TECHNICAL REPORT 2020

SENS
Swico
SLRS

Technical Report
2020

Pioneering benchmarks

The circular economy is the dominant topic in Europe and Switzerland. In Switzerland, in particular, we consume a lot of resources. Because it is also a country with few raw materials, recovery of secondary raw materials is extremely important.

In the common interest of society, the economy and the environment, in our highly developed country, we need solutions that help minimise the use of energy and materials in the manufacture of products and in the provision of services, that extend the service life of products, and help avoid or utilise waste wherever possible. The take-back system is closing the cycle.

The eRecycling system in Switzerland is one of the most successful in the world. The return rates are two to three times higher than in most other European countries. The benefits for the environment are impressive. Switzerland has had take-back quotas of around 65 per cent for decades, in contrast to countries in the EU, where these are between 25 and 50 per cent. We are setting pioneering benchmarks here.

The demands placed on recycling processes are also increasing as a result of rapid technological progress. The recycling of waste electrical and electronic equipment (WEEE) is particularly complex and constantly evolving. For example, WEEE is increasingly being used in a wide variety of electronics, batteries and plastics. The recycling technologies used today are not always the optimal solution for its removal or reuse. This must be recognised in order to subsequently be able to optimise processes. For example, the environmental relevance of PCB-containing capacitors was investigated over two years. What PCB load from capacitors ends up in recycled WEEE? Is this load environmentally relevant? What rules should apply when disposing of capacitors in the future?

Particularly in our industry, no progress can be made without sound know-how – for example, that of highly qualified Recyclists. Thorough education and further training in the recycling industry drives innovation. We are pleased to provide you with the latest insights into the progress of our industry in this year's Technical Report.

We wish you an enjoyable read.

Judith Bellaiche
Swico

Heidi Luck
SENS

Silvia Schaller
SLRS

A bold idea:
disposing of electronic toys from the comfort of your own home

Roman Eppenberger

On the occasion of International E-Waste Day on 14 October 2019, Swiss Post and SENS eRecycling tested the home collection for electronic toys in the two regions of Seefeld and Schwamendingen in Zurich. Over a period of two months, broken devices could be deposited in a recycling bag in each house's parcel box and Swiss Post would then transfer them to a recycling point.

Electronic toys have been collected and professionally recycled by SENS eRecycling for 30 years. Before, people had to drive to the collection point or retail store to return the defective device free of charge. How can we make the return even easier and more convenient? How can we recover even more recyclable materials that otherwise lie unused in people's cellars? Would it not be great if you could dispose of unused and defective devices directly at home? A bold idea that SENS put to the test with Swiss Post. Using electronic toys as an example, home collection services were put in place for two months starting on 14 October 2019 for two Zurich regions (Schwamendingen and Seefeld). About 30,000 households were sent a Recycling Hero mailing, which included a collection bag. Defective appliances could be deposited in the Hero bag in the house's parcel box, and Swiss Post would come and collect it during regular mail delivery. Our Recycling Heroes who took part in the pilot project were rewarded with a fabulous Hero keychain.

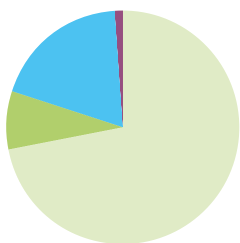
Why electronic toys?

Because probably every family with children still has an old electric car or a broken drone lying around at home that should have been disposed of long ago. This was a perfect opportunity and gave us a first impression of whether and how the population was using this new disposal option and whether we could recover additional recyclable materials in this way.

What was the effect of this programme?

And what happens next? We collected 300 Hero bags during those two months. The target group of families was expected to return 180 bags – this was exceeded by far. The electronic waste collected amounted to 207 kilograms, 89 per cent of which consisted of electronic appliances subject to an advance recycling fee (ARF), 10 per cent of electronic appliances without any ARF, with impurities making up only 1 per cent. The quality of the contents of the collection bags was very satisfactory. In addition, we received a lot of positive feedback directly from the population during the two months. There were also follow-up orders for collection bags placed, and schools inquired about talks and teaching materials.

We are again using the International E-Waste Day 2020 as an opportunity to think one step ahead, make visionary ideas possible and take eRecycling forward. We will therefore extend the pilot test to a larger target group and further regions. The next International E-Waste Day will be on 14 October 2020. The event was initiated by the WEEE Forum (International Association of Electronic Waste) – with the aim of raising public awareness for the recycling of electronic waste and encouraging consumers to recycle their electronic waste.



The SENS Foundation, Swico and SLRS
Competent and sustainable

For over 20 years, the three take-back systems Swico, SENS eRecycling and SLRS have ensured the resource-efficient take-back and recycling as well as the professional disposal of electrical and electronic appliances.

There are historical reasons for the existence of three systems: in the early years of institutionalised recycling, industry-specific systems were established. The aim of these was to guarantee proximity to the relevant industry in order to respond to its specific requirements. It also allowed initial reservations about participation in a take-back system, which remains voluntary to this day, to be broken down. Depending on the type of electrical or electronic appliance in question, SENS, Swico or SLRS is now responsible for take-back systems.

In 2019, the three systems disposed of around 127,600 tonnes[1] of old electrical and electronic appliances. This means that Swico, SENS and SLRS have also made a significant contribution to reintroducing valuable resources into the production cycle. With the international networking of the three organisations at a European level – for example as members of the Forum for Waste Electrical and Electronic Equipment (WEEE Forum) – they also help to set cross-border standards for the recycling of electrical and electronic appliances.

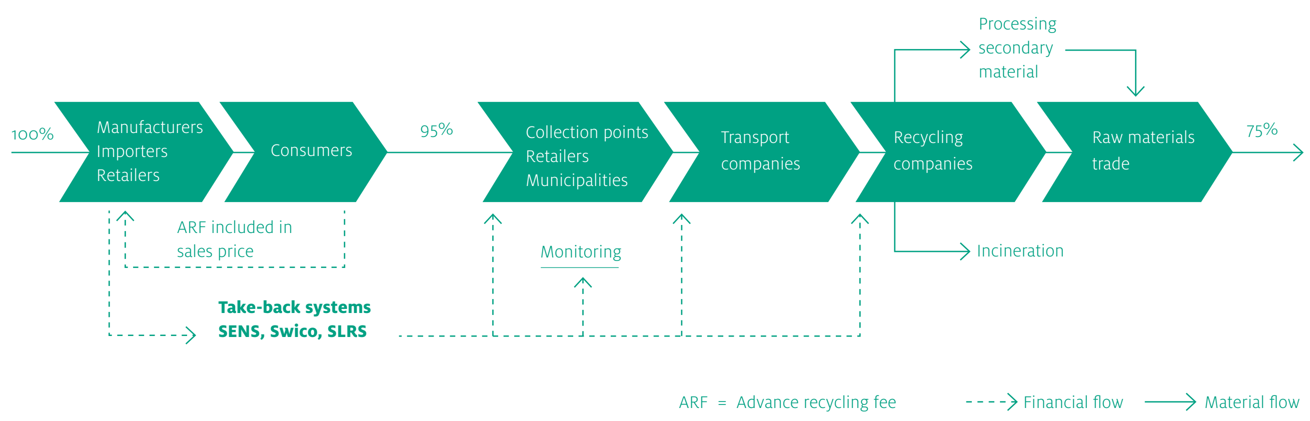
The Ordinance on the Return, Taking Back and Disposal of Electrical and Electronic Equipment (ORDEE) obliges retailers, manufacturers and importers to take back appliances they stock in their product range free of charge. In order to be able to finance sustainable and environmentally responsible recycling of electrical and electronic appliances competitively, an advance recycling fee (ARF) is included in the sale price for these appliances. The ARF is an efficient financing instrument which guarantees that SENS, Swico and SLRS can ensure proper processing of the appliances in their respective area and continue to face challenges in the future.

SENS
SENS eRecycling is an independent, neutral, non-profit foundation that operates under the SENS eRecycling brand. It focuses on the return, reuse and disposal of electrical and electronic appliances from the small and large domestic appliance sector, as well as construction, garden and hobby equipment and toys. To this end, SENS works in close conjunction with specialist networks in which the parties involved in the recycling of electrical and electronic appliances are represented. In cooperation with its partners, SENS is geared towards ensuring that the recycling of these appliances is compliant with economic and ecological principles.

Swico
Swico Recycling is a special fund within the Swiss Industrial Association Swico and deals exclusively with cost-covering recycling of old equipment. Swico aims to extract raw materials and dispose of hazardous substances in an environmentally friendly way. The focus of Swico is on equipment in the fields of computing, consumer electronics, office equipment, telecommunications, the printing industry as well as measuring and medical instruments, such as copiers, printers, televisions, MP3 players, mobile phones, cameras, etc. Close cooperation with the Swiss Federal Laboratories for Materials Science and Technology (Empa), a research and service institute for material sciences and technology development within the ETH, plays a crucial role in ensuring that Swico can enforce high and uniform quality standards throughout Switzerland with all waste management services.

Swiss Lighting Recycling Foundation
The Swiss Lighting Recycling Foundation (SLRS) bears basic responsibility for lamps and lighting equipment. SLRS deals with the organisation of comprehensive waste disposal systems for lamps and lighting equipment across the whole of Switzerland. In order to finance these activities, SLRS administers a fund each for lamps and lighting equipment, which is fed from the relevant ARF. Training and sensitisation of market participants with respect to the recycling of lamps and lighting equipment and providing information to all stakeholders also form part of SLRS's remit. SLRS maintains a close partnership with the SENS Foundation across all areas. For example, as a contract partner to SLRS, the SENS Foundation provides not only collection and transport via its take-back and recycling system, but also the recycling, monitoring and reporting with regard to lamps and lighting equipment on an operational basis.

Figure 1: Overview of the take-back systems.



[1] This is the quantity confirmed by the material flow reports from the recycling companies. It is not the same as the quantity calculated in accordance with the annual and company reports for SENS eRecycling and Swico Recycling.

WEEE recycling and circular economy

Heinz Böni and Roman Eppenberger

Since 2018, the Swico/SENS Technical Commission (TC) has increasingly been focusing on the extent to which the performance indicators for recycling waste electrical and electronic equipment (WEEE) that have been in use for years are still sufficient for deriving suitable measures that meet the requirements of circular waste management. The Swico/SENS TC also considered this and other issues in 2019.

The demand for a circular economy has dramatically increased in Switzerland and throughout Europe in the past five years. In a circular economy, raw materials are maintained in cycles, and hazardous substances are sorted out and disposed of in an environmentally friendly manner. In the European Union, a circular economy package went into effect in 2015. A total of EUR 10 billion will be invested in the action plan based on this package from 2016 to 2020. In Switzerland, the federal government has been making efforts to promote the circular economy for many years now. In recent years, an increasing number of private-sector initiatives have also emerged, for example through Swiss Recycling, öbu or Circular Economy Switzerland.

Managing cycles of materials such that the materials can be fully recovered and reused in as pure a form as possible while hazardous substances are sorted out and disposed of in an environmentally friendly manner requires suitable measurement and control parameters (indicators). In terms of the recyclable materials, these parameters are the recycling and recovery quotas, which are determined by means such as batch tests. In terms of hazardous substances, they are information on the amounts of hazardous substances in fractions of recycled materials.

A critical review of these indicators has revealed weak points, which were described in the 2019 Technical Report and have also been included in this report. This topic was a common theme linking the work of the Swico/SENS TC and various professional groups last year. The findings from the development of a coherent set of measurement parameters that meets the requirements for circular waste management will be tested this year in various pilot projects and are scheduled for gradual implementation starting in 2021. This will also affect the technical regulations that the audits are based on. The recycling partners will be involved in a suitable manner.

In addition, the Swico/SENS TC has also repeatedly considered further development of the basis for audits and updated the technical regulations that supplement the SN 50625 series of standards.

The SN EN 50625 series of standards will undergo a revision process from 2020 to 2022. One of the objectives of this process is to integrate certain technical specifications into the standards and to further streamline and harmonise the overall body of standards. Switzerland can participate in the CENELEC committee TC 111X/WG 6 through Electrosuisse in order to help shape the revision process. SENS will be represented in the committee by Büro für Umweltchemie, and Swico will be represented by the Swiss Federal Laboratories for Materials Science and Technology (Empa).

There has also been a change in the auditors: Arthur Haarman left the Swico auditing team at the end of 2019. He will be replaced by Andreas Bill, who was introduced to auditing in 2019 and will work as an auditor starting in 2020.

Photo 1: The members of the Swico/SENS Technical Commission including host.

Constant volumes and further change in composition

Michael Gasser

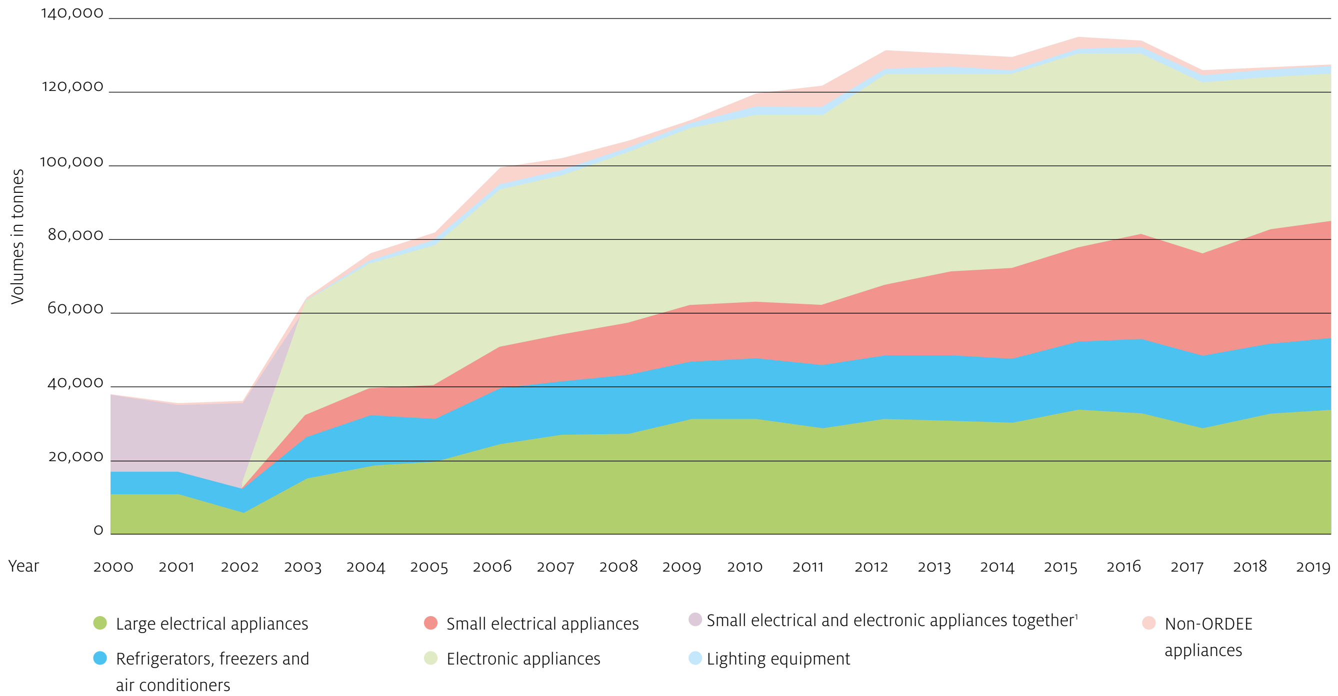
Compared to the previous year, the processed volumes of waste electrical and electronic equipment remained at the same high level. The composition according to individual categories changed further. The volumes of electronic appliances decreased once more, a development that was offset by the higher number of large electrical appliances and small electrical appliances.

