

Collect More, Collect Better

Presentations from CRM Recovery projects trial partners across Europe who have developed innovative methods to collect WEEE and recover CRMs



Mick Claes
Axion Recycling



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Dr. Sven Grieger
EARN



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The LIFE 2014 CRM Recovery project has received funding from the LIFE Programme of the European Union

WEEE Collection and CRM Recovery trials: UK

Mick Claes

AXION

Circular economy specialists

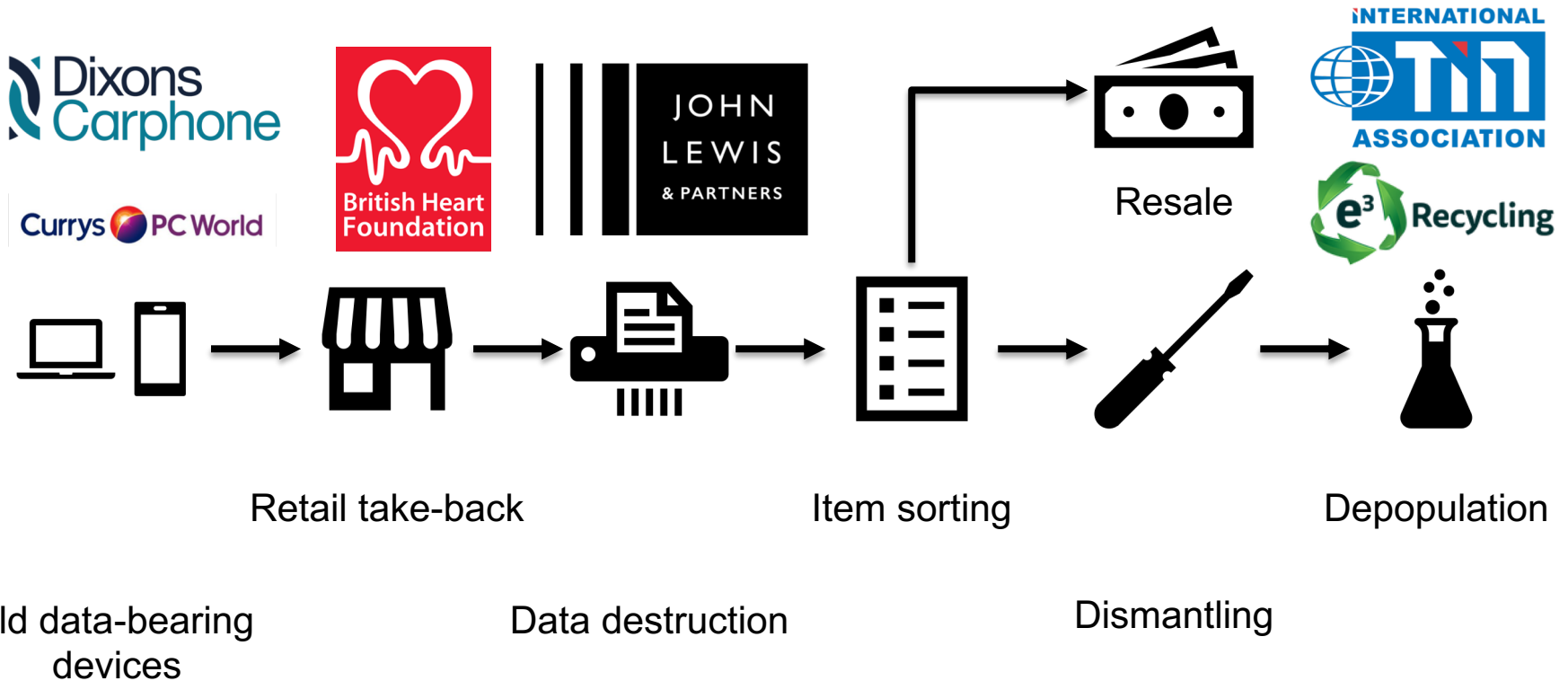
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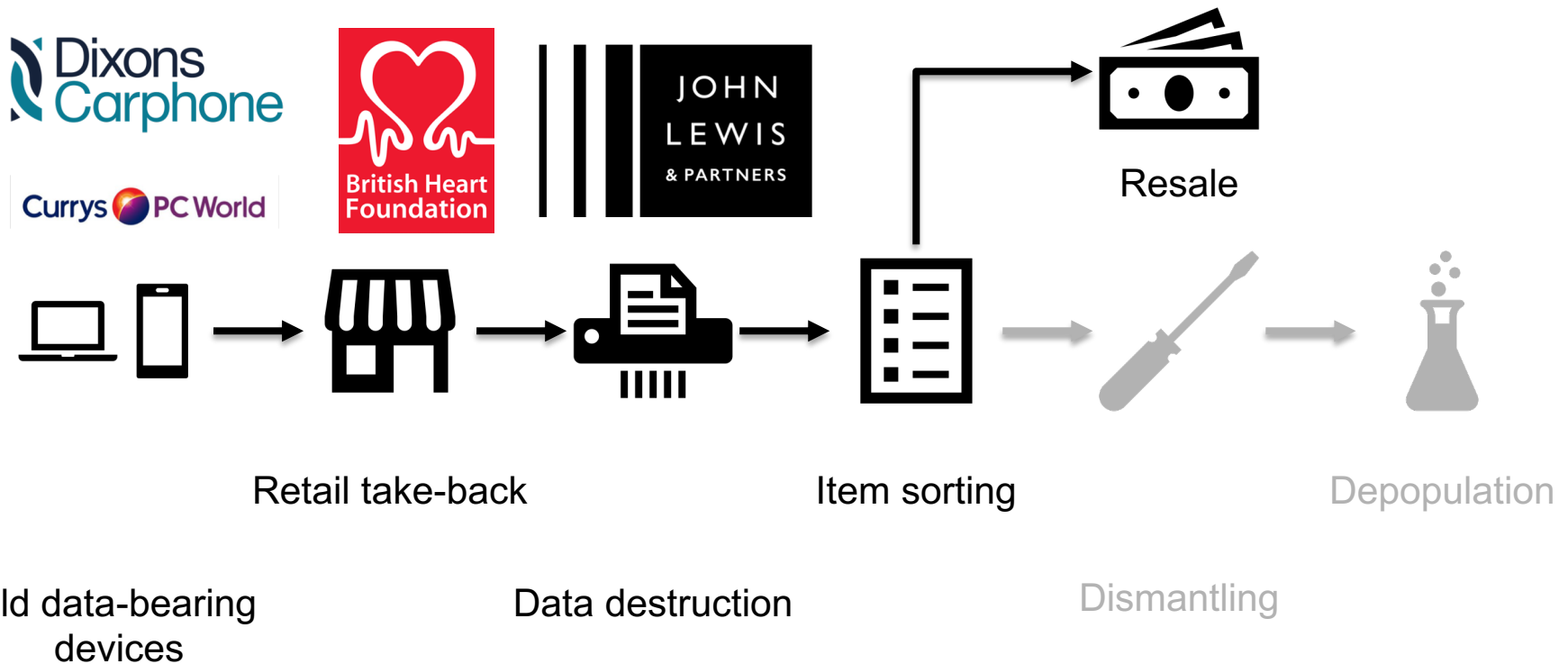
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Project approach and partnerships



Collection trial



Collection trial

Aim

To encourage return of high value WEEE to high street stores

Approach

In-store take back

Incentivised return

Social media campaigns

Data wiping

Data collection:

- Item description
- Make, Model, Serial number
- Age
- WEEE category

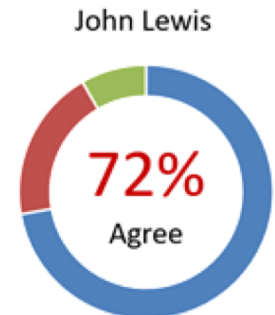
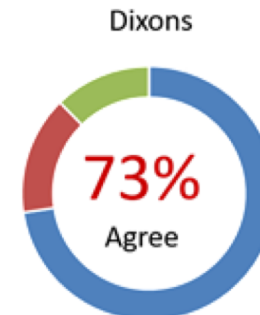


