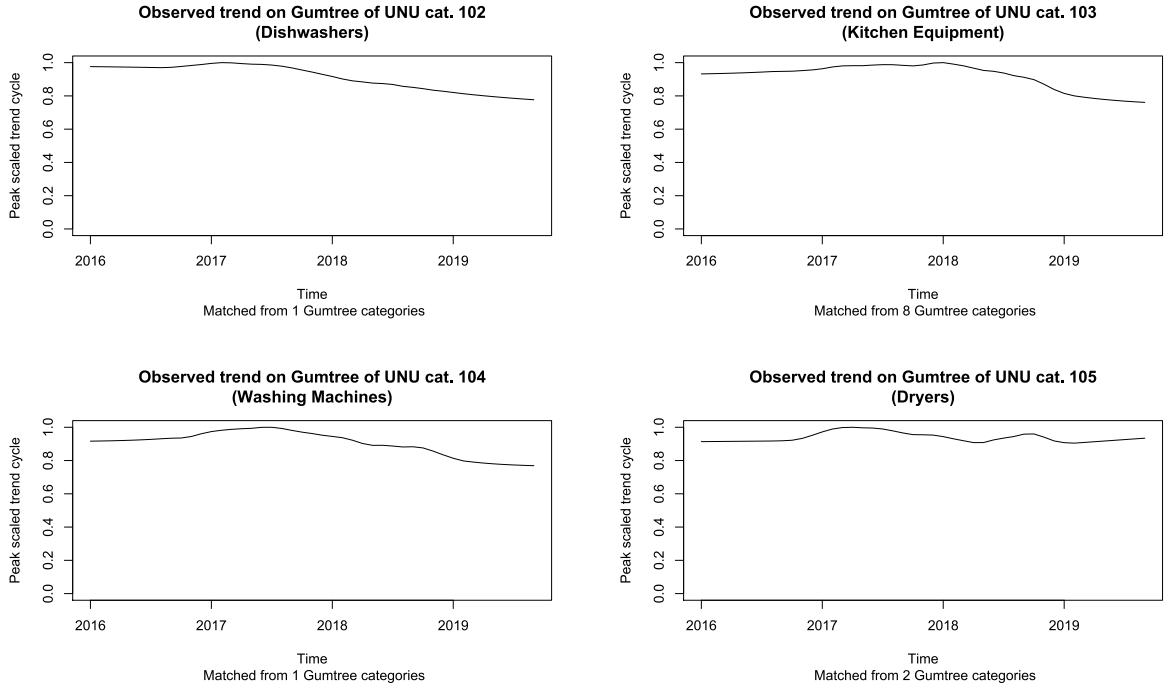
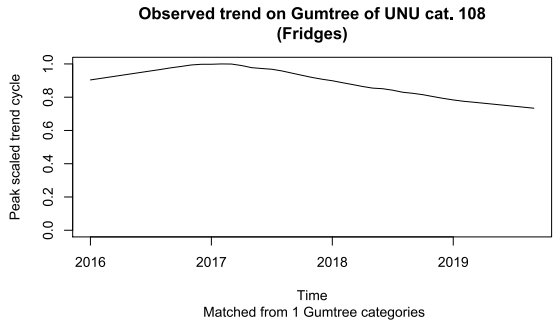


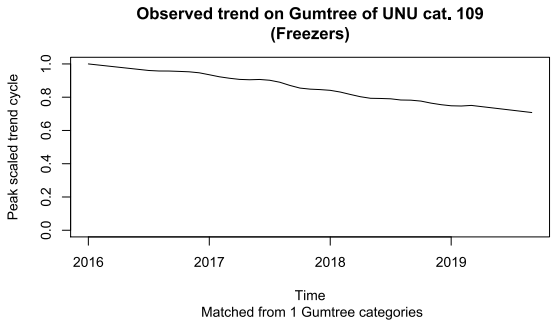
Figure 14 Trend of WEEE UK matching categories on Gumtree.

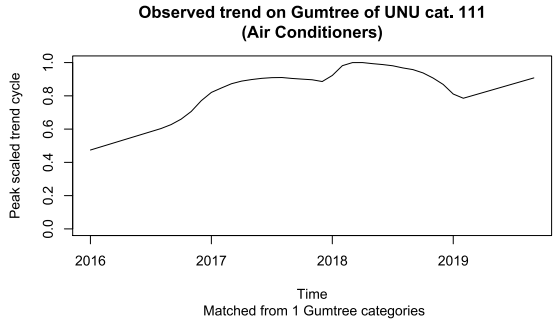
The trends on UNU level (Figure 15) are consistent with the overall UK trend except for air conditioners and coolers (UNU 111 & 112), where the overall number of listings has increased in recent years However, in absolute numbers, they are a relatively small category on Gumtree (Figure 16, right).

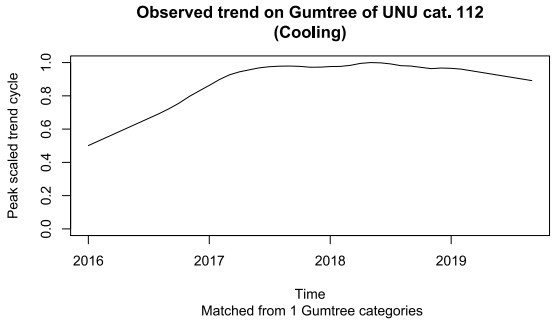
To summarise, although there is an overall increase in EEE product sales, our analysis indicates that in the past few years there seems to be a decline in numbers of listings for the investigated UK W/EEE categories. This trend is also reflected in a similar decline for search traffic popularity for second-hand keywords and the platform themselves. This change in behaviour might have long-term effects on the return and hoarding rate within the UK. To further generalise, we suggest to undertake a broader and more longitudinal study that also collects further details on the listing level. Ideally, covering multiple second-hand platforms and broader range of UNU categories for a longer period of time. This would allow the combination of text mining and time series analysis methods for additional insights on unreported flows and discrepancies between waste arising and waste collected.