In 2019, the SENS and Swico recycling companies processed around 127,600 tonnes of electrical and electronic (E&E) appliances. Compared to the previous year, this volume remained unchanged (see table 1 and figure 1). However, changes could be observed again in the various categories. The volume of non-ORDEE appliances, that is, those that are not included in the lists of the Ordinance on the Return, Taking Back and Disposal of Electrical and Electronic Equipment (ORDEE), as well as the volume of refrigerators remained unchanged. The volume of electronic appliances (–2 per cent) continued to decrease in line with the long-term trend. This was in part due to the decline in heavy cathode ray tubes (CRTs) from computer monitors and televisions. With the almost complete disappearance of these types of screens, however, the decline appeared to be slowing. Following a change to the recording methodology in 2017, an increase (+5 per cent) in the volume of large electrical appliances was observed for the second year in a row. As was the case in the previous year, a further increase (+4 per cent) was also recorded for small electrical appliances. The volume of processed photovoltaic equipment was unchanged relative to the previous year, and its proportion also remained small, amounting to a total of 300 tonnes.

Table 1: Total processed electrical and electronic appliances in Switzerland in tonnes from the material flow analysis

Year	Large electrical appliances	Refrigerators, freezers and air conditioners	Small electrical appliances	Electronic appliances	Lighting equipment	Photovoltaics	Non-ORDEE devices	Total tonnes per year
2009	30,400	15,300	14,900	47,300	1,100		1,200	110,200
2010	30,700	15,900	15,400	50,700	1,130		3,500	117,400
2011	27,800	16,800	16,300	51,300	1,110		5,200	118,500
2012	30,300	17,500	18,800	55,500	960		6,000	129,100
2013	30,600	16,700	22,300	53,200	1,100		4,000	127,900
2014	29,400	17,200	23,900	52,000	1,100		3,000	126,600
2015	32,900	18,100	25,000	51,900	1,100	100	3,000	132,100
2016	32,500	19,200	27,900	49,000	1,100	100	1,900	131,800
2017	28,100	19,400	26,700	46,000	970	300	1,300	122,800
2018	34,200	19,900	27,600	41,900	1,100	300	1,000	125,900
2019	35,800	19,900	28,700	41,000	1,000	300	1,000	127,600
Change on previous year	**5%**	**0%**	**4%**	**–2%**	**–9%**	**0%**	**0%**	**0%**

Figure 1: Development of the volumes of appliances processed in Switzerland in tonnes.



Materials recycling

Of the waste electrical and electronic equipment processed, the recyclables and hazardous substances are obtained through manual and automatic processing (see figure 2). The largest fraction of recyclable materials in 2019 was metals, at 59 per cent. Plastics-metal mixtures (19 per cent) and plastics (9 per cent) were the two next-largest fractions. The proportion of glass from CRTs processing declined by a quarter relative to the previous year, and now only makes up 1.1 per cent. The especially valuable circuit boards accounted for only 1.3 per cent of the total volume. Nevertheless, it is often worthwhile to manually remove these materials prior to mechanical processing and to recover them as completely as possible. The generated recyclable material fractions are processed further by downstream companies and recycled or utilised thermally where possible.

The recyclable material fractions from SENS and Swico recycling companies are sent for further processing. The SENS and Swico recycling companies are required to provide material flow evidence for further processing that describes the further processing of these fractions. In general, ferrous metals are ultimately processed in Swiss smelting plants and non-ferrous metals in European smelting plants. Plastics-metal mixtures are further separated; depending on the separation process and composition, the metals and, in some cases, also the plastics are recovered. Certain mixed fractions continue to be sent directly for energy recovery, although this share has fallen significantly in recent years thanks to new processing options, for example for toner cartridges, and sorting plants

[1] Until 2002, small electrical and electronic appliances were recorded together.

for plastics-metal mixtures. Special recovery methods, often performed abroad, are also used for glass fractions (screen glass, plate glass and recycled glass from lighting equipment), as well as cables, circuit boards and batteries.

Removal of hazardous substances

The proportion of hazardous substances accounted for around 1 per cent of the total volume in 2019 (see figure 2). Besides reintroducing recyclable materials into the material cycle, the removal of hazardous substances is one of the main tasks of Swiss recyclers. The hazardous substances are largely removed by hand at the disassembly facilities. For example, capacitors in large household appliances are removed, as well as batteries from electronic appliances and the background lighting of flat screens, scanners and photocopiers, which contains mercury. The removal of hazardous substances and the handling of these hazardous substances has to be constantly adapted to changing technologies and the latest state of the art. The companies must, however, also still be able to professionally remove and dispose of hazardous substances from older generations of appliances. This places high demands on the work of the recycling companies and necessitates robust quality assurance systems.

Take-back and composition of electronic appliances

Swico Recycling regularly investigates the take-back volumes and the composition of electronic appliances. To this end, Swico Recycling performs market basket analyses and processing tests of product groups (see table 2). In 2019, Swico Recycling took back 46,900 tonnes[1] of electronic appliances, 2.4 per cent more than in the previous year. The weights and quantities of CRT monitors and televisions taken back continued to fall in line with the long-term trend. For flat-screen monitors and televisions, the number of appliances taken back increased further, and there was also a rise in average weight. While the number of mobile phones continued to increase, the total volume rose only a little due to the further decline in average weight. A similar but less marked trend was also observed in the "Consumer electronics, mixed" category.

The composition of the individual appliance categories is determined by means of processing tests carried out by Swico recycling companies and supervised by the Swiss Federal Laboratories for Materials Science and Technology (Empa). In this process, a previously defined number of appliances is collected and the resulting fractions are documented. The detailed take-back quantities of electronic appliances and their composition are listed in table 2.

Left-hand page

[1] This number is larger than the 41,000 tonnes of electronic equipment in table 1, since this also includes electronic appliances which A-signatories have disposed of via direct contracts.

Right-hand page

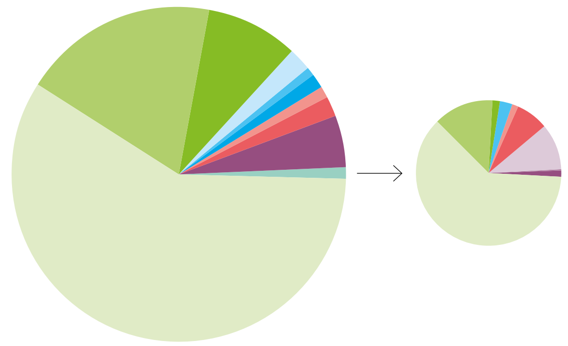
[1] FPD: flat-screen displays, different technologies (LCD, plasma, OLED, etc.).
[2] IT equipment, mixed, without monitors, PCs/servers, laptops, printers, large-scale copiers and equipment.
[3] Consumer electronics, mixed, not including televisions.
[4] Projection.
[5] Packaging and other waste, toner cartridges.
[6] This number is larger than the 41,000 tonnes of electronic equipment in table 1, since this also includes electronic appliances which A-signatories have disposed of via direct contracts.

Source: Michael Gasser, Empa, based on Swico processing and market basket analyses.

Figure 2: Composition of the fractions generated in per cent in 2019. Hazardous substances, which make up a total of just 1 per cent of the fractions generated, are shown separately (source: Toocy).

Recyclable materials

- **59%** metals
- **19%** plastics-metal mixture
- **9%** plastics
- **2%** cables
- **1%** toner cartridges
- **1%** circuit boards
- **0%** LCD
- **1%** cathode ray tubes
- **2%** glass
- **0%** photovoltaics metals
- **5%** other materials
- **1%** hazardous substances



Hazardous substances

- **0.634%** batteries
- **0.135%** capacitors
- **0.018%** components containing mercury
- **0%** pieces of broken glass
- **0.029%** phosphor
- **0%** getter pellets
- **0%** photoconductor drums with selenium coating
- **0.013%** appliance components containing asbestos
- **0.073%** CFCs
- **0.105%** oil
- **0.004%** ammonia (NH_3)
- **0.013%** other residues containing hazardous substances

Table 2: Swico volumes collected and composition by type of appliance.

Appliance type	Number[4] (in thousands)	Average weight (in kilograms)	Metals (in tonnes)	Plastics (in tonnes)	Plastics-metal mixtures (in tonnes)	Cables (in tonnes)	Glass and/ or LCD modules (in tonnes)	Circuit boards (in tonnes)	Hazard-ous sub-stances (in tonnes)	Other[5] (in tonnes)	Total (in tonnes)	Increase/ decrease compared to 2016
PC monitor, CRT	34	17.7	89	121	58	16	266	56	0	3	608	–3%
PC monitor, FPD[1]	561	7.2	1,584	1,277	77	50	631	285	37	100	4,041	15%
PCs/servers	389	12.1	3,856	270	13	144	–	390	15	–	4,687	2%
Laptops	493	2.5	374	348	126	6	109	179	85	5	1,233	–6%
Printers	456	11.4	1,834	2,784	318	28	36	91	2	84	5,176	–2%
Large-scale copiers/ equipment	52	121.8	3,422	235	2,248	114	4	50	54	161	6,288	–3%
IT, mixed[2]	716	3.1	1,212	80	803	40	1	17	19	56	2,229	13%
CRT TVs	102	27.7	279	579	94	10	1,830	35	3	2	2,830	–28%
FPD TVs[1]	297	20.4	2,932	1,091	639	84	532	510	68	211	6,065	48%
CE mixed[3]	3,441	3.2	5,969	396	3,954	199	6	85	94	277	10,980	1%
Mobile phones	873		20	44	–	–	6	28	25	–	124	6%
Remaining phones	1,216		1,329	88	880	44	1	19	21	62	2,444	–9%
Photo/video	214		91	6	60	3	0	1	1	4	167	3%
Dental											63	
Total in tonnes			**22,991**	**7,318**	**9,269**	**737**	**3,421**	**1,747**	**424**	**964**	**46,935**[6]	**24%**
Total in per cent			**49%**	**16%**	**20%**	**2%**	**7%**	**4%**	**1%**	**2%**	**100%**	

Dismantling
temperature exchange equipment

Geri Hug and Niklaus Renner

CENELEC standard EN 50625, which since 2020 has served as the basis of SENS certification, no longer uses the term refrigerators, but instead refers to temperature exchange equipment. This somewhat cumbersome term has become established among auditors as well as recycling companies. In 2019, the latter used three highly specialised plants to separate hazardous substances and recyclable materials from some 390,000 appliances (the equivalent of 19,900 tonnes).

The share of environmentally friendly volatile hydrocarbons (VHC) appliances that can be dismantled annually has risen steadily, and now includes 67 per cent of temperature exchange equipment with VHC compressors and 73 per cent that have VHC insulation foam. The share for ammonia-driven absorption appliances is just 2 per cent.

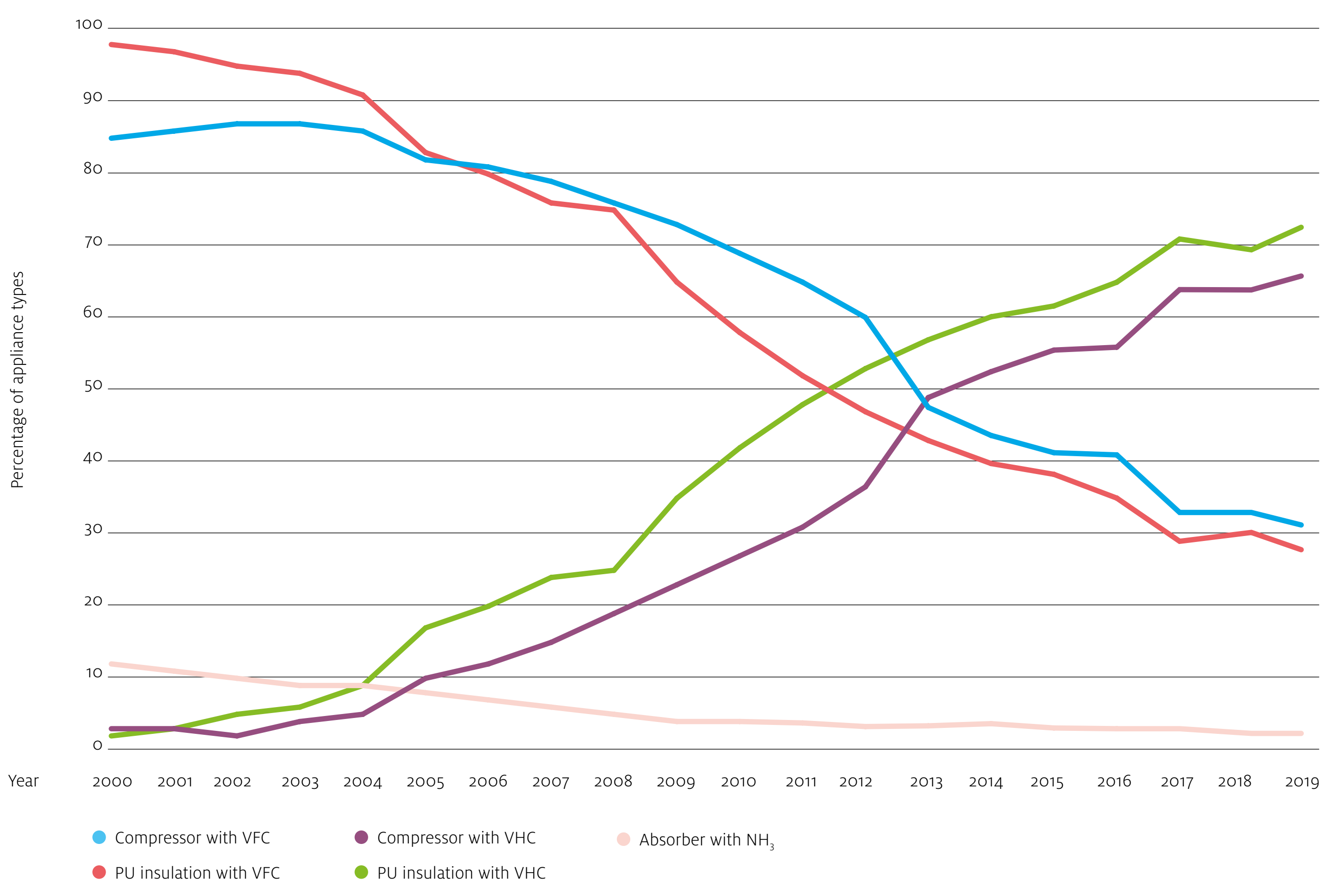
Why not simply shred the appliances? The reason behind the laborious handling process

