# Technical report 2019

**Swico, SENS and SLRS**
News about electrical and electronics recycling

# WE'RE FORWARD-THINKING

## ABOUT SYSTEMATIC RECYCLING

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# Contents

# Sometimes Switzerland really is an island

This technical report outlines an extremely important aspect of our communication activities: namely, the scientific and forward-looking aspect. And that's something we're proud of.

But why is it then that twice a year on average, the media circulate the story that our electronic waste is being burned and utilized on a large scale in Africa under atrocious conditions?

One thing that these articles have in common is that they are all reporting on waste equipment from 'Europe', when what they really refer to is the European Union. In other words, they miss the fact that Switzerland is not affected at all. Even reputable media aren't entirely blameless in that respect. Indeed, only last year, the Swiss TV ombudsman had to get involved to force the news program *10 vor 10* to clarify this online, after their report made the same mistake. We understand that it is more exciting for the media to report on something that relates to their own country. And certainly, it can be very difficult to distinguish between the EU and Europe (or even the Council of Europe). But we are tired, as Swiss take-back systems, to constantly have to defend ourselves against attempts to tar us with the same brush as the 'rest of Europe':

Switzerland has managed to set up a voluntary system that enables very high return rates – well above the average of neighbouring countries.

For once, Switzerland's 'island status' definitely benefits us. We still have border controls for goods and can thus monitor the flow of waste, too.

It is extremely important to state that the take-back obligation is cleverly regulated in Switzerland: Every retailer must take back all waste equipment in the product categories that they themselves sell locally. This is sensible in two respects: Consumers only approach them with specific equipment. For which the retailer has a working reverse logistics system. The correspondingly high number of take-back points and the fact that recycling is anchored into Swiss everyday living both contribute to the high return rate.

So indeed, let's be proud to operate take-back systems in Switzerland that are recognized as exemplary and successful role models in Europe (and in the European Union). And not just because of the quality of their annual technical report.

Judith Bellaiche
Swico

Heidi Luck
SENS

Silivia Schaller
SLRS

# Swico, SENS Foundation and SLRS: competent and sustainable

**For more than 20 years, Switzerland's three take-back systems, SENS eRecycling, Swico and the Swiss Lighting Recycling Foundation (SLRS), have been guaranteeing the resource-efficient return and reuse and proper disposal of electrical and electronic equipment.**

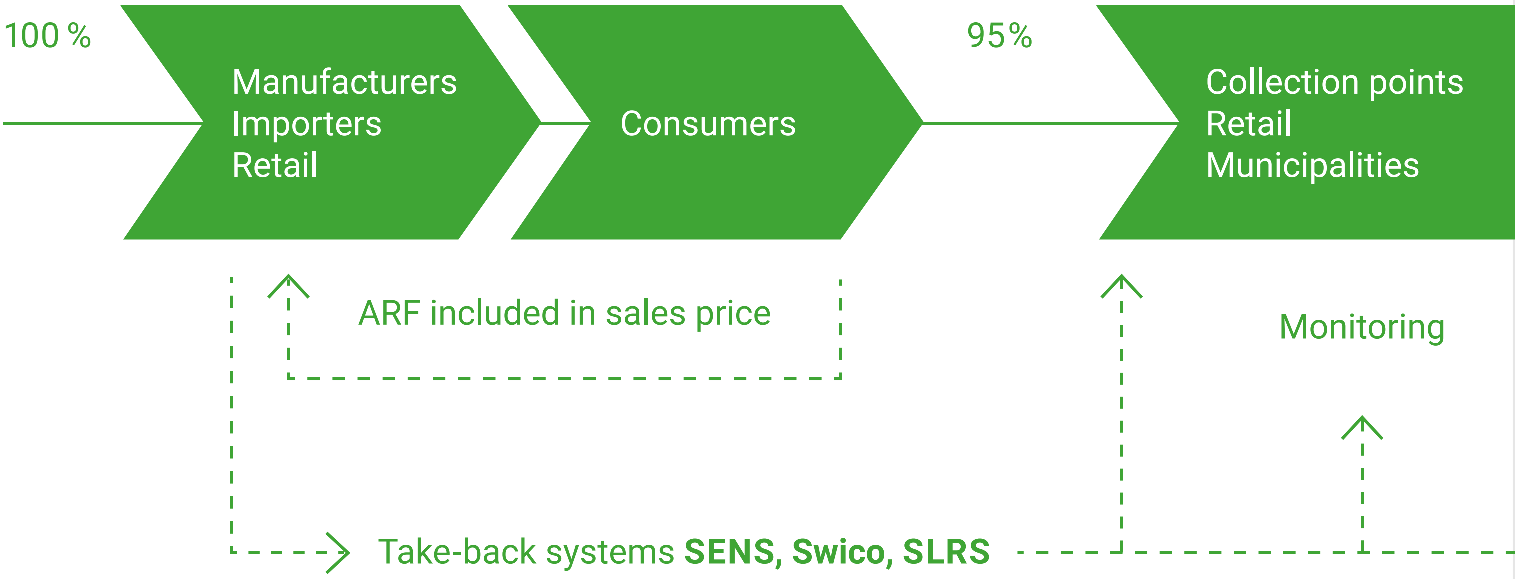
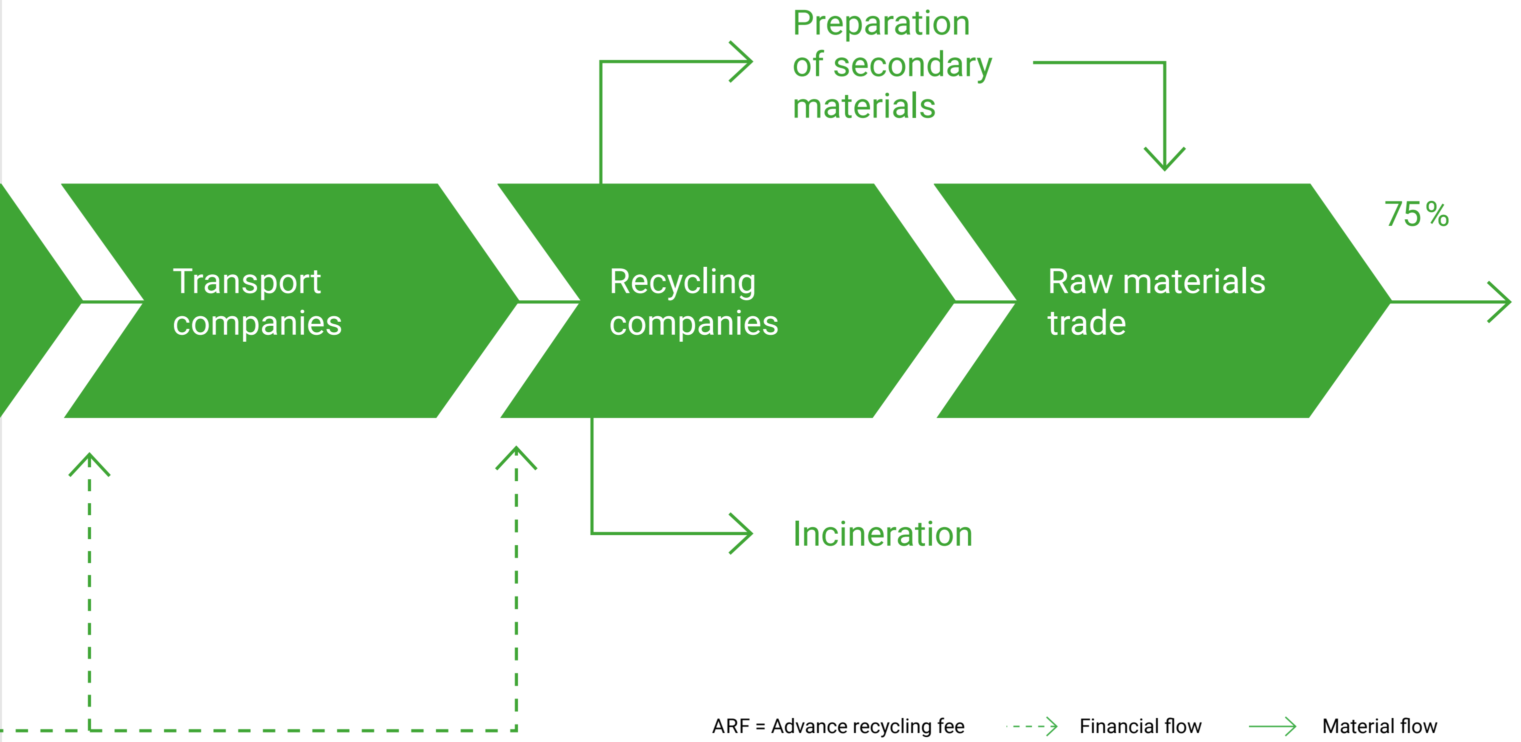



Figure 1: Overview of the take-back systems

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 answer 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 equipment in question, SENS, Swico or the Swiss Lighting Recycling Foundation (SLRS) is now responsible for recycling.

In 2018, the three systems disposed of around 122,800 tonnes of old electrical and electronic equipment. This means that Swico, SENS eRecycling 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) – they also help to set cross-border standards for the recycling of electrical and electronic appliances.




The Ordinance on the Return, Take-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, 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.

### Swico

Swico Recycling is a special fund within the Swiss Industrial Association Swico and deals exclusively with cost-covering recycling of waste electrical and electronic equipment. Swico aims to extract raw materials anddispose of pollutants 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 Testing and Research (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.

### SENS

SENS eRecycling is an independent, neutral, non-profit organisation 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.

### SLRS

The 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 light ing 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 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.