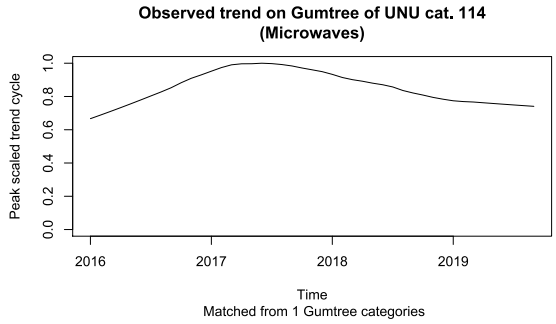


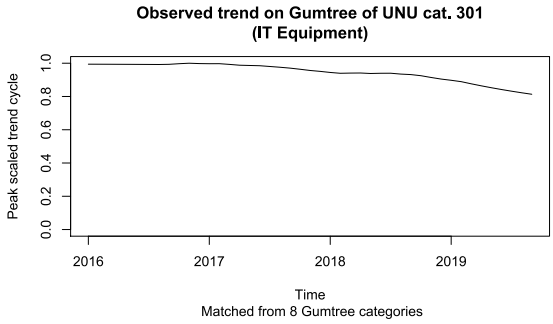

Observed trend on Gumtree of UNU cat. 108
(Fridges)
Peak scaled trend cycle
0.0 0.2 0.4 0.6 0.8 1.0
2016 2017 2018 2019
Time
Matched from 1 Gumtree categories

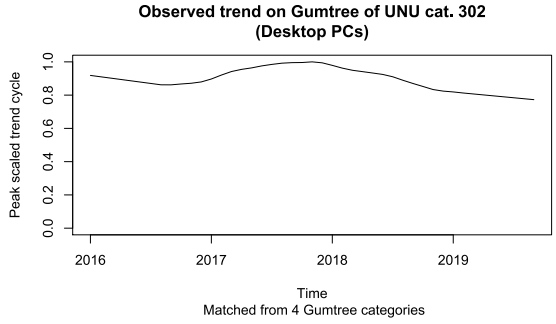

Observed trend on Gumtree of UNU cat. 109
(Freezers)
Peak scaled trend cycle
0.0 0.2 0.4 0.6 0.8 1.0
2016 2017 2018 2019
Time
Matched from 1 Gumtree categories

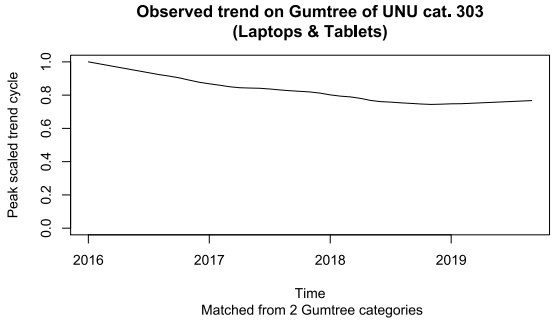

Observed trend on Gumtree of UNU cat. 111
(Air Conditioners)
Peak scaled trend cycle
0.0 0.2 0.4 0.6 0.8 1.0
2016 2017 2018 2019
Time
Matched from 1 Gumtree categories

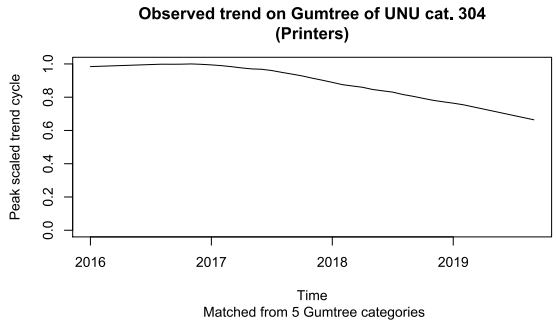

Observed trend on Gumtree of UNU cat. 112
(Cooling)
Peak scaled trend cycle
0.0 0.2 0.4 0.6 0.8 1.0
2016 2017 2018 2019
Time
Matched from 1 Gumtree categories

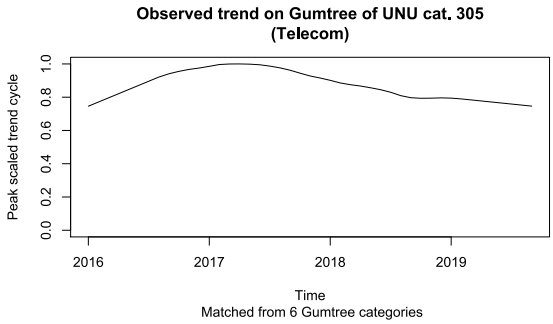

Observed trend on Gumtree of UNU cat. 114
(Microwaves)
Peak scaled trend cycle
0.0 0.2 0.4 0.6 0.8 1.0
2016 2017 2018 2019
Time
Matched from 1 Gumtree categories

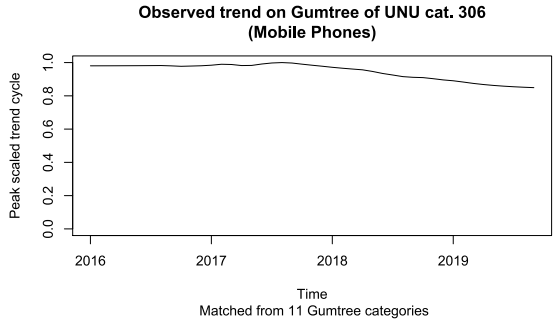

Observed trend on Gumtree of UNU cat. 301
(IT Equipment)
Peak scaled trend cycle
0.0 0.2 0.4 0.6 0.8 1.0
2016 2017 2018 2019
Time
Matched from 8 Gumtree categories