Collection trial

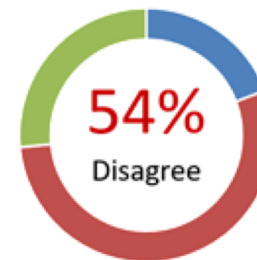
Survey results

- 311 surveys completed
- Questioned on awareness, disposal habits.
- Retailer takeback is convenient
- Consumer trust varies by retailer

Donating WEEE in this way
is convenient for me



I feel confident my
personal data will be kept
secure



Collection trial

Results

302 items were collected

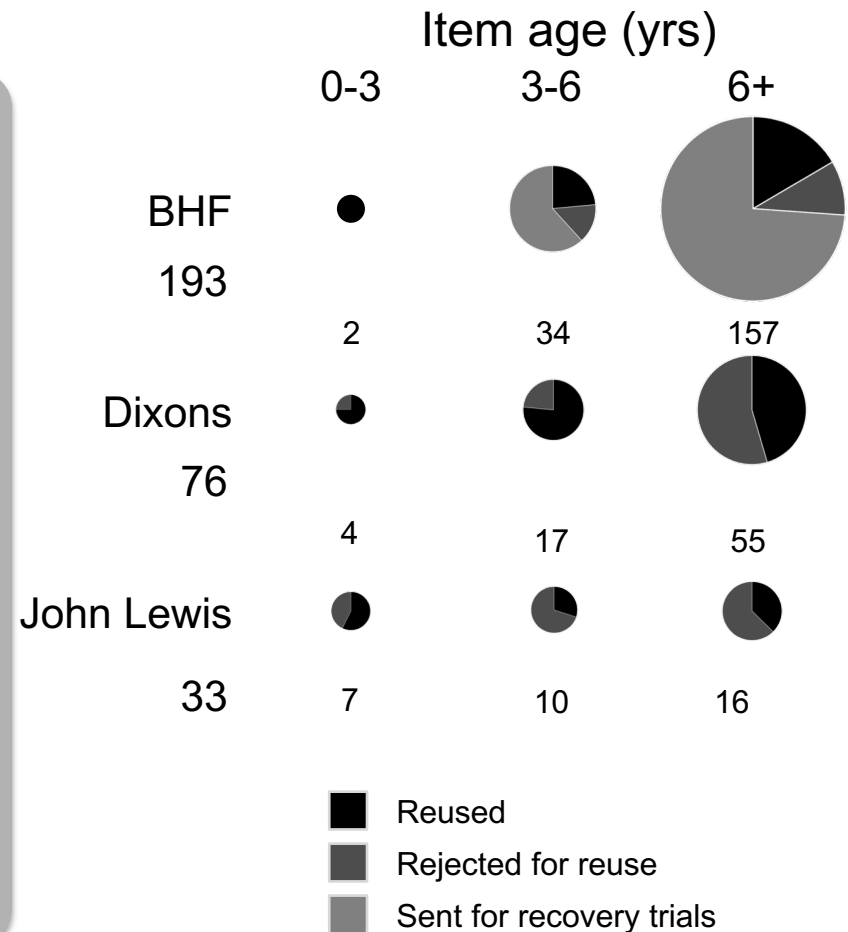
Most common items were:

- Laptops (66)
- PCs (47)
- Mobile phones (45)
- Unclassified/other (99)

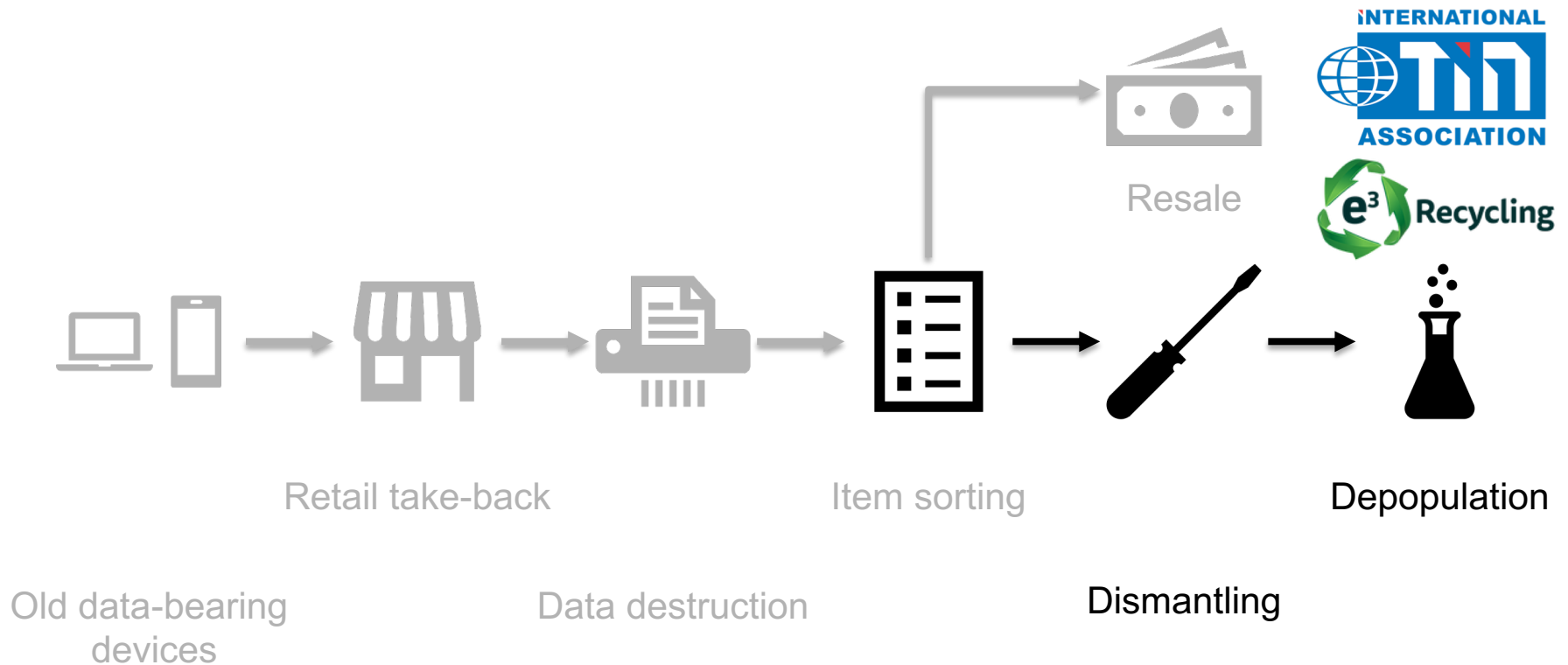
28 of these were resold for a total value of
£2,554.21

An analysis of the cost of processing these items determined that the net profit from the sales would be **£2,247.27**

The remainder were sent for recovery trials



Recovery trial



Recovery trial

Aim

To recover high-value components from the WEEE collected recovered in the collection trials.

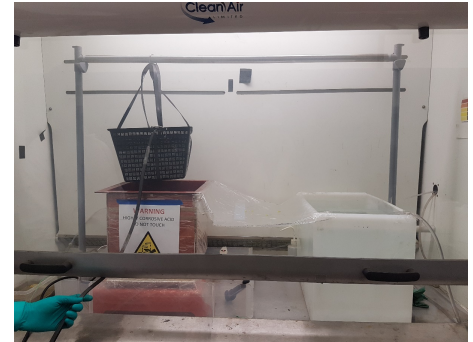
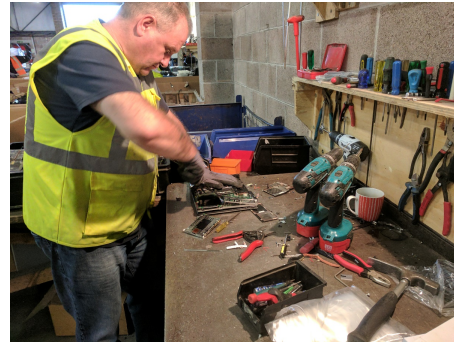
Approach

Manual dismantling to isolate circuit boards

Separate components from circuit boards through chemical depopulation

Segregate components:

- Magnet
- Size
- Density



Recovery trial

Aim

To recover high-value components from the WEEE collected recovered in the collection trials.