# HEADING DIRECT TO THE DESTINATION

## NO DETOURS, NO COMPROMISES: RECYCLING IS THE TOP PRIORITY FOR POLICYMAKERS AND SOCIETY.

# The ORDEE debate: casting a shadow over the Swico/SENS Technical Commission

Heinz Böni

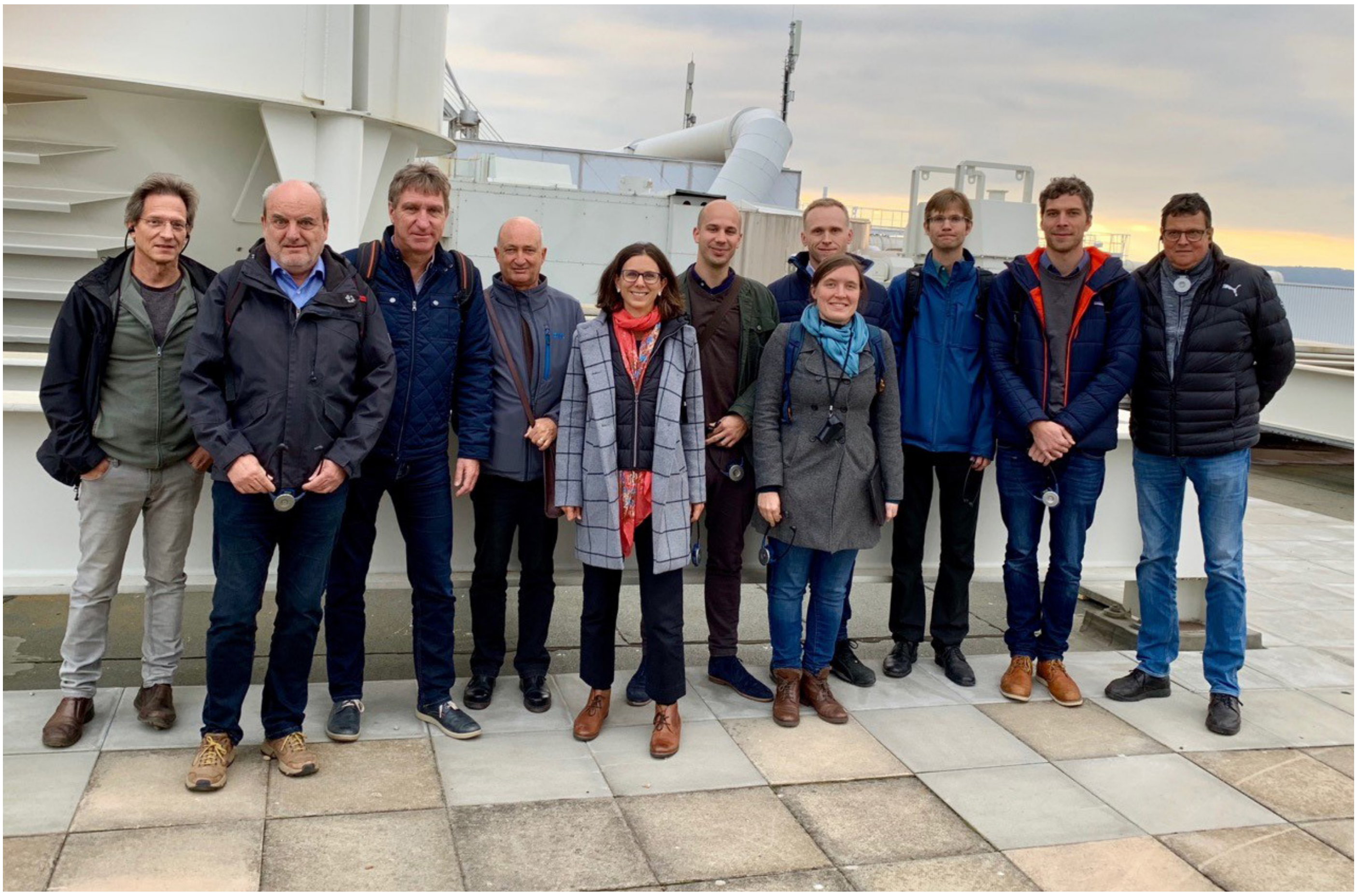
**More than five years have passed since the consultation on the draft revision of the Swiss Ordinance on the Return, Take-Back and Disposal of Electrical and Electronic Equipment (ORDEE). Although the future remains unclear, a great deal of effort is still being put into the technical work in the background. In 2018, the Swico and SENS Joint Technical Commission prepared the manual for auditing in line with the Swiss EN 50625 standard, among other things, and examined an extremely wide range of questions relating to pollutants.**

While everyday electronic equipment has been undergoing further technological development, it has also been becoming increasingly complex from a material standpoint in recent years due to the growing number of functionalities. But it's not just the pollutants in older equipment that are placing high demands on recycling and thus also on inspections by auditors – there are now new pollutants and risks resulting from lithium batteries. Heavy metals and flame retardants in plastics, PCBs and substances of concern in capacitors, equipment containing asbestos, and mercury in the backlights of flat-panel displays are just a few of the many examples.

Such pollutants should be largely removed from the equipment and disposed of separately before it is mechanically processed. More than 90 dismantling plants that work in cooperation with the recycling partners are currently pursuing this main objective. In addition to removing pollutants, they are also making a key contribution to maintaining the materials' value. Despite all efforts, pollutants can still be found in the groups from mechanical processing. Up until now, they have been looked for and found mainly in the fine groups from waste shredding, where they accumulate on the fine particles. If this fine group enters into a thermal process, these pollutants can usually be destroyed in a controlled manner. But what happens if pollutants in far smaller concentrations reach downstream processing procedures via valuable fractions, where they might no longer receive the same attention? This question is a key focal point of the work carried out by and the discussions held in the Swico and SENS Technical Commission. The study on liquids in capacitors identified substances of concern that occur in liquids of different capacitors. How great the risk is of these pollutants escaping during processing and where they might accumulate remains largely unknown. The SN EN 50625 standard rightly requires that pollutants be retained in a distinguishable and thus monitorable stream at the end of a treatment process, so as to verify that they are managed in an environmentally sound manner.

A manual that is accessible to the public and thus also to the recycling companies in particular has been drawn up to ensure that the auditors interpret the requirements set down in the standards consistently and check them during the audits.

What's more, a project that will probably have to be continued for another two to three years was initiated in 2018: namely, the complete redevelopment of the outdated material flow recording system. This is to be combined with computer-aided auditing of dismantling plants and recycling companies. The new tool will enable efficient, targeted and user-friendly auditing that will significantly reduce the time and effort required on both the plant/company side and the auditor side. The material flow recording system is to be adapted to the requirements set down in the existing laws and ordinances, particularly to those outlined in the Swiss Ordinance on the Avoidance and the Disposal of Waste (ADWO), the DETEC Ordinance on Lists relating to Movements of Waste (LVA) and the Swiss Ordinance on the Return, Take-Back and Disposal of Electrical and Electronic Equipment (ORDEEE) with regard to material coding and reporting obligations.



From left to right: Rolf Widmer, Geri Hug, Heinz Böni, Roman Eppenberger, Anahide Bondolfi, Michael Gasser, Flora Conte, Niklaus Renner, Daniel Savi, Arthur Haarman, Roger Gnos

# Manual processing: a key element of recycling

Anahide Bondolfi and Flora Conte

**Recyclers have increasingly efficient mechanical facilities to process waste electrical and electronic equipment. However, most of the equipment decontamination steps and some of the reusable material separation steps are performed manually. The following article provides an overview of manual processing in dismantling workshops and on recyclers' premises.**

## The purpose of mechanical facilities

Over the last 30 years, many companies have opened mechanical processing facilities in Switzerland designed to handle waste electrical and electronic equipment (WEEE). The primary purpose of most of these facilities is to separate reusable materials: the equipment is shredded, then the ferrous metals are extracted magnetically and the aluminium is removed using eddy current separators. The level of mechanisation varies when it comes to sorting other metals and plastic. But in the case of pollutants, most of the separation work is carried out manually. In most cases, pollutants are removed before mechanical processing, either in one of the 120 dismantling workshops affiliated with SENS and Swico, or in a manual dismantling area on the recycler's premises.sometimes also takes place during mechanical processing, following a visual inspection of equipment on facility conveyor belts. However, this practice is only permitted if the components containing pollutants are not damaged to prevent contaminating the other parts.

Manual sorting of recyclable and polluting materials from the conveyor belt, after shredding household appliances, at Metabader SA.

## Manual sorting of pollutants

As all equipment may contain pollutants, the manual stage is essential for ensuring the quality of decontamination, which is important from an environmental and health perspective. At least at one stage of processing, each piece of equipment should be inspected by a person trained to recognise potential pollutants from the vast SENS and Swico catalogue of equipment. This inspection can also help identify potential new pollutants – as equipment changes over time – or spot very old equipment that is likely to contain more pollutants (such as PCBs). In practice, sometimes the entire piece of equipment is removed from the WEEE stream and forwarded to the appropriate channel, as is the case for radioactive smoke detectors and alarm clocks, or for heat pump tumble dryers containing fluorinated refrigerants. But more often than not, only one component of the equipment is extracted, either by hand or using simple tools (pliers, screwdrivers, etc.). Such components include in particular:

- Lithium batteries used in laptops, garden tools, etc.
- Capacitors found, for example, in household appliances and on printed circuit boards
- Light sources from lamps, flat screens or certain scanners or photocopiers
- Asbestos from some old ovens, hair dryers, etc.

**Manual sorting of reusable materials**
Manual processing also enables extraction of reusable materials. Some dismantling workshops carry out more precise dismantling work that exceeds simple decontamination. As long as the equipment has been opened to remove pollutants, it's relatively easy to extract certain 'clean' reusable components, such as metals or some plastics, or 'composites', such as printed circuit boards, hard drives or motors. In contrast to other countries, where salaries are lower, in Switzerland precision dismantling of composite components, such as hard drives or motors, is not viable in the traditional economy. When they have been removed from the WEEE stream, these components, whether clean or composite, are processed directly by a specific facility without passing through a conventional WEEE shredder. This means that unnecessary steps (e.g. scrap metal removal and eddy current separation) can be bypassed, thus reducing processing costs and environmental impact. Sorting reusable materials before shredding also means that mixing and partial destruction are avoided. This results in better quality components; for example, in the recycling of plastic or printed circuit boards. What's more, manually separating printed circuit boards before shredding limits the risk of precious metals being lost. Reusable materials are also manually extracted on some recyclers' premises, mainly those using non-specific WEEE shredders. After shredding, employees manually remove certain components, such as motors, printed circuit boards or even concrete (found in washing machines) from the conveyor belt. This operation can only be performed efficiently if the sorting belt is moving at an appropriate speed.

Given the diversity, complexity and often small size of reusable materials and pollutants, and despite the fact that recyclers have increasingly efficient mechanical facilities, manual dismantling remains – and undoubtedly will remain – a key element of WEEE recycling for a long time to come.

Anne-Claude Imhoff
Engineer MSc EPFL and Co-director,
↗ www.lebird.ch

Where do you see things heading with regard to manual versus mechanical processing?

'Since it's particularly effective for processing flat screens, manual dismantling facilitates recovery of recyclable materials and separation of hazardous substances. It also offers meaningful work for hundreds of social assistance recipients, while competing little with mechanical processing. However, its future is subject to several conditions, such as the commitment of social associations and the support of public authorities, as well as sufficient remuneration and the delivery of compliant and properly packaged equipment.'

# While quantities have remained stable, composition has changed

Michael Gasser

**After the quantities of waste electrical and electronic equipment processed declined in 2017, they increased again slightly in 2018. While quantities of electronic equipment continued to fall, this decline was offset by higher volumes of large electrical appliances, small electrical appliances and refrigerators. However, the composition of the various categories has continued to change.**

In 2018, the Swico and SENS recyclers processed around 125,900 tonnes of electrical and electronic equipment (Waste Electrical and Electronic Equipment), a figure up 3 % on the previous year. (Table 1 and Figure 1). The largest decrease was in the processing of non-ORDEE equipment that is not included in the lists provided in the Swiss Ordinance on the Return, Take-Back and Disposal of Electrical and Electronic Equipment (ORDEE). The volume of electronic equipment processed also dropped (-9%). The numbers here are following a long-term trend that is due to the decline in heavy computer monitors and televisions. In the case of large electrical appliances, an upward trend is now apparent again following a change to the recording methodology in 2017 and an associated decline in volumes in 2018. A slight rise could also be observed in the quantities of small electrical appliances and refrigerators. At 300 t in total, the volume of processed photovoltaic equipment remained low compared to the previous year.

| Year | Large electrical appliances | Refrigerators, freezers and air conditioners | Small electrical appliances | Electronic appliances | Lighting equipment | Photovoltaics | Non-ORDEE appliances | Total Tonnes/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 |
| **Change on previous year** | **22%** | **3%** | **3%** | **-9%** | **13%** | **0%** | **-23%** | **3%** |

Table 1: Total volume of processed electrical and electronic equipment in Switzerland in tonnes from the material flow recording system