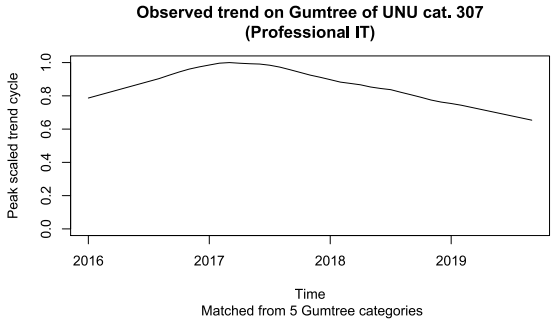

Observed trend on Gumtree of UNU cat. 302
(Desktop PCs)
Peak scaled trend cycle
0.0 0.2 0.4 0.6 0.8 1.0
2016 2017 2018 2019
Time
Matched from 4 Gumtree categories

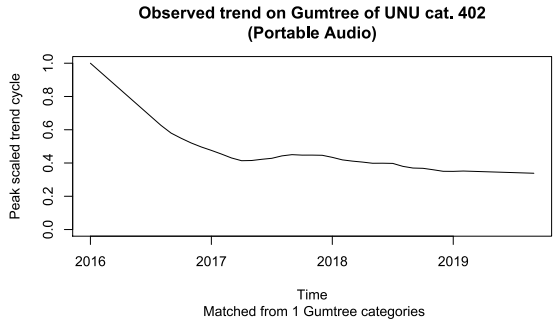

Observed trend on Gumtree of UNU cat. 303
(Laptops & Tablets)
Peak scaled trend cycle
0.0 0.2 0.4 0.6 0.8 1.0
2016 2017 2018 2019
Time
Matched from 2 Gumtree categories

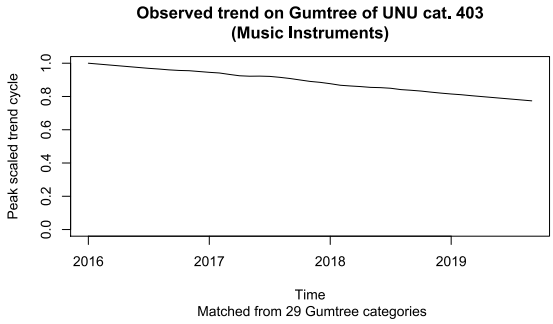

Observed trend on Gumtree of UNU cat. 304
(Printers)
Peak scaled trend cycle
0.0 0.2 0.4 0.6 0.8 1.0
2016 2017 2018 2019
Time
Matched from 5 Gumtree categories

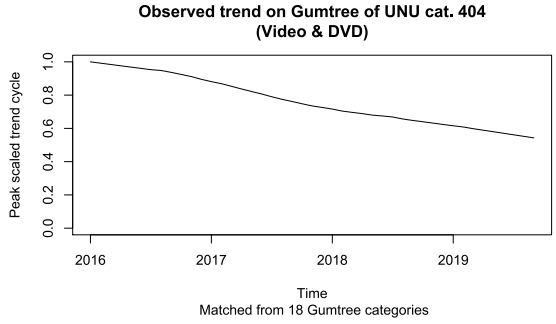

Observed trend on Gumtree of UNU cat. 305
(Telecom)
Peak scaled trend cycle
0.0 0.2 0.4 0.6 0.8 1.0
2016 2017 2018 2019
Time
Matched from 6 Gumtree categories

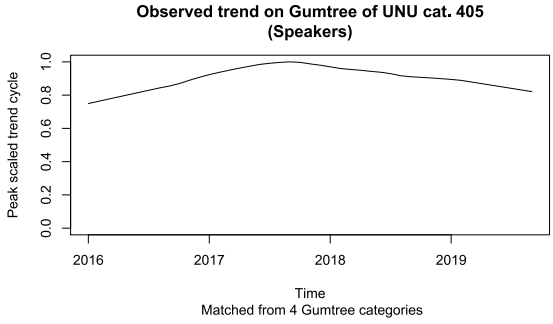

Observed trend on Gumtree of UNU cat. 306
(Mobile Phones)
Peak scaled trend cycle
0.0 0.2 0.4 0.6 0.8 1.0
2016 2017 2018 2019
Time
Matched from 11 Gumtree categories


Observed trend on Gumtree of UNU cat. 307
(Professional IT)
Peak scaled trend cycle
0.0 0.2 0.4 0.6 0.8 1.0
2016 2017 2018 2019
Time
Matched from 5 Gumtree categories


Observed trend on Gumtree of UNU cat. 402
(Portable Audio)
Peak scaled trend cycle
0.0 0.2 0.4 0.6 0.8 1.0
2016 2017 2018 2019
Time
Matched from 1 Gumtree categories


Observed trend on Gumtree of UNU cat. 403
(Music Instruments)
Peak scaled trend cycle
0.0 0.2 0.4 0.6 0.8 1.0
2016 2017 2018 2019
Time
Matched from 29 Gumtree categories


Observed trend on Gumtree of UNU cat. 404
(Video & DVD)
Peak scaled trend cycle
0.0 0.2 0.4 0.6 0.8 1.0
2016 2017 2018 2019
Time
Matched from 18 Gumtree categories


Observed trend on Gumtree of UNU cat. 405
(Speakers)
Peak scaled trend cycle
0.0 0.2 0.4 0.6 0.8 1.0
2016 2017 2018 2019
Time
Matched from 4 Gumtree categories

