Joint Trades Association

Final: Unreported WEEE Flows in the UK

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Anthesis

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Executive Summary

This project has been funded through the 2015 WEEE Compliance fee fund, administered by the Joint Trade Association (JTA). A report was commissioned after a 2016 study by Valpak and WRAP[1] into Waste Electrical and Electronic Equipment (WEEE) flows in the UK, identified that 139 kt of WEEE in the UK is treated through unreported channels. This value remains after discounting estimates for residual waste, theft, and WEEE in the light iron stream:

Estimated WEEE Generated, 2015	Reported WEEE Treatment, 2015	Estimated WEEE in the Residual Waste	Estimated WEEE Stolen	Other Quantified Treatment	Unaccounted WEEE, 2015
1,528 kt[2]	679 kt	366 kt	96 kt	336 kt	139 kt

Further investigation of this stream will help to identify areas where material capture rates can be improved, helping the UK to meet its WEEE recycling targets and reducing the amount of material which is processed inappropriately.

This study aims to characterise some of the routes that contribute to this 139 kt figure for unaccounted WEEE, as well as providing greater detail on electrical and electronic equipment (EEE) and WEEE flows within and out of the UK system. We created a material flow model as a foundation for this investigation, which considers routes by which material stays in the system ("in-loop") and routes by which material leaves the system ("out-loop"), characterised by the following 5 states:

Material State	Description	Example
In-loop	Material in-use in the UK	Secondary Markets; redistribution by charities or asset management
Long-term in-loop	Material kept in the UK system for the long-term (beyond expected product lifespan)	Long-term sporadic usage; hoarding or warehousing
Transitional	User decides to dispose of equipment, but this may be put back into circulation	WEEE taken to designated collection facility or to skip

[1] http://www.wrap.org.uk/content/weee-flows-report

[2] Circa 86% of the 1,769 kt sold that year (https://www.gov.uk/government/statistical-data-sets/waste-electrical-and-electronic-equipment-weee-in-the-uk)

Material State	Description	Example
Reported Out-loop	Authorised WEEE treatment	Recycled by an AATF[3] or an ATF
Unreported Out-loop	EEE leaves the UK; WEEE is processed via unreported channels	Export for re-use; scrap or landfilling

To prioritise material streams for further investigation, we compared tonnages of EEE categories placed on the market with the reported treatment of material by AATFs to generate a "deficit" value (i.e. showing which categories had the largest weight disparity between EEE placed on the market and WEEE processed), we then discounted the known 'alternative' treatment routes identified in the WRAP and Valpak Report (excluding residual).

We selected particular product streams for investigation based on this deficit tonnage and then additional criteria, including:

- low diversity of constituent products;
- large (>150 kg) items;
- availability of sales data;
- specialist equipment; and
- equipment with high refurbishment potential.

The priority product types are as follows:

Product Types	Market	Categories	Category Deficit, 2016 (= EEE Placed on Market - WEEE Treated)
Air Conditioning **Commercial Chiller Cabinets**	B2B* B2C**	12 Cooling Equipment	89.6 kt
Buildings-installed EEE: controls & lighting	B2B	9 Monitoring & Control 5 Lighting 2 Small Domestic Appliances	98.1 kt
Electrical and Construction Tools	B2B B2C	6 Electrical & Electronic Tools	80.6 kt

[3] Approved Authorised Treatment Facilities (i.e. permitted WEEE recyclers).

Product Types	Market	Categories	Category Deficit, 2016 (= EEE Placed on Market - WEEE Treated)
Household Small Mixed WEEE (SMW)	B2C	2 Small Domestic Appliances 3 IT and Telecomms 4 Consumer Equipment 6 Electrical & Electronic Tools 7 Toys, Games, & Leisure	287.7 kt
Vending Machines	B2B	10 Automatic Dispensers	8.9 kt
Medical Equipment	B2B	8 Medical Equipment	22.2 kt
Gym Equipment	B2B B2C	7 Toys, Games, & Leisure	57.5 kt

*B2B – Business to Business
**B2C – Business to Consumer

Findings

Air-Conditioning and Commercial Cooling (Category 1)

Commercial cooling makes up a significant part of non-household Category 12 equipment: around 32 kt of equipment is placed on the market each year, while only 2–4 kt is reported as treated by AATFs.

Household A/C: The market for household A/C is relatively small in the UK, with portable systems being more popular solution than fixed ones. While end-of-life portable units are relatively likely to be disposed via Designated Collection Facilities (DCFs) (therefore out of scope for this project), fixed systems are more at risk of being processed by different routes. We estimate that 1.6 kt of fixed household systems will be replaced each year, these different routes are likely to be the scrap industry or the Construction and Demolition (C&D) waste stream.

Commercial A/C: significant areas of office and retail space are now air-conditioned, and we expect that over 5 kt of equipment will be replaced each year (excluding units arising from institutions such as hospitals and schools as data are unavailable on uptake). It is likely that these units are largely disposed of in either C&D or scrap metal waste streams.

Commercial Retail Refrigeration: retail display refrigeration (e.g. supermarket chiller cabinets) is a substantial product stream, bolstered by the growth of convenience stores in recent years. We estimate that around 189 kt of display refrigeration equipment are deployed in supermarkets, convenience stores, and cafés around the UK (recall all commercial cooling sold is 32 kt pa). With typical unit lifespans of 10–15 years, we expect that 16 kt of equipment are disposed of as WEEE each year, and while some will be processed by AATFs by specialist recyclers, cabinets could also be disposed via inappropriate routes, such as the scrap metal sector. Interviews suggested it is likely that other forms of refrigeration (such as catering equipment) make up a considerable proportion of the EEE on the market in the UK.

Building-installed EEE: Controls and Lighting (Category 5)

Building management systems (BMS) and lighting account for significant tonnages in Categories 9 and 5, and both of these categories have been historically under-collected. Through engagement with stakeholders with experience in the BMS and C&D sector, we found that WEEE recycling is extremely rare during building refits and upgrade work. Demolition crews are more concerned with finding items that have high scrap metal value, and smaller items of WEEE are generally consigned to either skips or residual waste bins within C&D and Commercial and Industrial (C&I) waste streams.

Electrical & Construction Tools (Category 6)

Commercial Tools: through engagement with tool hire companies, we determined that the typical service life of Category 6 EEE is 2–3 years due to heavy usage. At end-of-life, unserviceable tools are typically disposed via scrap metal or through the general waste stream. Worn-but-functional tools will be sold in bulk at auctions or at plant sales; stakeholders speculated that these would most likely be exported for re-use. The mass of Category 6 sold is relatively stable (~75 kt), so we expect that at least 20 kt of Category 6 equipment is removed from the UK system each year through reuse channels (which does not include dual-use tools such as drills which are classed as B2C). Additionally, some tool manufacturers now offer fleet management services, including takeback of end-of-life products. This is a relatively new development, the impact of which should be monitored over the coming years.

Household Tools: Usage profiles suggest that many of these items are stored in the home over long periods of time. Following this, tools that are no longer stored are disposed either through a DCF or the residual waste (so out of scope for this study).

Household SMW: Categories 2, 3, 4, 6, and 7

Household SMW is the largest grouping of waste investigated here, and the hardest to characterise due to the diversity of products. Due to the small size of many of the products in these categories, they are extremely easy to consign to the residual waste stream; additionally, this makes equipment much easier to hoard.

Engagement with the representatives of retailers suggested that warranty returns are infrequent for small and cheaper items, with the retailer or manufacturers that issue warranties finding it to be more cost effective to not take back and repair the faulty equipment that they replace. The defective equipment is likely to then be disposed of either via a DCF, or in the residual waste stream. SMW is also the dominant stream in charity redistribution and in reuse programmes, which can give products a second life: charities handle significant volumes of equipment each year, consigning around a third of the WEEE that they collect to recycling. The export of SMW for re-use is relatively common, with Eastern Europe being a major destination.

To illustrate the diversity in this potential waste stream, we undertook a detailed case study of games consoles, which make up ~15 % (7 kt) of Category 7 EEE placed on the market each year. Of this, around 5–10 % of consoles are expected to fail within 1 year, and be returned to the manufacturer. After this, consoles appear to enjoy relatively long service lives, and retain their Consumer to Consumer (C2C) value long term. Using sales data from eBay, we determined that C2C markets for 'legacy' games consoles remains strong: for example, the rate of sales — the number of units sold in 1 year on eBay compared to total number of units sold in the UK — of Nintendo 64 units (on average, a 19-year old console) is similar to the rate of sales for consoles with an average age of 6 years.

Consoles' consumer attachment value will lead them to be hoarded or sporadically used long term, and older technology will retain attractiveness in niche markets (a similar SMW item might be record players); however, most SMW product streams do not have this attachment.

WRAP and Valpak estimated that 366 kt WEEE were disposed in the residual waste and our view is that a significant amount of the 287.7 kt deficit of SMW is accounted for in this estimate, considering that domestic items are generally small enough to fit in a residual waste bin.

Vending Machines (Category 10)

While the vending machine sector is relatively small in terms of overall tonnage sold (we estimate the UK's refreshment vending machine stock to amount to ~75 kt), it is a specialist product stream with strong re-use practices: a 15-year machine lifecycle (including refurbishment) is typical, with multiple leases and placements. A conservative estimate of WEEE arising from this sector each year is 3.8 kt (according to interview data): while regulated WEEE treatment of equipment from this sector does occur, we also expect that operators may choose to send machines to scrap instead.

Medical Equipment (Category 8)

Medical equipment typically has a long operational lifespan, and refurbishment and reuse in the sector is high. Additionally, it was reported in 2016 that collections for the Medical Equipment category were 3% of the weight being sold in in 2008 (the first year of EEE statistics), showing the slow rate of churn and the high rate of aggregation in the system. We estimated that the UK's EEE stock for large medical equipment (Radiation Therapy, Mammography, CT, MRI, and Gamma Camera) amounts to 13 kt, on a use cycle of 12–15 years. Some healthcare manufacturers now operate service models, with in-house refurbishing of equipment at the end-of-service in the UK - typically, the equipment is redistributed overseas as, while no longer cutting-edge technology, it is still useable.

Other medical equipment is typically handled in a similar way, and there are companies in this sector which specialise in logistics, servicing, and the auction of used medical equipment. Our findings suggest that a large proportion of the UK's medical EEE is lost from the system through export.

Gym Equipment (Category 7)

The UK fitness sector has been growing rapidly in the UK in recent years, with relatively high levels of consumer equipment ownership and a 10 % increase in the number of gyms in the last 4 years. For commercial equipment, despite the hard-wearing construction, some gym operators change their equipment every 2–3 years, though lower cost facilities tend to run equipment for much longer, with 10–15 years being relatively common. There is a healthy secondary market for used equipment (via used equipment traders), and reuse and refurbishment is quite widespread due to the robust design of equipment and the high compatibility of spare parts between different equipment models. When equipment does come to the end of life, we expect that the majority will be disposed via the scrap metal due to the high value of materials used in construction (metal frames, copper wiring, motors etc.).

For consumers, due to the size of gym equipment and lack of takeback programmes from most retailers, we expect that equipment could be hoarded for long periods of time in sheds or garages rather than being disposed of or sold due to transport difficulties; as such, we also expect that few units will be recycled via DCFs. It is likely that many of these items are sold to, or taken away for free by, fitness equipment traders and either reused or disposed via the scrap metal industry.

Overall, we conservatively estimate that 1–2 kt of commercial equipment and 6.5 kt of home equipment will arise as WEEE each year. These figures also exclude equipment arising from private clubs/gyms in residences, hotels etc.

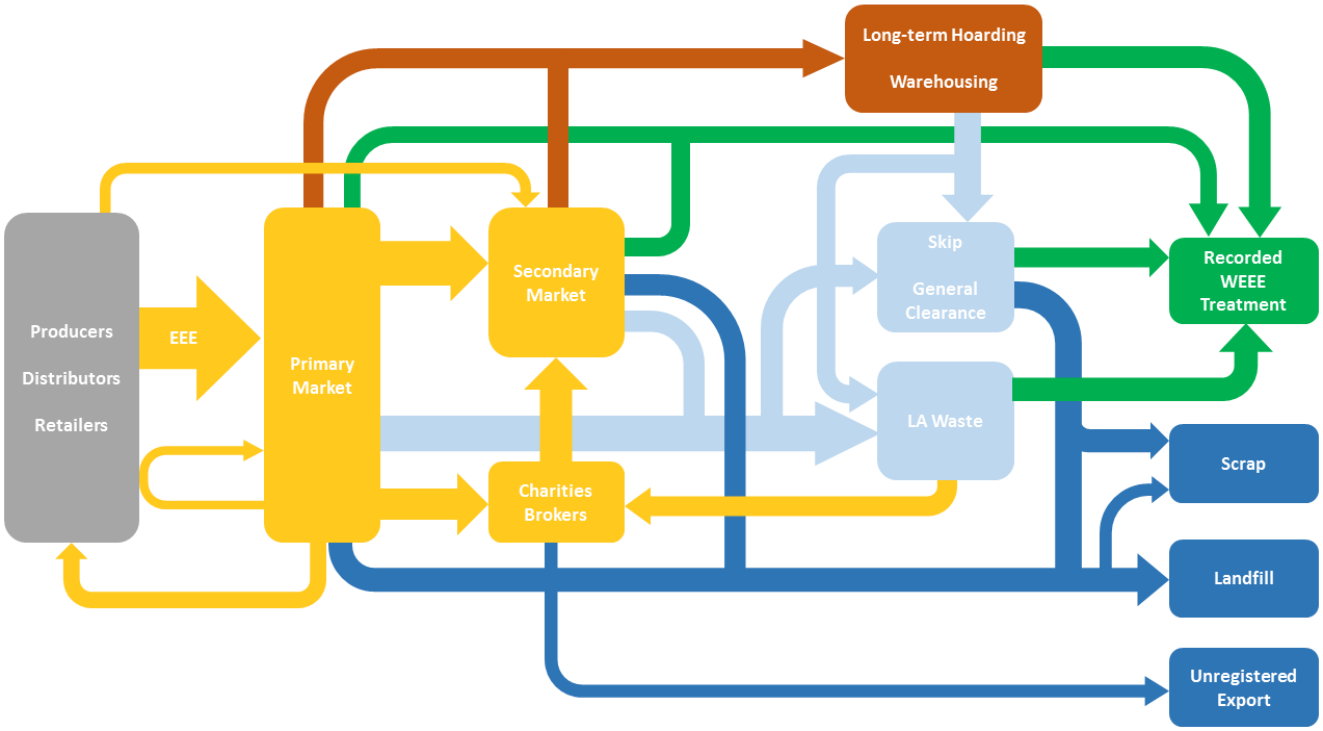
Overall findings

In summary, our findings show that disposal in the household residual streams and landfill/scrap via C&D streams makes up for a lot of the unaccounted WEEE, which is undesirable. There are however case studies of good practice around medical equipment and vending machines, although the picture for tools is less clear. C2C trading provides interesting insights into the behavioural drivers around reuse, but it is a niche concern when considered on a weight basis. Our recommendation is that efforts to account for more WEEE and have it treated properly focus on the inappropriate disposal of small items in the home and larger items in a C&D environment.