Approach – chemical depopulation

The Itrimex ‘smart’ chemical dismantling technology uses an acidic solution to chemically remove components PCBs efficiently and without damage

Axion took this process and optimised it for the specific PCBs that were recovered



Recovery trial



Category: Laptops (0-3 years), Component size 1-2mm



Category: Laptops (0-3 years) Component size: 2 -3.15 mm



Category: Laptops 0-3 years; Component size: 3.15 - 8mm



Category: Laptops (0-3 years) Component size: 8-16mm



Category: Laptop (0-3 years) Component size: 16+ mm

Recovery trial

Results - dismantling

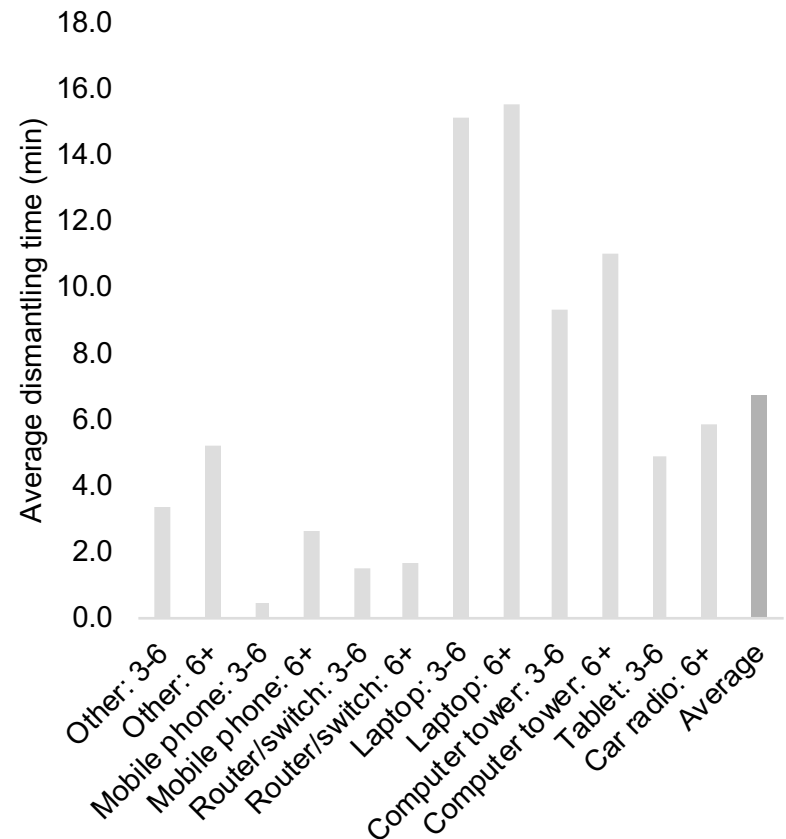
233 items were dismantled: 180 at E3 Recycling, the remainder by Axion.

Average dismantling time was 6.7 minutes

Laptops (~15) and computer towers (~10) took significantly longer than the average.

Overall, 2.82 kg of PCBs were recovered per hour.

Items consisted of an average of 13.6% PCBs by weight.



Recovery trial

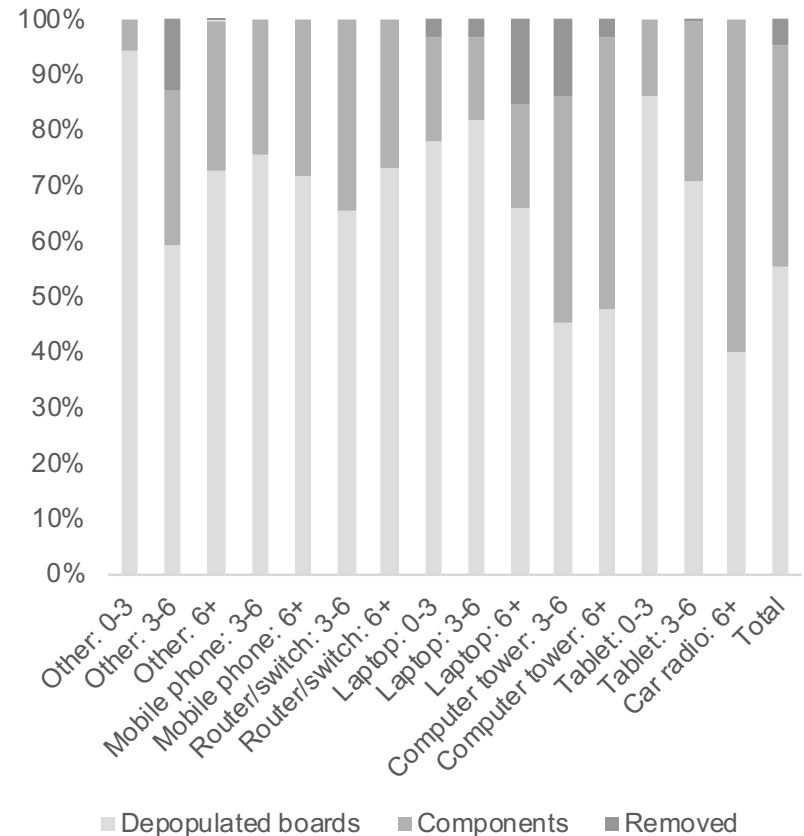
Results – depopulation & sorting

67 kg PCBs were processed in 77 batches

On average, 40% of the weight was recovered as components

Components were separated by magnets, size, and density.

Elemental analysis of the sorted fractions determined that certain fractions had a gold concentration of nearly 2,000 ppm (3-8 mm 2-3 SG) and that combinations of several fractions would recover >80% gold at concentrations of >1,500 ppm.



Lessons learned - collection

- Retail take-back is good for recovering equipment whole and undamaged
- Well established logistics already in place, but come with challenges (Data security, traceability of items)
- Proactive staff at each collection store increases engagement – "Recycling Champion"
- eBay proved to be a successful outlet for reusable items – fair market value
- Many high-street retailers already have a presence on eBay
- Collaborating with the retailers was essential to the success of the project
- Survey results indicated that consumers find retail takeback very convenient, but trust varies considerably.
- Consumers utilise a variety of disposal methods and are concerned for data security.

Lessons learned - recovery

- Well-lit and ventilated workstations are essential for effective dismantling
- Dismantling speed depends heavily on experience and familiarity
- Efficiency and speed of depopulation drops with successive batches
- Larger metal components reacted vigorously
- Manual removal of components could be replaced by tumbling drum or similar process at commercial scale
- An alternative depopulation process is available that uses heat to melt solder

Lessons learned - recovery

Size separation successfully concentrated interesting components into the smaller size fractions (<8 mm)

Magnetic and density separation further segregated the components in the 3.15-8 mm size fractions; in particular, chips tended to have a density of 2-3 SG, while tantalum capacitors and crystal oscillators tended to have a density >3 SG

A large (>80%) proportion of the gold present in the fractions <8 mm was concentrated in four fractions. These could be recombined to give a fraction with overall concentrations of greater than 1,500 ppm

Tantalum was found in one other fraction, while a large proportion of tin was found in the fine fractions.

Given the gold content in both magnetic and non-magnetic fractions of the 0.5-3.15 mm size range, there appeared to be little advantage to this separation.

There was also a large proportion of gold-containing chips and pins present in the fractions >8 mm. There did not appear to be an advantage of screening at 16 mm.



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Thank you!