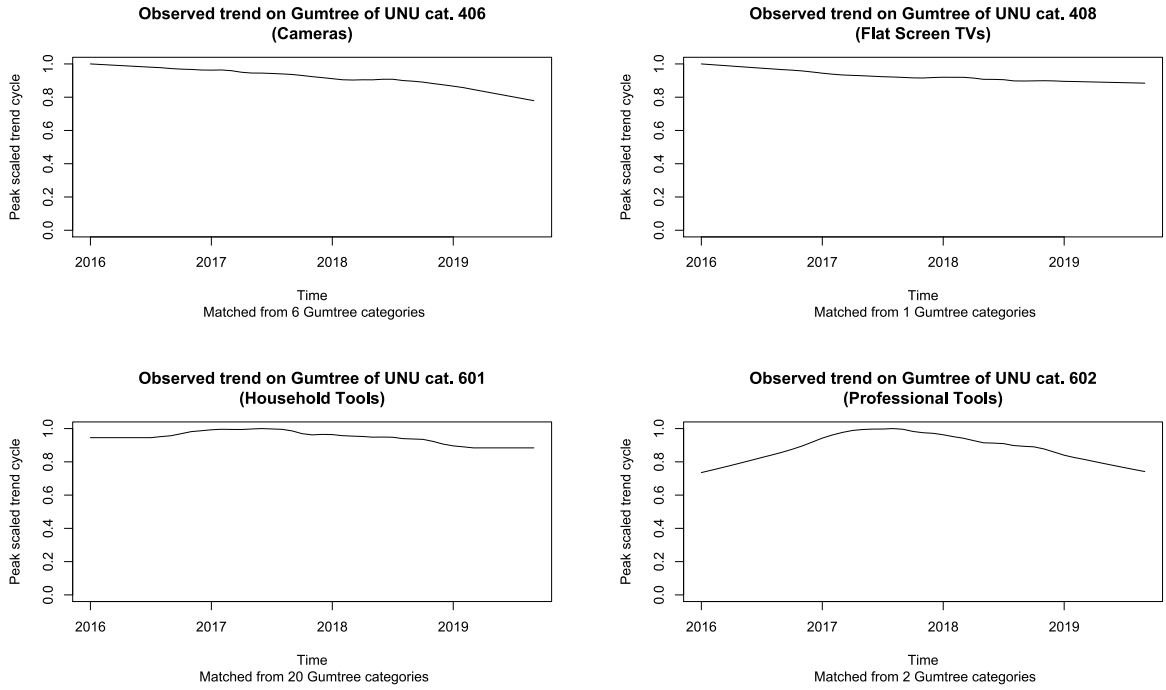


Figure 15 Trend analysis of UNU categories.

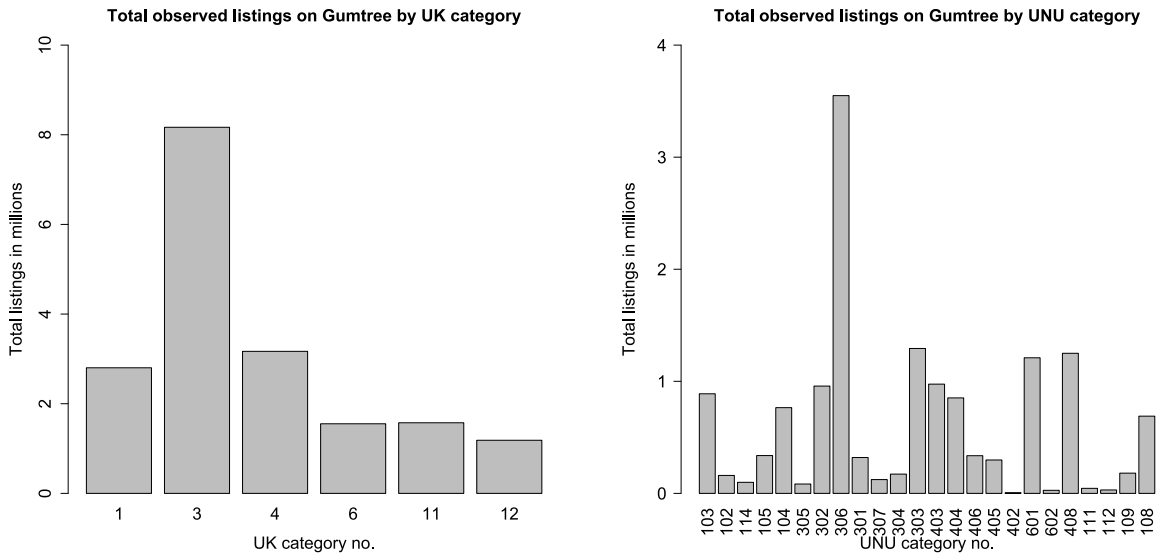


Figure 16 Total observed listings on Gumtree between 01/01/2016 and 17/09/2019.

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Appendix XIV: Extending WOT model to estimate WEEE flows and stocks

19.0 Converting metadata for times in use and storage, stocks in use and storage, and fates into WEEE flows

19.1 Data conversions

The harmonised probabilistic metadata for the five main variables (times in use and storage, stocks in use and storage, and product fates) was obtained from multiple studies (predominantly surveys, either identified in the literature or sourced by the Lancaster team). Most data is relatively recent (past five years), which means that the statistics of the five main variables is likely to represent present-day consumer behaviour in terms of buying, using, hoarding and disposing of electrical and electronic equipment. The data was harmonised between multiple sources individually for each UNU category available.

The metadata for the five variables was subsequently converted into flows of WEEE using the general relationship between units sold, units discarded and stocks. A suite of computer codes in MATLAB was developed to perform the analysis. The units sold (POM) were taken from WOT1.2 model (van Straalen et al., 2016) individually for each UNU category. The primary data source is Eurostat, and the POM estimates are based on the available trade and manufacturing statistics (this is known as Apparent Consumption).

The metadata was first analysed to identify the extended pool of UNU categories (34 in total) with at least one of the five metavariables available (times in use and storage, stocks in use and storage, and fates). A generic algorithm was then developed which scans the metadata according to the availability flags, and applies the generic relationship between stocks and flows in the following sequence:

- Stocks in use
- Stocks in storage
- Flow discarded after use
- Primary fates after use
- Flow entering storage
- Flow discarded after storage
- Secondary fates after storage
- Combined fates (destinations) turning into waste and/or recycling

The metadata for the five main variables is inconsistent in terms of its availability across the combined UNU pool (34 categories in total), which required making reasonable assumptions to fill the gaps. For times in use and times in storage, we grouped UNU categories together according to the wider similarity between them (UNUs separately in each broad "century"), identified those UNUs that have the time data and worked out average time distributions separately in each wider group. When no data for times is available for either of the UNUs in a given century, we used average time distributions across the entire pool of UNUs. The same approach was applied to the frequency splits for primary product fates. Secondary product fates (after storage) were approximated individually for each UNU by assuming that its primary hoarding split is allocated equally among other non-trivial fates; no secondary storage was assumed to take place.