Product types	Category Deficit (kt)	Long-term storage (in loop)	Disposal or export (out loop)
Cooling	89.6	A/C units: Significant quantities, unknown	4.4 kt household; 5.3 kt commercial. Likely disposed via C&D and then landfill or scrap
		Commercial display refrigeration: 10–15 year operating life	Almost 16 kt arising per year: • ~4 kt disposed as obligated WEEE • ~2.5 kt non-obligated WEEE, if B2B/B2C disposal ratio reflects sales • Significant fraction remaining, scrap or export a strong possibility
Buildings installed EEE	98.1	Significant, difficult to quantify; only removed during refit or demolition	Significant, difficult to quantify – likely disposed via C&D and then landfill or scrap
Tools	80.6	Household: majority of tools kept long term with infrequent use	Commercial: C&D/Scrap or export (significant), likely >20 kt per year

Product types	Category Deficit (kt)	Long-term storage (in loop)	Disposal or export (out loop)
Household SMW	287.7	Difficult to estimate, but SMW is easily hoarded	Likely to be a substantial fraction of the 366 kt identified by WRAP as being in the residual stream
Vending machines	8.9	Frequent reuse and redeployment, 10–20 year service is common	7.4 kt arising as waste and likely to be scrap
Medical equipment	22.2	Low	High reuse activity, generally for export, eventual dismantling for materials but likely in other countries
Gym equipment	57.5	Long service life, remanufacturing and redistribution frequent due to high availability of spares and simple construction	Household: 8.7 kt arising per year Commercial: 1.4 kt arising per year High scrap value

Overall map of unaccounted UK WEEE flows:



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1 Background

This project was commissioned by the Joint Trade Association using funds accrued from the UK WEEE Compliance Fee: A 2016 report, written jointly by Valpak and WRAP[4], estimated that around 139 kt of WEEE — approximately 9 % of the total projected WEEE arising— would be disposed through unregulated and unreported channels. The EU WEEE Directive (2012/19/EU) collection target for 2016 was 45 % of EEE put on the market (EEEPoM), calculated on the basis of the total weight of EEE collected and the average weight of EEEPoM over the previous 3 years; in 2019, the collection target will rise to 65% (or 85%) of EEEPoM, calculated on the basis of the total weight of EEE collected and the average weight of EEEPoM over the previous 3 years. In 2016, 1,739 kt of EEE were sold in the UK, and 719 kt of WEEE were treated via the appropriate channels (41.3 %)[5].

While the UK's future under the WEEE Directive is currently uncertain, given Britain's recent triggering of Article 50 and current negotiations to leave the EU, the country remains one of the foremost consumers of electronics in Europe — second to Germany in terms of total EEE sold, and fourth in EEE sold per capita[6]. As such, there is a strong need for the UK to maintain and improve its treatment standards and to capture the maximum residual value from its end-of-life electronics.

Table 1: Environment Agency WEEE data for 2016.

B2C EEE Placed on Market	B2B EEE Placed on Market	B2C Obligated WEEE Treated	B2B Obligated WEEE Treated	Non-Obligated WEEE Treated
1,416.3 kt	322.4 kt	581.6 kt	10.8 kt	127.0 kt
Total Reported EEE Placed on Market		**Total WEEE Treated by AATFs**		
1738.7 kt		719.4 kt		

The motivation to investigate non-mainstream waste flows is two-fold: i) robust information on alternative WEEE processing could be taken into consideration when setting or meeting collection targets; and ii) knowledge of disposal practices outside of the regulatory framework may be used to identify where further education programmes and regulatory devices may be employed, to improve overall WEEE treatment standards.

[4] http://www.wrap.org.uk/content/weee-flows-report

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

[6] http://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics_-_electrical_and_electronic_equipment

Furthermore, this report highlights re-use, refurbishment, and remanufacturing of specific product streams in terms of extending product lifetimes, which has been identified as a key component of the Circular Economy's technical cycle by the Ellen MacArthur Foundation and EU Circular Economy package[7,8]. While these practices are not yet mainstream, there are some product types which already have relatively mature lifetime extension practices. Further and more detailed investigation into the extension of product life could provide useful insight into both the current extent of, and potential of the sector.

2 Approach

Prior to engaging in our primary research, a review of the baseline data was conducted, covering the original WRAP report and its sources and the 2016 Environment Agency (EA) statistics on EEE and WEEE treated. A model of EEE/WEEE flow was then constructed, considering the different routes by which equipment moves within the system (i.e. remaining part of the UK's material stock), and the routes by which it can leave.

By combining this flow model with official EA data on EEEPoM and WEEE treated, we prioritised key EEE types to investigate, and investigated them via stakeholder engagement and desk-based research. Due to the scope of this study, the diversity of EEE products in each category, and sensitivity of key information (e.g. sales data or business practices), this study is predominantly qualitative in nature, although estimates are provided where data is available.

2.1 Baseline evaluation

The foundation data from the original WRAP study is given below in Table 2.

Table 2: WRAP and Valpak study data to estimate unaccounted WEEE.

WEEE	Source	Tonnage	Notes
Estimated Total WEEE Generated	European Commission	1,528 kt	Approx ±10 % variation when product lifespan averages altered by 30 %.
Total Reported WEEE Treated	Environment Agency	719 kt	WEEE treated at AATFs, including obligated and non-obligated
Cat 3 B2B Asset Management	HPi	63 kt	
Cat 1/12 Large Domestic Appliances in light iron stream		273 kt	Processing *via* scrap metal industry

[7] https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Ellen-MacArthur-Foundation-Towards-the-Circular-Economy-vol.1.pdf

[8] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52015DC0614

WEEE	Source	Tonnage	Notes
Other	WRAP	139 kt	Subject of this study
B2C Residual	WRAP	356 kt	Based on municipal waste sampling
Cat 3 B2B Residual	HPi	10 kt	
Cat 1 Theft	WRAP	77 kt	
Cat 2 Theft	WRAP	1 kt	
Cat 11 Theft	WRAP	10 kt	
Cat 12 Theft	WRAP	9 kt	
Total Unreported WEEE		475 kt	
Total Residual		366 kt	
Total DCF Diverted		96 kt	Assumed to be theft; subject of a study by 360 Environmental

As Table 2 shows, the "Unreported" 139 kt is essentially "leftover" and is strongly dependent on uncertain values, such as the overall WEEE arisings projections and residual waste — for example, a 30 % increase in product lifespan modelling from the original European Commission report figures could cause a roughly 10 % decrease in the total projected WEEE generated, which is close to the Unreported WEEE figure investigated in this study. Further to this, a recent study by Murakami *et al.*[9] also noted that recycling systems need to be designed to account for lifespan uncertainties, and suggest dynamic modelling of EEE flows within the system, rather than simply taking outflows into account.

Additionally, the residual waste estimations are much higher than those from other European countries: 5.5 kg/inhabitant in the UK, compared to 1 kg/inhabitant (France) and 1.6–2.3 kg/inhabitant (Italy)[10]. As this assessment was largely based on compositional analyses of Municipal Waste, it is likely to include contributions from the B2B sector, which are largely unaccounted for.

Consequently, the purpose of this study is to examine the waste flows of WEEE within the UK system, and to build up a picture of i) how EEE stays in circulation, and ii) routes by which either EEE or WEEE can leak out of the system without being accounted for.

2.1.1 Out of Scope

Due to robust data available for Category 1 (LDA) and Category 3 (IT & Communications) streams, as evidenced in WEEE Directive reporting and the substantiated evidence identified in the WRAP and Valpak study, we did not actively investigate them, although some discussion of IT equipment is included as part of discussion of the section on household Small Mixed WEEE (SMW). Additionally, we omitted investigation of Category 14

[9] http://www.sciencedirect.com/science/article/pii/S2212827116313981

[10] http://datashare.colchester.gov.uk/Download/recycling-and-rubbish/residual-waste-per-household

(Photovoltaics) due to the long lifespans of the equipment (panels often come with 25 year warranties[11]), and the fact that mainstream uptake has been a relatively recent phenomenon. However, we note that effective capture of this stream in the future would greatly help in meeting WEEE recycling targets, and that environmentally sound treatment is vital particularly for cadmium telluride (CdTe) based modules.

Lastly, we have not attempted to quantify waste entering the residual waste stream, although this is known as a major WEEE leakage point. However, we note that characterisation of this stream for both household and non-household waste would provide extremely useful information for informing future policy direction.

2.2 EEE Flow Model

To build an EEE/WEEE flow model, for all EEE placed on the market in the UK, we identified five distinct states that EEE/WEEE may occupy (Table 3 and Figure 1).

Table 3: Different states of electrical and electronic equipment during in-use, transitional, and end-of-life phases.

EEE/WEEE State	Treatment	Via	Sector
In-loop	Redistribution in UK	Asset Management & Brokers	Business
		Charities	Consumer
	Passing to secondary owner	Direct Consumer to Consumer (C2C)/second-hand shops	Consumer
		Ex-business sales	Consumer
		Auction	Business & Consumer
	Refurbishment	Manufacturers	Business & Consumer
		Independent	Consumer
	Warranty Returns	Manufacturers or Distributors	Business & Consumer
	Theft	Illicit	Business & Consumer
	Abandonment/Fly-tipping[12]	Illicit	Business & Consumer
	Hoarding/long-term use	In-house, storage	Consumers

[11] http://energyinformative.org/lifespan-solar-panels/

[12] For this study, we have largely overlooked EEE abandonment as collection of abandoned waste is usually conducted *via* Local Authorities; therefore, it is assumed that abandoned WEEE will, by and large, eventually be processed through the appropriate channels.

EEE/WEEE State	Treatment	Via	Sector
Long-term In-loop	Warehousing	Storage	Business
Transitional	WEEE Collection Point (e.g. a Designated Collection Facility)	Local Authorities	Consumers
	Skips	C&D House Clearance	Businesses, Consumers
Reported Out-loop	Regulated WEEE Recycling	AATFs	
	Approved Export	AEs	
Unreported Out-loop	Residual Waste Stream	Household refuse	
	Unreported Export (for re-use)	Charity	
		Asset Brokers	
	Unreported Export (Illegal)	Illicit Activity	
	Scrapping/non-WEEE recycling	Materials Recyclers	
	Dismantling/Component harvesting	Manufacturers/servicers	
	Landfill	Household and C&D refuse	

Here, "**In-loop**" refers to all routes by which EEE changes hands, but stays in operation as part of the UK's EEE stock. A distinction is made between "**In-loop**" and "**Long-term In-loop**", in which equipment stays in the system for much longer than its expected lifespan, either through long-term operation, or through hoarding or warehousing — this significantly delays the transition of an item to WEEE.

The "**transitional**" state arises once the EEE item's owner makes the decision to dispose of the item and transfers the item to a disposal entity. For consumer-owned goods, this usually leads to a Designated Collection Facility (DCF), while transfer to a skip is common with house clearance or in the C&D sector. Even though the majority of WEEE captured in the transitional state will go on for waste processing, it may still re-circulate back into the In-Loop system, either through redistribution (e.g. through a re-use programme), or through theft, which was detailed in the WRAP study, and is the subject of a separate stream of further research as part of the WEEE Compliance Fee-funded research programme.

Lastly, "**Out-loop**" states are the routes by which EEE/WEEE leaves the UK system, which can be further delineated into two categories: "**Reported Out-loops**" (i.e. recycling through regulated channels by Approved Authorised Treatment Facilities (AATFs) or through export for recycling via Approved Exporters (AEs)) in which the tonnage is accounted for by the Environment Agency; and "**Unreported Out-loops**", encompassing all routes by which WEEE is permanently disposed of outside of the WEEE treatment infrastructure, or leaves the country (e.g. labelled as export for re-use).

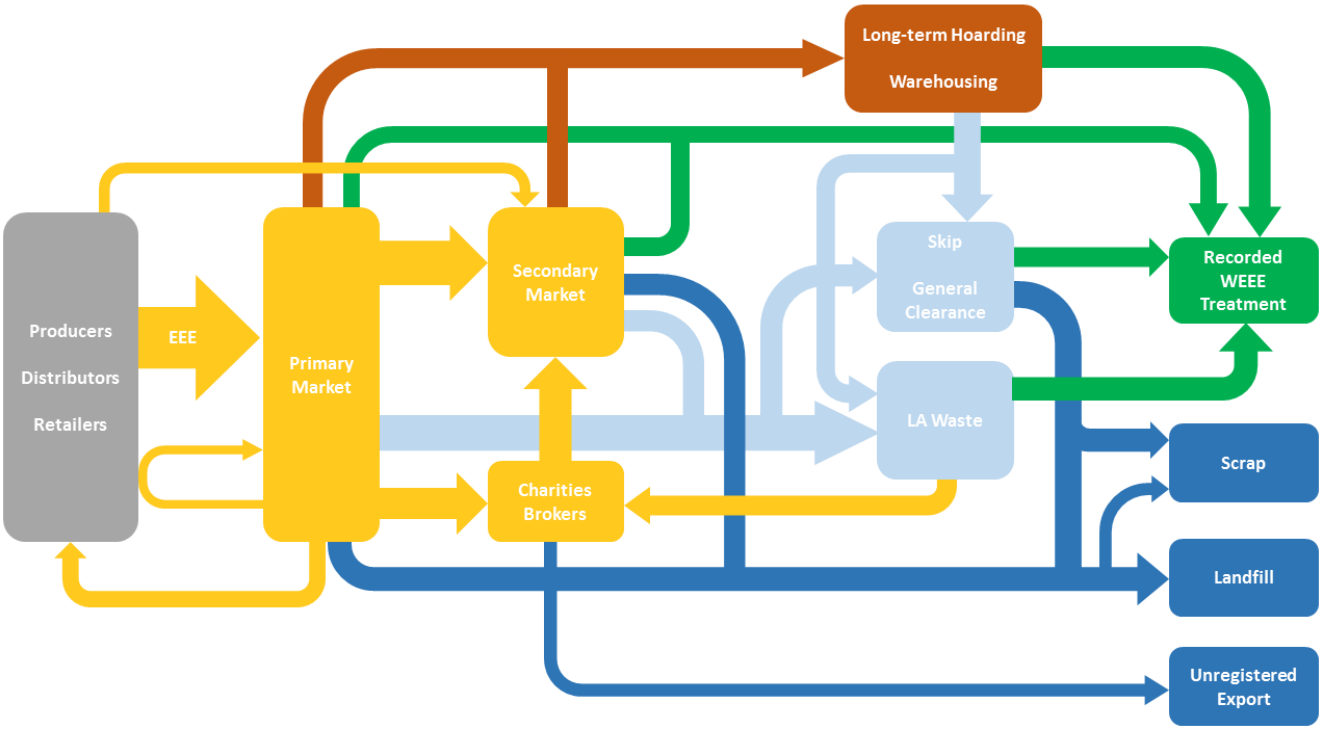

Figure 1: A general-case map for EEE flows in the UK. Yellow routes denote active distribution of EEE within the system; brown represents long-term retention of material (prior to it being classified as WEEE); light blue represents transitional stages for equipment classified as WEEE; green denotes authorized WEEE treatment, while dark blue covers unreported routes for WEEE leaving the system. Note that the relative sizes of the boxes and arrows are representative, and not proportional to tonnage data.