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WEEE collection and CRM recovery trial

Petr Smutný



Innovate UK
Knowledge Transfer Network





Current shareholders



ASEKOL

Not-for-profit company – established in 2005 in the Czech Republic, nowadays also present in Slovakia and Poland



Close to 7.000 clients on the Czech, Slovak and Polish markets

Largest WEEE and batteries compliance scheme in the region

Active member of several European organizations



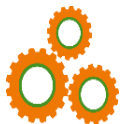
Compliance scheme for WEEE & batteries + cooperation with packaging system



Take back of all kinds of electronic waste + full scrap service



Environmental support, trainings + periodical legal newsletter



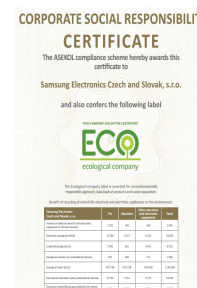
Individual approach based on customer needs



Easy reporting & control system, minimized admin workflow



Co-branded marketing campaigns promoting producers/importers



ASEKOL's collection points (17.000) and containers (10.000)



E-house



EKO-centre



Red container



E-box



**Collection containers
in schools**

Collection of WEEE

Three collection methods – collection yards, stationary containers and mobile containers

Collection was realized from March to July 2017 (all regions of Czech Republic)

Mobile containers were placed in each location for at least 2 days

Promo action before collection starting (mobile containers)

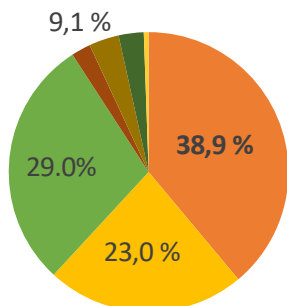
Monitored characteristics of WEEE: product type, weight and number of pieces, obsolete / new EEE, B2B products, battery sampling, selected appliances for reuse activities

Post-trial survey

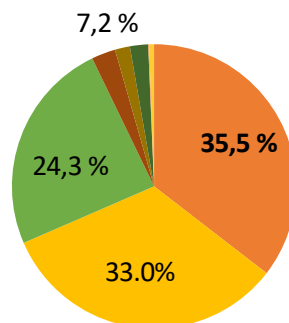
Stationary containers Mobile containers Collection yards

- Total weight of all 178 partial samples was **9 058,1 kg** (from which non WEEE was 487,6 kg)
- 7,876.9 kg (= 5,293 pieces) of WEEE were in groups 2-10

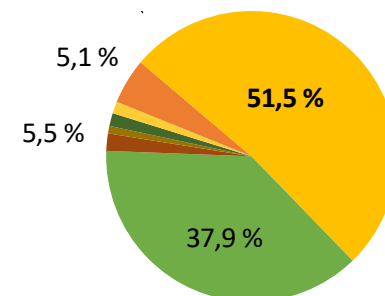
- 2 Small household appliances
- 3 IT and telecommunications equipment
- 4 Consumer equipment
- 5 Lighting equipment
- 6 Electrical and electronic tools
- 7 Toys, leisure and sports equipment
- 8 Medical devices
- 9 Monitoring and control instruments



- Total amount **1 659,8 kg** was 1 440 pieces of WEEE with a total weight of 1451,2 kg
- The largest category by mass is the category 2 with a total weight 514,6 kg (equal 35,5 % wt.) and the number of 341 pieces represented 23,7 % of all WEEE included among categories 2-10



- Total weight of all 54 samples was **17 664,3 kg** (from which non WEEE was 714,5 kg)
- Groups 2-10 represented 8 226 pieces of WEEE with a total weight of 14 745,9 kg
- Group 3 IT equipment and telecommunication equipment (7 600,9 kg) represented 51,5 % wt., predominates by mass and 3 084 kg



New WEEE ratio – stationary containers 27,8 %, mobile containers 33,0 %, collection yards 25,4 %

WEEE category 2-4 ratio – stationary containers 51,6 % (Category 3), mobile containers 38,9 % (Category 2), collection yards 33,8 % (Category 2)

All items (694 pcs.) Category 3 – IT and telecommunications equipment (PCs, laptops, tablets, cell phones and monitors)

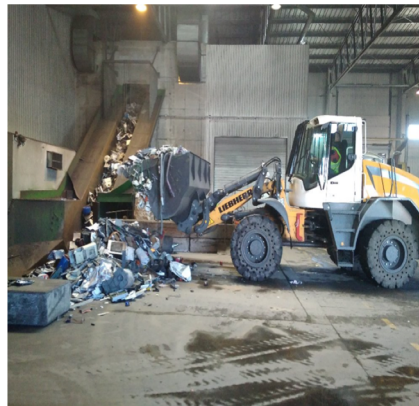
Unsuitable for re-use – economically advantageous, in good or repairable condition, obsolete (only 3,0 % of pcs., 8,9 % of weight)

Other facts of collection

Treatment trials

Trial were performed on special WEEE treatment line.

2 treatments campaigns - WEEE from collection yards and WEEE from stationary and mobile containers.



Results of the treatment trials

Output fractions depolluted from batches

Name of product	Collection yards /kg	Containers / kg
Toners	86	48
CRT screens	2	16
Big metal ferrous pieces	561	102
Wood	107	26
Waste	28	79
Batteries Pb	21	32
Batteries sets	17	55
Batteries monocouple	8	365
Capacitors	14	13
LCD panels	2	57
White glass	21	32
Lights	-	6
Paper	61	71
Cu cables	641	302
Al cables	203	9
CRT glass	19	11
Fine under screen fraction	487	950
Concrete	17	10
Cartridges	8	4
Batteries notebooks	3	20

Collection Yards		Stationary and Mobile Containers	
Sampling	17 664,3 kg	Sampling	10 717,9 kg
Reuse	1 989,5 kg	Reuse	528,6 kg
Amount to be treated	15 674,8 kg	Amount to be treated	10 189,3 kg

Stationary and Mobile Containers		Collection Yards
Fraction	Amount [kg]	Amount [kg]
Cyclone dust	201	288
Inner filter dust	6	9
Outside filter dust	86	155
Light fraction < 0,5 mm	335	391
Light fraction 0,5 – 0,71 mm	70	93
Light fraction > 1,5 mm	1 256	1 517
Fine ferrous fraction	83	111

Laboratory Trials

To identify three fractions with highest potentials for recovery trials

To develop suitable methods for recovery of elements of interest

Determination of precious metals by Flame Atomic Absorption Spectroscopy

Determination of Cu and rare-earth elements by Optical emission spectroscopy with induced coupled plasma



Input material	Tested methods				
Light fraction < 0.5 mm from the collection yards	Screening (0.3; 0.2; 0.1 mm)	Milling and screening (0.2; 0.1 mm)	Magnetic separation (Nd and Fe magnet)	Screening and wet gravity separation	Electrostatic separation
Light fraction < 0.5 mm from the stationary and mobile containers					

Input material	Tested methods				
Light fraction 0.71 - 1.5 mm from the collection yards	Screening (0.71; 0.4; 0.2; 0.1 mm)	Milling and screening (0.71; 0.4; 0.2; 0.1 mm)	Wet gravity separation	Milling and wet gravity separation	Milling and electrostatic separation
Light fraction 0.71 - 1.5 mm from the stationary and mobile containers					

Input material	Tested methods		
Fine ferrous fraction from the collection yards	Magnetic separation (Nd magnet)	Screening and wet gravity separation	Hand-picking
Fine ferrous fraction from the stationary and mobile containers			

Physical methods

Light fraction < 0,5 mm

- **Screening and wet gravity separation** – product with highest purity and concentration of precious metals

Light fraction 0,71 – 1,5 mm

- **Milling and electrostatic separation** – best method for CRMs recovery (precious metals)
- Rare-earth elements concentration in ***light fractions*** are very low, non effective methods for recovery

Fine ferrous fraction

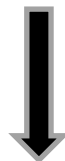
- **Magnetic separation** – only non-magnetic fraction is salable
- **Screening** – the most effective methods for rare-earth elements recovery, not enough for sale

Results of laboratory trials

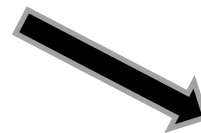
R&D Center



Testing section



Sample preparation
section



Analytical section



Testing section

- Sampling by instruments (automatic, manual)
- Size reduction
- Sample preparation (blending, quartering, splitting)
- Testing of materials (grain size analysis, screening)