Did you know that in an old household refrigerator, most of the fluorinated gases (VFC) are not in the compressor, but in the polyurethane (PU) foam insulation? And did you know that by recovering and then incinerating the refrigerant and propellant at high temperatures, a large amount of CO_2 equivalent is prevented from being released into the atmosphere, the same volume as for a journey by fossil-fuelled car to East Asia? While nearly 90 per cent of the appliance weight is free of hazardous substances and could, in principle, be processed using conventional recycling process technology, the remaining proportion of ozone-depleting and climate-active components necessitates a highly specialised plant. First, the refrigerant must be extracted from the compressors without any losses (treatment stage 1). After the emptied compressors have been removed, the appliance housing is dismantled into its component parts using rotary shears as well as downstream magnet and eddy current separators. The PU foam is then subjected to a thermal process using pellet presses or other heating elements, and thus to a final removal of the remaining propellants (treatment stage 2). This controlled degassing and condensation of propellants at stage 2 is performed using mechanical refrigeration technology or through the application of liquid nitrogen at low temperatures of as low as −90°C. The waste airflows of the plants are only released into the atmosphere after passing through various filter devices, whereby the VFC types R11 and R12 are measured continuously.

Share of VFC appliances continues to fall

The downward trend in recycled temperature exchange equipment with VFC compressors started in 2003. The reduction picked up speed from 2012 to 2013, but then continued on a more or less linear basis. While the volume of VFC refrigerants recycled in 2012 was still 60 per cent, this figure was just 48 per cent in 2013. In our last technical report, we reported a share of 33 per cent, but this figure was just 31 per cent during the current period. At the same time, the share of VHC compressors rose continuously to the current level of 67 per cent. Ammonia-containing absorption systems continue to decline and currently make up just 2 per cent. The curve representing the share of appliance housing with VFC-containing insulation foam is as expected. Similar to the curve for VFC compressor appliances, it is declining steadily (asymptotically?): for example, the share of VFC PU appliances was just 27 per cent in 2019 (previous year: 30 per cent) (see figure 1).

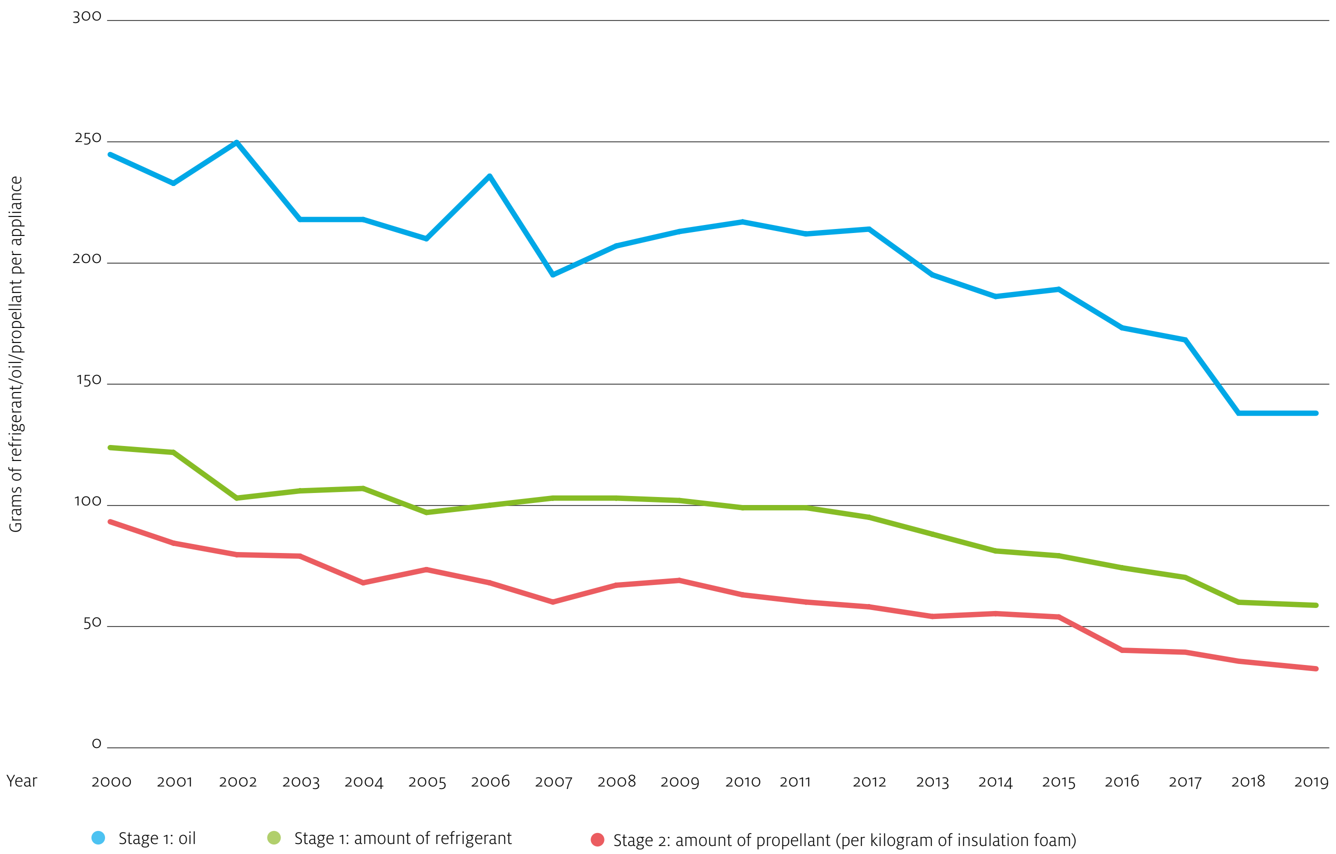
Figure 1: Development of appliance types processed at stage 1 (VFC-/VHC-containing compressors, ammonia-containing absorption systems) and stage 2 (VFC-/VHC-containing PU insulation foam).



Steady decline in recovery rates reflects inputs ratios

The decline in VFC appliances on the input side can also be observed at both treatment levels in terms of output in the form of lower recovery rates for refrigerants and propellants. Two factors are responsible for this effect: 1) the much lower VHC filling weights/concentrations in compressors/PU insulation and 2) the lower specific weights of isobutane/cyclopentane relative to conventional VFC (82 grams of VFC/38 grams of VHC per kilogram of PU foam according to performance tests and manufacturer specifications). The refrigerant recovered per appliance has fallen in recent years and now stands at just 54 grams (previous year: 57 grams); the figure for compressor oil was practically stagnant at 139 grams (previous year: 138 grams). With respect to propellants in PU foam, the amount fell during the same period from 37 to 35 grams per kilogram (see figure 2).

Figure 2: Development of recovery rates at stage 1 (grams of refrigerant and oil per appliance) and stage 2 (grams of propellant per kilogram of insulation foam).



Challenge of VIP appliances

Temperature exchange equipment whose housing walls are partially comprised of vacuum insulation panels (VIP) is now increasingly being dismantled as well. These panels, the support core of which is made of fibreglass or fumed silica, have been integrated in temperature exchange equipment for some time now and therefore have better energy efficiency (A+++). This appliance type, which is recycled more often as a result, initially presented a challenge for plants because of the increased issue of dust (prevention of dust and explosions). Technical adjustments have now shown that such appliance housing can also be processed at treatment stage 2 without any problems. Likewise, from the point of view of health and safety, VIP appliances are safe, as the fibres do not break longitudinally either in the original material or after processing (as is the case with asbestos fibres, for example). These statements are supported by a manufacturer report on experimental processing in Germany.

Photo 1: Temperature exchange equipment, ready for processing.

Photo 2: Output fraction: polyurethane powder.

Photo 3: Appliance infeed conveyor for the second processing stage.

The SENS life cycle assessment at a glance

Flora Conte and Thomas Kägi

The 2019 SENS life cycle assessment (LCA) clearly shows the current challenges in the recycling of waste electrical and electronic equipment that are particularly relevant in ecological terms. The environmental benefit corresponds to the comparison made with a scenario in which SENS does not exist. In contrast to CO_2 footprints, which are currently the focus of public attention, an LCA takes into account all the environmental effects of products, companies or activities.

There is no simple golden rule for determining which measures, initiatives and behavioural changes have a particularly positive effect on the climate or for the environment. While the effects of the climate crisis are global, environmental problems such as air, soil and water pollution or hazardous emissions are felt locally, and sometimes only insidiously.

An overview of our impact on the environment

An LCA is a scientifically supported method of measuring and assessing the impact of human activities on the environment and deriving optimisation potential from the results. Due to the complexity of nature and the global economic system, it is not enough to consider only individual problematic substances or effects. The LCA method aims to uncover environmental impacts in a very comprehensive way. This means that the entire life cycle of a product is included in the analysis and environmental impacts are quantified and assessed at the end. The process involved is outlined in figure 1.

The results of life cycle assessments can be used in a variety of ways: as a decision-making aid for product alternatives, to measure the relevant impacts of products, services or companies, or to identify potential for improvement and recommendations for action.

SENS recycling from an LCA point of view

The SENS Foundation has its environmental benefits from recycling SENS waste electrical and electronic equipment (SENS-WEEE) assessed annually by the environmental consultancy Carbotech AG by means of an LCA. To mark the 30th anniversary of the Foundation, the calculation bases of the SENS-WEEE recycling life cycle assessment were supplemented by the latest findings on hazardous substances and recyclable materials. The environmental footprint created by the SENS Foundation since its establishment was also extrapolated. The collection, sorting, manual and automated processing of WEEE and the proper disposal of hazardous substances such as chlorofluorocarbons (CFCs) or polychlorinated biphenyls (PCBs) were assessed. Moreover, the further processing of the recyclable materials into secondary raw materials was examined.

In order to assess the environmental benefits of the SENS recycling system, a comparative scenario is needed for the alternative: Switzerland without SENS. This scenario was defined as realistically as possible, also based on the scenarios in the Ecodom study on the climate benefits of recycling electrical and electronic appliances in Italy. The environmental benefit of the SENS system as calculated in the SENS LCA was therefore calculated from the difference between the actual situation analysis "With SENS" and the base scenario "Without SENS". The environmental impacts were weighted using the 2013 ecological scarcity method (Frischknecht & Büsser Knöpfel, 2013), a method that has been tried and tested in Switzerland, and combined into one indicator: environmental impact points (UBP).

Figure 1: The most important steps of a life cycle analysis. (Source: Carbotech AG)

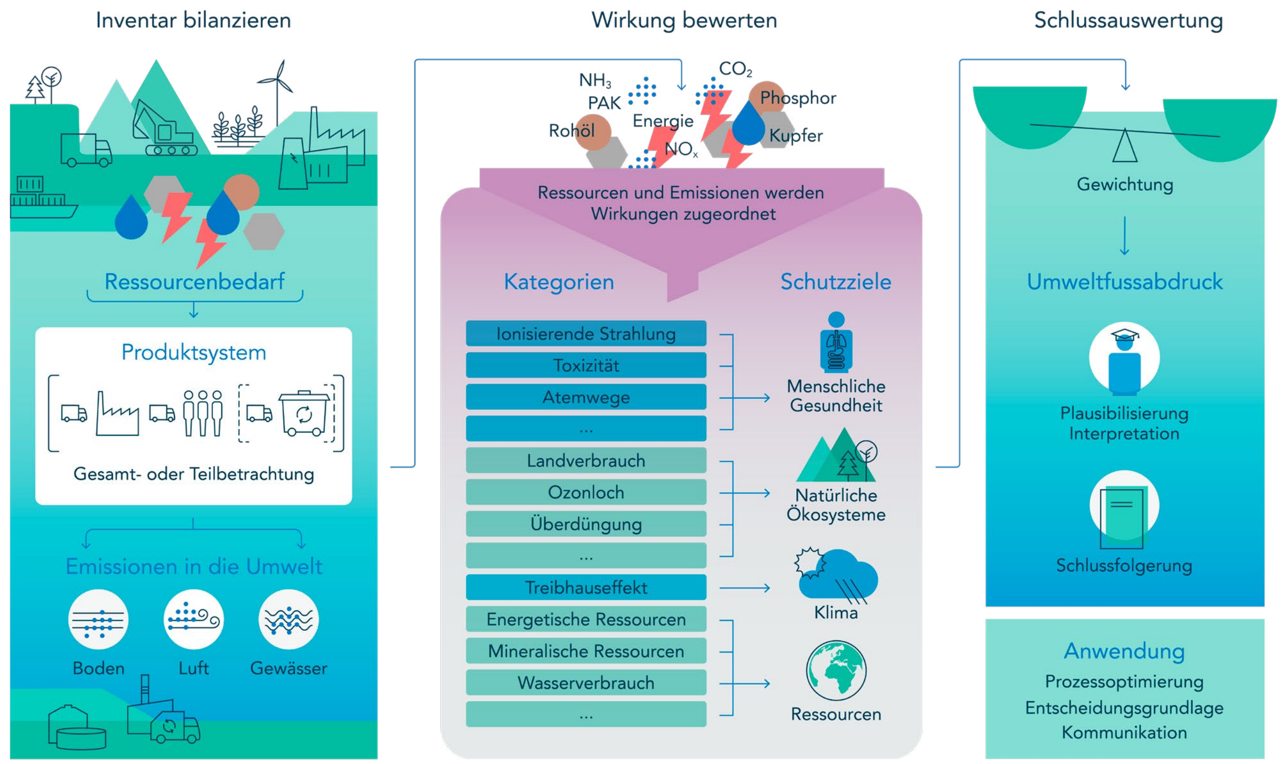


Figure 2: Distribution of the environmental benefit (UBP) of SENS eRecycling in 2019 (Source: Carbotech AG).