For the purposes of this study, we are considering EEE exported for re-use to be included as "lost WEEE": while such equipment is not technically WEEE as the owner has not taken the decision to dispose of it, it is a route by which material is lost from the UK's EEE stock, and extremely unlikely to return for treatment via the WEEE system. The original UNU models (outlined in the reference below) used to generate the WEEE arisings figures only considered historic EEEPoM and average product lifespans; modelling of export was recommended by the report to account for this potential overhang of material which is not currently captured — currently, there is no specific customs code for EEE exported for re-use. The 2014 UNU study "Study on Collection Rates of Waste Electrical and Electronic Equipment" is frequently referenced in this work, and is hereafter abbreviated to UNU (2014)[13].

A widely applicable flow diagram of the model is presented in Figure 1, based on these routes, and similar diagrams for specific product types and consumption models are included later in the report.

[13] Magalini *et al.*, Study on Collection Rates of Waste Electrical and Electronic Equipment (study for the European Commission), United Nations University 2014.

2.3 Identifying Key Sectors for Investigation

To identify key sectors for investigation, we used the Environment Agency's 2016 statistics for EEEPoM and WEEE received at AATFs (both obligated and non-obligated) as a guideline. For the purposes of this study, Categories 1 and 3 were not actively investigated, given that the existing data for these streams is fairly robust. We used the following process to construct our guidelines:

- Separate consideration of B2B and B2C markets.
- Split into EEE category (1–14).
- Created two matrices — one for B2B, one for B2C — covering the probable routes for each EEE category.
- Assessed the 'deficit' between EEEPoM and WEEE reported as treated.
- Added further consideration for more specialist or narrow EEE categories, i.e. giving preference to those with fewer probable flow routes.

We stress that the method used here was used for guidance only, and must take the following into consideration:

EEE Placed on the Market

The official EA statistics for EEEPoM do not represent all EEE sold. The WRAP/Valpak WEEE flows report used assumptions from the UNU study (2014), to estimate that a further 13 % of material (232 kt) is sold in the UK each year, made up of unregistered (133 kt) or exempt and unaccounted for (99 kt) equipment. Of this, 28 % was considered to be "unaccounted for" (28 kt), and 43 % were thought to be Photovoltaic (PV) panels (43 kt) and, as such, we expect that that this 'extra' tonnage will be highly variable year-on-year (with around 3–4 % as an average figure); it should also be noted that in the original UNU (2014) study, discrepancies between the modelled tonnage and the EA's official figures range from an –8 % underestimate to a 14 % overestimate depending on year.

WEEE Collection Practice in the UK

In practice, WEEE in the UK is broadly sorted into 6 collection streams, rather than into the 14 categories: A (Large Domestic Appliances); B (cooling); C (Cathode Ray Tube display); D (gas discharge lamps); E (small mixed WEEE); and F (PV Panels.

In particular, Stream E tonnages are usually calculated by a protocol including Categories 1, 2, 3, 4, 6, 7, 9, 11, and 12[14], rather than representing the precise weights for the individual categories. Category 1 (LDA) collections are also calculated using a different protocol to account for non-WEEE component weights.

[14] https://www.gov.uk/government/publications/weee-evidence-and-national-protocols-guidance/waste-electrical-and-electronic-equipment-weee-evidence-and-national-protocols-guidance#use-of-weee-protocols

Therefore, the reported tonnages cannot be assumed to be a wholly accurate reflection of the collection rates for the individual EEE categories.

Fluctuations in EEE Placed on the Market Trends

The weight of EEEPoM is subject to a complex array of factors, including trends in product design and technology, consumer requirements and demand, general economic outlook, etc. Therefore, the relationship between EEEPoM and WEEE collected for a single category will fluctuate year-on-year. A well-known illustration of this is the shift from bulky CRT displays and TVs to flat-panel technologies, which has greatly reduced the average unit weight for these products. Therefore, it is not expected that the respective EEEPoM and WEEE tonnages in a given year should reach parity.

Classification of B2B and B2C Equipment

B2B and B2C equipment are defined by function. However, items deemed to be dual-use (i.e. used by businesses and consumers alike, e.g. toner cartridges) are categorised as B2C, and therefore businesses will handle significant volumes of B2C equipment.

To prioritise the areas of study, firstly we targeted EEE products with the most unaccounted tonnage at end-of-life (while taking into account the caveats above). This deficit was calculated by subtracting the EEE collected from that sold and then supplementing the collections data with the substantiated evidence outlined in the WRAP/Valpak report from 2016 (Table 4). The estimate for WEEE disposed via the household residual waste was discounted at this stage, as it was our belief that there was significant interplay between that stream and the other unaccounted streams that are the topic of this report.

Table 4: Deficit of collections for different WEEE Categories.

Category	EEEPoM, 2016	Obligated WEEE Treated, 2016	Non-Obligated WEEE Treated, 2016	Substantiated estimate	Total 'deficit'
1	594.8 kt B2C	211.8 kt	44.3 kt	273 kt	84.5 kt
LDA	20.5 kt B2B	1.7 kt			
2	166.4 kt	38.1 kt	5.0 kt	1 kt	141.3 kt
SDA	19.1 kt	0.1 kt			
3	87.9 kt	53.0 kt	30.7 kt		14.7 kt
IT & Comms	75.5 kt	2.0 kt		63 kt	
4	56.8 kt	40.0 kt	4.4 kt		18.6 kt
Consumer Eqt.	6.3 kt	0.1 kt			
5	0.0 kt	0.0 kt	1.4 kt		46.3 kt
Lighting Eqt.	50.9 kt	3.2 kt			
6	78.7 kt	19.4 kt	2.8 kt		80.6 kt
Tools	24.5 kt	0.4 kt			
7	52.2 kt	2.6 kt	0.3 kt		57.5 kt

Category	EEEPoM, 2016	Obligated WEEE Treated, 2016	Non-Obligated WEEE Treated, 2016	Substantiated estimate	Total 'deficit'
Toys/Leisure	8.1 kt	0.0 kt			
8 Medical	3.2 kt	<0.1 kt	0.2 kt		25.4 kt
	22.6 kt	0.2 kt			
9 Control Devices	10.9 kt	0.2 kt	0.8 kt		48.5 kt
	38.7 kt	0.1 kt			
10 Dispensers	<0.1 kt	0.0 kt	0.5 kt		8.9 kt
	9.5 kt	0.2 kt			
11 Display	80.8 kt	74.6 kt	12.9 kt	10 kt	2.6 kt
	9.3 kt	0.1 kt			
12 Cooling	225.0 kt	136.1 kt	23.4 kt	9 kt	89.6 kt
	35.9 kt	2.9 kt			
13 Lamps	10.4 kt	5.8 kt	0.2 kt		5.8 kt
	1.3 kt	0.0 kt			
14 PV	49.2 kt	0.1 kt	0.0 kt		49.1 kt
	0.0 kt	0.0 kt			

2.3.1 Prioritising Product Streams

We selected areas for investigation by looking at both the overarching EEE categories, as well as specific product streams. Research priorities were determined by several criteria:

i) The size of the deficit for EEE categories, and for product streams which constitute a large part of an EEE category.

ii) Narrow product streams.

iii) If the product or category is generally used within a specialist sector.

iv) If a product stream contains large items (>150 kg).

v) Availability of data.

vi) If a product stream is a strong candidate for re-use or refurbishment, or if such practices are already widespread within the relevant sectors.

Subsequently, the following streams of electrical equipment were identified as targets of particular interest (Table 5). These priority streams include different product types, in some cases, as they reflect a comingled stream of collection and treatment.

Table 5: Priority WEEE Streams.

Rank	Product Type	EEE Categories	Sector	Criteria for focus					
				Tonnage	Narrow Stream	Specialist Sector	Large items	Data Available	Refurb
1	A/C, Commercial Chilling Cabinets	12	B2B B2C	✓			✓		✓
2	Buildings control and lighting	9, 5	B2B	✓	✓	✓			
3	Electrical & Construction Tools	6	B2B B2C	✓	✓	✓			
4	Household SMW	2, (3), 4, 6, 7	B2C	✓					✓
5	Vending Machines	10, 12	B2B		✓	✓	✓	✓	✓
6	Medical Equipment	8	B2B		✓	✓	✓	✓	✓
7	Gym Equipment	7	B2B		✓	✓	✓		✓

3 Findings

This section presents details of the findings from our secondary research and primary interviews, within the framework of the model detailed above. Details of how WEEE is collected and then treated (if at all) are presented and we, where possible, provide quantified estimates for annual collections. These estimates are collated and discussed in the conclusions.

3.1 Cooling Equipment: Category 12

Despite its high collection rate — old fridges and freezers are generally collected from households as part of a new purchase — cooling remains one of the streams with the highest 'deficit', 98.6 kt. This can be attributed partially to growing consumer preference for larger fridge/freezer units over the last ten years[15]. However, capture rates from the B2B sector are typically poor (~8 %); moreover, the scrap value of a lot of cooling equipment makes it a candidate for treatment outside of the WEEE framework which, given the Green House Gas (GHG)/ozone destruction potential of refrigerant gases, is highly undesirable. Yearly tonnages of B2B cooling equipment (Category 12) and non-household category 12 equipment treated by AATFs are displayed in Figure 2.

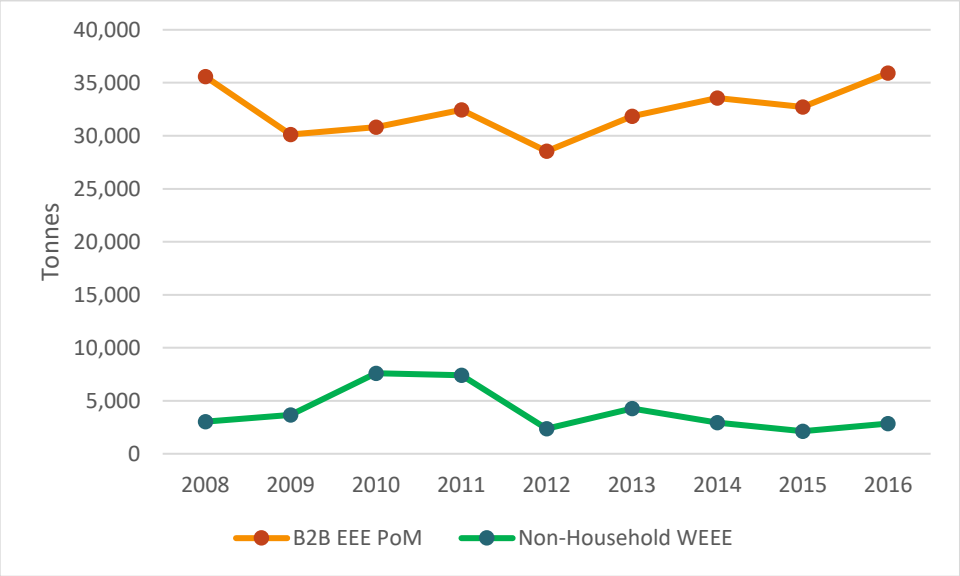

Figure 2: Comparison of year-on-year B2B cooling equipment (Category 12) placed on market, and non-household Category 12 equipment treated by AATFs.

To address this equipment category, we chose to focus on air-conditioning (A/C) equipment and commercial food and drink chilling cabinets.

[15] https://www.gov.uk/government/collections/household-electricity-survey#appliance-ownership,-use,-labels-and-demographics

3.1.1 Air Conditioning

Generally, A/C is not seen as an essential household item in the UK, when compared with countries such as the US. While household systems are relatively rare, it is widely used in the commercial sector. The UK A/C market suffered from the economic crash in 2008, and the market has mostly exhibited low-level, stable growth in the years since.

There have been various studies into growth of A/C in the UK, and therefore there are a number of datasets available: much of the interest in this area has been due to concerns over the high energy requirements of these systems and the potential for energy wastage, e.g. through poor user practice or installation of overcapacity systems. From these data, we have been able to generate some rough estimates for the UK's A/C equipment stock. We note that due to the dual-use nature of some types of A/C system, it is likely that a reasonable proportion of A/C installed in commercial settings would be classed as B2C.

3.1.1.1 Household Air Conditioning

We used BRE's 2013 Energy Follow-up Survey[16] to estimate household A/C usage. Due to the small sample size of responses, the generated figures are not robust, but it is clear that household A/C uptake is low.

The figures listed here are estimates and based on several assumptions: the average weight of portable systems was determined from an average of 15 different models; fixed household systems were assumed to be multi-split, consisting of an external heat pump unit (weight estimated from 19 different units), 2 indoor wall-mounted units and 1 indoor ceiling unit (estimated from 18 different units). Lifespan estimates were obtained from online research and stakeholder engagement.

Table 6: Expected WEEE arisings from household A/C equipment.

System Type	Household Usage (%)	Households w/ A/C	Avg. System Weight	UK Material Stock	Lifespan	Expected WEEE pa
Fixed	0.8 %	216,712	123 kg	26.6 kt	16 years	1.6 kt
Portable	2.0 %	541,780	26 kg	14.1 kt	5 years	2.8 kt

Portable systems are generally too large to be easily disposed of via the residual waste stream and are likely to be taken to DCFs. However, fixed systems are likely to be removed by contactors or during construction and demolition projects. The most likely route for disposal is the C&D waste stream which results in landfill, though some components might be diverted into the scrap metal industry.