Sample preparation section

- Sampling by instruments (automatic, manual)
- Size reduction
- Sample preparation (blending, quartering, splitting)
- Testing of materials (grain size analysis, screening)



Analytical section

Energy dispersive X-ray spectroscopy (ED-XRF)

- Purpose: preliminary element determination (Al, Cr, Cu, Fe, Mn, Ni, Pb, Sn, Zn, Cd)

Flame atomic absorption spectroscopy (FAAS)

- Purpose: precious metals determination (Ag, Au, Pt, Pd)

Inductively coupled plasma - optical emission spectrometry (ICP-OES)

- Purpose: determination of elementary metals (Al, Cu, Cr, Mn, Ni, Pb, Sn, Zn, Fe)





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COLLECT MORE, COLLECT BETTER

Italian trial

Luca Campadello
Projects and Researches Manager



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Italian trial: location and partnership

ECODOM

Consorzio Italiano
Recupero e Riciclaggio
Elettrodomestici

Largest take back scheme in Italy

- 105,000 tonnes managed in 2018
- 124 member companies



Coordination – dissemination – communication – quality control



ENEA

Agenzia nazionale per le nuove tecnologie,
l'energia e lo sviluppo economico sostenibile

Research Center



STENA
TECHNOWORLD



società
elettrica
valtellinese

S.E.val.
linee ecologiche

WEEE treatment operators

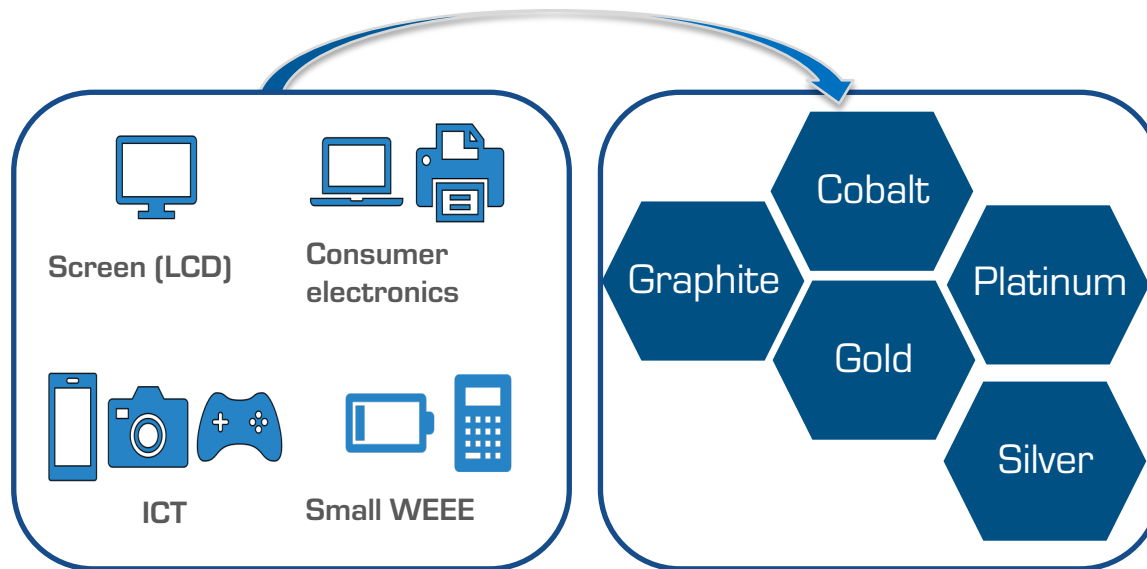
Collection phase

Treatment phase

TARGET

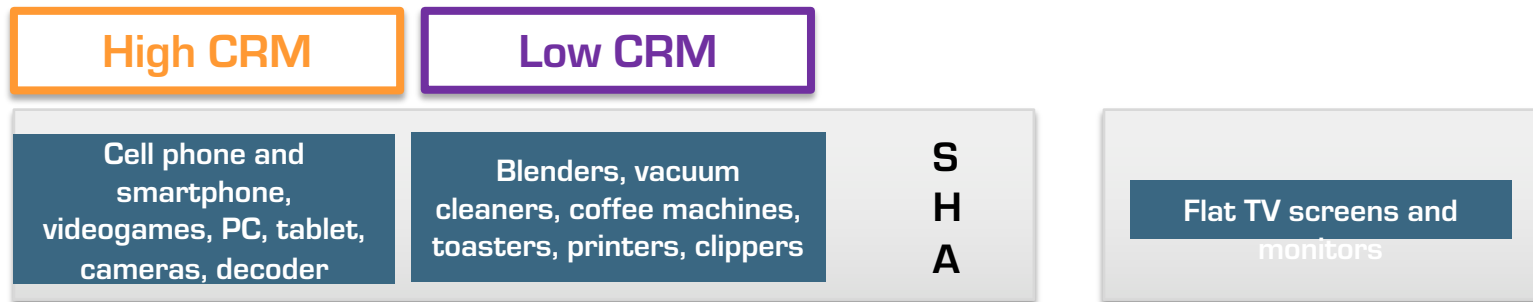
To link collection phase to treatment phase:

- applying the concentration principle: WEEE cluster strategies can be beneficial for further treatment steps
- increasing the amount of small WEEE collected



COLLECTION: methodology

- Concentrate:** CRM in dedicated streams during the collection



- Stay close to citizens:** multiplying collection opportunities



COLLECTION: key results

Where ?	Who?	Quantities (kg)	Monitor	High CRM	Low CRM
Squares	375	2,008	348 kg	539 kg	1,121 kg
		943	0 kg	540 kg	204 kg
Schools	149	2,710			
Shops	>500	TOT > 5 000 kg			
Reusable?					
Monitor	High CRM	Low CRM			
15.6%	28.6%	19.6%			



TREATMENT: objective and target materials



Test FPD for
**preparation for
reuse**



Separate treatment
of high grade/low
grade products



Extract CRM from
**Li-ion rechargeable
batteries**

100% recover of
CRM content

Au, Ag, Cu, PGM

Cobalt and
Graphite

TREATMENT: methodology

1. Testing preparation for reuse of

- ☐ **VISUAL INSPECTION**
- ☐ **FUNCTIONALITY TEST**: evaluation of 24 param



2. Precious Metal Recycling

- ☐ **Current technology**: 2 batches
- ☐ Test of the **CONCENTRATION** approach



3. Treatment of the batteries

- ☐ Liberation of the batteries
- ☐ Stabilization in a cryogenic atmosphere and shredding
- ☐ **Reducing leaching process**
- ☐ Selective extraction



TREATMENT: key results

- FPD testing procedures:

8 out of 43 screens fit for **preparation for reuse**
(7 of which declared not reusable by citizens)

- Precious Metal Recycling:

Increase of the quality of the output fractions in respect to the traditional waste mix performance due to improved quality of **high CRM content WEEE**

- Treatment of the batteries

Development of a procedure for the **hydrometallurgic extraction**

of Cobalt and Graphite

LESSONS LEARNT:

- If citizens are offered an easy/ convenient way to drop off items:
 - **collection of SHA increases significantly**
 - **the quality (CRM content) of collect items increases significantly**
- Low concern regarding personal data security
- Awareness raising/information campaign to support collection efforts are needed

Next steps:

Take advantage of the arosed opportunities:

- ☐ expand the tested collection system in a larger network of grocery shops
- ☐ follow up STENA decision of implementing a dedicated work station to explore the preparation for reuse of screens → creation of **1 full time job**

Continue researching:

- ☐ Design additional developments: e.g. QR code to facilitate FPD preparation for reuse



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Collection and recovery trials at Recyclingboerse and TU Hamburg-Harburg

Dr. Sven Grieger

Objectives

- Developing and validating new methods enhancing the current WEEE collection
- Considering the re-use aspect to extend the period of CRMs application
- Recovering high-grade Neodymium-based magnet materials from Hard Disk Drives
- Enriching Tantalum by new approaches