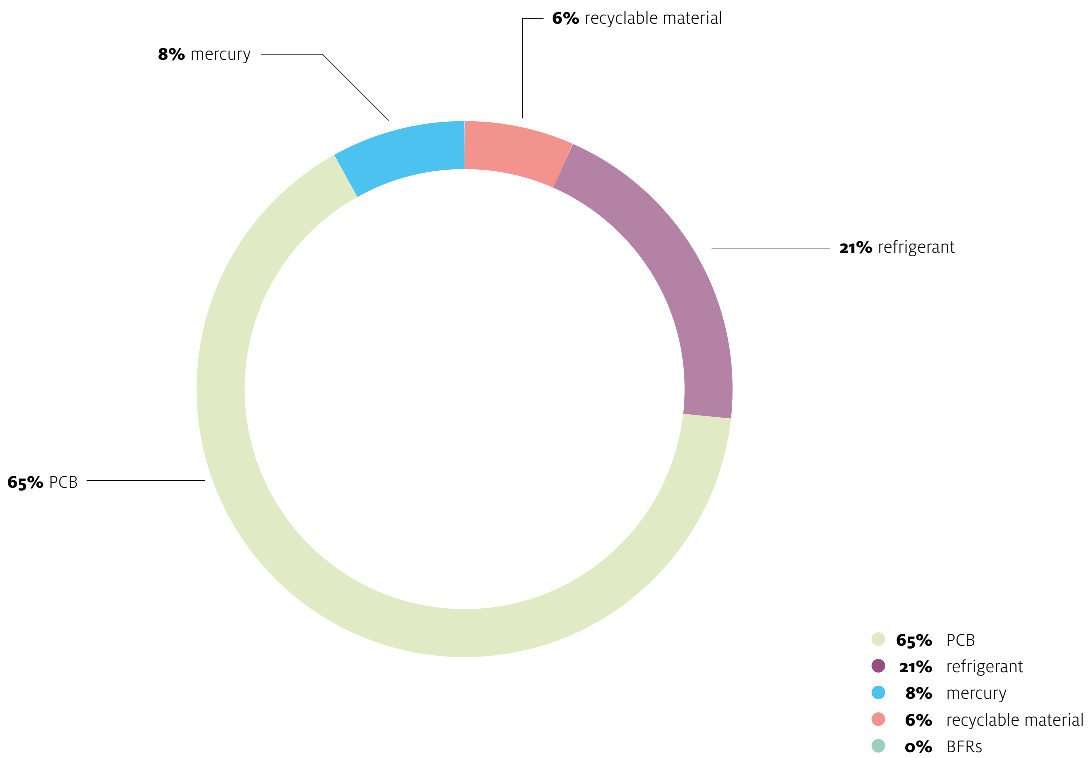
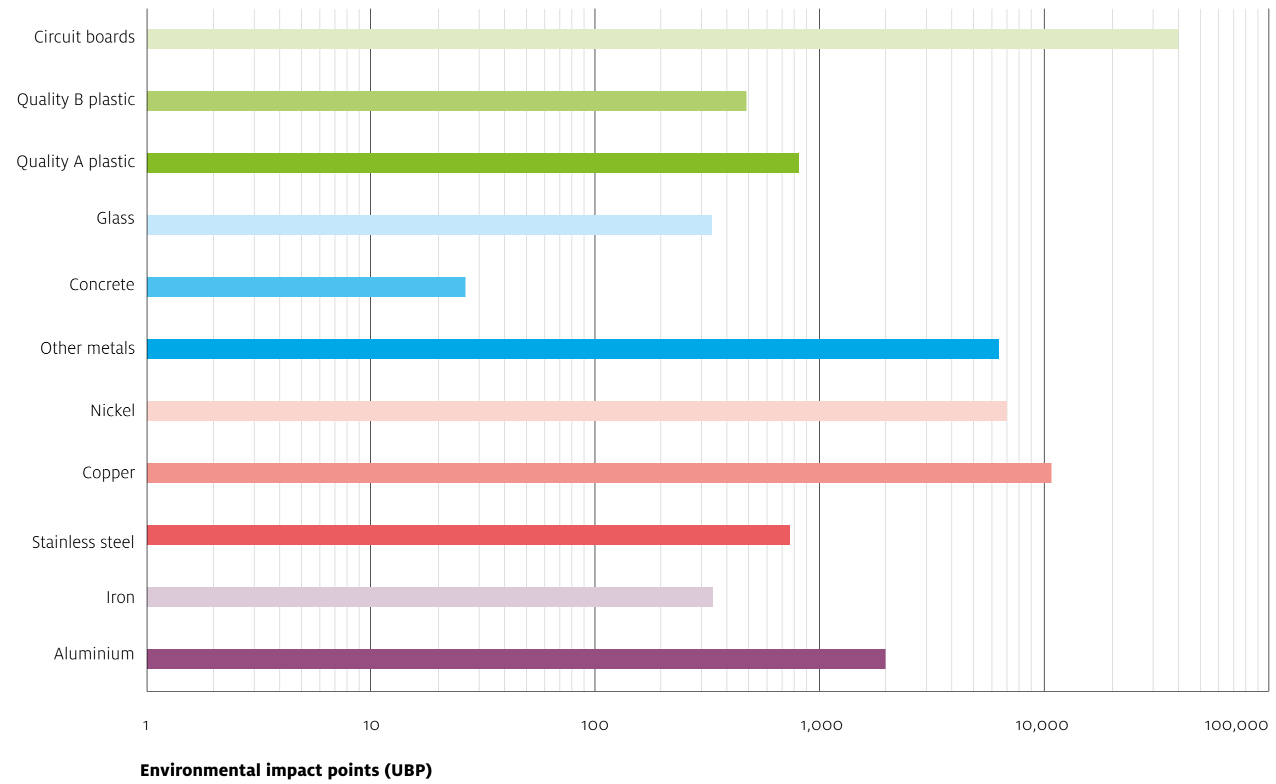


Figure 3: Benefit in UBP per kilogram of material (source: Carbotech AG).



The environmental benefits of SENS recycling in 2019

In 2019, the recycling of WEEE using the SENS system achieved a total net environmental benefit of 962 billion UBP (see summary in figure 2). Two thirds of these benefits are attributed to avoided PCB emissions. This figure is decreasing every year as the amount of waste equipment still containing PCBs is constantly declining. A substantial effect, namely 21 per cent of the environmental benefit and, viewed individually, 80 per cent of the climate benefit, is achieved by preventing emissions of fluorinated refrigerants and propellants (VFC) such as CFCs or HCFCs. The avoided mercury emissions account for 8 per cent of the environmental benefits. The recycling of recyclable materials accounts for 6 per cent of the environmental benefit.

Copper recycling benefits the environment

The comparably lower, but annually increasing proportion of environmental benefits from recyclable materials is determined by the dominance of hazardous substances. In absolute terms, however, recycling of recyclable materials has a very high benefit. Figure 3 compares the environmental benefits of the most common WEEE recyclables per kilogram. Recycled copper, which is recovered in much smaller quantities than iron but avoids greater environmental impact per kilogram, accounts for as much as 43 per cent of the environmental benefits of the SENS recycling system in 2019. This is a clear convergence of ecological and economic benefits.

The environmental impact of the SENS system itself is negligible in environmental terms compared with the benefits of avoiding hazardous substances and recovering recyclable materials. The transport of WEEE, the costs incurred by recycling companies, the production of secondary raw materials and the disposal of the hazardous substances together result in an environmental damage of 20 billion UBP compared with a benefit of 982 billion UBP from the avoidance of hazardous substances and the recycling of recyclable materials.

Real-life ecological challenges

Although the amount of collected PCB-containing capacitors is constantly decreasing, from an ecological perspective it is still clearly beneficial to dispose of PCBs properly. In addition to the systematic removal of capacitors from large household appliances, the identification of PCB-containing ballasts from lamps remains a logistical challenge. It is particularly difficult to identify components containing PCBs when large quantities of mixed metals are delivered, for example in the case of building demolitions. Raising the awareness of consumers and recyclers is very important in this regard. PCBs also present a risk of contamination on materials that are being recycled, such as plastics.

In the case of VFC gases, the quantities collected also decrease each year, but at the same time the range of appliances containing the refrigerants becomes broader as WEEE becomes more energy efficient. Here too, the key is proper sorting. A VFC-containing heat pump tumble dryer that is accidentally shredded together with VFC-free tumble dryers causes significantly more environmental damage through the emission of VFCs than the environmental benefits gained by the recovery of recyclable material from that same tumble dryer.

The SENS life cycle assessment cannot represent the damage that occurs in the event of a fire, for example due to improper storage of lithium-ion batteries.The trend in WEEE composition is continuously moving towards smaller amounts of more diffusely distributed and even more diverse hazardous substances. From an LCA standpoint, sorting WEEE with trained eyes, informing waste producers and manually dismantling SENS appliances increasingly appear to be the safest means of preventing environmental damage.

Are extended batch tests suitable for determining the recycling potential?

Roger Gnos and Rolf Widmer

In an investigation of the Swico-mix treatment stream[1] by means of batch tests at the beginning of 2019, the aim was to analyse the processing performance and quality of individual recycling plants in more detail (see also the article "Recycling and recovery potential" in the 2019 Technical Report). Among other things, the composition of the equipment mix was determined in a modified market basket analysis (MBA), as was the material composition of equipment previously not yet examined in a fine dismantling.

Samples were taken and prepared for circuit boards and cable mixtures from this fine dismantling as well as for selected output fractions of the subsequent treatment steps (shredding and sorting) and analysed for their chemical composition. Results of individual aspects of these investigations are presented and discussed below.

Categorisation of appliances

All waste electrical and electronic equipment (WEEE) collected for the batch test, with a total number of $\#_{tot}$ = 11,065 and a weight of m_{tot} = 40,436 kilograms, was divided into three groups[2]: WEEE of the group Non-Swico mix, which is returned to normal treatment, and Swico-mix WEEE intended either for Swico-mix batch testing or for fine dismantling.

The allocation of the WEEE to these groups is determined by the MBA software, in that each appliance is recorded, weighed and categorised by the MBA team[3] in a software-supported manner. One in ten Swico-mix appliances is selected for fine separation, which raises the question whether this blind selection results in a representative sample of the treatment stream. The first, simple test is to determine whether the sorting ratio of 1 : 9, i.e. 0.111, is reflected in the subsets batch test and fine dismantling. The calculation yields 0.133 for the number of appliances, which is an unexpectedly high deviation whose cause could not be explained in this experiment.

The selection procedure is only useful if the weight distributions of the subsets of the fine dismantling and batch test are similar, as illustrated by the two examples in figure 2. The conformity was investigated using the appropriate Kolmogorov–Smirnov test (KS test).

The results of the KS test show that out of 22 examined MBA categories[4] (bold), only nine (green) have a representative sample in the fine dismantling volume.

[1] The Swico mix comprises small Swico appliances without display units and screens > 100 cm², i.e. removable screens such as those of laptops, are also diverted from the treatment stream.

[2] The treatment stream is divided into "Non-Swico mix" ($\#_{nonSwicoMix}$ = 1,656 and $m_{nonSwicoMix}$ = 12,976 kilograms) and "Swico mix" (for the "batch test" [$\#_{BatchTest}$ = 8,212 and $m_{BatchTest}$ = 22,504 kilograms] and "fine dismantling" [$\#_{FineDismantling}$ = 1,087 and $m_{FineDismantling}$ = 4,673 kilograms]).

[3] The stationary MBA is set up at Leistungszentrum Rheintal (LZR, www.lz-rheintal.ch).

[4] 35 Swico MBA, v2.0, appliance categories: 10: PC monitors (CRT), 20: PC flat screens, 30: PCs/servers, 31: PCs/server components, 40: Notebooks, laptops, PowerBooks, **41: Laptop accessories,** 50: Printers, fax machines, scanners, typewriters, 60: Large-scale photocopiers, rollable plotters, **70: Office electronics/IT (remainder),** 80: Office electronics/IT accessories, **90: Consumables/CDs, 91: Toner cartridges,** 92: Ink cartridges, **100: Cash register scanners,** 110: TV cathode ray tube, 120: Flat-screen TV, 130: Consumer electronics (remainder), **140: Telephone switchboards,** 150: Landline telephones, **160: Mobile phones, 170: Photo and video cameras,** 190: Item without ARF, 191: One-kilogram merchandise, **200: Medical/cleaning, 210: Cables, 230: Metals (loose iron/metal parts),** 300: Batteries, 310: Lithium-ion batteries, **311: Lithium-ion batteries (defective), 320: Lead-acid batteries.**

Figure 1: Sankey diagram of the material flows of the Swico-mix batch test. The values given represent the material flows estimated for planning purposes.