[16] https://www.gov.uk/government/statistics/energy-follow-up-survey-efus-2011

3.1.1.2 Non-Household Air Conditioning

The Building Research Establishment's (BRE) study into air conditioning[17] in the UK provided figures which formed the basis for estimates of commercial A/C equipment stocks: the study contained data on the percentage of air-conditioned commercial space in the UK by area, with the data shown in Table 7. For office and retail spaces, to provide a rough estimate of installed A/C capacity (in terms of BTU per hr) in the UK, we applied the Energy Star Guidelines[18] for cooling; then, we considered commonly installed commercial multi-split and variable refrigerant flow (VRF) systems to estimate values of BTU per hr per kg of cooling EEE. We also compared these figures with estimates derived from A/C manufacturer case studies to determine whether the figures would be reasonable.

We stress that the tonnages presented here are rough and would require a more thorough survey to improve their robustness.

- While some air-conditioning systems are covered under the scope of the WEEE Directive, large-scale systems will be excluded under the Large Fixed Installation designation.
- The % air-conditioned floor space was noted by BRE to be very rough.
- Energy Star guidelines may lead to underestimates of A/C EEE as many buildings have substantial cooling overcapacity installed.
- The diversity in Heating Ventilation and Air Conditioning (HVAC) system and requirements mean that the cooling capacity per kg values may not be accurate.
- The Valuation Office Agency[19] data used in the BRE study categorised a number of location types under 'other' (e.g. casinos, gyms, and sports centres), and excluded various others (e.g. universities/schools, hospitals, hotels, and airports), many of which have strong cooling requirements. Therefore, we expect the installed cooling stock to be much higher than the figures presented here.
- The WEEE arising figures were determined using a system lifespan of 20 years, and assuming a steady-state AC stock (therefore replacing 5 % of the stock per year).
- Warehouse and factory systems will generally fall under the classification of large, fixed installations, and are therefore out of scope of the WEEE Directive.

[17] http://www.bre.co.uk/ac_energyuse

[18] https://www.energystar.gov/products/heating_cooling/air_conditioning_room

[19] https://www.gov.uk/government/statistics/business-floorspace-experimental-statistics

Table 7: Equipment stock for commercial A/C systems. Warehouse and factory units have been omitted as these are usually deemed to be large fixed installations and out of scope of the WEEE legislation.

Commercial Space	% Air-conditioned	UK Air-Conditioned Floor space (2012)	A/C EEE Stock	Expected WEEE Arising
Office	65 %	66.4×10^6 m^2	74.6 kt	3.7 kt
Retail	30 %	27.7×10^6 m^2	31.1 kt	1.6 kt
Warehouse	5 %	15.2×10^6 m^2	-	-
Factory	8 %	3.3×10^6 m^2	-	-

As with fixed household systems, units are likely to be removed by contactors or during construction and demolition projects and then routed to the C&D waste or landfill.

3.1.2 Commercial Refrigeration

Commercial refrigeration is a large sector, with display units being extremely commonplace in supermarkets, shops, and cafés. This sector will also cover refrigeration used in commercial kitchens, warehousing/distribution centres (non-fixed installations), ice machines, and others. For retail refrigeration, larger stores will tend to have a central plant installation with modular remote cabinets or roof-mounted condensers, whereas smaller stores will carry standalone cooling units.

To develop an idea of the tonnage of equipment placed on the market in this sector, we considered display refrigeration in businesses with available data sources. For these estimates, we aggregated store data for the top 9 supermarket operators in the UK, alongside less detailed data for small convenience stores; we also used data on cafés and alcohol off-licensed premises. These data would only represent a proportion of display cooling in the UK, given that refrigerators in venues such as pubs, clubs, and entertainment venues are commonplace; this also excludes non-display food storage solutions. We estimated that, on average, supermarkets would be equipped with 10 kg/m^2 of cooling equipment.

Table 8: Estimated equipment stock and projected annual WEEE arisings of retail display refrigeration in the UK. This is considered to represent only a portion of B2B Category 12 equipment.

Outlet Type	Estimated Number of UK Stores	Estimated Display Refrigeration Stock
Supermarket	19,520	162.1 kt
Convenience Store	21,820	24.1 kt
Cafés	6,950	3.5 kt
Total	48,290	189.7 kt
Projected WEEE Arisings		15.8 kt

From our research, we noted that small convenience stores (< 750 m^2) tend to have a high density of cooling equipment (typically several multideck units and a freezer) in order to maximise the use of sales space. The popularity of small stores has grown markedly in recent years and has cut into the market share of larger supermarkets; the proliferation of these stores has likely led to growth in the UK's stock of commercial cooling. Café culture has grown substantially in the UK in the last decade, with steady year-on-year increases in chain coffee outlets nationwide, and the surging popularity of specialty coffee, particularly in urban areas. These outlets are typically equipped with 1–4 multideck chiller units. The estimated stock for commercial display refrigeration is presented in Table 8. Given the aforementioned omission of venues which are likely to carry drinks refrigeration, as well as non-display cooling, we can expect that the total UK stock of commercial cooling covered by the WEEE Directive is substantial.

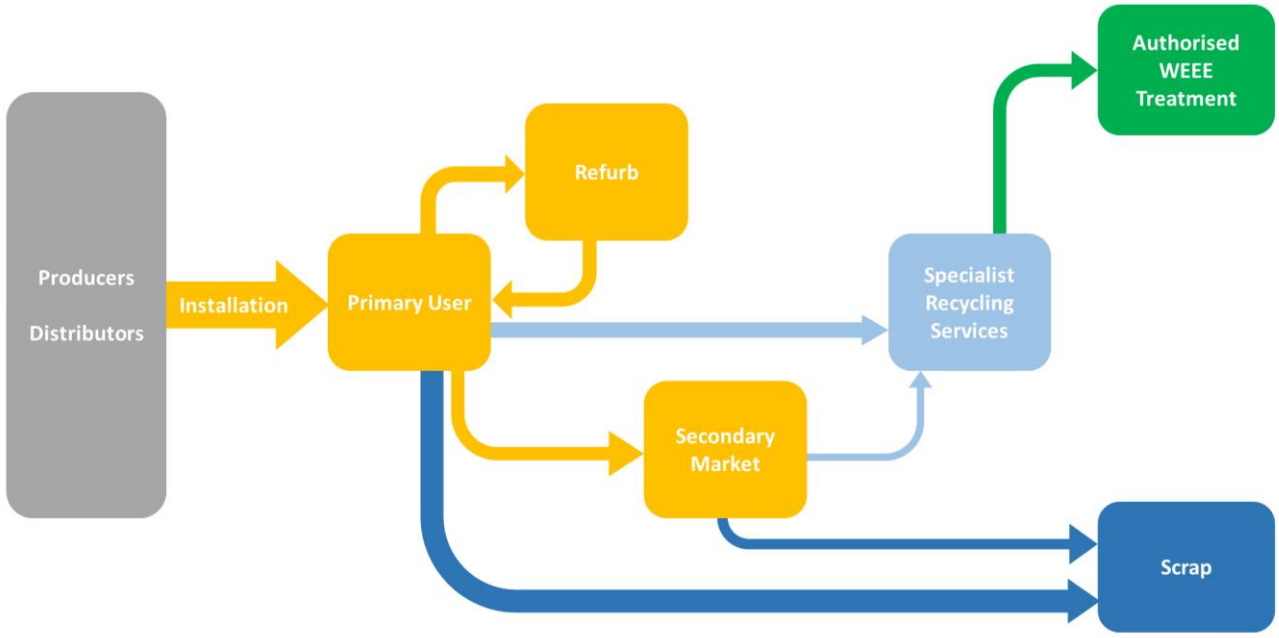

Figure 3: Flow diagram showing use and disposal routes of commercial display refrigeration equipment.

3.1.2.1 Management of Commercial Cooling Equipment

Commercial refrigeration typically has a long service life, and used equipment can be easily bought or sold in informal B2B markets. Both outright sales and service models are used in the industry, depending on the scope and design of the outfitting project.

Typically, a cabinet would be expected to have a service life of 10–15 years, depending on their design and operating temperature. Relocation may also have an impact on the lifespan of the equipment. Some businesses offer refurbishment of older cabinets – changes are largely cosmetic, but some component swaps can be undertaken to extend their lifetime. This is typically done on-site, as off-site refurbishment (i.e. disconnection, removal, and reinstallation) can be a costly process.

3.1.2.2 End-of-Life Treatment

For end-of-life treatment, there are a number of AATFs which specialise in commercial cooling equipment, and several manufacturers offer takeback under the WEEE Regulations. Over the last 8 years, around 4.1 kt of non-household cooling equipment has been treated every year by AATFs. This represents around 2 % of the commercial display refrigeration stock, though it is likely some of the non-obligated cooling WEEE is from a B2B source, and therefore it is likely that significant volumes of cooling equipment are processed by

alternative routes; for comparison, we estimate that nearly 16 kt of commercial display refrigeration will arise as WEEE year-on-year. Based on their weight and construction, cabinets could be disposed via scrap.

3.2 Building-installed EEE: Category 5, 9, and other mixed streams

Large volumes of EEE are removed from buildings during demolition, refitting, or systems upgrades. This typically includes:

- Category 5, Lighting Equipment: predominantly light fittings which have, historically, been under-collected for WEEE treatment[20].
- Category 9, Monitoring & Control Devices: including control panels, alarm systems, and environmental management controls (e.g. for heating regulation).
- Other mixed WEEE, such as boilers.

Considering trends in EEE placed on the market for Category 5 and Category 9 (shown in Figure 2):

- Category 5 generally covers professional lighting equipment, fluorescent light fittings (ubiquitous in the B2B market), LED luminaires, and street lights.
    - There has been a general decline in Category 5 tonnage over the period 2008–2016, which may relate to shifts away from fluorescent lighting.
- In addition to building management systems, Category 9 also covers street lights, traffic management barriers, and electrical measurement tools (such as voltmeters).
    - Category 9 tonnages vary significantly year-on-year, marked by a threefold spike in 2011, and an almost fourfold increase over the period 2013–2016.

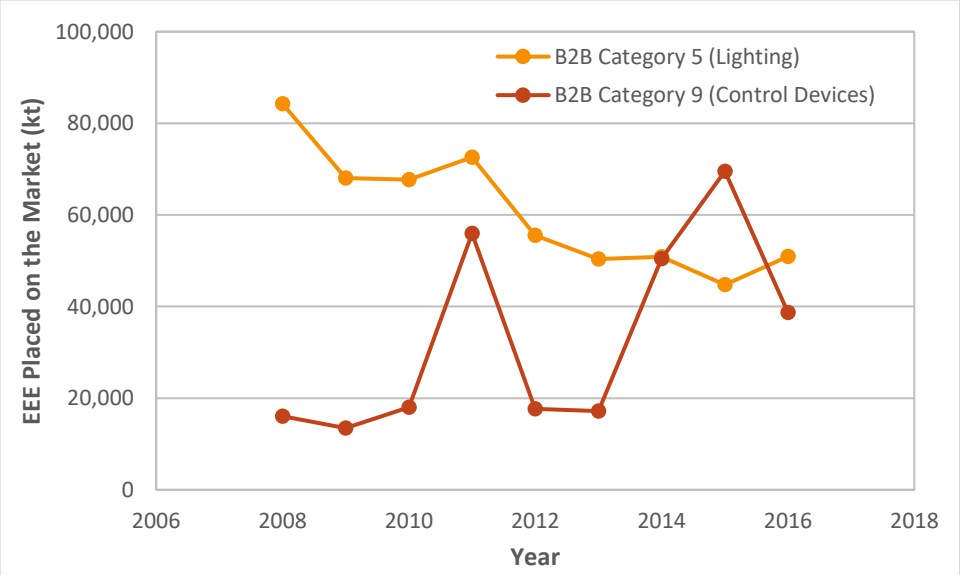

Figure 4: Placed-on-market data for Lighting (Cat 5) and Control Devices (Cat 9).

[20] WRAP, Market Flows of WEEE Materials, 2011

3.2.1 Disposal of WEEE during Upgrade, Refit, and Demolition Building Work

To gain an understanding of general WEEE disposal practices from buildings, we engaged with companies responsible for installing building management systems (which would typically fall under Category 9), and those with first-hand experience within the C&D industry.

During refits or systems upgrades, demolition crews are often subcontracted to strip the building, with the primary contractor providing skips for the waste. During this process, any items with scrap value are targeted for removal — crews are often instructed to search for and strip out valuable materials such as copper; WEEE with little scrap value will either be consigned to the skip, or to conveniently located residual waste bins. It was suggested that the general level of WEEE awareness in the sector is low, and that WEEE segregation rarely or never occurs.

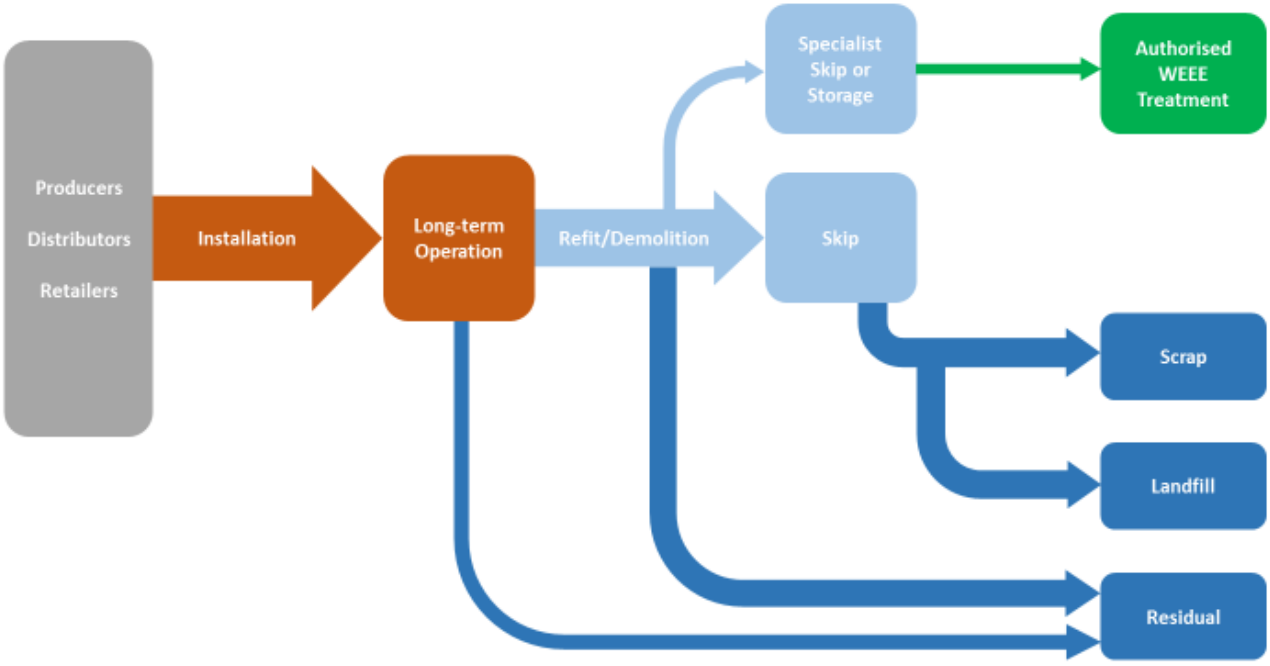

Figure 5: Map of disposal routes for Lighting and Building Control Devices.