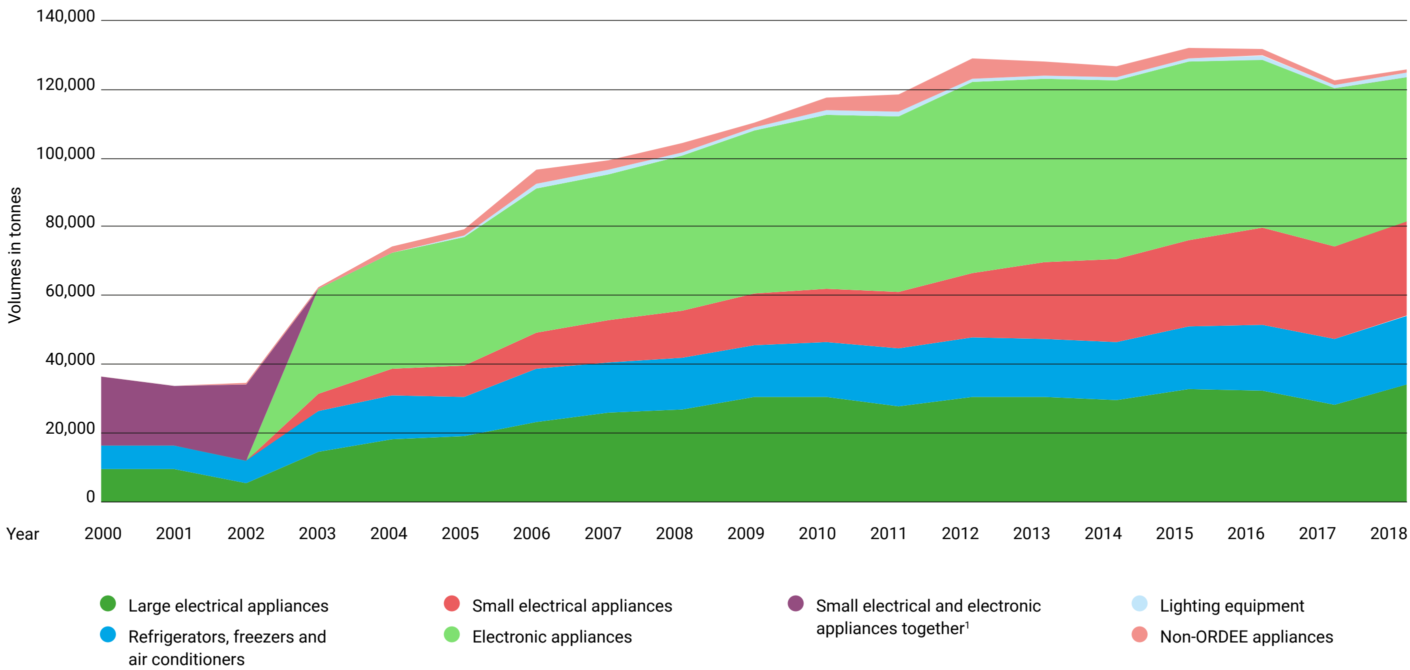



Figure 1: Development of the equipment quantities processed in Switzerland in tonnes

**Recovering recyclables**

Recyclables are recovered from the processed waste electrical equipment and pollutants are separated by means of manual and mechanical processing (Figure 2). Metals make up the largest group of recyclable materials (61 %). Plastic/metal mixtures (17 %) and plastics (9 %) are the next two largest groups. The particularly valuable printed circuit boards account for only 1.1 % of the total quantity. It is often worthwhile to remove these components manually prior to mechanical processing, so the precious metals they contain can be recovered in as complete a condition as possible. The proportion of glass from cathode ray tube processing decreased by one third year-on-year and still amounts to 1.4 %.

The groups of recyclables recovered are further processed in downstream plants and, if possible, recycled or used to generate energy. Recycling companies have to provide evidence of material flows to prove and document the further processing of these groups. Ferrous groups are processed in Swiss steelworks, while non-ferrous metals are handled in European smelting works. Plastic/metal mixtures are separated further. The metals and plastics that are of a single origin and are not contaminated by many pollutants are recovered during these separation processes. Individual mixed groups are directly used for energy recovery, although this proportion has fallen sharply in recent years thanks to new processing options for the likes of toner cartridges and sorting systems for plastic/metal mixtures. Glass groups (screen glass, flat glass and recycled glass from illuminants) as well as cables, printed circuit boards and batteries are also fed into special recycling operations.

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

**Pollutant removal**
The share of pollutant fractions produced sank slightly to 1%. (Figure 2). This is mainly due to a marginal decline in batteries and capacitors. In addition to returning recyclables to the material cycle, pollutant removal is one of the main tasks undertaken by recycling companies. Most of the pollutants are removed manually in dismantling plants. Larger capacitors, for example, are removed from equipment, while batteries are taken out or the backlights of flat-panel displays, scanners and photocopiers are disassembled. Pollutant removal and handling must be constantly adapted to changing technologies and the latest findings. Companies must also remain capable of properly removing and disposing of pollutants from older generations of equipment. This places high demands on the work undertaken by recycling companies and calls for high-calibre quality assurance systems.

**Take-back and composition of electronic equipment**
Swico Recycling regularly inspects the quantities taken back and the composition of electronic equipment. To this end, it conducts shopping basket analyses and performs product group processing tests (Table 2). In 2018, Swico Recycling took back 45,760 tonnes[1] of electronic equipment, 5.7 % less than in the previous year. The weights and quantities of CRT monitors and televisions taken back are still in decline, thus continuing the long-term trend. In the case of flat-panel displays, the trend of higher volumes and lower weights seen in previous years appears to be reversing, since the quantity of equipment taken back is decreasing while the average weight is rising. The number of mobile phones remains on the rise.

The composition of the individual equipment categories is determined by processing tests carried out by Swico recyclers and attended by Empa. During this process, a predetermined volume of equipment is collected and the groups resulting from the processing activities are documented. Using these composition details and information on further processing as a basis, it can be determined that around 60 % to 65 % of the fractions resulting from the processing of electronic equipment in Switzerland are sent for final treatment.

The detailed take-back quantities of electronic equipment and its composition are listed in Table 2.

[1] This figure is greater than the 41,900 tonnes of electronic equipment in Table 1, as it also includes equipment disposed of by A signatories under direct contracts.

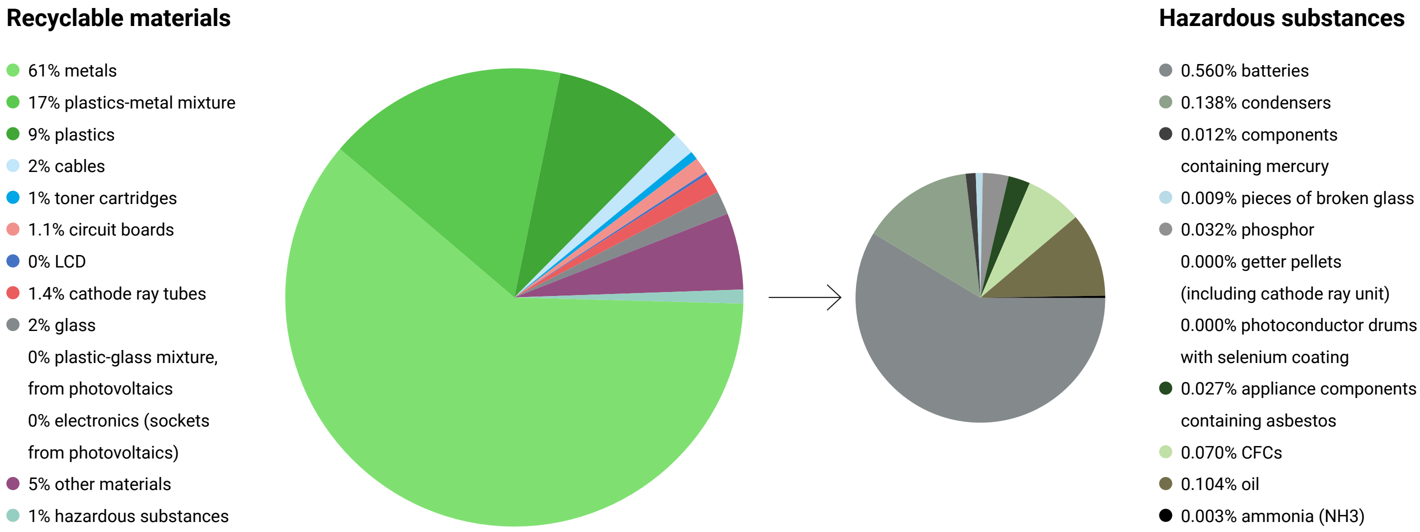



Figure 2: Composition of the fractions produced in % in 2018
Hazardous substances, which make up a total of just 1 per cent of the fractions generated, are shown separately. Source: Toocy

| Appliance type | Quantity[3] | Average weight | Metals | Plastics | Metal-plastics mixture | Cables | Glass and/or LCD modules | Circuit boards | Hazardous substances | Others[4] | Other | Increase/decrease compared to 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | in thousands | in kg | in tonnes | in tonnes | in tonnes | in tonnes | in tonnes | in tonnes | in tonnes | in tonnes | in tonnes | |
| PC monitor, CRT | 36 | 18 | 92 | 125 | 60 | 16 | 276 | 58 | 0.0 | 3 | 630 | -32% |
| PC monitor, FPD[1] | 558 | 6.3 | 1'373 | 1'107 | 67 | 43 | 547 | 247 | 32.1 | 87 | 3'503 | -4% |
| PCs/servers | 382 | 12 | 3'785 | 265 | 12 | 141 | – | 383 | 15 | – | 4'601 | 1% |
| Laptop | 502 | 2.6 | 396 | 368 | 133 | 6.6 | 115 | 190 | 90 | 5.4 | 1'305 | 2% |
| Printers | 460 | 12 | 1'874 | 2'845 | 325 | 29 | 36 | 93 | 1.6 | 86 | 5'290 | -7% |
| Largescale copiers and equipment | 47 | 138 | 3'530 | 242 | 2'318 | 117 | 4.3 | 52 | 56 | 166 | 6'486 | -10% |
| IT, mixed[2] | 614 | 3.2 | 1'071 | 71 | 710 | 36 | 1.0 | 15 | 17 | 50 | 1'971 | 0% |
| CRT TVs | 140 | 28 | 385 | 799 | 130 | 14 | 2'525 | 48 | 4 | 2.1 | 3'906 | -33% |
| FPD TVs[1] | 222 | 18 | 1'975 | 735 | 430 | 56 | 358 | 343 | 46 | 142 | 4'085 | 0% |
| Consumer electronics, mixed[3] | 3'241 | 3.4 | 5'920 | 393 | 3'921 | 197 | 5.6 | 85 | 93 | 275 | 10'890 | 2% |
| Mobile phones | 780 | | 19 | 42 | – | – | 6.1 | 26 | 24 | – | 117 | 5% |
| Remaining phones | 1'350 | | 1'468 | 97 | 972 | 49 | 1.4 | 21 | 23 | 68 | 2'700 | 15% |
| Photo/video | 200 | | 88 | 5.8 | 58 | 2.9 | 0.1 | 1.3 | 1.4 | 4.1 | 162 | 1% |
| Dental | | | | | | | | | | | 115 | 24% |
| **Total in tonnes** | | | **21'977** | **7'094** | **9'138** | **708** | **3'876** | **1'563** | **403** | **888** | **45'760[6]** | **-5.7%** |
| **Total in per cent** | | | **48%** | **16%** | **20%** | **2%** | **8%** | **3%** | **1%** | **2%** | **100%** | |

[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 46,000 tonnes of electronic equipment in table 1, since this also includes electronic appliances which A-signatories have disposed of via direct contracts.

Table 2: Swico volumes collected and composition by type of appliance.
Source: Michael Gasser, Empa, based on Swico processing and market basket analyses, 21 March, St. Gallen.