The assumptions above constitute the basic analysis. Neither of the distributions for the units in use or in hoarding were extrapolated between UNU categories.

To improve the accuracy of the estimates and fill in the gaps, we carried out an advanced analysis involving model optimisation to fit multiple datasets. The analysis was possible only for those UNUs with the data both for times in use and stock in use. It involved calculating the product stocks, both in use and in storage, based on the historic POM and discarded units (Wang et al., 2013) in accordance with the available time in use and in storage data. The time in use distributions were allowed to change shape relative to present going back in time (Stowell et al., 2018). The adjustment to the distributions was implemented using a single time-varying parameter, which was obtained by reconstructing UK-wide stocks (number of units) and matching them with the available metadata for stock in use per household for each UNU category, combined with ONS data for the number of UK households. As a result, an optimal historic scaling for time in use pdf was obtained. The algorithm used was MATLAB's "fmincon" algorithm, which is based on nonlinear programming.

Out of around ten UNUs with the data both for times in use and stock in use, which is necessary for the algorithm to work, eight turned out to have either good or very good solutions in terms of the accuracy of the fitting to the metadata stock sample (Figure 17). For all these UNUs, we introduced a composite solution for POM and discarded EEE, defined as arithmetic average between the basic and advanced solutions introduced above. This approach harmonises the results for the POM-based stocks and stocks

directly from the metadata, giving a more balanced set of estimates for the associated W/EEE flows. The results presented in the relevant sub-sections of the Section 2.2 in the main report are based on the composites solution.

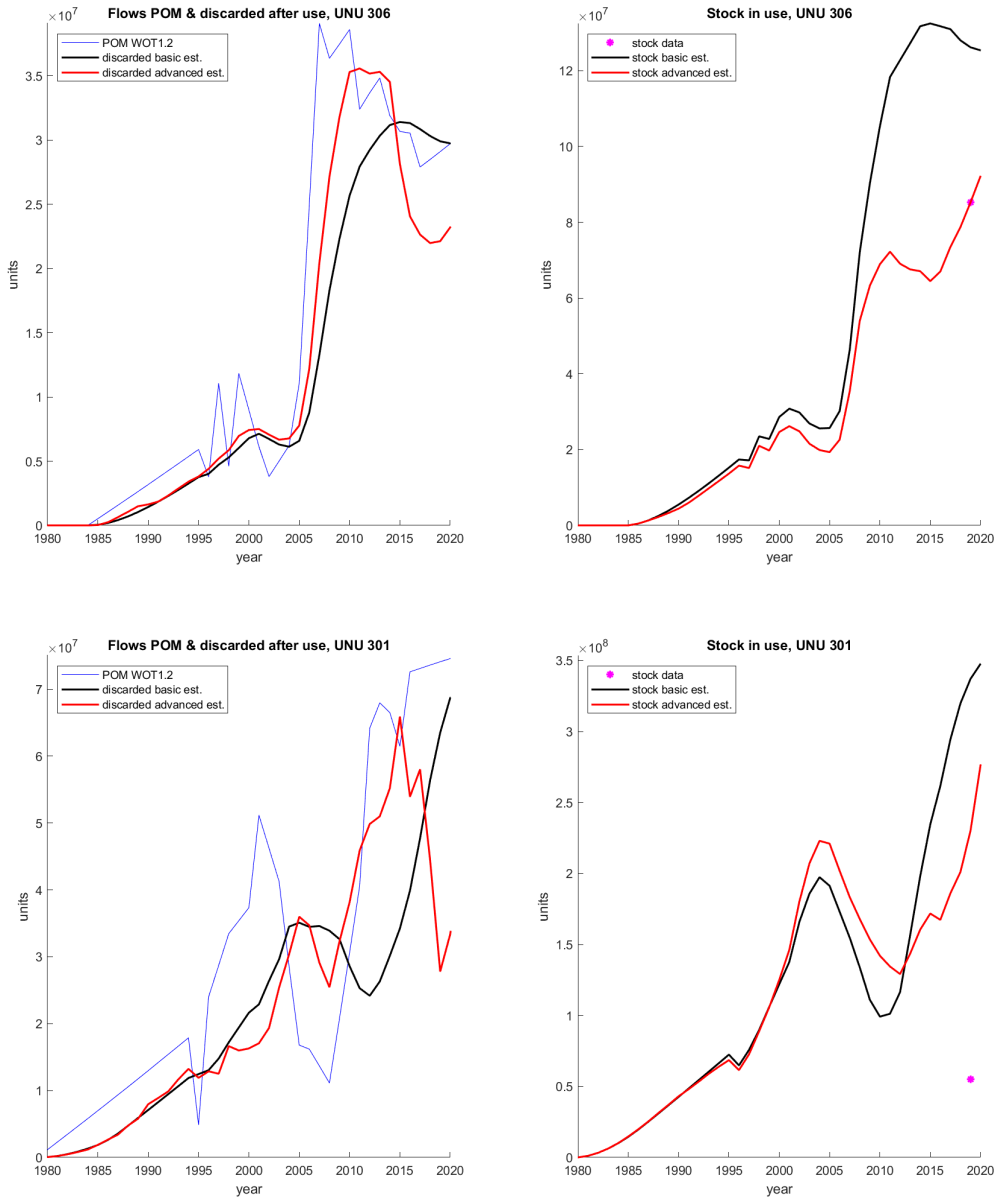

Figure 17 Reconstructing units discarded after use and stock in use for UNU306 "Mobile Phones" (top panels) and UNU301 "Small IT Equipment" (bottom panels) as part of the basic and advanced analyses (see the text for details). The differences between the two sets of results and two UNU keys are obvious. For UNU301 (Small IT Equipment), the metadata for stock in use appears to be low by around a factor of 5 even for the lowest possible stock reconstruction within reasonable space of model parameters (red curves).