One building management services company stated that they collected old Category 9 systems obtained during upgrade work and kept them in storage until they had a sufficient amount of WEEE to take to a recycler. However, this sort of initiative is probably limited to companies with strong environmental policies and awareness, given i) the cost associated with WEEE recycling, and ii) the ease of disposal via residual waste (Figure 5).

While direct data are not available, one stakeholder with expertise in the design and installation of buildings management systems highlighted that companies specialising in systems refits/upgrades would get through a high volume of work each year. For example, a BMS contractor with 20 crews would expect to receive 50–100 jobs a week, and UK city councils will refit thousands of homes a year to improve heating or lighting efficiency. Consequently, we can conclude that improving awareness of WEEE within the C&D sector and providing alternative paths of least resistance for WEEE disposal would help improve capture rates from the built environment.

3.3 Electrical and Electronic Tools: Category 6

A total of 103 kt of Category 6 equipment was placed on the market in 2016 and 23 kt were recorded as being treated at AATFs[21], yielding a collection rate of 22%.

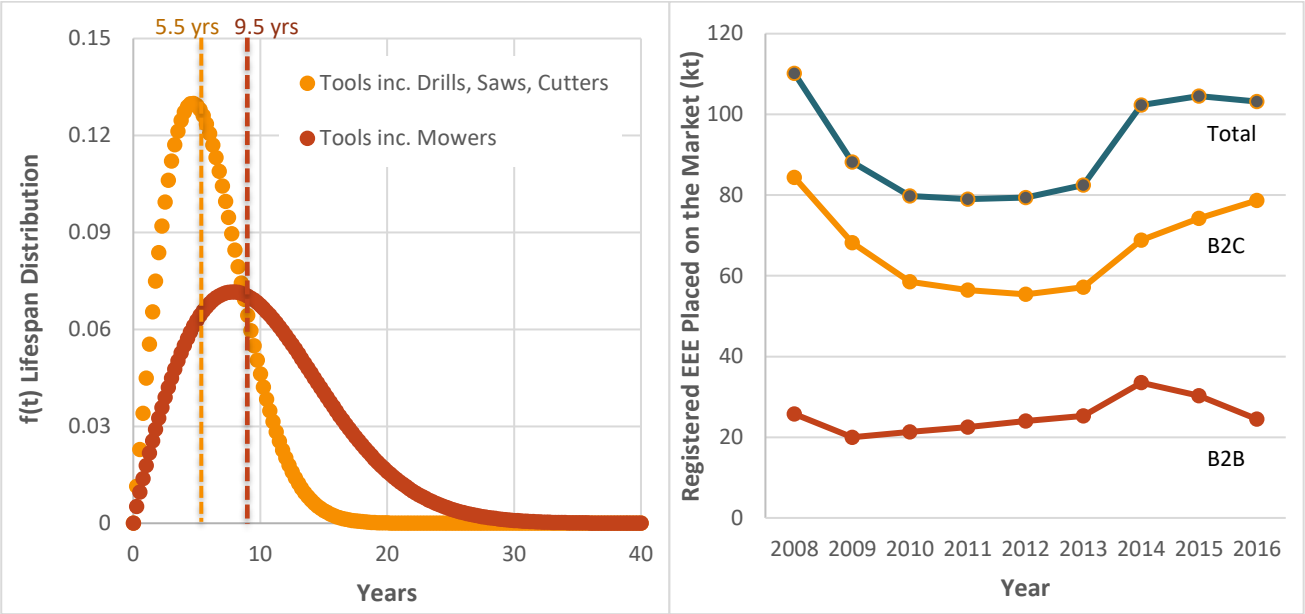

Figure 6. **Left**: Weibull[22] distribution model for product lifetimes of Category 6 equipment from the UNU (2014) study. Average lifetimes calculated by integration are represented by the dashed lines, yielding values of 5.5 years for tools such as drills, saws, and angle grinders, and 9.5 years for equipment such as mowers and hedge cutters. **Right**: EA data for Category 6 EEE placed on the market.

The EEEPoM trends for Category 6 equipment are shown in Figure 6 showing a substantial fall in the B2C tonnage sold during the 2008 economic crash, whereas the B2B sector has remained relatively stable. In comparing these two sectors, we considered that tools in the B2B sector are subject to heavy use, whereas consumers are more likely to use tools sporadically, thus lengthening their time of service. Note that many smaller tools used in commercial settings (e.g. drills) will be dual-use, and therefore designated as B2C.

Therefore, we consider that the flow of Category 6 EEE will proceed by very different routes in the respective sectors, and have split this section accordingly.

[21] Note that Category 6 tonnages are largely assigned by the Small Mixed WEEE protocol, calculated as being 12 % of collection Stream E.

[22] UNU recommended Weibull distributions when forecasting lifetimes for electronic products https://exp.unu.edu/media/project/174/E-waste-Guidelines_Partnership_2015.pdf

3.3.1 Commercial Tools

We engaged with tool hire companies to identify standard handling practices in the C&D sector, and considered that there would not be much of a difference between treatment of tools which were owned by C&D companies or by leasing companies. From these engagements, we found that:

- the majority of mechanical tools would be expected to be in service for 2–3 years, given their heavy workload. This is around half of the expected lifetime modelled in the UNU studies (5.5 years);
- as the EEEPoM trend in Figure 6 shows, the yearly B2B sales of Category 6 equipment are fairly consistent, which could be interpreted as regular turnover of equipment in the sector;
- some companies offer fleet management of their tools, including an internalised manufacturer takeback system;
- at the end-of-service, tools which are no longer functional or deemed unsafe are typically scrapped if they hold any material value, or they enter the residual waste stream; and
- worn but functional tools are then either sold in bulk at auction or at plant sales. While we were not able to engage directly with buyers of used equipment, stakeholders speculated that the equipment would most likely be exported.

From these engagements, it is clear that disposal of end-of-service Category 6 equipment in this sector aims to capture as much residual monetary value as possible. Ultimately, neither construction nor tool hire companies carry any obligation towards disposing of their WEEE through the appropriate channels, and it seems that general awareness of WEEE Regulations is low.

Trends in fleet management service uptake would be an area of interest: not only does this offer numerous benefits to operators in the C&D sector (better maintenance scheduling, less downtime, etc.), but manufacturer takeback would also help to divert end-of-service equipment from export and residual streams, given their producer responsibility obligations.

3.3.2 Household Tools

- The Consumer to Consumer (C2C) trading markets for Category 6 are less strong than for other SMW streams: in WRAP's 2013 study into C2C secondary markets, Category 6 tools were sold with a much lower frequency than Category 2, 3, 4, or 7 products[23].
    - Category 6 C2C sales were 22 % of the scale of Category 4, which we consider to be roughly comparable in terms of unit weight.

[23] http://www.wrap.org.uk/sustainable-electricals/esap/consumer-behaviour/reports/study-consumer-second-hand-shopping-identify-re-use-behaviour

- The overall EEEPoM tonnages for Category 4 (consumer equipment) and 6 (tools) streams have, historically, been comparable (63 kt and 66 kt on average per annum over the period 2008–2016).

- Category 6 products (tools) differ from many other SMW streams, in that the technologies themselves are generally quite mature: improvements in tool technology have tended to involve material changes, e.g. improved durability of components, or the change in battery technology from nickel-cadmium (NiCd) to nickel-metal hydride (NiMH) to Li-ion; therefore, the purchase of Category 6 equipment is generally not driven by technology.
- Consumers are likely to hold onto electrical tools "just in case" due to their inherent utility, and are likely to be retained by owners in the long term.
- When household tools are disposed, and it appears that many accumulate, we consider it likely from interview with stakeholders that they are disposed either at an Household Waste Recycling Centres (HWRC) or via the residual waste, so out of the scope of this study.

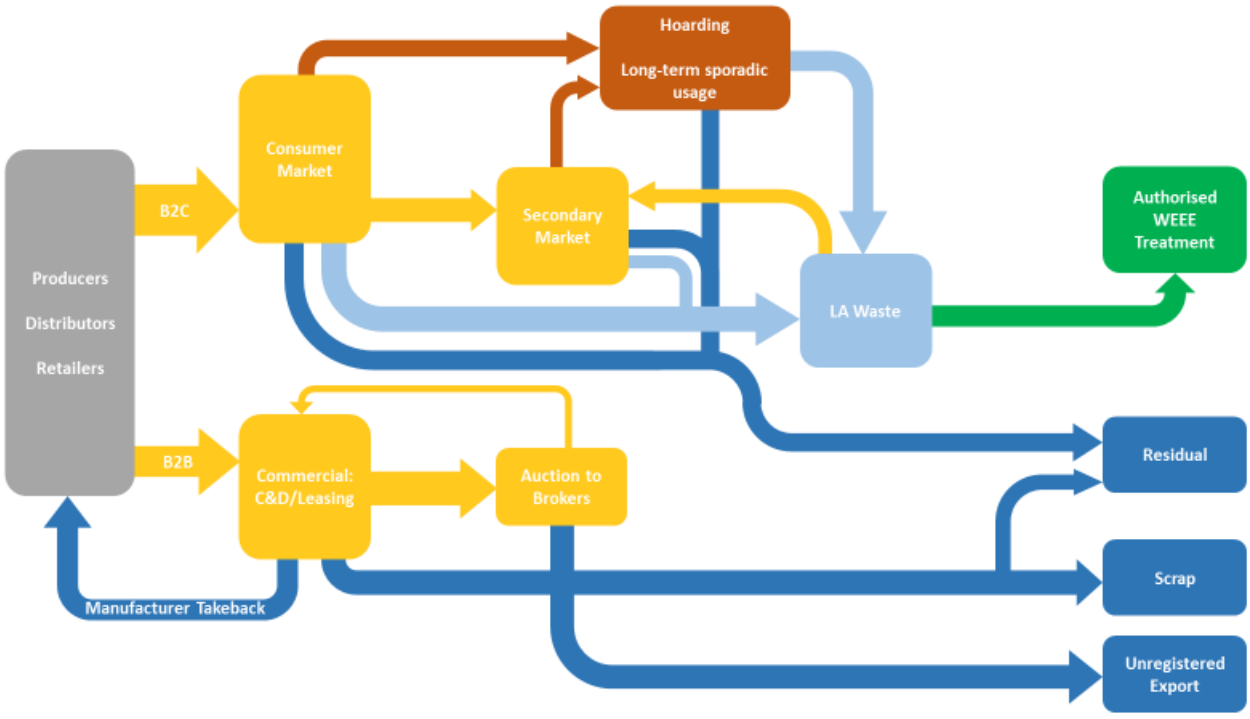

Figure 7: Flow diagram for disposal of Category 6 equipment (tools).

3.4 Household Small Mixed WEEE (SMW): Category 2, 3, 4, 6, and 7

Household SMW, covered by Categories 2, 3, 4, 6, and 7 represents a significant proportion of the UK's yearly WEEE arisings, given the high tonnage of equipment placed on the market every year, and the relatively short lifespans of several of the product lines which fall into these categories. However, the diversity of products, high C2C activity, and high likelihood of disposal via the residual waste stream makes characterisation of this sector particularly challenging.

Category	Category Type	2016 Household EEE PoM	2016 WEEE Treated at AATFs	2016 Non-obligated WEEE	SMW Protocol %
2	Small Domestic Appliances	166.4 kt	38.1 kt	5.0 kt	22.4 %
3	IT & Telecomms Equipment	87.9 kt	53.0 kt	30.7 kt	21.8 %
4	Consumer Equipment	56.8 kt	40.0 kt	4.4 kt	22.3 %
6	Electrical and Electronic Tools	78.7 kt	19.4 kt	2.8 kt	12.2 %
7	Toys, Leisure, & Sports	52.2 kt	2.8 kt	0.3 kt	1.5 %
	Total	442.0 kt	153.3 kt	43.2 kt	

Figure 8: Household Small Mixed WEEE categories. The remaining fractions of the SMW protocol include Cat 1 (LDA), small components of Cat 9 (monitoring and control), 11 (display), and 12 (cooling), and 6.1 % of non-WEEE and batteries.

Considering these 5 SMW categories, the deficit amounts to between 9.1 kg per household and 10.6 kg per-household, depending on whether non-obligated WEEE is included in the data (the larger estimate).

The application of the SMW protocol to calculate WEEE tonnages across these categories has received both support and criticism from different stakeholders in the UK system, and it precludes more detailed analysis of the recycling statistics.

Due to the diversity of the products within these categories, we chose three areas to investigate in more depth:

- Consumer takeback and warranty returns.
- Reuse and redistribution of EEE via charities and re-use networks which can extend the lifetime of products within the UK's EEE stock.
- A miniature case study on games consoles which fall under Category 7: a relatively narrow product stream with interesting long-term consumer behaviour.

3.4.1 Warranty & Retailer Returns

Engagement with retailers of the products that make up the Small Mixed WEEE stream, suggested that most UK retailers either pay into the Distributor Take Back scheme or participate in an initiative sponsored by RETRA

(the Radio, Electrical and Television Retailers' Association) and operated by REPIC, which coordinate collections from stores who offer returns. In both of these cases, the tonnes collected will already be included in the EA collection data for the UK. While the harvesting of components for reuse in IT specific stores is commonplace, the impact on the tonnages on the UK WEEE system would be minimal; in contrast, for white goods and consumer equipment, repair and component harvesting is very rare as it is not cost-effective.

Retailers are likely to discourage takeback for small items (unless they are highly valuable like mobile phones, which are often sold for reuse and are small so do not particularly impact the macro tonnage based data) and warranty returns rarely actually result in the return of a product, this is because there is a perception that consumers will be unwilling to wait for their unit to be repaired and that the reverse logistics cost will outweigh the cost of a new item.

The like-for-like, often paid, takeback of white goods is a different matter, with high takeback rates and with national retailers having high profile partnerships (e.g. Kingfisher Group and Environcom), but these units are already captured in the national WEEE reporting data.