Partners and roles



- Running collection trials
- Additional focus on re-use



PROJECT GROUP IWKS

- Ta capacitors fractionation
- Nd magnet recovery

Institute of Environmental Technology
and Energy Economics



- Product sorting campaign
- Bioleaching trial (Tantalum)



- Trials coordination

Collection trials

Re-Use Olympics

- 6 secondary schools participated
- Total WEEE amount collected : 3,550 kg
- Share of re-useable items: 6.3%



Functional tests



Collected material



School collection team



Re-use Olympics award

Collection trials

Re-Box collection

- Collection option for all re-useable items
- 3.700 boxes distributed,
39% returned within 6 months
- WEEE amount after 6 months: 92 kg
- Share of re-useable WEEE: 9%



Collection trials

Re-Bag collection

- Co-collection in clothes collection bag
- 100,000 bags distributed, 4,000 returned within 2.5 months
- WEEE amount after 2.5 months: 194 kg
- Share of re-useable WEEE: 11%



Re-Bag



Collected WEEE



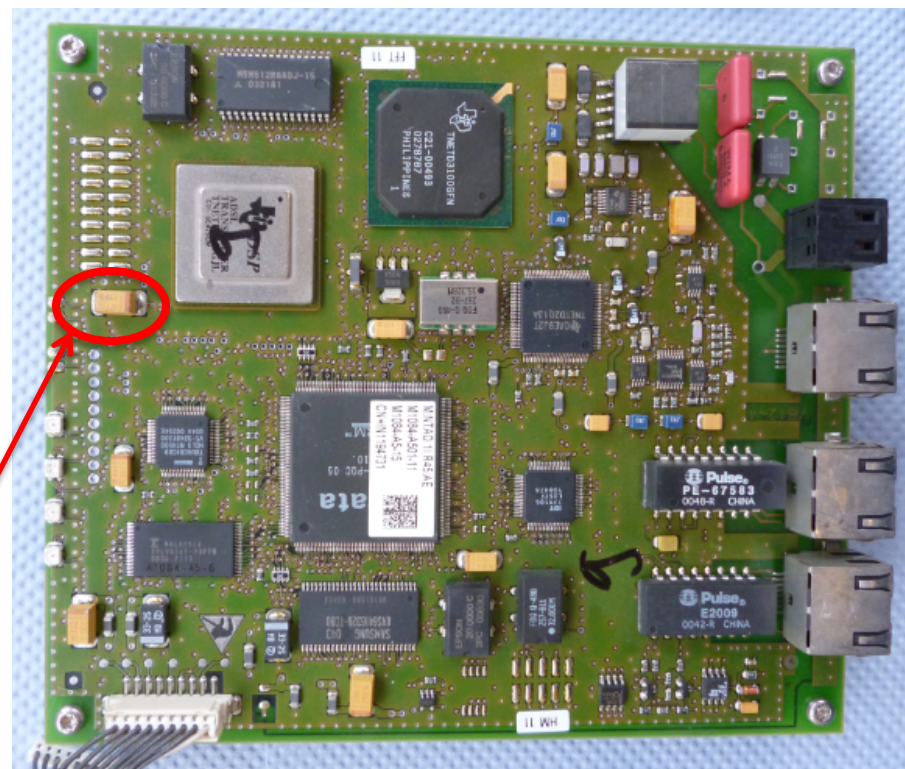
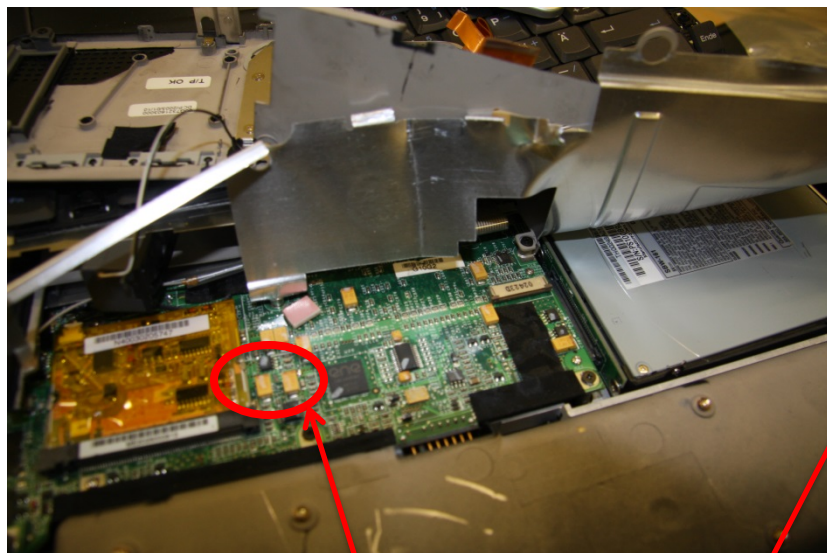
Re-Bag content - example

Lessons learnt - Collection trials

- Increase convenience by
 - Close to home services (Re-Bag, Re-Box), to avoid discarding CRMs in mixed household waste
 - Combined methods for different household wastes (e.g. clothes + WEEE, other re-usable items + WEEE)
- Raise awareness by
 - Offering bins - close to home - with printed instructions/further explanations (Re-Bag, Re-Box)
 - Getting in touch with public via families by collection events (Re-Use Olympics)