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# Hazardous fraction requirements for recording material flows in future

Michael Gasser and Anahide Bondolfi

**SENS and SLRS, Swico's recycling partners, record the quantities of processed equipment and the resulting fractions annually. This data is at the very heart of annual operational inspections and public reporting. Since documentation requirements are becoming tighter in connection with the SN EN 50625 series of standards, to name but one example, the system of recording material flows must be revised and processes updated.**

Every February, it's that time again: once the annual statements on the circulation of waste that is subject to inspection requirements have been submitted at the end of January on ↗ VeVa-Online, Swico's recycling partners SENS and SLRS prepare the annual material accounts for received equipment and produced fractions. The software Toocy (Tool Recyclage) has been used for recording purposes for the last 12 years. Despite constant further development, the software no longer meets today's expectations in terms of userfriendliness. Frustrations are widespread. For example, the software does not allow transfer of data from VeVa-Online and manual input is prone to errors.

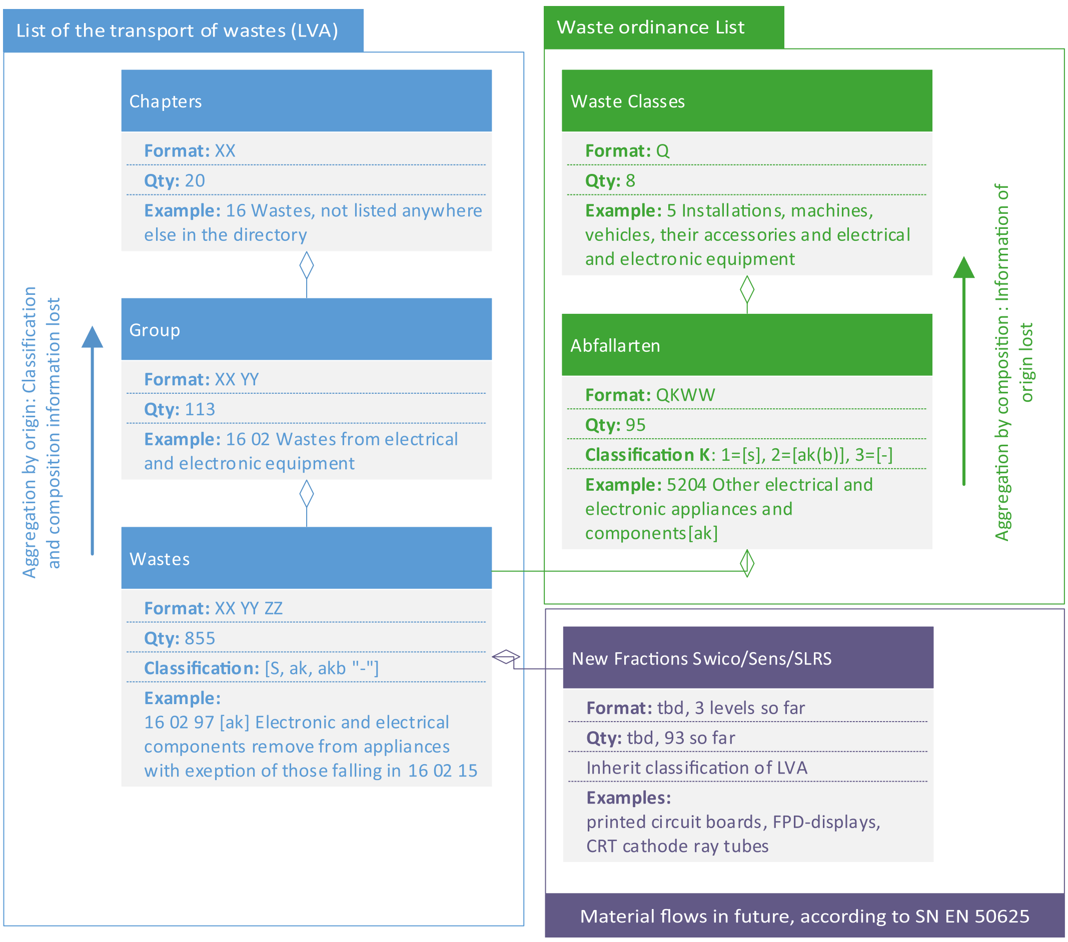
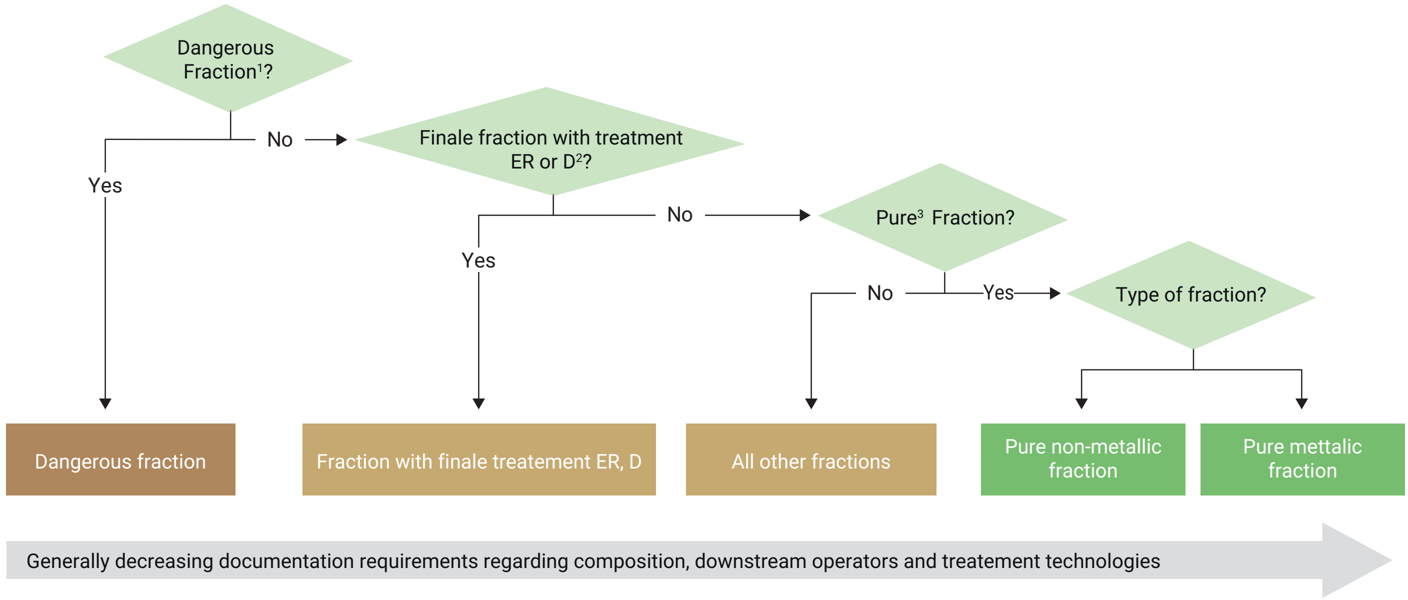



Figure 1: Waste categorisation systems set down in LVA and ADWO and a future compatible Swico/SENS/SLRS material flow recording system




[1] According to the Swiss waste codes list (LVA), european waste codes (EWC) or listed in SN EN 50625-1 Annex F
[2] ER: Energy Recovery, D: Disposal
[3] mass fraction of foreign matters < 2% (e.g. aluminium in copper, printed circuit boards in plastic fraction, PS in ABS plastics)

Figure 2: Categorisation of output groups according to SN EN 50625 documentation requirements

**Increased documentation requirements for recycling companies**
With the Swiss Technical Ordinance on Waste (TOW) being replaced by the Waste Ordinance (↗ ADWO), a new reporting requirement for waste was introduced in 2016. In addition to the quantities of transported waste that is subject to inspections as per the Swiss Ordinance on Movements of Waste (OMW) and the corresponding lists (LVA), waste that is not subject to inspections according to the newly introduced ADWO categories will also need to be recorded with effect from 1. January 2021.

ADWO reporting primarily benefits the cantons and the Confederation in waste planning. Accordingly, waste is grouped under the ADWO codes according to waste properties (composition and level of risk). This is in contrast to the common grouping by waste origin (industry and manufacturing processes) in movement operations (ADWO and LVA). Both grouping approaches are based on the six-digit waste codes from the LVA used by industry (Figure 1). The ↗ enforcement aid for ADWO reporting, which is in development, assigns the LVA waste codes to the ADWO codes. The SN EN 50625 series of standards places new demands on the recycling industry with regard to the documentation of waste composition and waste recycling routes. A company compliant with SN EN 50625 will submit different information depending on the properties and composition of the group produced (Figure 2).

The material flow coding used nowadays in Toocy is neither compatible with the six-digit LVA waste codes nor with the requirements set down in SN EN 50625. Likewise, the system limit for recording in Toocy is at recycling partner level. In other words, flows between different operating sites run by the same recycling partner (dismantling plants and different locations for mechanical processing) are not accounted for. However, both the series of standards and the ADWO require that material flows be recorded at individual plant level.

**Meeting different needs with harmonised underlying data**
The material flow recording system must be revised if the rising requirements are to be met. A new solution should draw on existing data as far as possible and create harmonised underlying data to cover the different needs:

- Industry is provided with a harmonised tool for reporting material flow data, reducing the risk of duplication.

– Automatic inspection functions simplify monitoring of compliance with regard to the shipment and processing of WEEE and produced fractions.
– The use of basic data that has been verified in detail for ADWO reporting increases the quality and consistency of data available for waste planning.

To create harmonised underlying data, the group categories used in the future to record material flows must be clearly allocated to the six-digit LVA waste codes (Figure 1). For a conformity assessment that meets SN EN 50625, data needs to be of a higher resolution than according to LVA in many cases. For example, printed circuit boards that contain no hazardous components and flat-panel displays must be identified separately in the material flow recording system due to other treatment regulations, even though both groups fall under the same LVA waste code (↗ 16 02 97 [ak] electronic components removed from waste equipment, except components mentioned in 16 02 15). Direct assignment means that data can be aggregated automatically for further purposes.

When different data and functions are linked more closely together on a common platform, important questions regarding data protection arise, as the conformity assessment is to a certain extent based on confidential data. Clearly formulated access rights help to establish transparency and trust between the players involved.

**Outlook**
Using the general definition of requirements as a basis, the detailed requirements and possible ways of collecting the data are elaborated together with representatives of the recycling industry. The companies are thus informed of any necessary adjustments early on. The solution to be developed for the material flow recording system is to be combined with other tools to support the Swico and SENS auditors.

Sandra Wessels
E-Waste Manager,
Thévenaz-Leduc SA

SENS/Swico is planning to develop a new solution for Toocy. The new solution should make use of existing data as far as possible create a harmonised data base. What do you make of this?

‘Ordinarily, data is determined by economic efficiency and legal conformity and must work. Legal audits should simplify our daily operational controlling activities to allow us to identify possible deviations in a shorter space of time. Dynamically checking existing data should be the goal for that very reason. Ultimately, it’s about protecting the environment and conserving raw materials, and that should be the first priority for each and every one of us.’

# What liquids do capacitors contain?

Daniel Savi

**Nowadays, capacitors are mainly removed from waste electrical equipment (WEEE) by hand if they are larger than 25 mm in one dimension. This rule is intended to separate any capacitors containing PCBs from WEEE, where possible, and to ensure that they are disposed of in a controlled manner. PCB-free capacitors that are larger than 25 mm must be removed if they contain substances of concern. More than 30 years after PCBs in capacitors were banned, capacitors containing PCBs account for an ever smaller proportion of the capacitors removed. This raises the question of how substances of concern ought to be defined and which of these substances occur in liquids in PCB-free capacitors. To answer them, SENS and Swico have been conducting a broad-based capacitor study over the last two years.**

**Substances found in PCB-free capacitors**
The study approached the issue of questionable liquids in PCB-free capacitors from two sides. Firstly, the available literature was evaluated, and secondly, the substances in capacitors from WEEE were subjected to laboratory examination. Capacitor types that always contain liquids are the polarised aluminium electrolytic capacitors and the non-polarised capacitors from microwave ovens. The non-polarised, cylindrical capacitors, which are used in large household appliances or refrigerators, for example, may contain liquids. But there are also designs that are completely dry. The study found that about 55 % of the non-polarized cylindrical capacitors contain liquids. The capacitor study identified more than 60 pollutant-containing liquids that may be incorporated in capacitors. The compounds differ depending on the design as well as the model.