Only two UNUs, 301 (small IT equipment, see the Figure above) and 901 (household monitoring and control equipment) showed non-correctable inconsistencies between reconstructed POM-based stocks and stocks directly from the metadata (difference by a factor of 5), raising questions about the consistency of the

available POM and stock data. For these particular categories, we gave preference to POM-based stock reconstruction, ignoring the metadata stock samples.

For the remaining 20 or so UNUs with no stock in use data, we adopted the same approach of reconstructing the stock based on historic POM and time in use, but with no variations in time in use (assuming present-day distributions applied to historic data). For the units in storage, the available metadata appears to give much higher numbers per household than is feasible according to POM and the estimated fraction of the flows discarded after use that enters into storage. The POM-based stocks in storage are an order of magnitude lower than those extracted from the metadata, again raising questions about the consistency of the various datasets. In the advanced analysis, we adopted stocks in storage calculated from POM, times in use and primary probabilities of entering into storage across all UNUs. The advanced analysis, therefore, produced a more consistent set of results, while also highlighting the most problematic areas that require further investigation. The corresponding confidence scores are provided in the summary spreadsheet ***flows_and_stocks_meta_advanced.xlsx***, along with the reconstructed flows and stocks based on the metadata. The MATLAB software developed to perform the analysis is available as part of the Lancaster University online dataset.

We summarised the UNU-level composite results for W/EEE flows derived from the meta-analysis in

Table 6, Table 7 and Table 8

Table 6. EEE POM, rate of change of stock in use, and flow discarded after use for the 34 UNU categories analysed. 2017 estimates.

UNU	Description	POM (kton/yr)	Rate of change for stock in use (kton/yr)	Flow discarded after use (kton/yr)
104	Washing Machines	253.218	84.287	168.931
106	Household Heating	111.494	-7.280	118.773
108	Fridges	166.793	36.470	130.323
109	Freezers	40.530	7.363	33.167
114	Microwaves	89.329	1.011	88.318
201	Small Household Items	92.825	34.801	58.023
202	Food Preparation	123.027	25.512	97.515
203	Hot Water Preparation	25.937	10.844	15.094
204	Vacuum Cleaners	52.455	4.738	47.717
205	Personal Care	27.418	4.377	23.041
301	IT Equipment	29.251	9.272	19.978
302	Desktop PCs	37.691	-0.064	37.756
303	Laptops & Tablets	14.165	3.284	10.882
304	Printers	87.062	15.078	71.983
305	Telecom	32.319	8.155	24.164
306	Mobile Phones	2.512	0.039	2.472
308	CRT Monitors	0.000	-9.569	9.569
309	Flat Screen Monitors	0.882	-6.551	7.433
401	Consumer Electronics	3.461	-1.610	5.070
402	Portable Audio	0.672	-1.301	1.973
403	Music Instruments	6.117	-27.933	34.050
404	Video & DVD	26.388	2.306	24.083
405	Speakers	20.694	2.836	17.859
406	Cameras	0.585	-0.940	1.525
407	CRT TVs	0.000	-60.639	60.639
408	Flat Screen TVs	110.231	53.522	56.709
501	Lighting	5.490	0.740	4.750
502	Compact Fluorescent	0.997	-2.832	3.829
503	Straight Tube Lamps	2.193	-3.059	5.252
504	Special Lamps	1.478	0.036	1.442
505	LED Lamps	3.132	-0.172	3.305
506	Household Luminaires	99.914	17.252	82.662
702	Game Consoles	9.475	-2.316	11.791
901	Household Monitoring	21.322	8.382	12.940

Table 7. Flow into hoarding, rate of change of stock in hoarding, and flow discarded after hoarding for the 34 UNU categories analysed. 2017 estimates.

UNU	Description	Flow into "Hoarding" (kton/yr)	Rate of change for stock in hoarding (kton/yr)	Flow discarded after hoarding (kton/yr)
104	Washing Machines	19.555	1.131	18.424
106	Household Heating	13.749	0.755	12.994
108	Fridges	7.819	0.341	7.478
109	Freezers	1.990	0.014	1.976
114	Microwaves	20.072	2.162	17.911
201	Small Household Items	14.054	0.547	13.507
202	Food Preparation	8.013	0.647	7.366
203	Hot Water Preparation	1.240	0.108	1.132
204	Vacuum Cleaners	3.921	0.292	3.630
205	Personal Care	1.893	0.032	1.861
301	IT Equipment	0.000	0.000	0.000
302	Desktop PCs	0.000	0.000	0.000
303	Laptops & Tablets	3.370	0.155	3.214
304	Printers	0.000	0.000	0.000
305	Telecom	0.000	0.000	0.000
306	Mobile Phones	0.871	-0.036	0.907
308	CRT Monitors	2.104	-3.579	5.683
309	Flat Screen Monitors	1.634	0.057	1.577
401	Consumer Electronics	3.536	-0.435	3.971
402	Portable Audio	0.000	0.000	0.000
403	Music Instruments	0.000	0.000	0.000
404	Video & DVD	6.865	0.112	6.753
405	Speakers	9.249	0.306	8.943
406	Cameras	0.000	0.000	0.000
407	CRT TVs	16.145	-2.682	18.826
408	Flat Screen TVs	16.226	2.455	13.771
501	Lighting	0.823	-0.003	0.826
502	Compact Fluorescent	0.663	-0.005	0.668
503	Straight Tube Lamps	0.910	-0.002	0.912
504	Special Lamps	0.250	-0.006	0.256
505	LED Lamps	0.572	0.086	0.486
506	Household Luminaires	14.315	0.870	13.445
702	Game Consoles	0.000	0.000	0.000
901	Household Monitoring	5.561	0.719	4.842

Table 8. Main disposal fates for the 34 UNU categories analysed. 2017 estimates.