The defective small equipment that is not replaced under a warranty or taken away with the delivery will either be stored, disposed at a DCF (so accounted in the national data) or in the household residual waste. There is some product specific C2C trading and we have profiled the case of games consoles in Section 3.4.3, but this is a minority concern.

3.4.2 Charity and Re-Use Networks

EEE reuse is becoming a growing theme, particularly with the EU's Circular Economy package: for example, Spain has recently mandated that a percentage, albeit small, of LDA and IT equipment must be prepared for re-use in 2017; in addition, Belgium has operated subsidised reuse programmes for several years[24],[25].

Charity shops play a large part in the UK's re-use network. Additionally, many DCFs now partner with programmes which aim to improve redistribution of working WEEE, such as the waste management company FCC's Reuse programme. While most equipment handled by charities is acquired second-hand from consumers, retailers also contribute end-of-range goods. SMW is the dominant stream handled by charities, with LDA also being significant for bigger operations. One stakeholder mentioned that CRT TVs are handled regularly, although the demand is limited.

Of equipment acquired by charities, approximately twice as much is sold on to consumers as is sent for recycling via PCS collections. Additionally, there is some export for re-use activity around SMW items, with Eastern Europe being the major destination. The degree of activity around export varies between 2–15 % of the handled annual tonnage, depending on the organisation.

[24] http://www.triplepundit.com/2013/01/europes-best-recycling-prevention-program/

[25] http://www.rreuse.org/spain-first-eu-country-to-mandate-reuse-of-electrical-goods/

3.4.3 Games Consoles: Category 7

We selected Games Consoles for a miniature case-study, based on the good availability of historic unit sales data, sourced from Statista (details of UK Market), VGChartz (trade press, aggregating format specific sales trends) and official company reports.

- We estimate that the UK market accounts for roughly 6 % of the global sales of major consoles/handhelds, depending on the relative popularity of a particular console.
- In 2016, we estimate that around 7 kt of games console units — excluding peripherals — were placed on the market. This accounts for around 15 % of Category 7 EEEPoM.
- We expect yearly tonnages to vary by around 15 %, depending on the point in a console generation's release cycle, and the ratio of consoles to portable sales (given the order of magnitude difference in average weights between the two console form factors).
- In our calculations, we have considered the weight of the console unit only, excluding other EEE components which would be shipped as part of a new sales unit (e.g. controller, transformer brick etc.), as well as any additional peripherals.

To assess the long-term use of consoles, we focused on the major devices of the 5th, 6th, and 7th generation of home consoles, excluding handheld devices which tend to follow a different cycle and which tend to be around 1/10th of the weight of home console. The current (8th) generation of consoles is included in Table 9 for completeness in estimating the UK stock.

Table 9: Tonnage of the major home consoles sold in the UK since 1995 (Statistica and company reports).

Generation	Console	Sales Period	Peak Sales Year	Estimated UK Tonnage (lifetime)
5	Sony Playstation	1995–2005	1998	6.2 kt
	Nintendo 64	1996–2003	1998	2.2 kt
6	Sony Playstation 2	2000–2013	2002	17.8 kt
	Microsoft Xbox	2001–2009	2002	5.6 kt
	Nintendo Gamecube	2002–2007	2003	3.3 kt
7	Microsoft Xbox 360	2005–2016	2011	25.1 kt
	Nintendo Wii	2006–2013	2008	7.9 kt
	Sony Playstation 3	2007–2017	2011	24.4 kt
8	Nintendo Wii U	2012–2017	2014	1.1 kt
	Sony Playstation 4	2013–Present	2014	10.2 kt
	Microsoft Xbox One	2013–Present	2014	10.6 kt
		Total		114.2 kt

Each home console generation has seen progressive growth in terms of units sold: this is indicative of the increasingly mainstream status of gaming and strong uptake amongst the so-called 'casual' gamer base. We consider that casual gamers would be less likely to hold onto games console units long term, as compared to enthusiasts; however, the increasing functionality of gaming systems (including DVD/Blu-ray, internet, and access to streaming services) may encourage many users to retain their consoles over a longer period of time, even if they don't necessarily use the console as a gaming platform.

Of these consoles, we conservatively estimate the total weight of these units sold in the UK, as of Q2 2017, to be 114 kt. On top of this, we expect that other Category 7 equipment shipped with a single sales unit could easily amount to over 0.5 kg, and this does not account for additional peripherals. Therefore, we consider 0.75 kg to be a conservative estimate for additional equipment sold per unit, boosting this figure to around 150 kt.

The reasons behind product failure tend to become more complex with increasing design complexity. Games consoles have become far more advanced in the last 20 years: the mainstream shift from game cartridges to disks and the addition of hard disk drives with the 6th generation Xbox introduced mechanical points of failure and, in general, the increased power of consoles with each generation has increased the challenges associated with thermal management.

The UNU (2014) study used an average console lifespan value of 3.75 years[26] derived from the Weibull distribution shown in Figure 6 to model WEEE arising. In this distribution, around 9 % of consoles are expected to fail within the 1st year of service, which would be attributed to units carrying manufacturing defects. Despite plenty of anecdotal evidence, there are few sources of detailed information of console failure rates.

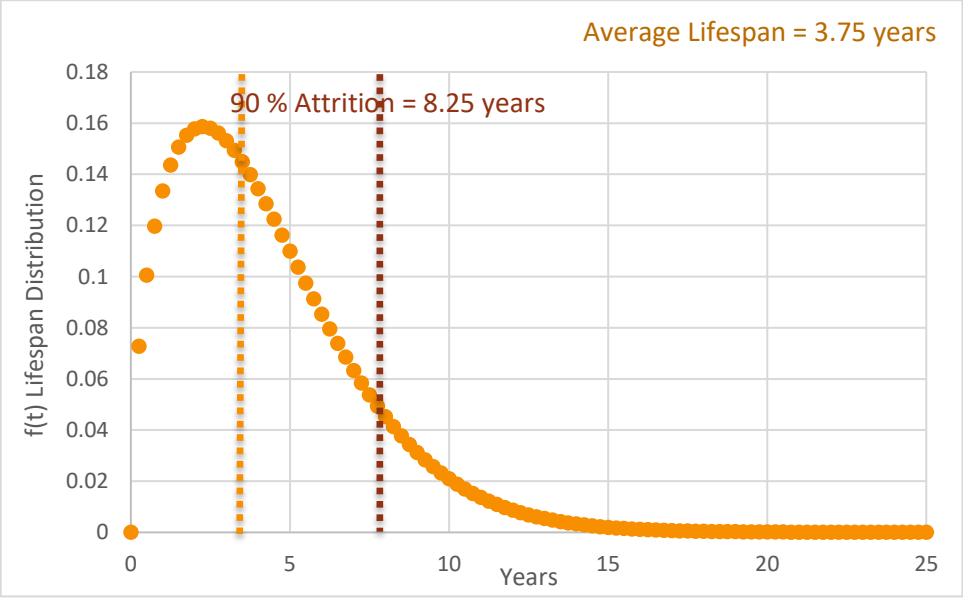

Figure 9: Weibull distribution for the lifetime of games consoles, originally calculated in the UNU (2014) study.

[26] https://unu.edu/news/announcements/report-reveals-e-waste-flow-and-market-structure-in-belgium.html#info

For the 7th generation of consoles, one warranty company cited 2-year failure rates of 2.7 %, 10.0 %, and 23.7 % for the Nintendo Wii, Sony Playstation 3, and Microsoft Xbox 360, respectively; in comparison, a survey by a gaming website reported rates of 6.8 %, 10.6 %, and 54.2 %, albeit without specifying timeframe[27,28]. One stakeholder stated that the Xbox 360 was widely known to have numerous hardware problems, including a total failure known colloquially as the 'red ring of death', and so this particular product was an outlier — however, using a year-1 fail rate of 20 %, in 2008, 0.7 kt of the consoles would have been returned.

Due to the high value of console equipment and typical business models in the sector (many home consoles are sold at a loss, particularly in the first few years of sale)[29], manufacturers now engage in in-house refurbishment and resale, and also operate takeback schemes for out-of-warranty equipment. One stakeholder indicated that this is a highly favourable treatment route, although health and safety of refurbished equipment is a major concern and may limit the growth of the practice. Takeback data are not publicly available, and it is unclear as to what happens to unsalvageable consoles; while we would expect that these units would be harvested for parts wherever possible, whether this occurs in the UK or abroad is not known, nor how unusable components are treated.

3.4.3.1 Long-term Secondary Market and Usage

To gauge long-term usage and consumer behaviour, we used Ebay sales data for the 5th, 6th, and 7th generation consoles as a foundation: these consoles have all been on the market for 10 or more years. The 5th and 6th generation have been discontinued for several years, while the 7th generation were taken off the market much more recently — however, sales of these units were relatively low in these years. Ebay represents a large part of the C2C market for games consoles, although other internet marketplaces, internet forums/communities, and specialist gaming shops will also be active in this area.

Surprisingly, the second-hand market does not appear to change a huge amount with time for 'legacy' consoles, indicating that they retain long-term value in the eyes of consumers (Table 10). As such, we expect that the 'tail' in product lifespan, as shown in Figure 9 to be somewhat longer than expected; we would also expect that console usage would become increasingly sporadic with time, helping to extend the product lifespan. We note that the increasing complexity of newer consoles is likely to lead to earlier failure than older models, but we expect that healthy C2C activity will remain for years after release for units with above-average reliability.

In conclusion, we expect that the UK's stock of games consoles will continue to grow year-on-year, with gradual bleed-out of material from the system. A significant proportion of consoles will be returned to manufacturers early on due to malfunction, and as a general rule we expect that the majority of consoles will be disposed of only after failure due to strong secondary markets. As with other SMW products, we expect that a large proportion of dead consoles will be disposed of in residual waste; we also consider that, due to

[27] https://www.squaretrade.co.uk/htm/pdf/SquareTrade_Xbox360_PS3_Wii_Reliability_0809.pdf

[28] https://consumerist.com/2009/08/17/xbox-360-failure-rate-is-542-percent-game-informer-finds/

[29] https://brage.bibsys.no/xmlui/bitstream/handle/11250/2453489/masterthesis.PDF?sequence=1

consumer attachment and sentimental value, older consoles are will often be kept in storage far beyond their expected lifespans.

Table 10: Volume of UK C2C sales of the major games consoles on Ebay in 2017.

Generation	Console	Time Since Peak Sales Year (years)	Youngest Console (years)	Estimated Total UK Sales	% of Total UK Sales Traded on Ebay in 1 year
5	Sony Playstation	19	12	6,150,000	0.17 %
	Nintendo 64	19	14	1,980,000	0.50 %
6	Sony Playstation 2	15	4	9,280,000	0.27 %
	Microsoft Xbox	15	8	1,440,000	0.37 %
	Nintendo Gamecube	14	10	1,310,000	0.57 %
7	Microsoft Xbox 360	6	1	7,710,000	0.64 %
	Nintendo Wii	9	4	6,060,000	0.85 %
	Sony Playstation 3	6	< 1	5,180,000	0.67 %
			Weight of traded consoles		0.5 kt

3.4.4 Summary for Household SMW

We estimate that the deficit of unaccounted WEEE in this category is 287.7 kt per year, and WRAP estimated that there was 356 kt WEEE disposed in the household residual waste stream each year. Given that the products in the SMW stream are used in the home and are generally small enough to fit into a household waste bin, it is intuitive that a significant fraction of the WEEE in the waste stream is made up of the small household appliances that categorise SMW. While this is difficult to prove without significant national sampling, we consider it to be very likely. The example of games consoles shows how niche interests drive reuse via C2C trading, which is interesting from a behavioural perspective, but a minority concern in terms of tonnage.

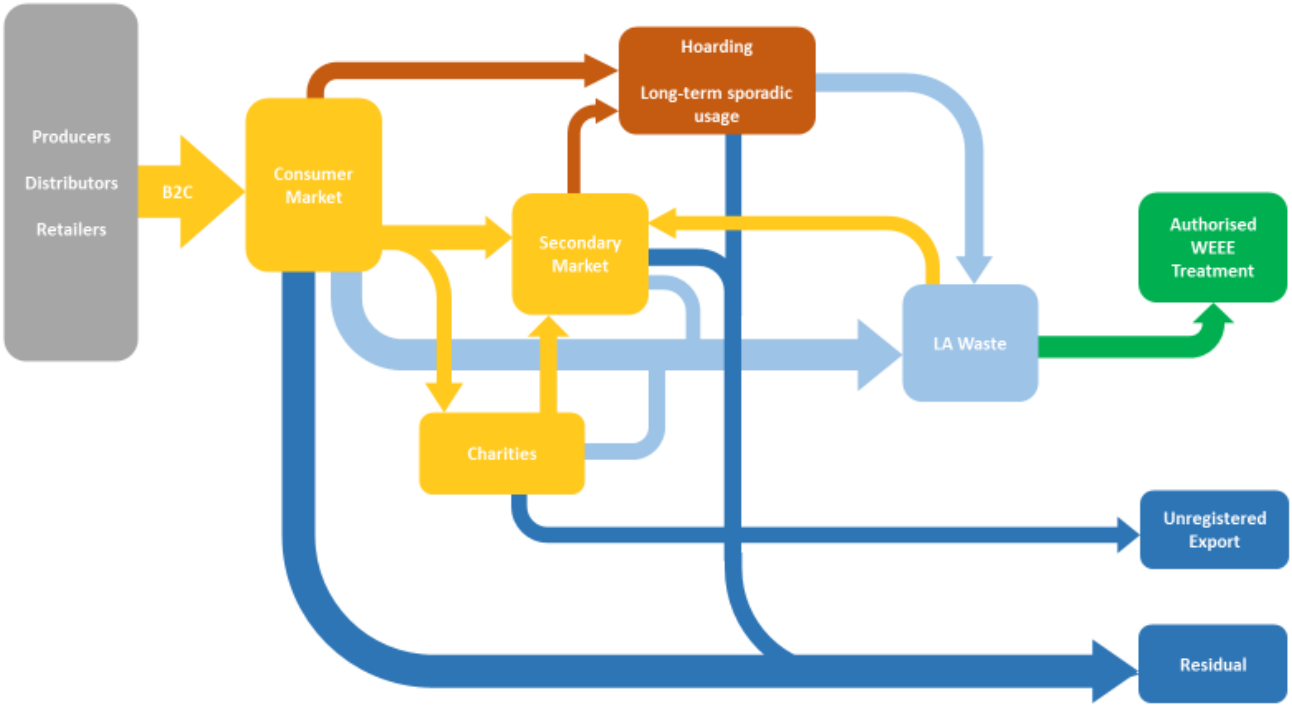

Figure 10: Flow map of disposal routes for household small mixed WEEE.