Sorted electrolytic capacitors

**Substances of concern in PCB-free capacitors**
To assess the environmental and health hazards posed by the liquids found, the term 'substances of concern' first had to be defined. While the concept of 'substances of concern' is indeed taken from the EU's WEEE Directive, it is not defined in it or in legislation. The study defined the term using the substances' H phrases according to the regulation on the classification and labelling of substances (EU CLP Regulation). We recommend compiling a list of H phrases that qualify a substance as a 'substance of concern' in capacitors. A number of principles have been followed in deriving the list. Substances that have chronic effects on organisms even at low concentrations and, of course, substances that are life threatening are classified as substances of concern. Any substance that is 'toxic' or 'very toxic' to aquatic life is considered to be a substance of concern. These principles lead to the list of H phrases in Table 1. In addition to the H phrases, a substance's stability in the environment was taken into account in the classification.

Percentage of capacitors with liquids per capacitor category (unit %)


Apolar cylindrical capacitors


Electrolytic capacitors


Microwave capacitors

| Hazard Statement | Danger |
|---|---|
| H300 | Fatal if swallowed. |
| H310 | Fatal in contact with skin. |
| H330 | Fatal if inhaled. |
| H340 | May cause genetic defects |
| H341 | Suspected of causing genetic defects |
| H350 | May cause cancer |
| H351 | Suspected of causing cancer |
| H360D | May damage the unborn child |
| H360FD | May damage fertility / May damage the unborn child |
| H360Df | May damage the unborn child / Suspected of damaging fertility |
| H361 | Suspected of damaging fertility or the unborn child |
| H361d | Suspected of damaging the unborn child |
| H370 | Causes damage to organs |
| H372 | Causes damage to organs through prolonged or repeated exposure |
| H400 | Very toxic to aquatic life |
| H410 | Very toxic to aquatic life with long-lasting effects |
| H411 | Toxic to aquatic life with long-lasting effects |

**Capacitors with substances of concern**
Substances of concern could be detected in all capacitor types, so it is still necessary to remove the capacitors during treatment. In recycling practice, capacitors with substances of concern are undistinguishable from capacitors that do not contain substances of concern. The study's authors thus recommend to stipulate the removal of all capacitors above the existing size criterion of 2.5 cm from electrical equipment. SENS' and Swico's conformity assessment bodies will conduct further investigations to clarify whether procedures other than manual removal comply with the requirement of removal into a distinguishable stream, as prescribed by the Swiss EN 50625 series of standards. Until then, there will be no changes to the requirement for manual capacitor removal.


Electrolytic capacitors

**Further results of the study**
The study report will be published this year by SENS and Swico. It contains additional insights into the capacitors in WEEE. For example, the proportion of capacitors containing PCBs was determined for large household appliances, refrigerators, air conditioners and freezers, as well as for luminaires. For certain pieces of IT and CE equipment in the Swico system, the mass proportion of electrolytic capacitors in the respective appliance weight was recorded (from 0.6 % to 7 %). The mass proportion of electrolytic capacitors smaller than 2.5 cm in the total weight of electrolytic capacitors was also determined (approx. 50 % on average).

A capacitor model from ballasts

Sampling for the liquids' lab analysis

Inner workings of a microwave capacitor

# TIME FOR A RETHINK

GET INVOLVED IN THE THOUGHTS, DISCUSSIONS AND ACTIVITIES: RECYCLING ONLY WORKS IF EVERYONE PULLS TOGETHER.

# Monitoring pollutants: mass fractions versus mass flows

Arthur Haarman and Anahide Bondolfi

**Currently used indicators to monitor the depollution performance include the mass fraction (mg/kg) of polychlorinated biphenyls (PCBs) and cadmium in selected output fractions from mechanical treatment. However, these indicators suffer from a main limitation: they do not consider the absolute loads (kg) of hazardous substances.**

WEEE management has two main goals: detoxification and recovery. Firstly, WEEE management should ensure that hazardous substances are dealt with in an appropriate manner (see also chapter 4). Secondly, it should maximise the conservation of resources by redirecting valuable substances towards appropriate recovery channels (see also chapters 11 & 12).

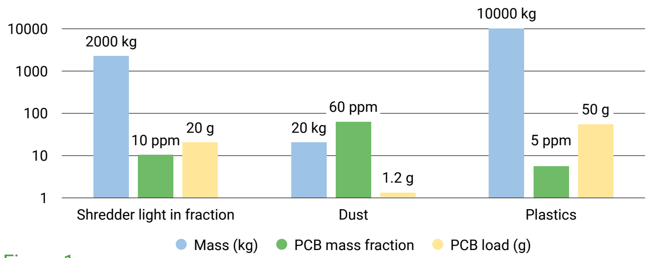



Figure 1

The WEEE treatment standard SN EN 50625 as well as the technical specifications Swico/SENS introduce quantitative indicators, often accompanied by limit or target values, to monitor the performance of WEEE treatment operations. In the 'Recovery' dimension, such indicators include the recycling and recovery rates. In the 'Detox' dimension, two of these indicators are the mass fractions of PCBs and cadmium in fine non-metallic fractions from mechanical treatment (e.g. shredder light fraction, dust or fine plastic fractions). The mass fractions of PCB and cadmium in the fine none-metallic fraction are considered as indicators of the depollution performance, under the assumption that higher mass fractions are due to insufficient manual depollution.

However, these indicators suffer from a main limitation: mass fraction-based indicators do not consider absolute loads (in kg) of hazardous substances flowing through WEEE treatment systems. They focus on relative levels (in % or ppm[1]). Under that view, a dust fraction with a mass of 20 kg and a PCB mass fraction of 60 ppm would 'look worse' than a shredder light fraction (SLF, also known as RESH) having a mass of 2'000 kg and a PCB mass fraction of 10 ppm. However, in absolute terms, the dust fraction contains 1.2 grams of PCBs whereas the shredder light fraction contains 10 grams of PCBs (see Figure 1). An even more problematic case is that of residual PCBs in plastic fractions sent for recycling: although having only low PCB mass fractions, the total loads can be high due to the total mass of plastics sent for recycling. The fate of PCBs in plastic recycling operations is not well documented, the risk however exists that such hazardous substances are 'kept in the loop', recycled together with the polymers.

[1] Often incorrectly referred to as 'concentration', which refers to a mass per unit of volume (e.g. in kg/m$^3$). A mass fraction can be expressed in ppm. 1 ppm = 1 part per million = 1 mg/kg = 0.0001%

In this context, a working group of the TK Swico-SENS was set up at the end of 2018 to revise the set of indicators used for the monitoring of hazardous substances removal during WEEE treatment.

Initial work based on results of chemical analyses and batch tests conducted between 2015 and 2017 provided interesting information on the loads of hazardous substances flowing through the Swiss WEEE treatment system. Results indicate that, as far as PCBs are concerned, although mass fractions are on average ten times higher in SLF/dust fractions than in plastic fractions, absolute loads could be in the same order of magnitude. A concerning amount of PCBs could therefore be present in plastic fractions delivered to plastic recyclers, with an uncertain fate. As far as cadmium is concerned, results also indicate that significant quantities are found in plastic fractions. This cadmium load can partially be explained by the use of cadmium as plastic additive in the past. In contrast, PCB in plastic fractions most probably result from cross-contamination. These findings should be considered as indicative only, as information gaps exist in the data collected so far.

In the future, the working group will develop a new, more relevant, set of indicators that not only consider mass fractions but also loads and downstream fate. It should allow for more meaningful comparisons between recyclers, as well as over time for a single recycler. Furthermore, the range of substances considered could be extended to include additional hazardous substances. Costs related to chemical analyses will also be considered, as the goal is not to bring an additional financial burden to recycling partners. It is possible that in the future analyses are required per sampling campaign (more fractions, more substances analysed), but that the frequency of such sampling campaigns diminishes.

Roman Eppenberger
Technology & Quality,
SENS Foundation

‘Currently, the maximum permissible copper mass fraction in shredder residues is set at 1%, with a tolerance of 4%. However, the reflection on loads could also be applied to copper in residues. Indeed, by calculating the copper load, we obtain a better estimate of the actual quantity of metal “lost”, and therefore of the efficiency of the metal recovery process, than by considering the percentage of copper in shredder residues. The thresholds currently in use could therefore be questioned.’

# Avoiding mercury emissions during manual flat-panel display disassembly

Heinz Böni

**Older LCD flat-panel displays feature mercury-containing fluorescent tubes to illuminate the image-transmitting surface. They must be removed from the equipment and disposed of in a special process. Since they are very thin, well-trained staff are needed to extract them. The SN EN 50625 standard specifies that 95 % of the tubes must remain intact during manual disassembly. Swico's Technical Commission carried out a pollutant removal test with five recycling companies in 2018 to verify whether this requirement could be met.**

Flat-panel display technology has developed dramatically over the last 10 years. Now that flat-panel displays with LED backlighting have become widespread, thin OLED screens without backlighting are increasingly being offered in laptops and TVs. But older flat-panel displays still have mercury-containing backlights, which means there are special requirements for their disposal. For example, they must be removed with great care during the manual disassembly process so as to prevent breakage and mercury leakage. Once the backlights have been extracted, they must be disposed of in special facilities. To remove the pollutants in a way that is kind to both human health and the environment, the technical specifications set down in the SN EN 50625 standard require 95 % of the tubes to remain intact. In 2018, Swico's Technical Commission required all recycling companies to carry out a pollutant removal test with at least 3 tonnes or 150 pieces of equipment to verify compliance with this standard.

In total, just under 10 tonnes or 1,400 pieces of equipment were dismantled in five plants. 40 % of this equipment were laptops, 30 % PC monitors and 40 % flat-screen TVs. On average, 28 % of these had LED backlights, which were excluded from the test. This was also the case for approx 15 % to 30 % of the laptops, 15 % to 40 % of the TVs and roughly 10 % to 30% of the PC monitors. The percentage of LED appliances has thus increased noticeably compared to 2016 (see the 2017 technical report: TVs 11% to 26 %, PC monitors 0 % to 12 %). (See table)

Quoted studies:

- ↗ "Disposal of Flat Panel Display Monitors in Switzerland – Final Report", Swico Recycling, 3.2011
- ↗ "Anforderungen an die Behandlung spezifischer Elektroaltgeräte unter Ressourcen- und Schadstoffaspekten", Umweltbundesamt, DE, ISSN 1862-4359, 2016
- ↗ S. 391-398, Gefahrstoffe - Reinhaltung der Luft, Fachmagazin Deutschland, Nr. 10 10/2018

| Company | Dismantled FPD devices (number) | | | | | | | | CCFL backlights | | | Quality of pollutant removal (% intact CCFL) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Laptop-FPD | | PC-FPD | | TV-FPD | | TOTAL | | Total removed | Breakage before dismantling | Breakage from dismantling | |
| | CCFL | LED | CCFL | LED | CCFL | LED | CCFL | LED | (g) | (g) | (g) | |
| Company 1 | 0 | 0 | 75 | 8 | 83 | 16 | 158 | 24 | 8’999 | 557 | 18 | **99.79 %** |
| | | | | **10 %** | | **16 %** | | **13 %** | | **6.18 %** | **0.21 %** | |
| Company 2 | 337 | 161 | 127 | 52 | 83 | 48 | 547 | 261 | 8’650 | 1’261 | 292 | **96.05 %** |
| | | **32 %** | | **29 %** | | **37 %** | | **32 %** | | **14.58 %** | **3.95 %** | |
| Company 3 | 0 | 0 | 0 | 0 | 176 | 83 | 176 | 83 | 19’001 | 2’549 | 850 | **94.83 %** |
| | | | | | | **32 %** | | **32 %** | | **13.42 %** | **5.17 %** | |
| Company 4 | 2 | 0 | 108 | 0 | 22 | 11 | 0 | 0 | 2’328 | 144 | 70 | **96.82 %** |
| | | **0 %** | | | | **33 %** | | | | **6.16 %** | **3.18 %** | |
| Company 5 | 50 | 0 | 54 | 7 | 30 | 20 | 134 | 27 | 5’710 | 156 | 156 | **97.19 %** |
| | | **0 %** | | **11 %** | | **40 %** | | **17 %** | | **2.73 %** | **2.81 %** | |
| **TOTAL** | 389 | 161 | 364 | 67 | 394 | 178 | 1015 | 395 | 44’688 | 4’666 | 1’385 | **96.54 %** |
| | | **29 %** | | **16 %** | | **31 %** | | **28 %** | | **10.44 %** | **3.46 %** | |
| | | **ca. 30 %** | | **10–30 %** | | **15–40 %** | | **15–30 %** | | | | |
| | | 550 | | 431 | | 572 | | 1410 | | | | |
| | | 39 % | | 31 % | | 41 % | | | | | | |

**FPD** Flat Panel Displays
**CCFL** Cold Cathode Fluorescent Lamp

Table 1: Comparison of the quality of pollutant removal from background lighting in flat-panel displays from various companies (2018)

The pollutant removal tests revealed that, on average, 3 % to 15 % of the mercury-containing backlights had already broken during dismantling, despite being transported in pallets and frames. These results reflect findings from Germany (UBA 2017), where around 20 % and 13 % of tubes removed from televisions and PC monitors respectively had already been damaged.

Manually dismantling a PC monitor

During manual dismantling as part of the test, 0 % to 5.17 % of the still-intact backlighting was disassembled by well-trained employees. The companies involved were thus all able to comply with the requirement set down in the standard. However, it is important to bear in mind that the test conditions are not necessarily consistent with everyday life. In day-to-day operation, this strict requirement tends to be more difficult to meet.

Mercury is the only metal that is liquid at room temperature. It evaporates at room temperature, which is why workplace exposure is of particular interest when manually dismantling backlights containing mercury. To estimate the possible exposure risks, individual companies carried out workplace measurements in cooperation with SUVA (the Swiss National Accident Insurance Fund) or by

Background lighting containing mercury

engaging specialised companies. Altola AG, which had the measurements carried out by Carbotech AG, deserves special mention as a model example. In 2017 and 2018, personal and stationary measurements were carried out. During LCD disassembly, the MAK value (MAK= maximum workplace concentration) for metallic mercury of 50 µg/m$^3$ was more than 30 times lower at 1.5 µg/m$^3$ for personal measurements, while the measured value of 2.1 µg/m$^3$ for stationary measurements was around 20 times lower. As a general recommendation for occupational health and safety protection, and irrespective of the mercury issue, the authors advise that wet cleaning of work surfaces be carried out as well as using industrial vacuum cleaners with particle filters (filter class H) to clean hall floors. Dry wiping should generally be avoided to prevent stirring up dust.

Measurements in Germany showed slightly higher values. At a workplace featuring workbench extraction, an average concentration of 1.8 µg/m$^3$ (max. 6.4 µg/m$^3$) was found at the worker's head height. Where a workplace was unprotected, the value depending on the number of tubes already destroyed was 6.8 µg/m$^3$ to 17.1 µg/m$^3$ and 20.2 µg/m$^3$ when all the tubes were completely destroyed (UBA 2017). A recently published study revealed values in the range of the Carbotech AG results (Wegscheider 2018), both for dismantling workplaces with and without workplace extraction.

As has already been established, the collection barrels containing broken tubes are the largest source of emissions (Swico 2011 and Wegscheider 2018). Values of over 1,000 µg/m$^3$ and of 180 µg/m$^3$ were measured inside and directly above the barrel respectively, with Wegscheider measuring concentration peaks of over 800 µg/m$^3$ above the barrel. A barrel with a smaller round opening 30 cm above it still produced 80 µg/m$^3$; in the breathing zone, the value was below the 10 µg/m$^3$ measurement limit. Mercury concentrations of between 10 µg/m$^3$ and 100 µg/m$^3$ are also measured in open collection containers with intact tubes, which indicates that illuminants broke during storage. The concentration was below 2 µg/m$^3$ in the breathing zone. Special care should thus be taken when handling both intact and defective tubes.

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Solid Alternative Fuels Manager
and Member of the Executive Board,
↗ www.altola.ch

What are the most important/surprising findings from the mercury measurements?

'The measurement campaigns confirmed our expectations. Dismantling mercury-containing backlights illustrates the importance of properly coordinated technical, organisational and personal (TOP) protective measures. The work must be closely monitored if good results are to be achieved in the long term.'

# WEEE plastics – State of affairs

Arthur Haarman and Michael Gasser

**The WEEE plastic recycling industry has been plagued by a lot of challenges in the past, and 2018 has been no different. The recycling of WEEE plastics is currently facing technical, regulatory and economic challenges, despite being widely promoted due to environmental benefits and circular economy objectives.**

**WEEE plastics recycling in a nutshell**
WEEE plastics represent on average about a fourth of WEEE by weight and consist of a complex mixture of different polymers containing a wide range of additives such as flame retardants, fillers, pigments and stabilisers (Figure 1). HIPS, ABS, PC-ABS and PP are the most commonly found polymers in WEEE. They can be mechanically separated from each other at a high degree of purity, using a combination of technologies that includes density separation, infrared and x-ray transmission sorting and triboelectrostatic separation. Recycled HIPS, ABS, PC-ABS and PP pellets produced in state-of-the-art recycling facilities can retain sufficiently good technical properties to replace virgin materials in new products. Other polymers found in WEEE are usually not recovered unless they are particularly valuable and can easily be removed during manual dismantling (e.g. PMMA from flat-panel displays).

However, the complexity of plastic mixtures resulting from WEEE pre-processing and limitations in current plastic sorting technologies lead to relatively high material losses. The additive content can have a detrimental effect on the selectivity of density sorting, infrared technologies are often unable to sort dark coloured plastics, and tribo-electric separation is very sensitive to moisture. As a result, typically less than half of the input to WEEE plastic recyclers is effectively recycled. What is not recycled has to be sent for energy recovery (waste incinerators with energy recovery or as a fuel substitute in cement kilns). Manual separation of WEEE plastic prior to mechanical processing often results in higher yields, but is often prohibitively expensive due to high labor costs.

**Brominated flame retardants – Current levels and future limits**
An important family of WEEE plastic additives are brominated flame retardants (BFR), often used in EEE plastics to reduce their flammability, particularly in casings, insulating foams, printed circuit boards, cables and connectors. Evidence of the persistence, bioaccumulation potential and toxicity of some BFR compounds has led to their classification as persistent organic pollutants (POP) under the international Stockholm Convention. POP-BFRs are PBDEs (pentaBDE, octaBDE and decaBDE), HBCDD and hexaBB. Their manufacture and use is prohibited with exemptions in some applications.

Wastes containing POPs above a certain limit value ('low POP content') must be treated to destroy these substances. WEEE plastics containing POP-BFRs above the low POP content may therefore not be recycled, unless they undergo a separation process producing a BFR-rich fraction that needs to be disposed of, and a BFR-poor fraction below the 'low POP content' that can be recycled (Figure 2). Due to the difficulty of measuring POPs themselves, bromine is used as an operational tracer in recycling operations. WEEE plastics may only be recycled if their total bromine content is below 2,000 ppm as set by the SN EN 50625 standard series.

BFRs are not found at uniform levels across WEEE categories (Figure 3). The highest concentrations are found in plastics from cathode ray tubes (CRT) and, to a lesser extent, flat-panel displays (FPD). Levels are smaller in small household appliances (SHA) and large household appliances (LHA), and lowest in cooling and freezing appliances (CFA).

The EU POP Regulation, which implements the Stockholm Convention at the EU level, is currently under recast. Heated discussions have been taking place since a first list of proposed amendments was published by the European Parliament in May 2018. Particularly contentious are the limit values for substances, mixtures and articles containing decaBDE. DecaBDE is the latest addition to the list of POP-BFRs, and is still widely found in WEEE plastic streams despite restrictions having been in place for over a decade. While the legislative process is still ongoing, a limit value of 500 ppm for the sum of PBDEs seems to have been agreed upon by both the European Parliament and Council. The limit value covers decaBDE, pentaBDE and octaBDE and is valid for both wastes (Annex IV) and products (Annex I). If confirmed, WEEE plastic mixtures containing more than 500 ppm PBDEs would be considered 'POP waste' and downstream separation of the POP content would have to be documented. Furthermore, the product (recycled pellets) would need to contain less than 500 ppm PBDEs. The newly proposed limit values are considerably lower than the ones currently applicable[1]. The operational threshold of 2,000 ppm for WEEE plastic recycling defined in the SN EN 50625 standard series may have to be revisited and eventually reduced, which could require additional investments for plant operators. Furthermore, a higher administrative burden for the transport and treatment of WEEE plastics could drive costs upwards, and recycling rates could decrease due to higher amounts needing to be disposed of.

**Plastic scrap market under deep restructuring**
China's sudden decision to shut its doors on imports of scrap materials in 2018 had the effect of a seismic shock and shifted the global plastic scrap trade patterns (WasteDive, 2018). Europe, the US and various developing nations have long relied on China to absorb their plastic scrap. Following the import ban, exports to other Asian countries such as Malaysia, Vietnam and Thailand surged. These countries were however quick to introduce measures limiting imports of plastic waste. As a result, Europe's plastic scrap markets were flooded, and scrap prices remain low to this day. Recycled plastic granulates are however in great demand and prices have remained stable over the past year, despite price falls in virgin polymer prices. The current situation, with high

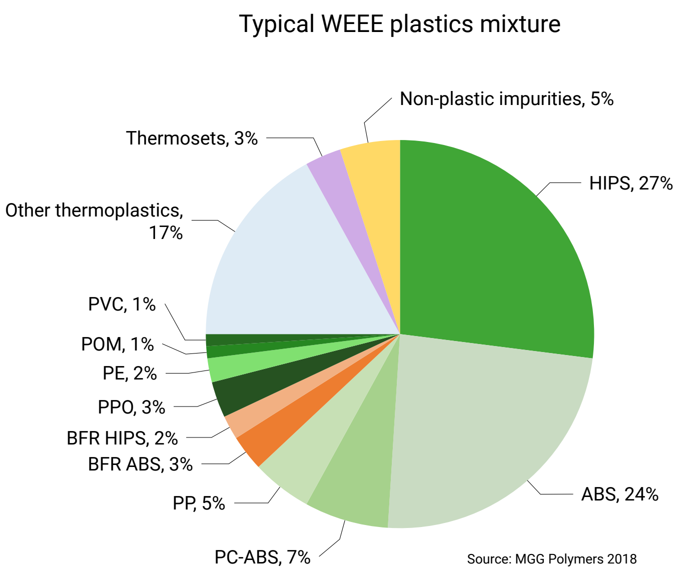


Figure 1: Slijkhuis, C., 2018. Recycling plastics from WEEE requiring a sensible and practical approach on POPs, in: Going Green Care Innovation 2018.