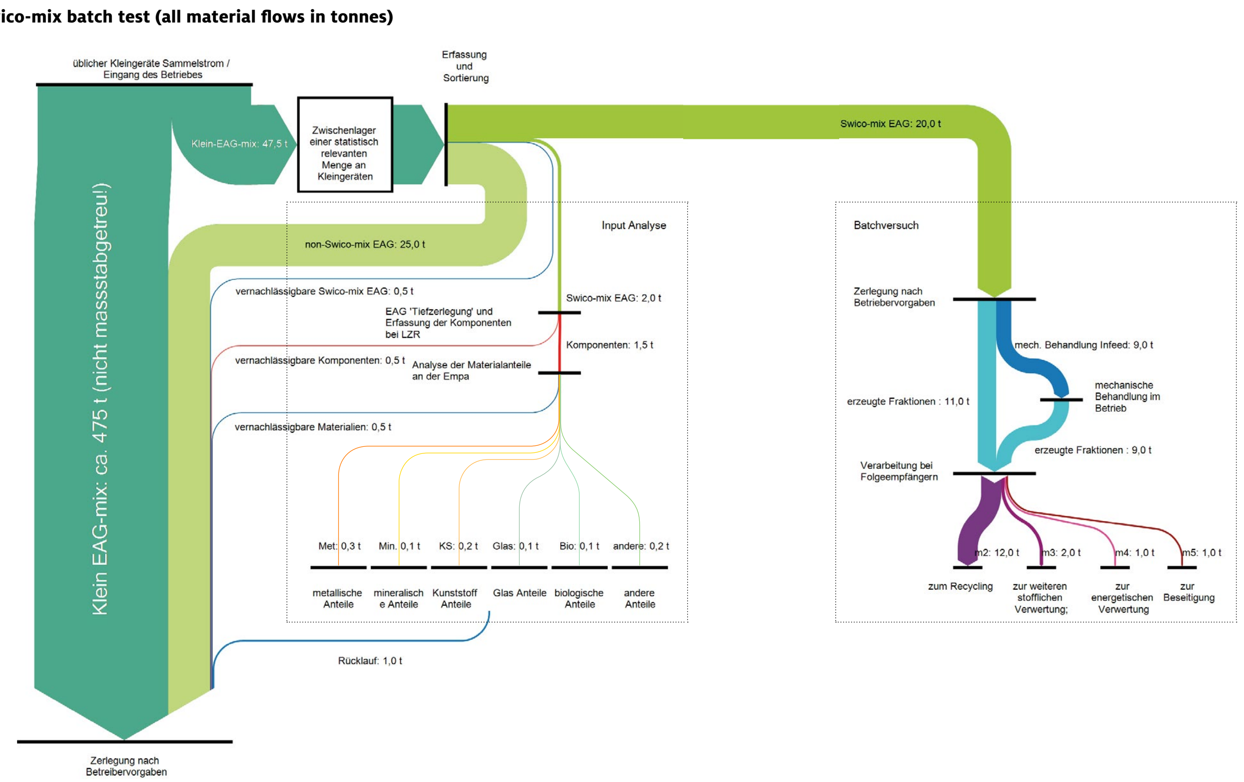


Figure 2: Histograms of the weight distribution of WEEE of category 50 (printers, fax machines, scanners, typewriters) and category 30 (PCs/servers). The appliances that are separated for fine dismantling are recorded in blue – once as frequency in weight classes of 2 kilograms each and once as cumulative frequency. The appliances that go to the batch test are shown in red.

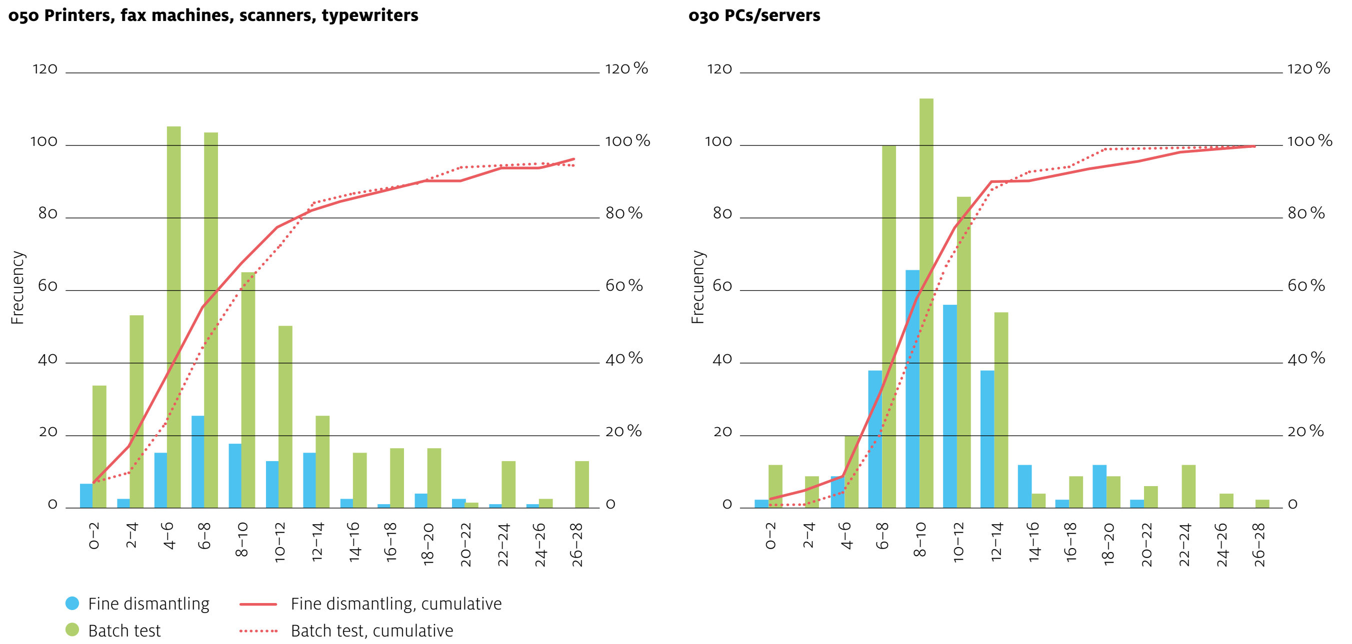


Figure 3: Finely dismantled boom box.

Figure 4: Examples of fractions produced (from left to right): Class 1 circuit boards obtained from the fine dismantling of modern electronic equipment; plastic fraction with a high precious metal content (significant fraction of broken circuit boards) screened out in batch tests; aluminium fraction obtained in batch tests by means of an eddy current separator. A number of electrolyte capacitors can be seen which, although slightly damaged during processing, were almost completely separated in this fraction.

Figure 5: Examples of fractions processed (from left to right): Screen fractions of different grain sizes of ground circuit boards (CB), used to study the distribution of different substances (especially precious metals) in the various matrices; pyrolysed CB fraction, from which all volatile components were removed and separated in solutions and analysed; grinding fractions produced in cryogenic mills (from bottom to top: plastic fraction, wet scrubber sludge, RESH).

In other words, this method was used to inadequately sort most of the WEEE categories, both in terms of number and weight. From this point of view, a comparison of the components of the input and output flows is unreliable.

Fine dismantling

A total of 240 different appliances are assigned to the 22 Swico-mix MBA categories. These appliances are broken down into components in the fine dismantling process. An additional selection list of 50 components is available, for example indicating screws, CPU or memory IC, circuit boards (CB) and drive. Components like the latter are further disassembled until they can no longer be dismantled with hand tools. If possible, the weights of the remaining components are assigned to their main material components such as metals (iron, copper, etc.), plastics (common polymers), glass, wood, etc. (an additional selection list of 27 materials is available). A data sheet is prepared for each finely disassembled WEEE.

Sample taking and preparation

The samples for the chemical analysis were prepared mechanically and partly by pyrolysis. For the analysis of the input, the selection of the dismantling fractions produced is limited to circuit boards, divided into two qualities, and to connecting cables from IT equipment, including associated connectors. Detailed time series for all other important fractions from dismantling exist at Leistungszentrum Rheintal (LZR) derived from systematic dismantling tests of the important equipment categories in the Swico mix. For the analysis of the output from mechanical processing, selected fractions were sampled during the test by taking samples from the material stream at fixed intervals and combining them in a collective mixed sample. These samples were also prepared to provide a "fingerprint" of the most important elements with a semi-quantitative but inexpensive XRF measurement and to be able to perform accurate quantitative measurements (ICP-OES) for hazardous substances (PCB and FSM) and precious metals (Au, Ag and Pd).

Chemical analyses

The batch test processed 22,550 kilograms of WEEE. From this, 19 manually produced fractions with a total weight of 6,750 kilograms and 27 mechanically produced fractions (these comprise the remainder) were separated. Seven of these fractions were analysed. Not examined were pure metal fractions (iron [Fe]: 5,671 kilograms, aluminium [Al]: 1,263 kilograms, copper [Cu]: 1,709 kilograms; Fe/Al/Cu from electric motors: 1,163 kilograms), which together accounted for almost 45 per cent of the total batch weight.

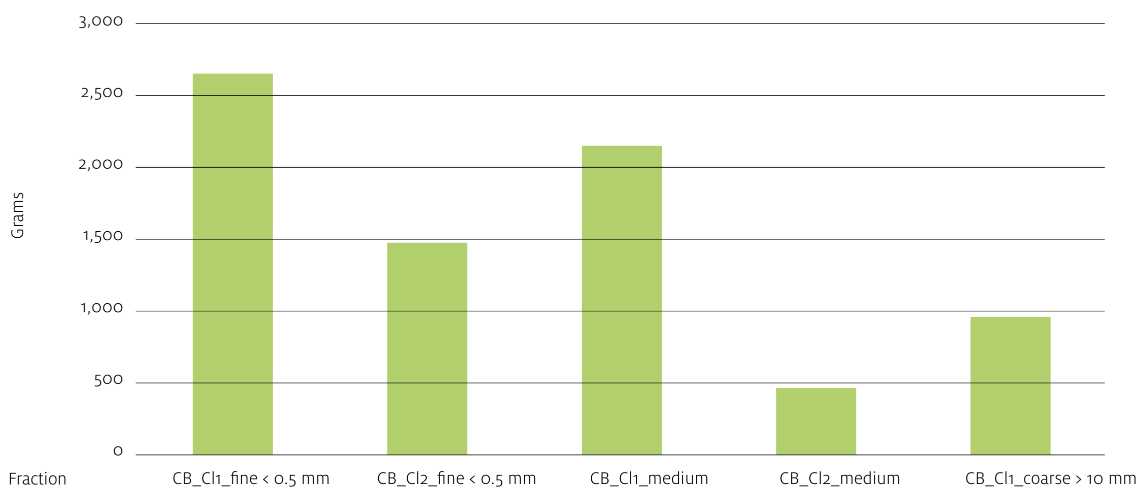
Four of the six plastic fractions from mechanical processing were examined. If they contained circuit boards, they were taken to copper smelters and, if they contained metal or were pure, to external separation processes to recover the metals they contained (especially Cu and precious metals) and polymers. At 2,744 kilograms, 2,843 kilograms and 1,830 kilograms, respectively, the corresponding fraction materials made up almost 35 per cent of the total batch weight.

Three of the shredder light fractions (SLFs), which are transported via air flow, were also studied. The chemical analysis shows that circuit boards and IT cables/connectors are still the largest carriers of precious metals and that mechanical processing of their mass contents in the fine-grained dust fraction can enrich them somewhat, but that other fractions, in particular plastic fractions, can absorb and transport the largest precious metal quantities. It is important to know about the whereabouts of these precious metals (but also about other target substances such as PCBs) and to plan treatment paths accordingly.

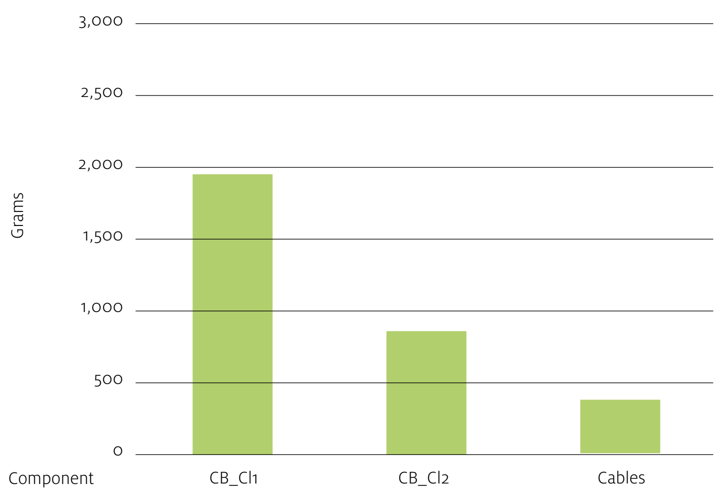
Conclusions and outlook

In this batch test, the material input composition is determined by combining more than 50 types of appliances from 22 categories. Despite systematic fine dismantling at LZR over many years, more than one third of the input material of a Swico-mix batch test is determined insufficiently. The production of a representative quantity of WEEE for additional fine dismantling by means of a blind selection procedure, one of the objectives of this experiment, proved to be insufficiently robust, which increases the uncertainties in the target substance balances to more than 50 per cent. This leads to statements that cannot be substantiated, for example regarding the possible metal yields of a Swico batch. Moreover, this type of analysis is too costly and time-consuming to be applied regularly. Other approaches, such as measuring the losses of target substances in the source fractions, will therefore be pursued.

Precious metals from finely dismantled circuit boards



Precious metals from finely dismantled circuit boards



Precious metals from KS and SLF batch test

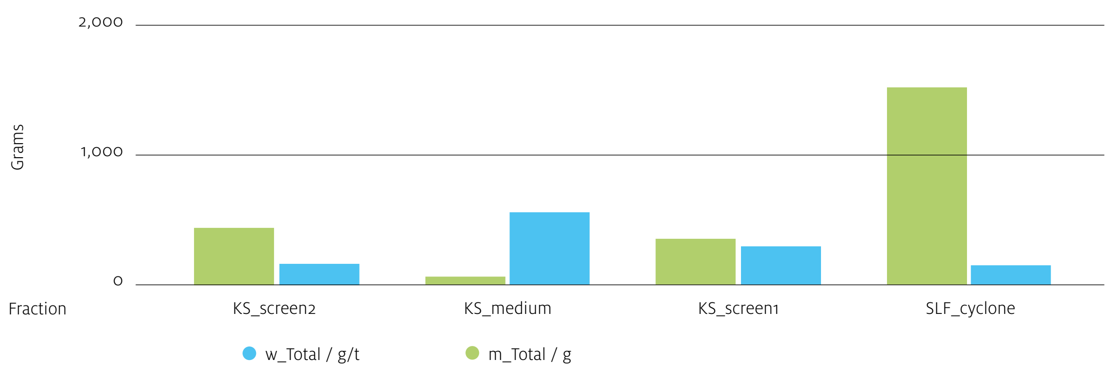


Figure 6: Analysis result (from top to bottom): Total mass fraction of the three precious metals gold (Au), silver (Ag) and palladium (Pd) in grams per tonne (or ppm) in circuit boards from fine dismantling which have been ground and screened. The precious metal mass fraction increases with smaller grain size and for Class 1 CB reaches levels of more than 2,500 ppm. Not surprisingly, the precious metal mass fraction is the highest in Class 1 CB, reaching values of 2,000 ppm. Rather surprising is the high precious metal content in IT cables and in associated connectors. Not surprisingly, the precious metal mass content in initial fractions from mechanical processing is highest in a shredder light fraction separated by means of a cyclone filter. However, the plastic fraction with the smallest precious metal mass content is the one that transports the largest precious metal mass.

A growing industry is looking for new talent

Flora Conte

The recycling industry is growing steadily. The recycling of waste electrical and electronic equipment (WEEE) is becoming increasingly demanding. Thanks to the Recyclist apprenticeship, a new generation of competent and committed specialists is being trained.