Tantalum Recovery

(1) dismantling of PCBs

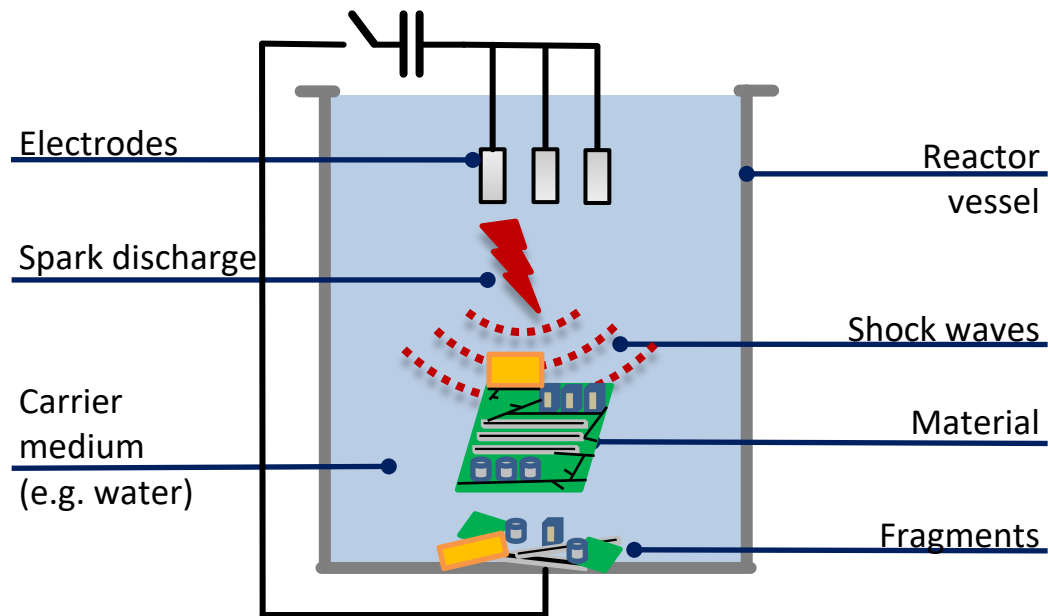


Tantalum capacitor

Tantalum recovery

(2) removing the capacitors

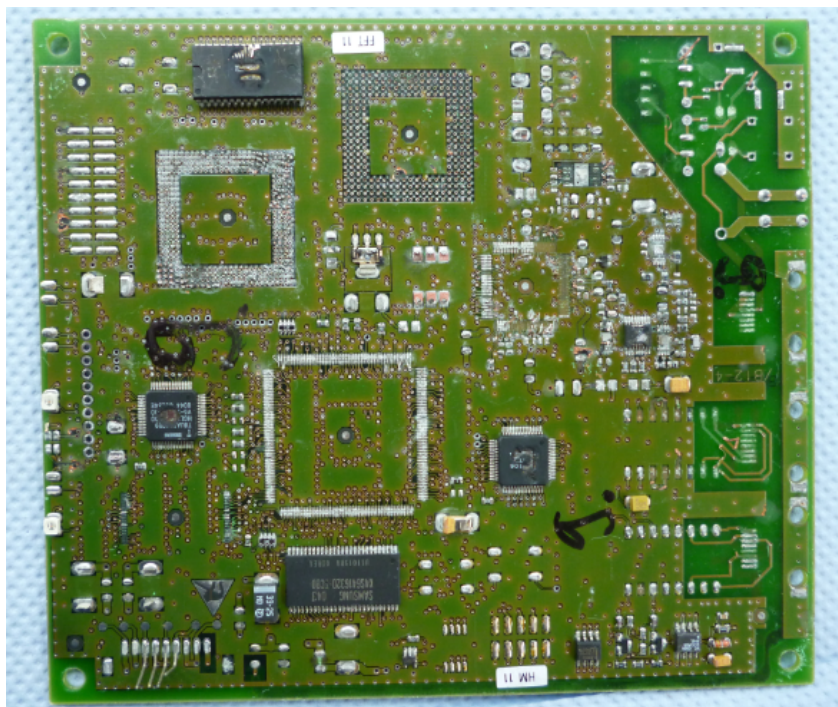
Electrohydraulic fragmentation



Source: Fraunhofer Project Group IWKS

Tantalum recovery

(2) removing the capacitors



Tantalum recovery

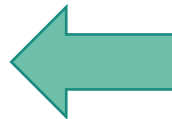
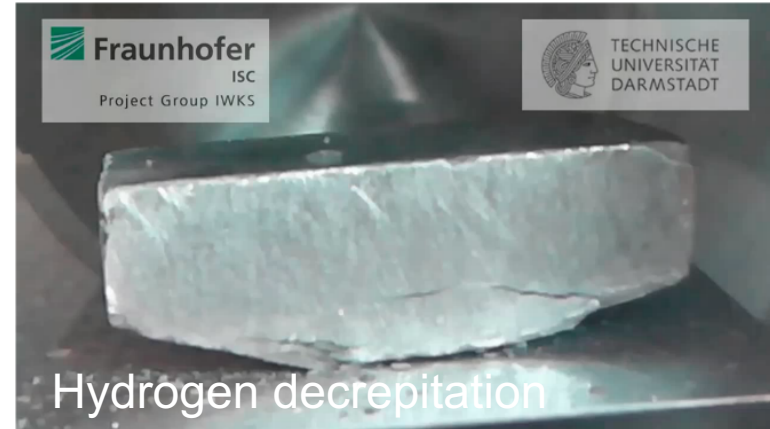
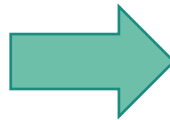
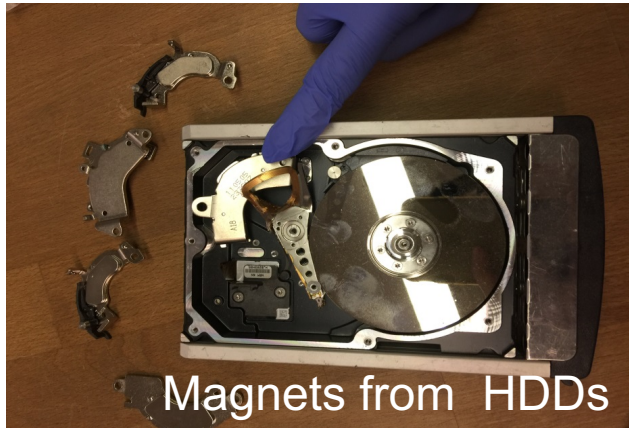
(4) Bio-Leaching

- Tantalum capacitors crushed (< 0.25 mm)
- Leaching tests in 8 different agents (fungi and bacteria)
- Best agent showed following leaching rates:
 - 5.3 % after 15 days
 - 15.4 % after 70 days

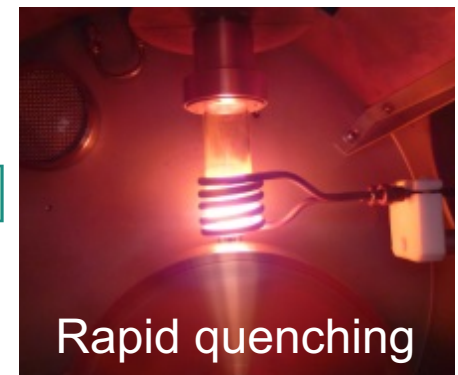
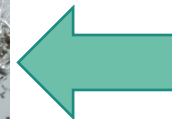


Flasks with different agents

Neodymium magnet recycling



Production of isotropic
hot-pressed and
anisotropic hot-
deformed magnets



Source: Fraunhofer Project Group IWKS

Lessons learnt – Recovery trials

- Ideas for innovation
 - Promising results like bioleaching of Tantalum are not directly transferable into direct applications (low TRL)
 - Innovation projects have to be defined and addressed accordingly
- Call for collaboration
 - It was shown that the recovery of Nd-Fe-B magnets is technically feasible and economically viable
 - Collaborations along the value chain could demonstrate a role model for CRM circular economy approaches

Summary and outlook

- Convenience and awareness are key drivers for implementing new collection methods
- Collection trials carried-out at Recyclingbörse are validated and can be multiplied in other urban and rural areas
- Innovation projects for new recovery methods are needed to increase technologies towards higher TRLs
- Collaboration and entrepreneurship needed for putting established CRM recovery methods into practice



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WEEE Collection and CRM Recovery Trials