3.5 Vending Machines: Category 10 & 12

Although the vending machine (VM) sector is relatively small, it is a specialist sector with a small operating base and fewer out-loop routes than other product streams. Additionally, due to the modular nature of VMs, we expected that there would be significant refurbishment and re-use in the sector, extending the lifetime of these products.

In the refreshment sector (i.e. drinks and snacks), VMs are largely split into three categories: hot drinks, including both large freestanding machines and smaller table top units; cold drinks, typically large refrigerated units; and snacks, which can be ambient or chilled, and can include combination snack/drink machines. Hot drinks and ambient snack machines will fall under Category 10, while all refrigerated units would be Category 12.

Freestanding hot drinks machines typically weigh around 160–200 kg, although larger machines do exist. Table top machines are comparatively quite small, around 15–80 kg, depending on the unit's functionality. Meanwhile, large, freestanding cold drinks/snacks units typically fall in the range 180–360 kg.

3.5.1 Use models in the vending machine sector

Due to their modularity, VMs are relatively easy to maintain and keep in service for a long time, and refurbishment is a common practice in the sector: one stakeholder stated that they had personally worked on a VM which had a 32-year service record.

The main service models for VMs in the refreshment sector are: Free-on-Loan (FoL, where the VM is placed for free by a company which entirely manages VM stock and service, and who also takes the profit from the VM); leasing; rental; and sold for cash. For a freestanding VM, the following lifecycle would be typical:

- New VM rented, leased, or FoL on a 5-year contract.
- At end-of-contract, rented/FoL machines would be given a full service and clean-up and re-rented for 3–5 years.
- At this point, machines are typically refurbished or, if deemed unserviceable, they will be harvested for working components and disposed of.
- Machine sold or placed through rental/FoL schemes, typically for around 10 years.
- End-of-life machines are harvested for components, and frames loaded with unserviceable parts prior to disposal.

Generally, spare parts are readily available and, typically, VM operators will keep several years' worth of spares for machines. Refurbishment appears to be fairly commonplace in the sector, with the AVA reporting that 55 % of VMs taken out of service in 2016 were refurbished and re-deployed in the system. From this

information, it appears that the product lifespan modelling[30] from presented in Figure 11 is a reasonably accurate estimation.

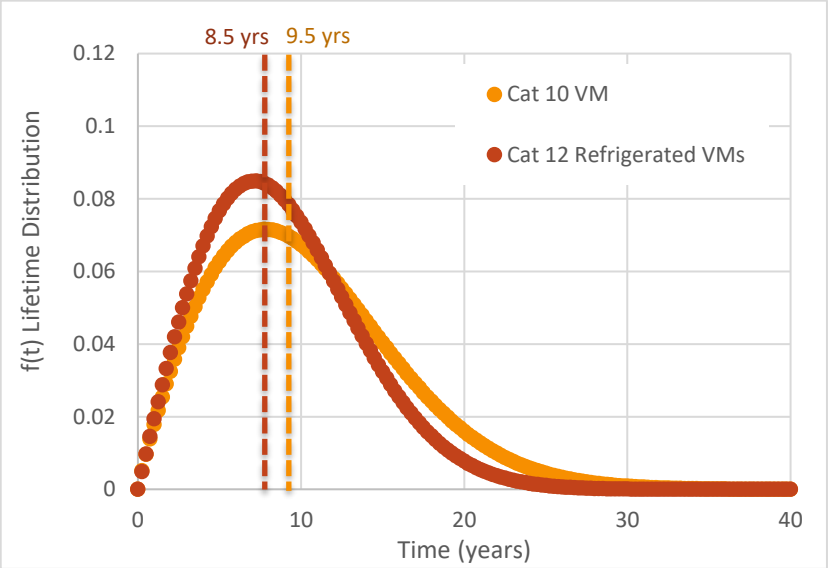

Figure 11: Weibull distribution model for the lifetime of vending machines, originally from the UNU (2014) study.

3.5.2 Estimating WEEE arising from the VM sector

We estimated the UK's refreshment VM stock of ~416,500 units in 2016, to weigh around 75 kt: this can be taken to represent roughly half of the total VM population[31]. By weight, we roughly estimated that 50–60 % of the refreshment VM stock would be non-refrigerated, therefore falling into Category 10 (Table 11).

To estimate the amount of material removed from the system each year, we used data published by the Automatic Vending Association[32]:

- From 2015 to 2016, the overall refreshment VM stock experienced a net decrease of around 4,000 machines, which we calculated to amount to 1 kt.
- By comparison, over the period 2007–2009, the stock decreased by around 4.5 kt a year, a figure which we consider to be somewhat closer to the actual attrition rate (although far from equivalent to it), given the economic crash at that time.

[30] http://the-ava.com/wp-content/uploads/2017/05/AVA-Census-2016-Publication.pdf

[31] http://the-ava.com/wp-content/uploads/2017/05/AVA-Census-2016-Publication.pdf

[32] http://the-ava.com/wp-content/uploads/2017/05/AVA-Census-2016-Publication.pdf

- The 2006 VM census suggested that 20–25 % of the UK's VM stock would be replaced year-on-year (which would amount to 15–20 kt of refreshment VMs), but we would expect the present rate to be lower due to increased economic pressure.
- Therefore, in Table 11, we have included attrition rates of 5 %, 10 %, and 15 % to derive estimates for WEEE arising from the refreshment VM sector.

Table 11: Estimated material stock and WEEE arisings from vending machines in the UK.

	Hot Drinks VM	Chilled Beverage VM	Snacks VM
EEE Category	10	12	10 / 12
2016 Stock (estimated weight)	30.0 kt	17.3 kt	27.3 kt
Total EEE Stock		74.6 kt	
Assumed Attrition Rate (low / mid / high)	5 % / 10 % / 15 %	5 % / 10 % / 15 %	5 % / 10 % / 15 %
Estimated WEEE arising *pa* (low / mid / high)	1.5 kt / 3.0 kt / 4.5 kt	0.9 kt / 1.7 kt / 2.6 kt	1.4 kt / 2.7 kt / 4.1 kt
Estimated Total WEEE arising per annum (low / mid / high)		3.8 kt / 7.4 kt / 11.2 kt	

3.5.3 Disposal of VM WEEE

In 2016, the total tonnage of Category 10 devices recorded as being received by AATFs in the UK was 0.67 kt: this figure is less than half of the projected WEEE arising from just Hot Drinks VMs, even when considering the lowest attrition rates. Considering that Category 10 would also contain items such as non-refreshment VMs and ATMs[33,34], it appears that a large proportion of this waste stream does not go through the appropriate channels. We have considered the following points in assessing treatment routes for VMs:

- Freestanding VMs would be candidates for scrap due to their weight and high steel content.

[33] http://data.worldbank.org/indicator/FB.ATM.TOTL.P5?end=2015&locations=GB&start=2005&view=chart

[34] For comparison, in 2015 the IMF estimated that the UK holds ~131 ATMs per 100,000 adults: this roughly amounts to an ATM stock of 66,000. Assuming a low attrition rate (5 %) and average weight of 220 kg, this would generate 0.72 kt of WEEE per year.

- Table top drinks machines may enter the system as SMW (Stream E), or as LDA. Using the lowest attrition rates, these would account for ~0.27 kt of VM WEEE arising per year.

Discussion with stakeholders in the refreshment VM sector suggested that there is an awareness at the management level for appropriate WEEE treatment. However, it is unlikely that this is uniform throughout the sector, and the most probable out-loop route for VMs will depend on the outlook of the machine's final owner (Figure 12).

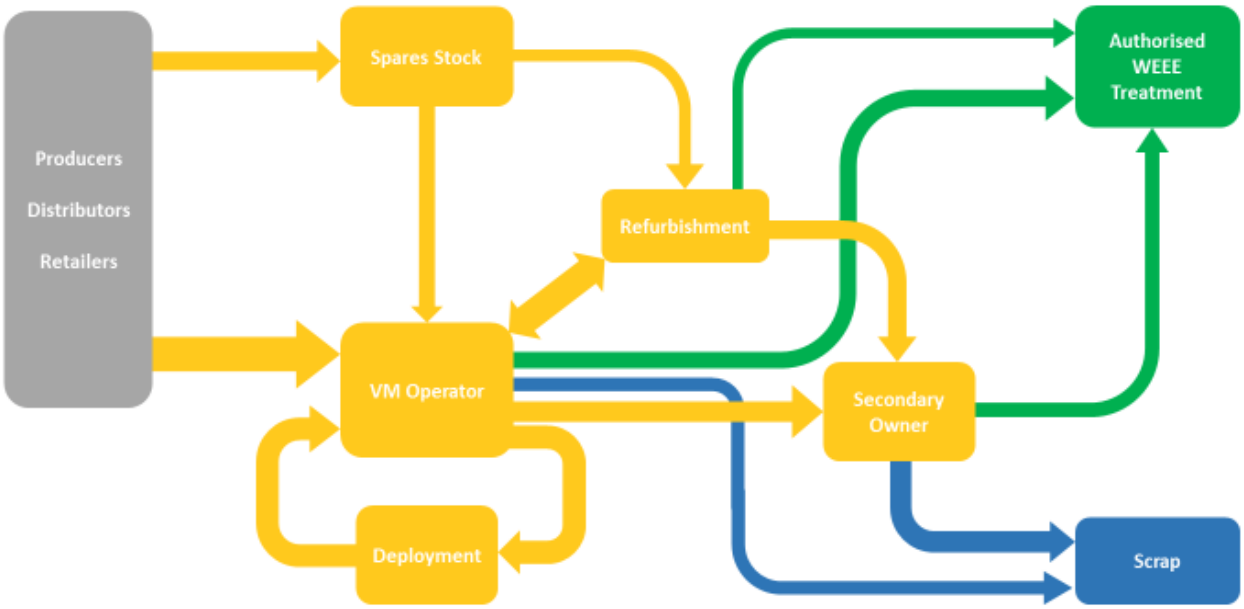

Figure 12: Flow diagram of use and disposal routes for vending machines in the UK.

3.6 Medical Devices: Category 8

We chose Category 8 as an area to investigate due to the public availability of data on the numbers of large medical devices in the UK[35]— namely Radiation Therapy Equipment, Mammography Equipment, CT scanners, MRI scanners, and Gamma Cameras. From these data, we estimated the weight of the UK's EEE stock for these 5 equipment types to be around 13 kt, with the weights of the individual streams presented in Figure 13.

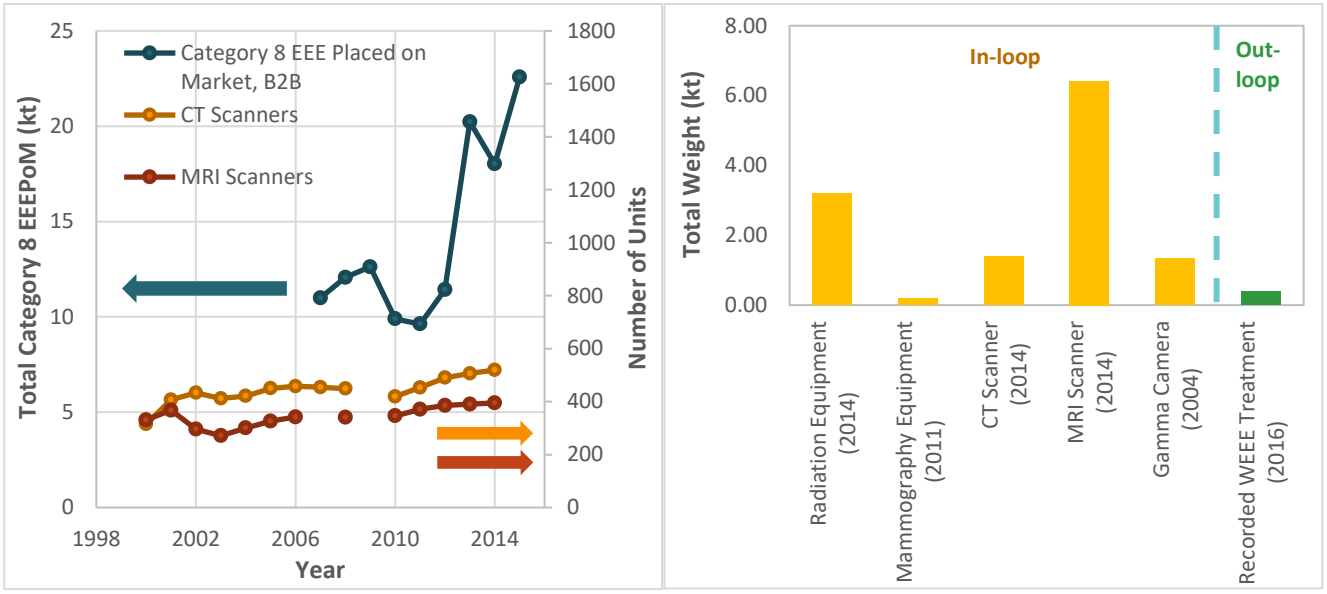

Figure 13. **Left**: placed on market data for medical equipment (kt, left axis) compared with UK population of CT and MRI scanners (units, right axis). **Right**: UK populations (weight) of 'big ticket' medical equipment items, compared with the weight of Category 8 equipment processed at AATFs in 2016.

The UK has generally experienced a slow growth in major medical equipment stock since 2000. However, as shown in Figure 13 the year-on-year tonnage of Category 8 material placed on the market is highly variable and likely relates to several factors, including the point in the various lifecycles of existing equipment stocks, funding availability, and trends in technology development.

The volume of Category 8 WEEE treated via AATFs amounted to 0.4 kt in 2016, which is only 3 % of the EEEPoM in 2008, the first year of record-keeping. Through engagement with stakeholders, we found that:

- Medical equipment tends to have a long operational life (10–15 years) with its first user.
- Equipment is usually replaced in order to keep up with the technology curve, even though the equipment will still provide "good enough" performance in many contexts.
- Re-use and refurbishment are fairly common practices within the sector.

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

- Used equipment is often sent to a third-party company who handle logistics, servicing, and auction, and the majority of equipment is expected to be exported for use abroad.

Given the high residual value of a lot of medical equipment, some of the major equipment manufacturers are tapping into the secondary market by offering asset management services to healthcare providers: this includes equipment servicing and upgrades, and in some cases, the manufacturer will take back the equipment at the end-of-service, refurbish or remanufacture it, and resell it, usually outside of the UK.