The circular economy and recycling technology are currently among the fastest growing branches of the economy. The demands placed on recycling processes are also increasing as a result of rapid technological progress. The recycling of WEEE is particularly complex and constantly evolving. For example, WEEE is increasingly being used in a wide variety of electronics, batteries and plastics. The recycling technologies used today are not always the optimal solution for its removal or reuse. This must be recognised in order to subsequently be able to optimise processes. This requires the expertise of well-trained Recyclists, for example.

Recyclist VET (Federal Diploma of Vocational Education and Training) has been an apprenticeship profession in Switzerland since 2000. To date, this title is still unique in the world and thus offers graduates of this apprenticeship very good career prospects – not only in the steadily growing environmental industry in Switzerland.

We spoke to Steve Hörler, who heads the SENS/Swico collection point Verwert AG in Au, St. Gallen, where Zingg Industrieabfälle AG is located. We asked him how his training would affect his professional career and his everyday work.

What motivated you to choose the Recyclist apprenticeship?

I already had a few trial days for different apprenticeships, but I didn't find the right one then. My grandmother drew my attention to a short film shown on Swiss TV about Thommen Ltd and the Recyclist profession. I was curious and went for a trial day. I realised very quickly that I had found the right profession for me. I started my apprenticeship in 2009.

How has your professional career developed since then?

After completing my apprenticeship in 2012, I initially stayed with the company that trained me. In November 2013, I started working as an excavator driver at Zingg Industrieabfälle AG. After an accident at work in 2015 I had long periods of absence, but fortunately I had a supervisor who helped me to look for ways to continue working for him. I started working half-days in the office, and earned a diploma in office and business administration on the side. I was able to benefit greatly from the company by doing an internship year and simultaneously an apprenticeship as a Specialist in Business Administration and Applied Technical Management. After graduating in January 2019, I was given the opportunity to spend six months getting to know the ropes of the trade and to play an active role in it. In October 2019, the position of site manager at Verwert AG, the subsidiary of Zingg Industrieabfälle AG, became vacant. My superior gave me the opportunity to take up this challenge.

Photo 1: Steve Hörler, Head of Verwert AG recycling collection point (source: Steve Hörler).

To what extent has your apprenticeship prepared you for the growing demands of rapid technical developments?

The apprenticeship has given me the knowledge and the tools to deal with new challenges. When I see a new appliance for the first time, I already disassemble it in my head, plan the various steps and estimate the time it takes to do so. This requires good analytical skills and common sense. Both of these skills are honed during the apprenticeship. Well-trained Recyclists are in demand because they have the ability to analyse and solve problems and also have a very broad basic knowledge of recycling.

What do you like most about the job?

The diversity. On the one hand there is the practical work and the handling of heavy machinery, and on the other hand there is office work, sorting, planning and analysis. I also have the opportunity to work outdoors a lot and be in contact with customers.

Photo 2: Recyclists have a diversified everyday working life (source: R-Suisse).

Photo 3: The trained eye of Recyclists increases sorting quality (source: Flora Conte).

Recycling quota of large household appliances – an update

Geri Hug and Anahide Bondolfi

By 2019, the target value for the recycling quota of large household appliances in Switzerland was 75 per cent. However, in recent years it has become apparent that some recyclers have had problems in reaching this level. One of the reasons for this is that the recycling quota depends on the composition of the individual appliances and the mix of appliances. With the new "Supplementary technical regulations of SENS and Swico for the SN EN 50625 series", in effect since 1 January 2020, SENS therefore decided to set the reference value for the recycling quota of large household appliances according to the incoming mix of appliances.

Update to the data collected in 2018

In 2018, the Swico/SENS Technical Commission started to collect detailed data on the composition of each type of large household appliance and to look for new methods to set adequate targets for recycling quotas. The first data were published in the 2019 Technical Report. New data were obtained in 2019. This article summarises the information contained in the 2019 report and presents the new, updated data.

Recycling quotas are influenced by the mix of incoming appliances

The main purpose of conducting batch tests is to determine the recycling quota, i.e. the material recovery quota, for each recycling company and treatment stream in a standardised manner. Until 2019, the minimum recycling quota was based on the WEEE Directive and was accordingly set at 75 per cent for large household appliances. Since 2014, however, several Swiss recycling companies have reported problems in meeting this requirement. A lower recycling quota can have various causes, some of which are related to the company's treatment processes, including, above all:

- No or little recovery of recyclable plastics, glass or concrete
- Low efficiency of metal recovery with high metal losses, especially in the finest non-metallic shredder fraction (RESH)

However, a low recycling quota can also result from other causes that are independent of the processing methods of the recycling company, in particular:

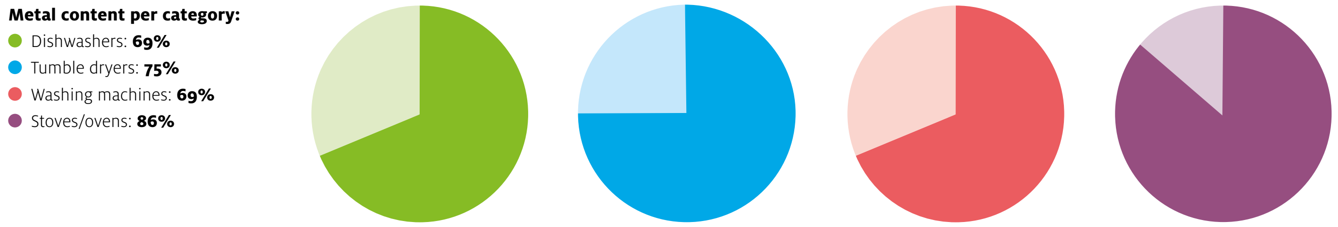
- Low weight, especially of newer appliances with higher plastic and lower metal content
- Change in the mix of appliances to be processed with a reduction of appliances containing a lot of metal, such as stoves/ovens

Method for analysing the composition of appliances by category

As no reliable data on the composition of these appliances were available to date, SENS launched a project to determine the proportions of metals (iron, copper and aluminium), plastics, glass and concrete for four categories of household appliances (dishwashers, tumble dryers, washing machines and cookers or ovens). To this end, around 10 tonnes of appliances per category were mechanically processed in separate batches by two companies specialising in mechanical recycling. In addition, around two tonnes of appliances per category were manually disassembled by a dismantling company.

An average weight per category was calculated (see figure 2). The weights of all output fractions per category were also determined. The composition of each output fraction was then estimated, either by further separation steps or by analysis.

Figure 1: Composition of the appliances.

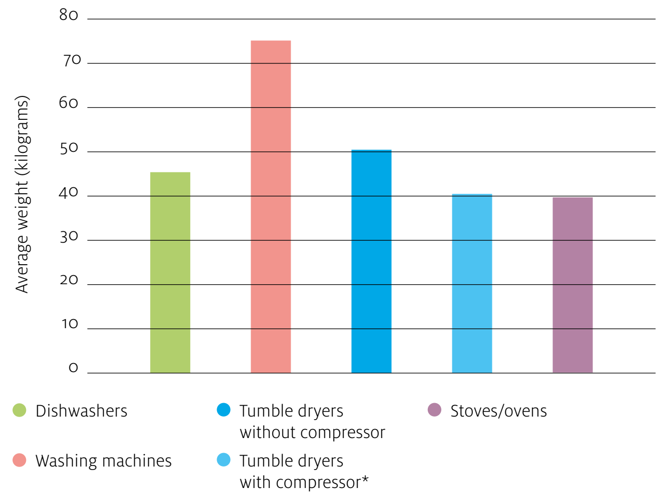


The recycling quotas achieved per category were calculated on the basis of the data recorded in the WF RepTool. The results are shown in figure 1. The metal composition of each category shows how much metal could theoretically have been recovered if there had been no losses in the treatment process.

Outlook

The data shown in figures 1 and 2 will be used from 2020 onwards to calculate indicative recycling quotas for batches of large household appliances. The indicative recycling quota is thus calculated specifically for each batch, based on the quantity of each appliance category contained in that batch, using the average weight shown in figure 2. As defined in the new "Supplementary technical regulations of SENS and Swico for the SN EN 50625 series", these recycling quotas are reference values and no longer targets. As the differences between the calculated recycling quotas (theoretical amount of metal) of the three recyclers are considerable (standard deviation of 7 per cent), further similar campaigns will be carried out in 2020 to collect more reliable and complete data. In addition, SENS intends to analyse in more detail the potential for improving the recycling quota for batches and investigate the causes of metal losses, i.e. the metals that are lost during material recycling. To be continued …

Figure 2: Average weight per category.



* Weight of the appliance after removal of the compressor

Heat pump tumble dryers

Heat pump tumble dryers have been on the market for around 20 years. Since 2012, only tumble dryers equipped with a heat pump have been sold in Switzerland, as only this technology makes it possible to achieve energy class A (A has been obligatory since 2012; A+ since 2015). These tumble dryers can be found more and more often among the older appliances collected. The compressors are removed using the same procedure as for refrigerators and freezers (stage 1). Tumble dryers whose compressors have been removed can then be processed with other large household appliances. However, as shown in figure 2, these appliances are lighter (weight without compressors). In addition, the amount of metals in these appliances (after removal of the compressor) is lower according to the test conducted in 2019. The metal content of 75 per cent in the dryers shown in figure 1 corresponds to a mix of about one-third heat pump tumble dryers (after removal of the compressor) and two-thirds conventional tumble dryers. The metal content in the tests performed exclusively with conventional dryers is 78 per cent.

PCB load in capacitors still relevant

Daniel Savi

The proportion of capacitors containing PCBs in waste electrical and electronic equipment from the SENS and Swico take-back systems was surveyed two years ago. What PCB load from capacitors ends up in recycled WEEE? Is this load environmentally relevant? What rules should apply when disposing of capacitors in the future?

How much PCBs does waste electrical and electronic equipment contain today?

In the past, larger capacitors in electrical or electronic appliances frequently contained polychlorinated biphenyls (PCBs). As a result, the rules for the removal of hazardous substances have been strongly focused on preventing the release of PCBs in recycling. Since the ban on using capacitors containing PCBs was introduced in 1986, it is becoming increasingly important to examine whether the equipment being disposed of today still contains capacitors containing PCBs and whether the rules for the removal of hazardous substances are still reasonable. The proportion of capacitors containing PCBs in waste electrical and electronic equipment in Switzerland was last determined in 2018. Back then, the proportion of PCB-containing capacitors in large appliances fluctuated between 1.7 to 2.2 per cent and 55 to 76 per cent in ballasts in lamps. How significant are the resulting annual PCB loads in the capacitors of waste electrical and electronic equipment? The Swiss consultancy firm Büro für Umweltchemie (BFU) was commissioned by SENS to examine this question in a follow-up study.

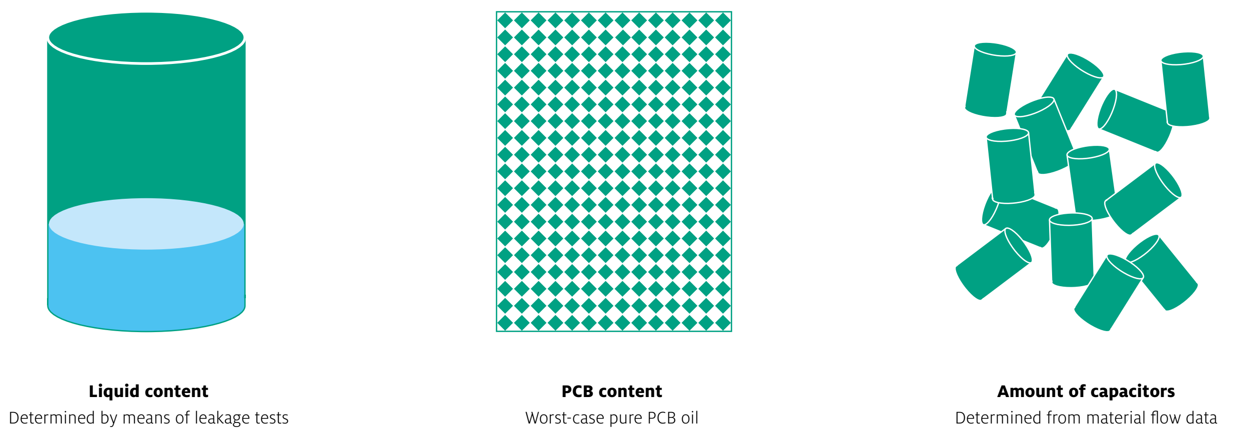
How much PCBs does a capacitor contain?

In order to answer the question, the liquid content in non-polarised cylindrical capacitors was first determined. A non-polarised cylindrical capacitor is a capacitor that is larger than 1.5 centimetres and must be removed manually. This definition does not include the polarised electrolyte capacitors, since they do not contain PCBs. The oil was drained from 22 capacitors. After the oil that immediately flowed out was separated and weighed, we allowed the remaining liquid to drain from the capacitors that were opened at the top and bottom for four months. The weight of the solids and liquids was then measured separately. This revealed a mass proportion of the liquids to be 15 per cent of the total weight of the capacitors. Previous studies have demonstrated that the PCB content in the oil of capacitors containing PCBs may exceed 90 per cent. We therefore assumed a PCB content in the oil of 100 per cent for calculating the PCB load.

What is the resulting annual PCB load?

The material flow data that SENS and Swico collect annually from the recyclers provides us with the total weight of the capacitors that are removed from waste electrical and electronic equipment. The material flow data only refers to appliances that are subject to the Swiss Ordinance on the Return, Taking Back and Disposal of Electrical and Electronic Equipment (ORDEE). Appliances from the professional sector, such as industrial machines, are not reported in the material flows.

Figure 1: The PCB flow was determined from the liquid content in capacitors, a PCB content of 100 per cent and the annual amount of capacitors removed.



According to material flow data, 38 tonnes of capacitors are removed annually from large household appliances. Another tonne is removed from lamps. This indicates that capacitors from large household appliances contain around 120 kilograms of PCBs per year. There is an additional 100 kilograms of PCBs per year in the capacitors from lamps. The total quantity of PCBs in the capacitors from waste electrical and electronic equipment therefore amounts to around 200 to 250 kilograms per year.

Does this PCB load pose a problem?

How should this load be classified? Does it pose a risk to the environment? In order to answer these questions, we compare the load in capacitors with the background load in Switzerland. The measurement data acquired from monitoring the Rhine river near Basel can be used to calculate how much PCBs leave Switzerland each year via the Rhine. The total for 2016 was around 30 kilograms per year. A recent study estimates the air emissions of PCBs in Switzerland to be approximately 400 kilograms per year. Comparing these figures suggests that PCBs from capacitors still represent a relevant load. Measures must be taken to prevent the uncontrolled release of these PCBs into the environment. The capacitors that are larger than 1.5 centimetres and contain liquids must therefore still be removed separately and disposed of in a hazardous waste incineration plant. Special attention must be paid to the capacitors from ballasts. They already account for half of the PCB load. This proportion will continue to grow in future, since lamps have a longer service life than large household appliances.