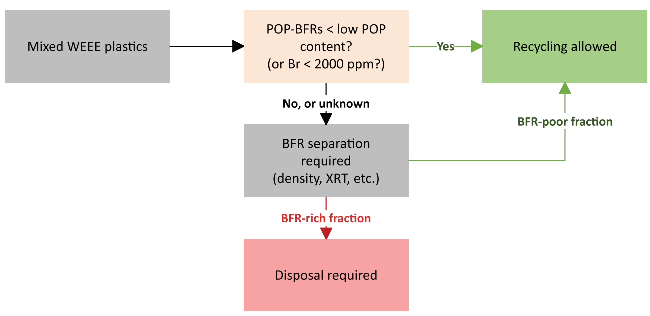


Figure 2: Treatment of WEEE plastics according to SN EN 50625

[1] In wastes (POP regulation): 1'000 ppm for the sum of penta- and octa-BDE. In products (RoHS Directive): 1'000 ppm for the sum of penta-, octa- and deca-BDE.

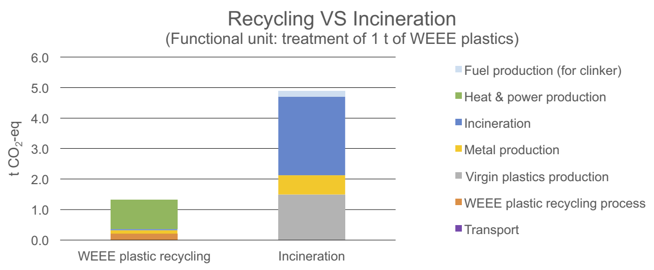


Figure 3: Levels of brominated flame retardants in different WEEE streams (Source: Wäger & Hischier 2015)

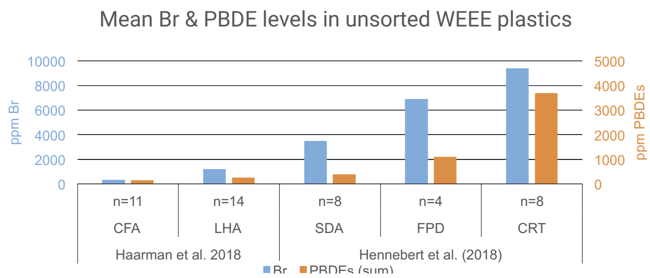


Figure 4: Results of LCA study conducted by Empa in 2015

availability and low price of scrap coupled with stable prices of recyclates, is actually beneficial for the European plastic recycling industry. Investments are being made and processing capacity is reportedly ramping up (Bundesverband Sekundärrohstoffe, 2018).

While recent market developments may be good news for the European plastic recycling industry, the drop in plastic scrap prices burdens WEEE recyclers. Often, the costs of transport to a plastic recycling facility may be higher than the price obtained. Regardless, recycling remains economically superior as long as it is less costly than incineration.

**Consequences of decreasing WEEE plastic recycling**

Stricter regulatory restrictions and unstable market conditions endanger the viability of WEEE plastic recycling in Europe. Unfavourable conditions could lead to less WEEE plastics being recycled, and therefore more being incinerated, and may increase exports to countries where waste treatment has little regulatory oversight. This would directly impact the overall recycling rates, treatment costs and environmental impacts.

From an environmental perspective, the recycling of WEEE plastics is clearly preferable to their incineration in a MSWI plant (with energy recovery, R1 value of 64% assumed) (Wäger and Hischier, 2015). Particularly in the global warming potential ('carbon footprint') impacts of incineration are almost four times as high as those of recycling (Figure 3). The main difference is the incineration process itself, which directly generates $CO_2$ emissions, while the impacts of transporting the plastic to a recycling facility are negligible even for longer distances (1'000 km).

A decrease in recycling rates may thus jeopardise Europe's commitment to lower its carbon footprint. Due to the lack of a multi-faceted study, also considering health risks, economic and social aspects, it remains unclear whether such a strategy is a viable trade-off.

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- ↗ WasteDive, 2018. 5 charts that show the trade flow effects of China's import policies.

# CHAPTER

## IN AN INTERNATIONAL COMPARISO
## ONE STEP AHEAD.

# THE NEXT

ON, SWITZERLAND IS ALREADY

# How well is the recycling potential of electronic waste being used today?

Roger Gnos and Rolf Widmer

**The shopping basket analysis (SBA) 2.0 developed by Swico Recycling is used to determine in a differentiated manner the return flow of waste electrical equipment (WEEE), and this can be used to update the advance recycling fee (ARF) levied on the equipment, among other things. The compensation for the processed quantities is indexed in the Swico recycling system. In other words, it is linked to the equipment mix, which is also determined with the SBA. At present, a combined SBA and analysis of the input's material composition is being carried out in an extended batch test to investigate the recycling and utilisation potential of the Swico-Mix treatment stream.**


Figure 1: Finely disassembled ghetto blaster

**Key data sources: shopping basket analysis and batch tests**

The mobile and stationary shopping basket analysis (SBA) 2.0 developed by Swico Recycling is a vital tool for determining the differentiated return flow of waste electrical and electronic equipment (WEEE). To name but a couple of examples, the resulting data is used as a basis for calculating or updating the advance recycling fee (ARF), which is levied on new equipment. When data is collected, the WEEE is divided into approximately 35 different categories and individually weighed and described – for example, information is provided on whether a piece of equipment has been stripped of its recyclables or whether it still contains lithium batteries.

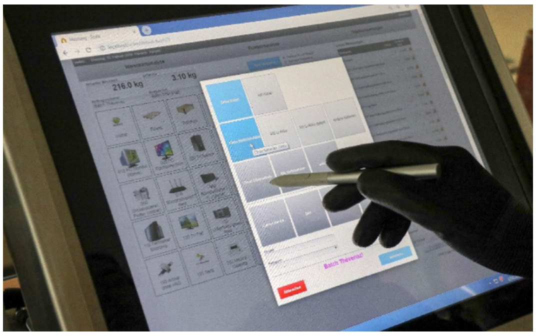


Figure 2: SBA 2.0 touch panel

The compensation for the recycling service is indexed in the Swico recycling system. This means it is linked, among other things, to the individual equipment mix, which is also determined from the SBA data. The recycling and utilisation potential of the Swico-Mix treatment stream is currently being examined in a complex batch test in addition to the usual analysis of the output fractions by means of analysing the batch input (Swico small appliances without monitors). Between 2015 and 2016, six Swico recycling partners with different mechanical processing activities carried out a batch test on their Swico-Mix treatment streams with ready-made, i.e. as identical as possible, input compositions for the first time (cf. ↗ 2017 technical report). The aim of the test was to obtain a performance comparison between these companies in addition to determining the individually achieved recycling and utilisation rates as well as pollutant removal as usual.

**Determining the recycling potential**

The current 2018/19 Swico-Mix batch test is set up to examine a single recycling company's processing performance and quality in more detail. This process (see Figure 3) starts with 'blank' container elimination (pallets with three frames) from the small appliance mix in the recycling company's input stream. These ejected containers are transported unchanged from the collection point to a specialised dismantling plant, where they are temporarily stored and analysed by the SBA team (see Figure 2). Each individual piece of equipment is therefore weighed, assigned to one of the 35 Swico equipment categories and itemised with further details. The SBA software instructs the team to either reject the equipment as 'not Swico-Mix' or to allow it to run in batch mode. Every tenth approved piece of equipment is selected by the software so the material composition can be analysed in detail, given an identification number (barcode) and then sent for fine dismantling (see Figure 1).

**Swico-mix batch test** (all material flows in tons)

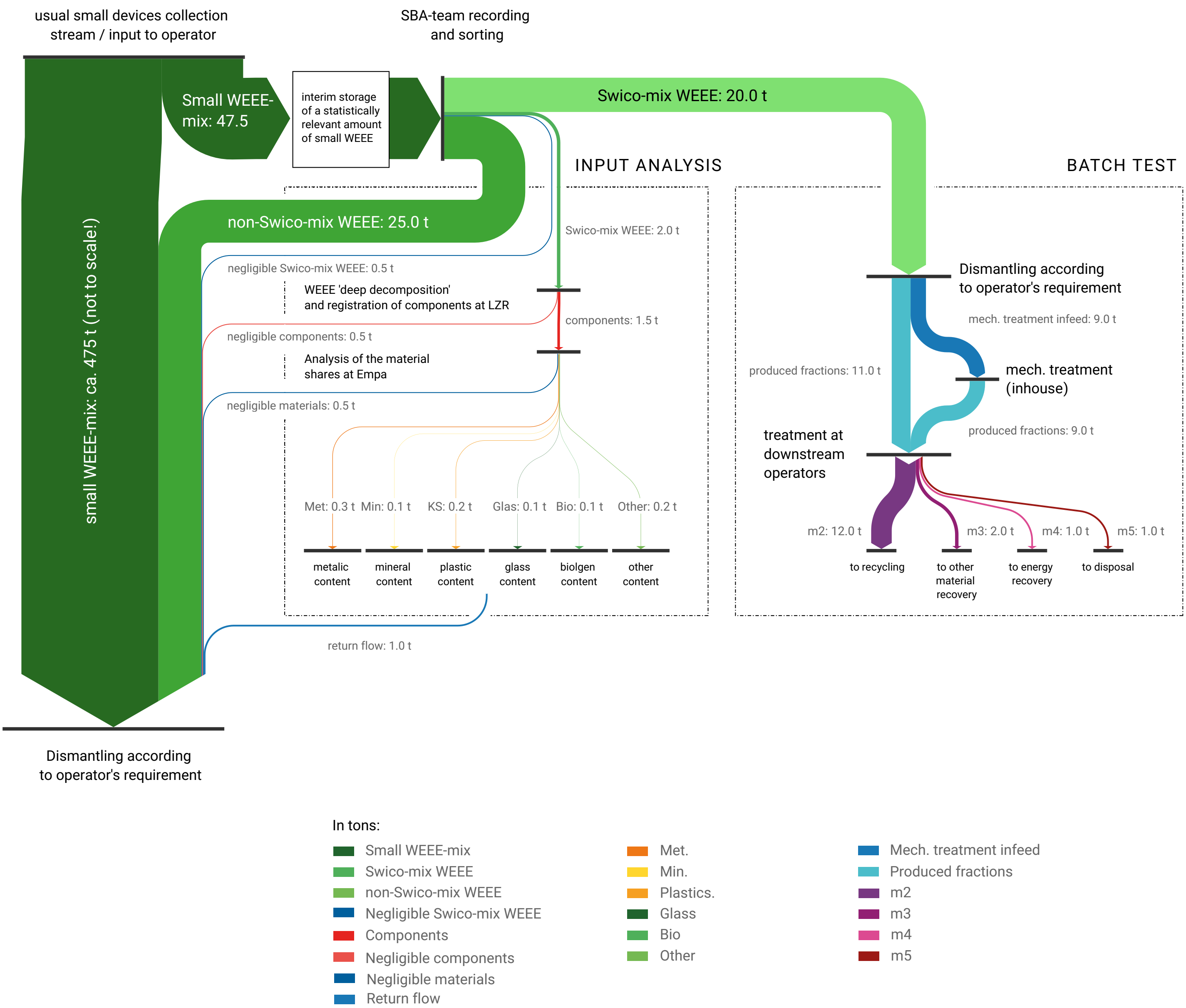



Figure 3: Sankey diagram of the Swico-Mix batch test's material flows.
The values given are the flows estimated for test planning.


Figure 4: Equipment sorted and registered for the batch test following the SBA

Once this process is complete, all WEEE is divided into three groups: ‘non Swico-Mix’ (WEEE returning to normal treatment), ‘Swico-Mix’ (WEEE intended for batch testing) and WEEE for ‘fine dismantling’ (see Figure 4).