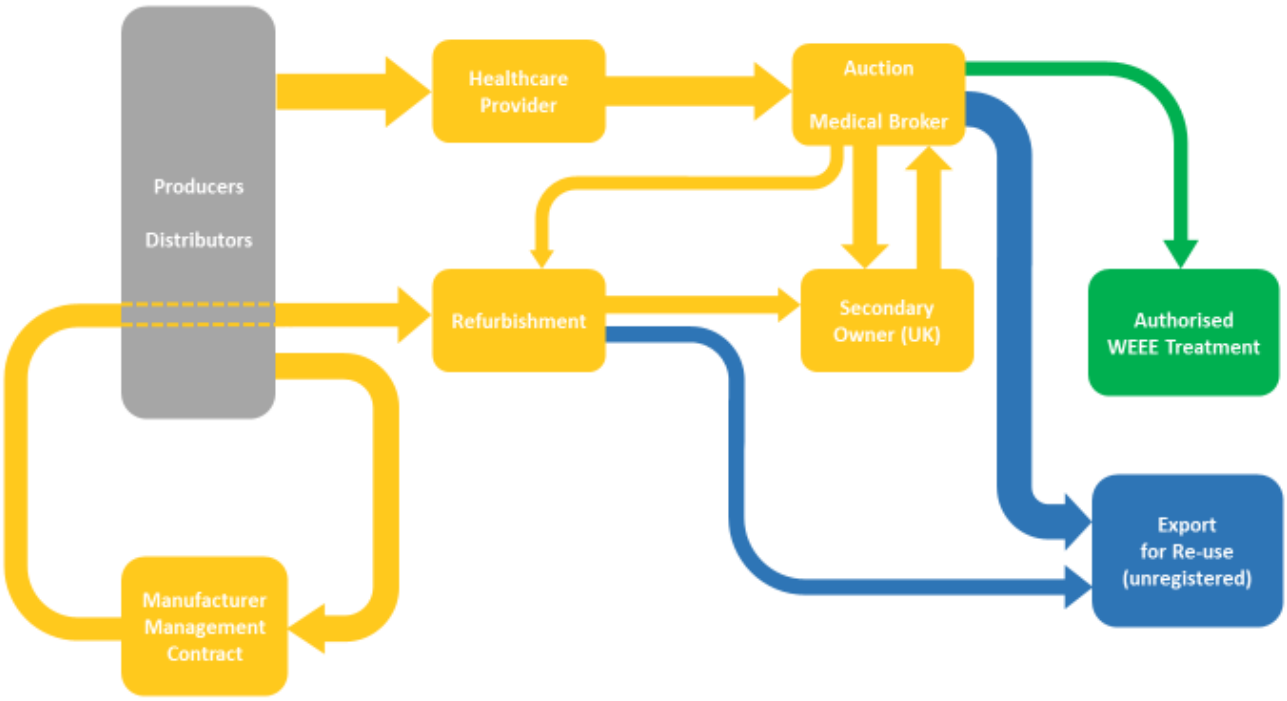

Figure 14: Flow diagram of use and disposal of Category 8 equipment in the UK.

3.7 Gym Equipment: Category 7

Fitness is a growing sector in the UK, with the number of gyms growing by ~12 % between 2013-2017. Additionally, there has been strong uptake in home fitness equipment and the number of consumers building home gyms.

Table 12: Estimated equipment stock and projected annual WEEE arisings for gym equipment in the UK.

	Household PoM, 2016	Non-household PoM, 2016		
Category 7	52.2 kt	8.1 kt		
		Projected Annual WEEE Arising		
Sector	**Estimated UK Equipment Stock**	**Low**	**Medium**	**High**
Home	104.0 kt	6.5 kt	8.7 kt	13.0 kt
Commercial	14.4 kt	1.0 kt	1.4 kt	1.8 kt

Using data on provided by Statista, LeisureDB, and other survey results, we drew up some conservative estimates for the UK's total stock of gym equipment, both for homes and for commercial gyms (these figures omit equipment owned by hotels, private clubs and gyms operated by private residence management as the data is unavailable): these are presented in Table 12. We note that there is potential for these figures to be much higher, and we would suggest conducting surveys to gauge the extent to which Category 7 equipment has penetrated the consumer market. The WEEE arising scenarios given are based on simple estimations of equipment attrition rate.

Repair and refurbishment is a common practice in the sector: despite its heavy usage, equipment tends to be hard-wearing, and maintenance and part replacement are usually quite straightforward. While new models contain desirable updates such as media capabilities (TVs, music connectivity) and updated programming/software to reflect new fitness trends (e.g. better training programmes), older models are adequate for the average user, and are well-suited to lower intensity settings (private residential gyms, schools and amateur sports clubs, hotels). Equipment frames and components tend to be quite similar across different brands, with the greatest differences being in the outer cladding and programming, and this has enabled the growth of a strong reuse industry.

The construction of fitness equipment makes it attractive from a scrap perspective: to withstand the rigours of use, the inner frames and rollers are typically metal, and copper wiring and motor components will hold significant material value. Therefore, we expect that many end-of-life machines will end up being sent for scrap, particularly those returned to second-hand equipment specialists as there is no incentive to send these for treatment via WEEE recycling channels.

3.7.1 Commercial Gym Equipment

A number of purchasing models are available to commercial gyms: outright purchase, leasing, and rental from manufacturers, the terms of which can be highly variable due to the compressed nature of the fitness market. For electrical equipment, a typical lease period is 5 years, and extended warranties cover parts and machine replacement. Additionally, it is common for gyms to enter into service contracts either with equipment

management companies, or directly with manufacturers. In these cases, after logging an issue with the service provider, the equipment will be repaired or replaced within a specified time period.

There is considerable variation in the first service life of electrical fitness equipment, depending on the operator: a large number of gyms replace their equipment every 2–3 years, despite the fact that the biggest differences between new and old stock will be in their aesthetics; in comparison, lower cost gyms tend to keep their equipment in service for a much longer period, with a 10–15 year lifespan being easily attainable, and machines often still work when they are eventually replaced.

Gyms rarely handle direct disposal of gym equipment: many gyms have contracts directly with equipment manufacturers which includes provisions for takeback should the operator wish to upgrade their equipment. For operators owning their own equipment (having bought outright at the point of sale or completed a leasing arrangement), they will often sell their stock on to used equipment traders (there are now app-based platforms which enable matching between gym operators and traders); in some cases, gyms will informally sell off equipment to its membership, although this tends to be the case for older stock. Traders often recondition or refurbish equipment before selling it on, and we expect that unsalvageable equipment is harvested where possible, before being scrapped.

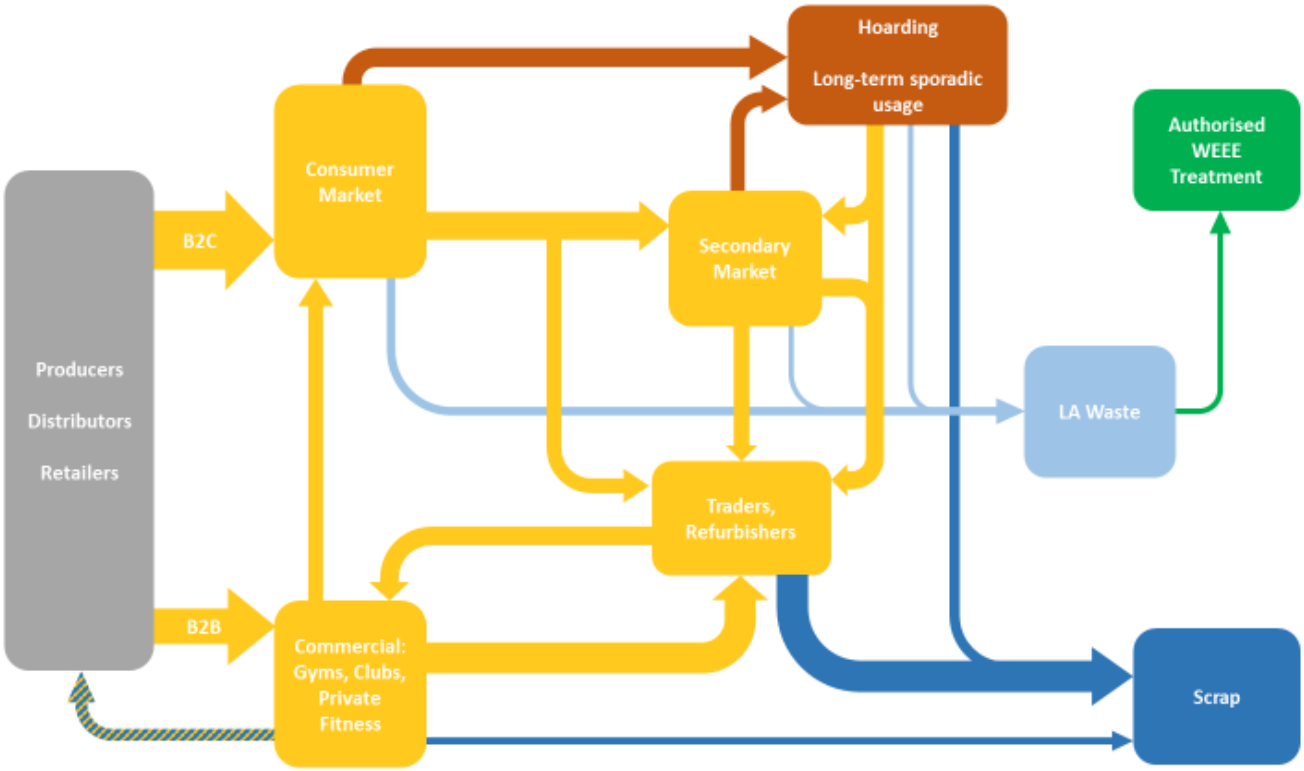

Figure 15: Flow diagram of use and disposal of gym equipment (Category 7) in the UK.

3.7.2 Household Fitness Equipment

Consumer uptake of fitness equipment has been strong in the last few years particularly with growing fitness trends. While the size of equipment will deter many consumers, exercise bikes and foldable treadmills are popular solutions for many. Surveys of consumer equipment usage suggest that exercise equipment will often be purchased but used infrequently, or not at all. Moreover, the size of the equipment makes transport difficult, and retailers rarely offer takeback or collection services; therefore, we expect that many consumers will choose to store their equipment rather than dispose of it, or sell or trade for free where possible to avoid

paying collection costs. As such, disposal of gym equipment via DCFs is probably infrequent, and it is currently unclear where the bulk of these equipment is currently captured. While we expect that a proportion of this equipment will be sold to used equipment traders (which predominantly handle commercial models), home gym equipment tends to hold less value due to its lighter construction.

3.7.3 Summary

From a reuse perspective, further characterisation of the fitness sector to gain more detailed insight into practice in the sector would be of interest. For commercial equipment, machine design is geared towards long-term service (>10 years), easy maintenance, and availability of compatible spare parts. Through interviews with stakeholders in the sector, equipment replacement is predominantly driven by consumer perception of age: as such, many gym operators feel pressure to replace equipment much more frequently than is needed. This suggests that many consumers will likewise replace their equipment on a relatively frequent schedule, compounded by the fact that domestic servicing call-outs can be expensive. We expect that very little equipment is processed via the WEEE infrastructure due to its high scrap value.

4 Conclusions

The objective of this study was to further investigate unaccounted streams of WEEE, within an estimated 139 kt left of the estimated WEEE generated, after discounting official national WEEE reporting, substantiated evidence of alternative processing, and an estimate for WEEE disposed in the residual waste. We prioritised collection and treatment streams for investigation to articulate where this deficit tonnage was; either being disposed or being held up in the system in long-term storage, or in long-term applications. Table 13 shows our findings.

Table 13: Summary of our findings for unallocated WEEE arisings.

Treatment route	Deficit (kt)	Long term storage (in loop)	Disposal or export (out loop)
Cooling	89.6	A/C units: Significant quantities, unknown	4.4 kt household; 5.3 kt commercial. Likely disposed via C&D and then landfill or scrap
		Commercial display refrigeration: 10–15 year operating life	Almost 16 kt arising per year: • ~4 kt disposed as obligated WEEE • ~2.5 kt non-obligated WEEE, if B2B/B2C disposal ratio reflects sales • Significant fraction remaining, scrap or export a strong possibility
Buildings installed EEE	98.1	Significant, difficult to quantify; only removed during refit or demolition	Significant, difficult to quantify – likely disposed via C&D and then landfill or scrap
Tools	80.6	Household: majority of tools kept long-term with infrequent use	Commercial: C&D/Scrap or export (significant), likely >20 kt per year
Household SMW	287.7	Difficult to estimate, but SMW is easily hoarded	Likely to be a substantial fraction of the 366 kt outlined by WRAP
Vending machines	8.9	Frequent reuse and redeployment, 10–20 year service is common	7.4 kt arising as waste and likely to be scrap
Medical equipment	22.2	Low	High reuse activity, generally for export
Gym equipment	57.5	Long service life, remanufacturing and redistribution frequent due to high availability of spares and simple construction	Household: 8.7 kt arising per year Commercial: 1.4 kt arising per year High scrap value

Small items in the household that are not reported in the WEEE system, when they are disposed, are likely to disposed in the household refuse bin, particularly as items “returned” under warranty are rarely actually returned (outside of specialist sectors like Games Consoles). Conversely, large items that are built into buildings or handled in a buildings management environment are likely to be disposed via landfill via the C&D (i.e. skip) waste. These values account for a significant fraction of the unaccounted WEEE tonnage and are undesirable treatment routes for WEEE.

There are examples, however, of good practice including for medical equipment and vending machines. There are ready secondary markets for these items and the manufacturers are closely involved in the reverse logistics and redeployment of units, making these sectors good circular economy case studies. While less formal loops are in place for gym equipment, the robust construction and standardisation of parts across different equipment models encourage long-term refurbishment and redeployment of these products. The case of tools seems be unclear, the legitimacy of the exports and bulk brokerages of worn equipment is questionable and warrants further analysis.

4.1 Next steps

Our recommended outcome from this research would be further outreach to the C&D, fitting, and servicing sectors on the proper disposal of electrical equipment and to stem the flow of material into landfill via this route. Also, to engage household users on the proper disposal of small household electrical items. It would, however, be desirable to confirm our assumption that the WEEE disposed in the household residual waste is made up of small household items; it seems very likely, but should be confirmed before further action is taken.

Outreach to the medical equipment and vending machine sectors could highlight good practice, with learnings potentially to be transferred into the tools sector, as we suspect that the treatment and quality standards are not as high as in others with high reuse.