Project Partners: Re-Tek, the University of the West of Scotland and Enscape

Targeted Equipment

Laptops

Audio Devices

Printers

PCs

Digital Cameras

Tablets

Components

Flat Screen Monitors

Network Items

Flat screen TVs

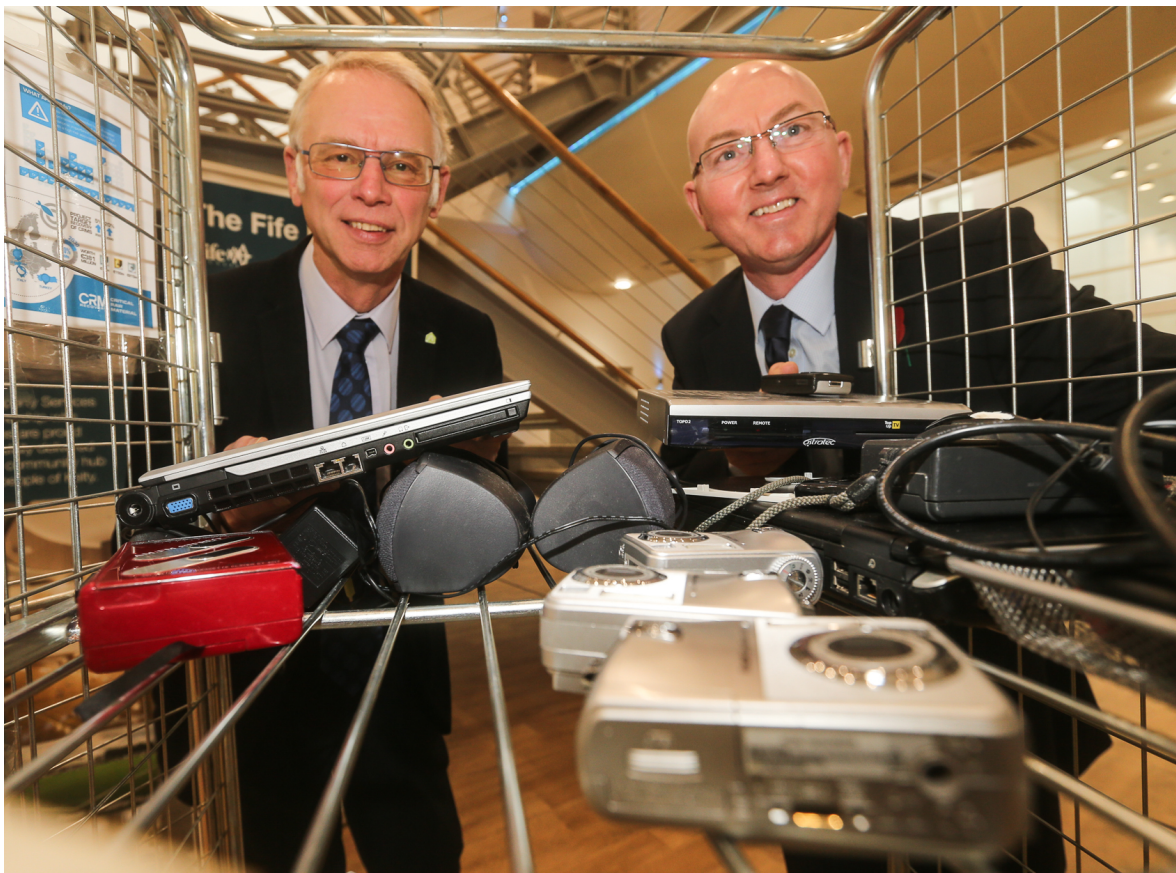
Digital set boxes

Mobile phones

Gaming devices

Printer Cartridge

Phase 1 Collection Models



Workshops and Awareness Raising



Summary of Collections

Collection Model	Weight, Kg	Total Collection		Items Collected by Age Range		
		<u>Items Collected</u>	<u>Items Re-used</u>	<u>0 to 3 yrs</u>	<u>3 to 6 yrs</u>	<u>>6yrs</u>
		<u>%</u>	<u>%</u>	<u>Pieces</u>	<u>Pieces</u>	<u>Pieces</u>
HWRC	4,243	409 100.0%	111 27%	40 9.8%	240 58.7%	129 31.5%
Halls	0.4	4 100.0%	0.00 0%	0 0.0%	0 0.0%	4 100.0%
Schools	190	66 100.0%	20 30%	1 1.5%	44 66.7%	21 31.8%
B2B	1,331	286 100.0%	76 27%	27 9.4%	171 59.8%	88 30.8%
Social Enterprise	621	64 100.0%	23 36%	3 4.7%	40 62.5%	21 32.8%
TOTAL	829	829 100.0%	230 28%	71 8.6%	495 59.7%	263 31.7%

Outcomes

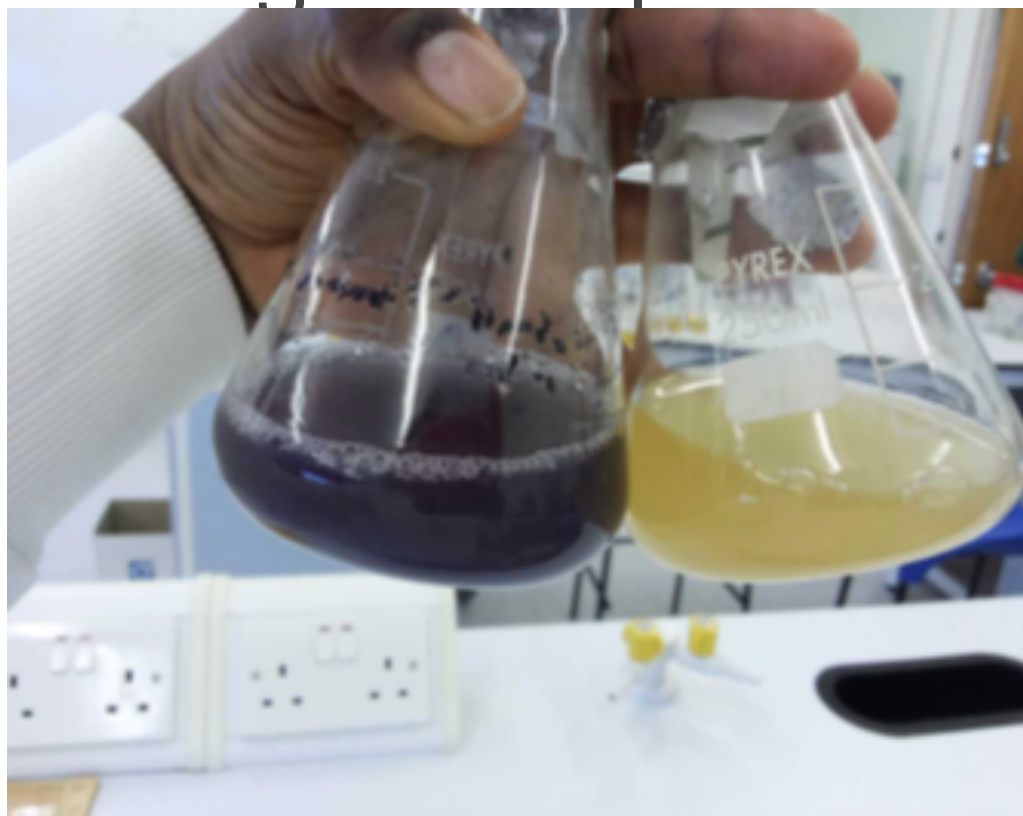
- Re-use from collections ranged from 27% (HWRCs) to 30% (schools) and 36% (social enterprises).
- 96% of equipment in Phase 1 in two categories: ICT (71%) and TVs and monitors (24.7%).
- Phase 1 trials - consumers prefer to donate data bearing equipment to community schemes (rather than HWRCs)

Phase 2

“Proof of concept” benchtop experiments using biological and chemical separation techniques to extract gold (Au), silver (Ag) and cobalt (Co) from PCBs.



Biological Separation



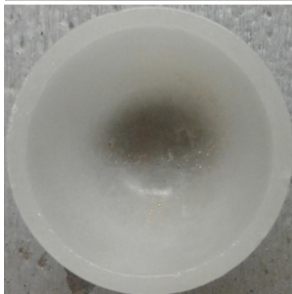
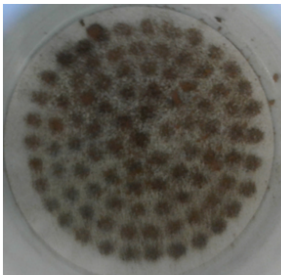
Starter cultures of cyanogenic bacteria *C. violaceum* culture (purple) and *B. megaterium* culture (yellow)

Chemical Separation

200 ppm Solution



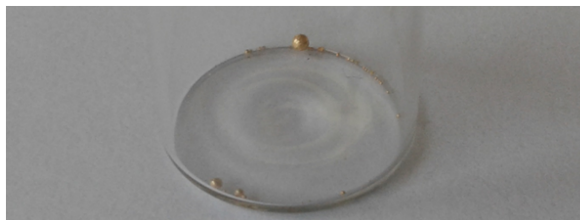
1,000 ppm Solution



Weight – 0.0282g



Weight – 0.0749g



Electro-Chemical Separation



Summary of recovery performance for target metals

Experimental Method	PCB or Reference Sample	Starting Concentration (ppm)				% of Target Metals in Samples Recovered			
		Au	Ag	Co	Cu	Au	Ag	Co	Cu
2-stage Bioleach ^b	PCB	-	-	-	-	70%	-	96%	99%
Hydroquinone ^a	Gold standard	200	-	-	-	314%	-	-	-
	Gold standard	1,000	-	-	-	166%	-	-	-
EC Cells ^a	Ref solution	200	200	200	-	99.6%	94.7%	98%	-
Precipitation	Ref sample	1	1	1	1	95.9%	96.3%	50.1%	53.6%

Lesson Learnt: General

- “baseline” work using a variety of techniques, to determine total concentrations of CRMs (and other elements of interest) is required.
- Based on the complexity of trying to recover CRMs from a heterogeneous PCB, it would appear to be economically and environmentally sound to ensure that collection schemes enable as many items as possible to be processed for reuse markets, prior to recovery/ recycling.

Conclusions

- Very high recovery rates obtained from some benchtop experiments.
- However, phase 2 is proof of concept, and although some of the results appear promising, it will be necessary to obtain further funding to refine the processes of interest.

Further Information

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