UNU	Description	Flow "Donation or re-use" (kton/yr)	Flow "General bin" (kton/yr)	Flow "Other" (kton/yr)	Flow "Recycling" (kton/yr)	Flow "Sold" (kton/yr)	Flow "Take-back scheme" (kton/yr)	Flow "Unknown" (kton/yr)
104	Washing Machines	0.000	67.705	50.615	49.480	0.000	0.000	0.000
106	Household Heating	0.000	47.618	35.600	34.801	0.000	0.000	0.000
108	Fridges	0.000	55.270	44.246	30.466	0.000	0.000	0.000
109	Freezers	0.000	14.097	11.285	7.771	0.000	0.000	0.000
114	Microwaves	0.000	30.328	18.257	37.571	0.000	0.000	0.000
201	Small Household Items	1.182	35.316	2.520	14.668	2.136	1.655	0.000
202	Food Preparation	1.500	62.964	0.000	22.605	3.599	2.541	3.658
203	Hot Water Preparation	0.232	9.741	0.000	3.497	0.557	0.393	0.566
204	Vacuum Cleaners	0.735	30.825	0.000	11.067	1.762	1.244	1.791
205	Personal Care	0.358	14.951	0.000	5.369	0.856	0.605	0.870
301	IT Equipment	2.005	0.199	0.000	17.775	0.000	0.000	0.000
302	Desktop PCs	3.789	0.376	0.000	33.591	0.000	0.000	0.000
303	Laptops & Tablets	1.361	2.476	0.000	3.713	1.282	0.000	1.893
304	Printers	7.224	0.716	0.000	64.043	0.000	0.000	0.000
305	Telecom	2.425	0.240	0.000	21.498	0.000	0.000	0.000
306	Mobile Phones	0.459	0.312	0.131	1.035	0.241	0.149	0.182
308	CRT Monitors	2.754	0.388	0.000	9.612	0.000	0.000	0.394
309	Flat Screen Monitors	1.529	0.131	0.000	5.580	0.000	0.000	0.135
401	Consumer Electronics	0.712	1.410	0.000	2.322	0.000	0.000	1.061
402	Portable Audio	0.049	0.697	0.000	0.557	0.212	0.000	0.458
403	Music Instruments	1.139	19.833	0.000	10.859	0.000	0.000	2.219
404	Video & DVD	2.283	1.157	1.014	15.528	1.469	0.000	2.519
405	Speakers	2.489	4.133	0.000	8.961	0.000	0.000	1.969
406	Cameras	0.000	0.555	0.000	0.241	0.255	0.053	0.420
407	CRT TVs	6.869	5.554	2.306	44.437	0.000	0.000	4.154
408	Flat Screen TVs	13.227	3.901	3.271	19.951	3.174	0.000	10.730
501	Lighting	0.345	1.288	0.253	2.309	0.178	0.058	0.323
502	Compact Fluorescent	0.279	1.039	0.204	1.862	0.143	0.047	0.261
503	Straight Tube Lamps	0.382	1.424	0.280	2.552	0.196	0.064	0.357
504	Special Lamps	0.105	0.392	0.077	0.703	0.054	0.018	0.098
505	LED Lamps	0.233	0.874	0.170	1.568	0.119	0.037	0.218
506	Household Luminaires	5.934	22.178	4.343	39.771	3.043	0.976	5.548
702	Game Consoles	1.183	0.117	0.000	10.490	0.000	0.000	0.000
901	Household Monitoring	0.000	1.004	3.208	1.812	2.106	0.000	4.090

19.2 Reconstructing time in storage (hoarding) based on distributions for time in use and combined time in use and storage.

One of the data sources covering around 15 UNU categories had probability distributions for the oldest product in use and oldest product in storage (hoarded), both measured from the year of purchase. According to our definitions, however, time in storage is measured from the moment the product is no longer used, rather than from the year of purchase. In order to harmonise this particular dataset with other datasets that have the time and storage data for the same UNU categories, it was necessary to extract the correct time in storage data from the available distributions. This was done by using the fact that the pdf

for combined time in use and in storage is a convolution of the individual pdfs for the two components, time in use and time in storage, assuming the two are independent. A suite of computer codes in MATLAB was developed to perform the analysis. The convolution formula had to be inverted, which was achieved by means of applying MATLAB's "fmincon" algorithm based on nonlinear programming. High fitting accuracies (below 5% relative error) were achieved for all the UNUs in the data sample in question. The reconstructed times in storage (measured from the end of use, see Figure 18) were added to the metadata samples. The MATLAB software developed to perform the analysis is available as part of the Lancaster University online dataset. See Appendix Residence time (time in use and storage) at the UNU categories level", and Appendix XIV for bottom-up results presented in sections 2.2.1 and 2.2.3.

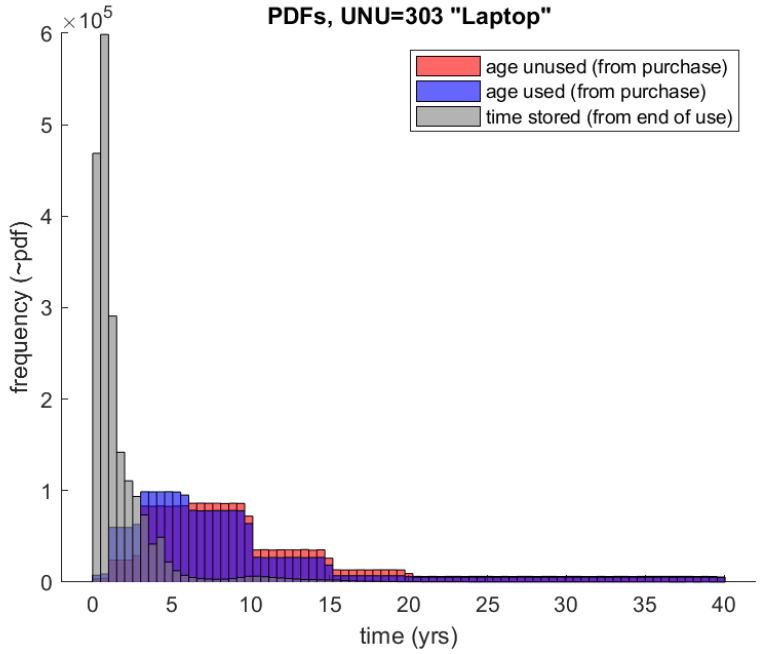

Figure 18 Reconstruction of the pdf for time in storage (hoarding, measured from end of use) based on available pdfs for time in use and combined time and use and storage (both from purchase). UNU303 "Laptops & Tablets".