Photo 1: Separation of solids and liquids after four months of draining.

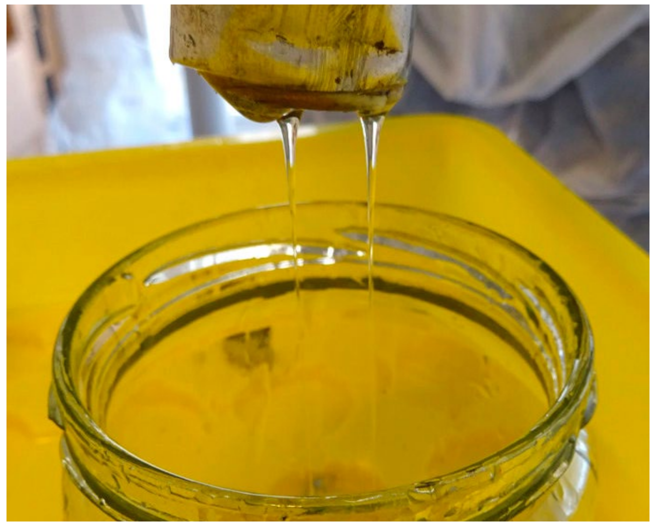


Photo 2: Most of the liquid flows out spontaneously after opening.

Innovation in the recycling of lighting equipment

Flora Conte

Many visitors to collection points have already racked their brains over the distinction between ORDEE-required lighting equipment and incandescent lamps. The current sorting process is becoming even more complex for lighting equipment recyclers. For example, LEDs of different shapes must not be confused with gas discharge lamps. What does this mean for recyclers of lighting equipment?

Mercury-containing gas discharge lamps are still frequently handed in at collection points today. At the same time, an increasing number of different LED lamps are being collected. The constant change in our lighting equipment types reflects the general decision-making trends in the environmental and health sector. Despite their pleasant light, it is no longer possible to sell incandescent lamps, as they are considered energy-inefficient, and their sale has been banned under current laws. The mercury in gas discharge lamps is no longer acceptable today for toxicological reasons. LED lamps are a more energy-efficient and less polluting solution available on the market. Nevertheless, LED lighting is not the most suitable light for every application. Research is ongoing and innovative developments are taking place on a regular basis. The first Laser Crystal Ceramics (LCC) lamps are already entering the market.

New solutions, new problems

What does this mean for the recycling of lighting equipment in the medium term? Lighting equipment containing hazardous substances continues to decline. Nonetheless, the proper disposal of mercury from lamps should remain a priority in the future. The composition of recyclable materials will change at the same time: less glass, more electronics. The shapes of the lamps will vary greatly. Increasingly durable and smaller lighting equipment is already being integrated into lamps, with the result that some lighting equipment cannot be distinguished or separated from the lamp itself.

The future of lighting equipment recycling

What is certain is that lighting equipment will continue to contain electronics in the future and should be collected and reused by appropriate recycling systems. Lighting equipment containing hazardous substances will continue to accumulate. Part of the lighting equipment recycling could merge with the recycling of small appliances, while another part will require specific lighting equipment recycling facilities, as is the case today. In the years to come, lighting equipment recyclers will be faced with the challenge that, within the SLRS system, lighting equipment containing hazardous substances and lighting equipment free of hazardous substances must be treated separately and not be mixed during recycling. There will be a corresponding increase in sorting costs. The multifaceted development of lighting equipment requires experienced specialist staff, additional time and increased space at recyclers. Consequently, the necessity for cooperation with SLRS remains despite technological changes in the lighting equipment.

Photo 1: Without experienced personnel, discarded LED lamps are often very difficult to distinguish from energy-saving lamps or light bulbs (source: Flora Conte).

Photo 2 on the following page: The distinction between incandescent lamps and lighting equipment subject to ORDEE is already a challenge today (source: SLRS).

Correct

All mercury vapour lamps, sodium vapour lamps, metal halide lamps, energy-saving lamps, induction lamps and LED lamps

Without cardboard packaging!
Without cardboard boxes!
No waste!

Wrong

All types of incandescent lamps

A circular economy for WEEE recycling: Are we heading in the right direction?

Heinz Böni and Rolf Widmer

Waste electrical and electronic equipment (WEEE) contains a range of materials with different properties. Mobile phones, for example, need to contain around 40 different metals in order to function. The presence of economically valuable materials, rare materials that may not be economically valuable, and materials with toxic or hazardous properties in the same device or appliance makes recycling a highly complex process.

WEEE recycling currently has two main goals: (1) the recovery of recyclable material and (2) the removal and environmentally friendly recycling or disposal of hazardous substances.

In Switzerland, the WEEE goes through an initial manual sorting process following collection. This involves removing parts and components that contain particularly dangerous hazardous substances and high proportions of recyclable materials. The waste from this process is then mechanically processed at facilities in Switzerland, with the fractions being either recycled or thermally processed, or taken to specialised final processing facilities abroad, where metal, individual plastic polymers in particular can be recovered directly or by means of a chain of processes. The percentage of raw materials that can be recovered during the final treatment process is massively affected by the type and quality of the method used for pre-processing work and its effectiveness. In other words, the first step of the process is the decisive factor for ensuring the materials end up in the right place and can be recycled rather than being lost and disposed of as waste.

The SN EN 50625 series of standards defines the administrative, organisational and technical requirements that apply to the entire WEEE treatment chain, from collection to recycling or disposal. Specifically, they contain quantitative indicators for evaluating and monitoring the performance of WEEE treatment processes. There are target values for the removal of components containing hazardous substances such as capacitors or batteries, limit values for hazardous substances such as polychlorinated biphenyls (PCBs) or cadmium (Cd) in the mechanical processing residues in the finest non-metallic fraction, and there are performance requirements for recovery based on target values for recycling and recovery quotas and yields for copper (Cu), gold (Au), silver (Ag) and palladium (Pd) in specialised copper smelters.

In order to determine the recovery rate of material from electronic waste that is recyclable or can be recovered in the form of energy, the recycling and recovery quotas are determined based on standardised tests. The recycling quota (RcQ) puts the total mass of base metals and plastics recovered and reusable in relation to the total mass of appliances processed. In addition to the RcQ, the recovery quota (RvQ) takes into account the mass of thermally recoverable materials, i.e. those materials that cannot be recycled, but which have a usable energy content that can replace other energy sources. For WEEE, this mainly applies to plastics whose content of hazardous substances is above the legal limit and that therefore have to be thermally processed.

Both quotas are proportions of the total mass, which does not take into account the main quality concerns for the treatment of WEEE:

- In the case of RcQ, it is mainly high-mass metals such as iron (Fe), copper (Cu) and aluminium (Al) and plastics that determine the quota. This means that substances that are less important in terms of mass, such as gold (Au), palladium (Pd) or silver (Ag), are not included. Accordingly, RcQ does not provide information on the degree of recovery of substances that are less significant in terms of mass.
- The achievable quotas depend on the composition of the input material, which varies in time and space independent of the processing. This means that the RcQ does not provide information on the degree of recovery of a treatment process (ratio between the recovered target substance and its occurrence in the processed WEEE).
- The environmental effects of the recovery of individual materials from WEEE are not recorded despite the fact that the recovery of rare technology metals (RTMs) from WEEE in particular usually has a much smaller environmental impact than producing them from mined materials. This means that the recycling and recovery quotas (RcRvQ) do not provide any information regarding the environmental benefits of treatment.

To determine whether parts and components containing hazardous substances have been removed from the appliances before a mechanical process, certain fractions are analysed to find out how much hazardous substances they still contain, and compared with limit values:

- The comparison of the mass fraction of a target substance in a fraction to its limit value is independent of this fraction mass. This is suitable for a single measurement, but unsuitable for maintaining an overview. This is because the important information about how the total mass of the hazardous substance is distributed among all fractions is lost, especially for those where the hazardous substance can no longer be separated. For example, at first glance, a dust fraction with a PCB content of 60 ppm is more problematic than a shredder light fraction (SLF) with a PCB content of 10 ppm. However, if the fraction masses are taken into account (for example 20 kilograms of dust and 2,000 kilograms of RESH), it becomes clear that the dust fraction contains "only" 1.2 grams of PCBs, while the SLF fraction contains 10 grams of PCBs. Both fractions are currently incinerated, which eliminates all PCBs. However, the fact that at a limit value of 50 ppm the monitoring is blind with regard to the larger load of PCBs is problematic. This becomes a matter of concern when significant amounts of PCBs below the limit are recycled via plastic fractions. There is thus a risk that hazardous substances are not detected or are knowingly recycled together with the polymers and thus kept in the cycle.
- The assessment is based on a small number of hazardous substances. Hazardous substances that are not monitored include asbestos, other substances of concern in capacitors, chlorinated paraffins, phthalates, antimony (Sb) and chrome (Cr).

The weaknesses of the current indicators described above suggest that they give an incomplete, distorted or even wrong picture of the quality of recovery of recyclable materials and of the removal of hazardous substances from WEEE and thus do not meet the requirements of a recyclable waste management system. A successful circular economy must be able to ensure that the end products of the recycling process are of the same quality, or that they are separated and disposed of in an environmentally friendly manner. To achieve this goal, indicators are needed to assess both the circularity of the target substances and their environmental impact. This means that the recovery of the highest amount of recyclable materials is not by default the best result for the environment. Indicators that meet the aforementioned requirements have a positive steering effect towards a sustainable circular economy. The objective of the further development of the indicators is to improve the WEEE treatment with regard to the recovery of recyclable material and the removal of hazardous substances, taking into account the environmental impact, by means of an appropriate methodology and appropriate indicators.

The SRI programme enters its second phase

Andreas Bill and Heinz Böni

In their role as members of the advisory support committee, SENS eRecycling and Swico participated in implementing the Sustainable Recycling Industries (SRI) programme financed by the State Secretariat for Economic Affairs (SECO) between 2014 and 2018. Starting up again in mid-2019, this programme has now entered its second phase, which is designed to run for a further four years. In its role as contractor and technical competence centre, the Swiss Federal Laboratories for Materials Science and Technology (Empa) thereby continues to undertake core tasks in the programme roll-out and implementation.

The long-standing experience and successful cooperation with the Swiss systems and recyclers have laid an important foundation for effectively supporting the development of national e-waste management systems in the SRI partner countries Colombia, Peru, Egypt, Ghana and South Africa.

In many developing and emerging countries, the uncontrolled recycling of electronic waste in the so-called informal sector causes high levels of environmental pollution and health risks for the people involved. At the same time, however, the recycling of electronic waste in these countries also offers many people a livelihood. In particular, the collection process is often efficiently organised, because of the high material value of electronic waste, and does not involve any major risks. In addition, a large number of appliances are repaired and intact components from defective appliances are resold as spare parts. Compared to direct recycling, the respective resources are thus maintained at a higher level within the material cycle. The existing structures in countries where electronic waste is primarily processed by the informal sector can therefore also be interpreted as potential opportunities. For these reasons, the programmes, which have been financed by SECO since 2003, have always adopted a comprehensive approach and endeavoured to jointly develop institutional and private sector capacities with a special focus on the inclusion of the informal sector.

The second phase of the SRI programme[1], which is led by Empa[2] in cooperation with the World Resources Forum Association (WRFA)[3]and other international and national partners, continues to expand on the previous successful model. The programme's overall objective is to create favourable framework conditions for the development of a sustainable electronic waste recycling industry. Partner countries taking part in the second phase include Ghana, Egypt, South Africa, Colombia and Peru. In collaboration with the respective government and private industry bodies, standards organisations and recycling partners, the following general objectives are aimed at under the programme's country component:

1. Development of a national policy and legal framework with regard to the handling of electronic waste
2. Definition of normative requirements and conformity criteria in e-waste recycling, including the establishment of an independent audit system and training of auditors
3. Optimisation of sustainable value chains and professionalisation of the recycling industry
4. Development and implementation of local best practices for handling problematic fractions

The general programme structure will remain the same for all partner countries; however, the activities will be planned individually and priorities will be tailored to the respective requirements. This will allow the different development stages of electronic waste management in the partner countries to be taken into account in a focused manner.

In order to enhance the cooperation and exchange between SRI partner countries and with the international community, the second phase of the programme additionally includes an overarching global component. This is to ensure that synergies both between the target countries and with other programmes and initiatives are put to optimum use, and that the programme results are systematically processed, communicated and made available to the public.

One of the first products to be developed in this global component was a handbook on sorting and processing of plastics derived from electronic waste[5], which was produced last year in cooperation with the Solving the E-waste Problem (StEP) Initiative[4]. The content of this document is based on the experience and process knowledge acquired during the first phase of the programme, particularly in India (refer to the article on SRI I in the 2018 Technical Report). The content was subsequently integrated in workshops and training sessions in other SRI partner countries. The handbook offers general information on plastics and additives, and demonstrates how relevant electronic waste plastics can be identified and sorted using simple methods and how fractions containing problematic substances can be removed (see figure). Additional chapters address possible subsequent recycling processes and the marketing of recovered plastics, as well as the handling and disposal options of non-marketable and/or contaminated fractions in a local context.

By gathering and promoting the results of the SRI I programme in a practical handbook published with open access, the methods that were developed under SRI in the area of plastics recycling are to be transferred beyond the scope of the programme itself. The cooperation with the StEP Initiative has also allowed this document to be made available, right from the beginning, to a wide network of organisations and stakeholders active in the plastics and electronic waste sector. Such partnerships will now continue to be forged and harnessed under the global component of SRI II in order to scale the concepts and methods developed in SECO-funded programmes within a global context.

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1. www.sustainable-recycling.org – Sustainable Recycling Industries.
2. www.empa.ch/tsl – Swiss Federal Laboratories for Materials Science and Technology/Technology and Society Lab.
3. www.wrforum.org – World Resources Forum.
4. www.step-initiative.org – Solving the E-waste Problem (StEP) Initiative, an independent multi-stakeholder platform for designing strategies that address all dimensions of electronics in an increasingly digitised world.
5. www.sustainable-recycling.org/reports/processing-of-weee-plastics-a-practical-handbook – Link to the PDF.

Worst practices: Incineration of cable plastics for copper recovery in Ghana. Process for the systematic identification and sorting of electronic waste plastics.

Second life: Defective appliances can often be repaired and resold on second-hand markets.