19.3 Confidence levels

Table 9 summarises data availability over the five output variables for each UNU in the extended pool (34 UNU categories in total; see ***flows_and_stocks_meta_advanced.xlsx*** for the descriptions of the UNU categories), and provides confidence indicators for the following steps:

- Extrapolating pdfs for times in use, times in storage and fates between UNUs in the same generics group ("century"), or using the entire pool
- Matching the stock in use data (units per household) from the meta-analysis with the reconstructed stock based on WOT1.2 POM and historic variations in the pdf for times in use (obtained through optimisation)

Table 9. Data availability and confidence of the extrapolations employed in the advanced analysis for the set of 34 UNU categories with the meta-data.

UNU	avail time in use (0/1)	avail time hoarded (0/1)	avail stock in use (0/1)	avail stock hoarded (0/1)	avail fates (0/1)	total avail (0/5)	score extrap time use (of 5)	score extrap time hoarded	score extrap fate (of 5)	stock in use match (reconstr. vs metadata)
104	1	0	0	0	0	1	5	2	3.5	NA
106	1	0	0	0	0	1	5	2	3.5	NA
108	1	0	0	0	1	2	5	2	5	NA
109	1	0	0	0	1	2	5	2	5	NA
114	1	0	0	0	1	2	5	2	5	NA
201	1	0	0	0	1	2	5	2	5	NA
202	1	0	0	0	1	2	5	2	5	NA
203	1	0	0	0	1	2	5	2	5	NA
204	1	0	0	0	1	2	5	2	5	NA
205	1	0	0	0	1	2	5	2	5	NA
301	1	0	1	0	1	3	5	3.5	5	mismatch
302	1	1	1	1	1	5	5	5	5	match
303	1	1	1	1	1	5	5	5	5	match
304	0	0	0	0	1	1	3.5	3.5	5	NA
305	0	0	0	0	1	1	3.5	3.5	5	NA
306	1	1	1	1	1	5	5	5	5	match
308	0	0	0	0	1	1	3.5	3.5	5	NA
309	1	1	0	0	1	3	5	5	5	NA
401	1	1	0	0	1	3	5	5	5	NA
402	1	1	1	1	1	5	5	5	5	match
403	1	0	1	0	1	3	5	3.5	5	match
404	1	1	1	1	1	5	5	5	5	macth
405	1	1	0	0	1	3	5	5	5	NA
406	1	0	1	1	1	4	5	3.5	5	match
407	1	1	0	0	1	3	5	5	5	NA
408	1	1	1	1	1	5	5	5	5	match
501	0	0	0	1	0	1	2	2	2	NA
502	0	0	0	1	0	1	2	2	2	NA
503	0	0	0	1	0	1	2	2	2	NA
504	0	0	0	1	0	1	2	2	2	NA
505	0	0	0	1	0	1	2	2	2	NA
506	0	0	0	1	0	1	2	2	2	NA
702	0	0	0	0	1	1	2	2	5	NA
901	1	1	1	0	1	4	5	5	5	mismatch

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Appendix XX: Free riders

Raw data and industry insights contributing to an updated estimate of EEE producer free riders

Category	Weight (tonnes)	Description
Total POM	1,748,280	Total POM from "STUDY ON COLLECTION RATES OF WEEE", European Commission, October 2014: 88.41% applied to 2017 Reported
Total registered	1,545,655	2018 reported EEE
TOTAL unregistered	**45,926**	**sum of below categories**
LDA	-	Negligible - AMDEA
SDA	4,723	Nominal 3% of total POM – TechUK
IT & telecoms	4,561	Nominal 3% of total POM – TechUK
Consumer	6,012	Assigned 12.5% of total POM: midpoint between toys and lighting
Lighting	2,292	Estimated 5% of total POM – Recolight
Tools	12,179	Assigned 12.5% of total POM: midpoint between toys and lighting
Toys	2,770	Estimated 5% of total POM – BTHA
Medical	-	Assumed negligible
Monitor and Control	-	Assumed negligible
Auto dispensers	-	Assumed negligible
Display	-	Negligible - TechUK
Cooling	-	Assumed negligible
GDL	1,989	Estimated 20% of total POM - Recolight, Lumicom
PV	11,400	Prorata'd 2017 -18 based on Feed in Tarriff data on mega watt hours
TOTAL exempt/ unaccounted for	**156,699**	**sum of below**
Toys	1,662	BTHA estimate 2-4% (used 3%) of total POM - there is no apparent change as a result of open scope for POM
Household Luminaires	50,000	Lumicom estimate
Other unassigned	105,038	Gap between total and all that is already assigned

Material Focus is an independent, not-for-profit organisation on a mission to save valuable, critical and finite materials inside electricals from going to waste. We do this through

Insights

We identify, produce and share insights to improve the UK e-waste system and inform policy decisions.

Investments

We identify and fund projects that make it easier to reuse and recycle; or that encourage circular design.

Inspiration

We inspire, educate and encourage the UK public to fix, donate, sell and recycle their unwanted electricals through our Recycle Your Electricals campaign.

www.materialfocus.org.uk