Delegated cantonal enforcement powers – a success story

Roman Eppenberger and Alois Villiger

The delegation of cantonal enforcement powers to Swico and SENS has proven a true success story. The close collaboration between the systems and the environmental agencies of the cantons is of benefit to all.

The requirements for the disposal of electrical and electronic appliances have been enshrined in the Swiss Ordinance on the Return, Taking Back and Disposal of Electrical and Electronic Equipment (ORDEE) since 1 July 1998. The detailed regulations necessary for the practical implementation of the Ordinance and, in particular, the technical requirements for environmentally friendly and resource-saving disposal were devised in different working groups with representatives from the waste management sector, associations and authorities and set out in guidelines for enforcement.

Established while drafting the enforcement guidelines, the cooperation between responsible system operators Swico and SENS and the relevant specialist agencies of the cantons of Zurich and Aargau continued into the practical implementation phase. In fact, it was expanded even further, with the monitoring of disassembly facilities added to the scope of services.

Based on this positive experience, the cantons of Zurich and Aargau decided to officially delegate the monitoring of companies in the field of electrical and electronic recycling to the two organisations Swico and SENS. Details of the delegated supervisory tasks and reporting to the cantonal specialist agencies have been set out in a contract between Swico, SENS, the canton of Zurich and the canton of Aargau.

Swico and SENS have been monitoring ORDEE-relevant aspects as well as issues of water conservation legislation and air quality since as far back as 2007. Since 2011, SENS and Swico have been seeking more actively to add to those cantons delegating enforcement powers. In the years that followed they succeeded in adding Thurgau, St. Gallen, Appenzell Ausserrhoden, Schaffhausen, Basel-Landschaft and Zug to the group of delegating cantons.

The year 2015 saw a new topic appear: the CENELEC standard series SN/EN 50625 is officially available and is now being trialled by Swico and SENS as a basis for audits as part of a pilot project.

Following the successful test phase Swico has been conducting audits solely in line with SN/EN 50625 since 2017, and SENS audits will also be conducted in accordance with this series of standards from 2020 onwards. However, following the launch of the CENELEC standard series SN/EN 50625, the report templates for the inspection audits and the auditors' manual had to be adapted to the new requirements too. Since rules are imposed in the European series of standards that infringe upon Swiss law or which do not go far enough, the Swico/SENS Technical Commission (TC) has issued an additional document (CENELEC-CH) outlining the differences. This document was revised in 2019 and renamed supplementary Technical Guidelines (eTV). All the revised documents were submitted to the cantonal environmental agencies to keep them up to date on the new alignment with the international industry standard.

The inspection of collection points has now been added to the list of delegated tasks. Since Roger Gnos from Swico and Roman Eppenberger from SENS have long since been participating in annual meetings with the cantons in their capacities as auditors for the collection points, this addition could be implemented quickly and easily.

A regular item on the agenda for these annual meetings is the issue of lithium-ion batteries. Due to the fire risk and handling risk associated with these powerful battery types, there is a need to exercise more care when handling these and, at the same time, to conduct more training for all facilities throughout the collection chain. In summary, close collaboration between the systems and environmental agencies of the cantons offers the following advantages:

- Less effort for the monitored companies and the specialist cantonal agencies
- Systematic inspection and assessment of companies on the basis of clearly defined inspection cycles and criteria
- Intensive professional exchange between Swico and SENS and the specialist cantonal agencies, including the discussion of optimisation options

The well-used support offered to the specialist cantonal agencies during audits of recycling companies is testament to the fact that they value the competent auditing of the Swico/SENS TC auditors and that this vibrant cooperation, entered into willingly, is by all means a modern and viable resource for the future.

Flora Conte
Swico/SENS TC, Carbotech AG

Flora Conte completed her Master's degree in environmental science, with a major in biogeochemistry and pollutant dynamics, at ETH Zurich. She has been working in the environmental consulting department of Carbontech AG since 2013. She manages various projects in areas such as renewable energy, recycling and entrepreneurship at a national and international level. Since 2015, she has been a member of the SENS and Swico TC and an auditor for SENS and Swico dismantling companies and collection points. Flora Conte has been auditing SENS recyclers since 2016. In addition to her activities as an environmental consultant, she is also involved in setting up and managing small companies in Switzerland and abroad.

Roman Eppenberger
Head of Technical Audits SENS,
Head of Technology and Quality at SENS

Roman Eppenberger completed his degree in electrical engineering at ETH Zurich. In tandem with his professional activities, he completed the post-graduate course Executive MBA at the University of Applied Sciences of Eastern Switzerland (FHO). He gained his first industrial experience as an engineer and project manager in the field of medical and pharmaceutical robotics. As a project manager, he moved to the Contactless Division of the company Legic (Kaba), where he was responsible for the worldwide purchasing of semiconductor products. Since 2012, Roman Eppenberger has been a member of the Executive Board of the SENS Foundation and is the Head of the Technology and Quality Division. In this position, he coordinates the Swico/SENS TC in conjunction with Heinz Böni.

Anahide Bondolfi
Swico/SENS TC, Abeco GmbH

Anahide Bondolfi holds a Bachelor's degree in biology and a Master's degree in environmental sciences from the University of Lausanne. She began her work in the field of electronic waste in 2006 while working on her Master's thesis in South Africa, in collaboration with Empa. She then worked for almost 10 years as an environmental consultant and project manager at two Swiss environmental consulting firms, first at leBird in Prilly and then at Sofies in Geneva. In January 2017 she founded Abeco Sàrl. She has been a member of the Swico/SENS TC since 2015. She is responsible for almost half of all the audits of the Swico and SENS dismantling plants. Since 2016 Anahide Bondolfi has also been auditing several SENS recyclers and collection points.

Alois Villiger
Retiree

After completing his studies and doctorate at the Department of Organic Chemistry at ETH Zurich, Alois Villiger worked for six years as an analytical chemist at Empa St. Gallen. He then headed the newly founded Swiss Association for Hazardous Waste (Schweizerische Gesellschaft der Entsorgungsunternehmen für Sonderabfälle, GESO) in Emmenbrücke. From 1988 until his retirement in 2014, he held various positions in the Waste Management Department of the Office of Waste, Water, Energy and Air (WWEA) of the canton of Zurich. His areas of responsibility included looking after the disposal companies for electrical and electronic appliances in the canton of Zurich. As a representative of the authorities, he was also involved in various committees and working groups that dealt with the practical implementation and further development of the legal regulations regarding the Ordinance on the Return, Taking Back and Disposal of Electrical and Electronic Equipment (ORDEE).

Michael Gasser
Swico Conformity Assessment Office
SN EN 50625, Empa

Michael Gasser completed a Master's degree in environmental science at ETH Zurich. Since 2014, he has worked as a research associate in the Technology and Society Department at Empa, where he supports and manages various projects in the area of recycling. His areas of expertise include, in particular, the development and monitoring of recycling systems in Switzerland as well as in developing countries and emerging markets and the recovery of plastics. He has been part of the Swico/SENS TC since 2017. He has recorded the annual material flows and audited Swico recyclers since 2018.

Rolf Widmer
Swico Conformity Assessment Office
SN EN 50625, Empa

Rolf Widmer graduated in electrical engineering (MSc ETH EE) with a NADEL postgraduate qualification (MAS) from ETH Zurich. He spent several years researching at the Institute for Quantum Electronics at ETH and currently works at the Technology and Society Lab at Empa, which is the materials research institute for the ETH division. Rolf Widmer is currently managing several projects involving electronic waste management and, in this context, is dealing with closed material circuits for electromobility. He is particularly interested in the extraction of rare metals which are increasingly being accumulated in "urban mines".

Niklaus Renner
Swico/SENS TC, IPSO ECO AG

Niklaus Renner studied environmental sciences at ETH Zurich. Since 2007, he has worked as a research associate and project manager at IPSO ECO AG in Rothenburg (formerly Roos + Partner AG in Lucerne). As part of various studies, he deals with the environmental compatibility of scrap metal and e-waste recycling. Among other things, he was involved in conducting a survey on the mercury levels of fractions of processed lighting equipment for the SENS and SLRS Foundations. He also dedicates himself to the monitoring of environmental law, maintaining the legal compliance tool LCS and acting as an expert for legal issues relating to contaminated sites and soil protection.

Roger Gnos
Technical Audits, Hazardous Materials Officer
Swico and Swico/SENS TC member

Roger Gnos has been rooted in recycling since 1991 and has actively experienced and shaped the development in the recycling of waste electrical and electronic equipment. He worked for almost 20 years as a plant manager at an e-waste processing company. He has been with Swico Recycling for around eight years, advising the collection points and acting as Hazardous Materials Officer. He is fascinated by technology, but also by the people behind recycling.

Heinz Böni
Head of Swico Conformity Assessment Office
SN EN 50625, Empa

After graduating as an agricultural engineer at ETH Zurich, and a post-graduate course in domestic water supply construction and water conservation (NDS/EAWAG), Heinz Böni worked as a research associate at EAWAG Dübendorf. After holding the position of project manager at the ORL Institute of ETH Zurich and a stint at UNICEF in Nepal, Heinz Böni took up the position of Managing Director of Büro für Kies und Abfall AG in St. Gallen. After that he was a co-owner and Managing Director of Ecopartner GmbH St. Gallen for several years. He has been at Empa since 2001, where he is Head of the CARE (Critical Materials and Resource Efficiency) group. Since 2009, he has held the position of Head of the Technical Audit Department of Swico Recycling and has been an audit expert for Swico since 2007.

Dr Geri Hug
Swico/SENS TC, IPSO ECO AG

After studies in chemistry and a subsequent thesis at the Institute of Organic Chemistry, University of Zurich, Geri Hug was a research associate and project manager at IPSO ECO AG in Rothenburg (formerly Roos + Partner AG in Lucerne). From 1994 to 2011, he was a partner, and from 1997, managing director of IPSO ECO AG. He offers environmental consulting in 15 sectors in accordance with the EAC codes, accompanies environmental audits and prepares environmental compatibility reports in compliance with the Ordinance on the Environmental Impact Assessment (EIAO). In addition, Geri Hug produces short reports and risk analyses according to the Ordinance on Protection against Major Accidents (MAO) as well as operational and product life cycle assessments and validates environmental reports. Geri Hug is the Control Officer of the SENS Foundation in the field of electrical and electronic waste disposal and lead auditor for environmental management systems pursuant to ISO 14001 at SGS. He is a member of the CENELEC Working Group on the development of standards for the environmentally friendly recycling of refrigerators. Since March 2019 he has been available to the Swico/SENS TC for project work.

Daniel Savi
Swico/SENS TC, Büro für Umweltchemie

After graduating as an environmental scientist from ETH Zurich, Daniel Savi joined SENS as Head of Collection Centres and Head of Quality Assurance. He held these positions for seven years before joining Büro für Umweltchemie GmbH as a research associate. Since 2015 he has been co-owner and Managing Director of Büro für Umweltchemie GmbH. He deals with health hazards and the environmental impact of construction and waste recycling.

Andreas Bill
Swico Conformity Assessment Office
SN EN 50625, Empa

Andreas Bill completed his Master's degree in Energy Management and Sustainability at the Swiss Federal Institute of Technology (ETH) in Lausanne and subsequently gained initial experience in the field of e-waste at Empa while completing is civilian service. Since 2019 he has been working there as a research assistant in the Technology and Society Department. His core task is to support projects for the establishment of electronic waste recycling systems in developing and emerging countries. He is also a member of the Swico/SENS TC and will audit Swico recyclers from 2020.

13 Links

International links

www.weee-forum.org
The WEEE Forum (Forum for Waste Electrical and Electronic Equipment) is the European association of 40 systems for collecting and recycling electrical and electronic waste.

www.step-initiative.org
Solving the E-waste Problem (StEP) is an international initiative under the auspices of the United Nations University (UNU), which not only includes key players involving the manufacturing, reuse and recycling of electrical and electronic appliances, but also government and international organisations. Three additional UN organisations are members of the initiative.

www.basel.int
The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, dated 22 March 1989, is also known as the Basel Convention.

www.weee-europe.com
WEEE Europe AG is an amalgamation of 19 European take-back systems and since January 2015 has allowed manufacturers and other market players to fulfil their various national obligations from a single source.

National links

www.eRecycling.ch
www.swicorecycling.ch
www.slrs.ch

www.swissrecycling.ch
As the umbrella organisation, Swiss Recycling promotes the interests of recycling organisations operating in the separate collection sector in Switzerland.

www.empa.ch/care
Since the beginning of Swico's recycling activities in 1994, the ETH Department of Materials Science and Technology's research centre Empa has been responsible for auditing the recycling partners – as the conformity assessment body for the Swico recycling partners. The group CARE – Critical Materials and Resource Efficiency headed by Heinz Böni is responsible for this.

www.bafu.admin.ch
In the "Waste" section of its website, the Swiss Federal Office for the Environment (FOEN) provides a range of further information and news on the topic of recycling electrical and electronic appliances.

Cantons with devolved powers

www.awel.zh.ch
On the website of the Office of Waste, Water, Energy and Air (WWEA), the "Waste, raw materials and contaminated areas" section provides a raft of information of direct relevance to the recycling of electrical and electronic appliances.

www.ag.ch/bvu
On the website of the Department for Construction, Traffic and Environment of the canton of Aargau, the "Environment, nature and agriculture" section provides further information on the topics of recycling and reusing raw materials.

www.umwelt.tg.ch
On the website of the Office for the Environment of the canton of Thurgau, the "Waste" section provides relevant regional information about the recycling of electrical and electronic appliances.

www.afu.sg.ch
The website of the Office for Environment and Energy St. Gallen contains general information, notices on individual issues and information on current topics, which can be found under "Environmental information" and "Environmental facts".

www.ar.ch/afu
The website of the Office for Environment Appenzell Ausserrhoden contains general information and publications on individual issues and all matters involving the environment.

www.interkantlab.ch
The website of the Intercantonal Laboratory of the canton of Schaffhausen offers a wide range of information on recycling electrical and electronic appliances, which can be found under "Information on specific types of waste".

www.umwelt.bl.ch
The website of the Office for Environmental Protection and Energy (AUE) of the canton of Basel-Landschaft contains information on recycling and reusing raw materials in electrical and electronic appliances, which can be found under "Waste>Controlled waste>Electrical waste".

www.zg.ch/afu
The website of the Office for Environmental Protection of the canton of Zug contains general information and notices on the topic of waste, which can be found under "Waste management". Detailed information on the collection of individual recyclable materials is available from the Association of Local Authorities of the Canton of Zug for Waste Disposal Administration (ZEBA) at www.zebazug.ch.

14 Contact and legal information

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