The WEEE selected for the batch test with a given target weight of 20 t in total have the pollutants removed in the usual way, are mechanically processed and the groups produced are put to final use in the established downstream treatments. However, the analysis of the output groups from primary treatment is extended compared to routine treatment, so as to examine pollutants from electrolytic capacitors or the distribution of detectable pollutants over different groups, for example. The weights of the materials that have finally been recovered in terms of substance and/or energy are converted to the achieved recycling and utilisation rates with the ‘RepTool’ software.

The WEEE intended for fine dismantling (11.1 % = 1:9 of the batch weight) is manually disassembled into its individual parts as far as possible. Components such as printed circuit boards are opened up further using conventional laboratory processing methods with a view to determining the content of various materials, particularly certain metals and polymers. These contents are extrapolated to the total input, taking uncertainties into account. The yield of the examined materials can thus ultimately be determined over the entire treatment chain. This provision extends beyond the requirements set down in the SN EN 50625 series of standards, which stipulates that the yield to be verified in smelting plants is at least 90 % for gold, silver, palladium and copper only.

### Initial results

The table below shows the batch test input data. This test's final results are expected towards the end of the first half of 2019.

| Classification | Number | Weight/kg | Description |
|---|---|---|---|
| 'Not Swico-Mix' | 1,659 | 12,974.32 | Eliminated material that does not belong to 'Swico-Mix' |
| 'Swico-Mix' | 8,261 | 22,473.02 | 'Swico-Mix' material that is processed in the batch test |
| 'Input analysis' | 1,096 | 4,397.85 | 'Swico-Mix' material that is finely dismantled |
| 'Other' | 110 | 282.03 | This is 110 pieces of neglected WEEE from the SBA operational tests |
| **Total** | **11,126** | **40,127.22** | **Total quantity of all WEEE examined** |

Table 1: Results of the SBA sorting show that the targeted
– batch weight of 20,000 kg to be processed in the test was exceeded by approx. 2,500 kg (approx. +10 %)
– WEEE quantity diverted for fine dismantling (11.1%) was exceeded by +13% in terms of number and by +2 % in terms of weight.

'It is in our own interests to have in-depth knowledge of our goods input's recycling potential and, at the same time, of just how selective our processing activities are with regard to recyclables and pollutants. Making progress in this field is part of our DNA!'

Markus Stengele
SOREC AG, Gossau
↗ www.sorec.ch

# Recycling rate of large household appliances

Geri Hug and Anahide Bondolfi

**The target recycling rate (RR) for large household appliances in Switzerland is 75 %. In the past, it has been apparent that individual recyclers have problems reaching this value, since the RR depends on the composition of the individual appliances and the equipment mix. This is precisely why the SENS TC collects detailed data on the composition per equipment type and searches for new methods to define RR targets more appropriately.**

**Starting situation**
Batch tests are performed to determine in a standardised manner the recycling and utilisation rate (RUR) per treatment stream within an individual recycling company. The RUR is intended to assess recycling companies' utilisation performance. For assessment purposes, specific RUR minimum requirements for material and energy recovery are defined using the WEEE Directive as a basis. The recycling rate (RR) is defined as the proportion of materials from equipment processing that are recycled. The utilisation rate (UR) is the sum of the RR and the proportion of materials to be diverted towards energy recovery.

The minimum requirement for the RUR of large household appliances (HHAs) is 75 % (RR) and 80 % (UR) respectively. Since 2014, recycling companies in Switzerland have had problems meeting the 75 % minimum requirement for the RR. There can be several reasons for a lower RR.

On the recycling company's side:

– No or little recovery of recyclable plastics and glass or concrete
– Low efficiency in metal recovery with high metal losses, particularly in the fine, (largely) non-metallic shredder residue (ASR, "RESH")

In contrast, other reasons have nothing to do with the recycling company:

– Newer equipment weighs less, has a higher plastic content and fewer metals
– The mix of equipment to be treated has changed, with less metal-rich equipment.

**Analysing the input composition and the recyclable yields**
Since no reliable data on the amounts of metal, plastic, glass and concrete was available up until a year ago, SENS launched a project to determine the proportions of metals (iron, copper and aluminium), plastics, glass and concrete per per type of large household appliance equipment type. To this end, approx. 10 t each of the dishwasher, tumble dryer, washing machine and cooker/oven appliance types had their pollutants and impurities removed and were mechanically processed in separate campaigns at individual recycling companies. Additionally, approximately 50 appliances per appliance type were manually disassembled by a dismantling plant. As well as

the number of appliances, the input weights and all the output fractions were calculated. An average weight was calculated for each appliance type (see Figure 1).

In further steps, the material compositions for the fractions were determined either by taking additional separation steps or by conducting analyses. The data entered in WF RepTool was used to calculate the RURs achieved per appliance type. The initial results are shown in Figure 2. The metal input composition illustrates how much metal could theoretically be utilised if there were no losses during processing. Other similar campaigns will be carried out in 2019 to make the data more reliable and comprehensive.

**Outlook**
Notwithstanding the requirements set down in the WEEE Directive, a comparison of the theoretical values can be used to assess the performance of the recycling process examined. The SENS TC is planning to proceed according to the following approaches (among others) in future:

- Definition of RR target values in relation to weight-related target values: e.g. 98 % or 100 % of the theoretical metal content must be achieved upstream of steelworks
- Definition of RR target values with respect to the ecological significance, e.g. printed circuit boards (precious metals and rare metals)
- Checking the plausibility of the achieved RRs by analysing the fine non-metallic shredder residue (ASR or "RESH") and by comparing with theoretically achievable RRs per appliance type (see Figure 2), depending on the appliance mix in the input.

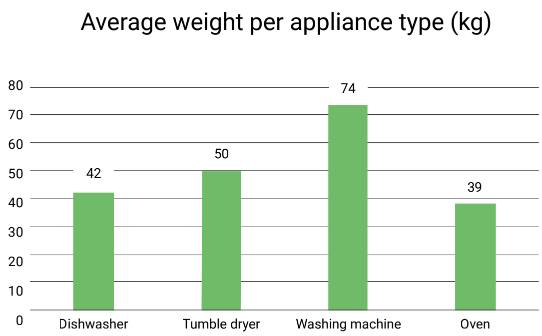



Figure 1

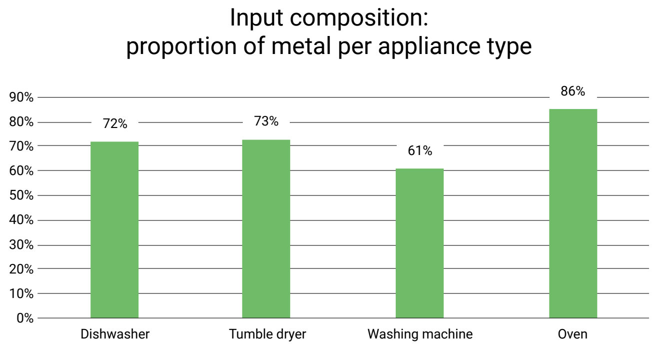



Figure 2

The achievable RR essentially depends on the composition of the appliance mix per batch. The applicability of the RR minimum requirements according to the WEEE Directive is therefore more than called into question. This is particularly the case because the requirement was increased by 5 % to 80 % with effect from 15 August 2015 in the revised WEEE Directive. At European level, there were additional uncertainties that are not dealt with in detail here, e.g. when the waste property ends and where the RR should be determined: before or after the final recycling process (usually the smelting plant)? The Swico/SENS TC has decided to keep the previous values on account of the various unanswered questions.

# HEADING IN THE RIGHT DIRECTION

BEING SUSTAINABLY INNOVATIVE IS THE WAY FORWARD.

# Dealing with broken illuminants and ADR-compliant containers

Roman Eppenberger

**Correctly recycling mercury-containing illuminants remains an important aspect of SENS and SLRS. Lamp breakage is now being added to the list too.**

The take-back quantities for lamps remained at a constantly high level overall in 2018 too. A slight shift from rod-shaped to non-rod-shaped lamps is recognisable. Even though LEDs are increasingly being integrated in new installations, SENS eRecycling and SLRS assume that mercury-containing lamps will still be recycled at today's level for several years to come. So a marked decline in the take-back volume isn't to be expected just yet. The recycling of mercury- containing lamps thus remains an ecologically important part of recycling.

One topic that has received little attention for a long time is the breakage of lamps, which is referred to as 'illuminant breakage'. The majority of mercury-containing lamps are made of glass, meaning they are prone to breakage. What happens to the broken lamps? Broken lamps are either collected and delivered to the illuminant recycler or thrown out with the waste – and thus into the waste incineration plant (WIP). To date, there is no standardised solution in Switzerland.

We are repeatedly asked what ought to happen with broken lamps, so SENS eRecycling and SLRS have decided to create a uniform regulation for illuminant breakage. In terms of a general ecological view, we consider separate collection when the illuminant breakage occurs to be the most sensible and best solution. Even if it is a modest amount (SENS eRecycling assumes less than 5 % of the total amount), it should not end up in the WIP. Broken lamps should be recycled. In specific terms, this means that all collection points are equipped with a collection container for broken Lamps.

The collection container is a 30 litre container with a lid. A problem needs to be solved in this regard before distribution. The vacuum in the collection container means that the fluorescent powder or gaseous mercury can be stirred up when the lid is removed and the operating personnel can be exposed to a high mercury load. SENS eRecycling has contacted SUVA (the Swiss National Accident Insurance Fund) to develop appropriate solutions. The approach is that the lid is not firmly closed when closing but, rather,

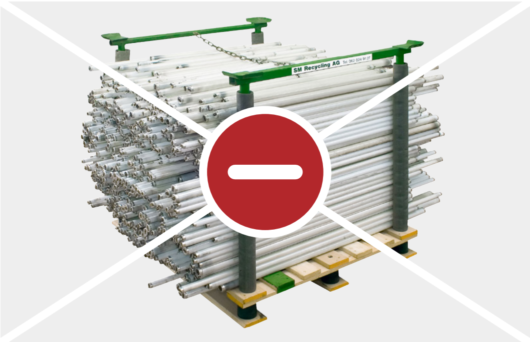
lamp breakage

only placed on the container so that a small opening remains. When opening, the lid doesn't need to be lifted; instead, it's only pushed to the side. We do not expect any impairment for personnel with this solution. As soon as the clarification work is complete and an agreeable solution has been found with SUVA, container procurement and distribution on the market can both commence.

The roll-out of the ADR-compliant inliners for post pallets started in early 2018. Roman Eppenberger, who has been responsible for collection points since spring 2018, is regularly on site and supports the collection points by providing information and instructions. While implementation is not yet complete, most of it is ongoing. Especially at smaller collection points, it takes a long time for a post pallet to be filled and made ready for collection. Only then can work be started with an empty post pallet and an ADR-compliant inliner. There is a video on the SENS eRecycling and SLRS websites explaining how to install this inliner.

At this point, it should again be clearly pointed out that the material dispatcher is responsible for ADR-compliant transport. However, the transporter is jointly responsible insofar as they believe it is obvious that a post pallet without an inliner is not packaged in accordance with the ADR.

Post pallet with inliner



Post pallet without inliner, red cross

# 25 years as a Swico and SENS auditor: Patrick Wäger is devoting his energies to new tasks

Heinz Böni

**As Patrick Wäger has been with us since day one, his name appeared in Swico Recycling's first activity report in 1994. Patrick Wäger has been an auditor since the Swico Recycling Guarantee was introduced on 1 April 1994. On 31 March 2019 – exactly 25 years later – he officially resigned.**

It all started in the 1994/1995 reporting year with 3,700 tonnes of processed waste electronic equipment per year: Swico had 46 Convention signatories and 12 licensed recycling companies on its books when it launched the recycling system. From the very outset, Empa was entrusted with the mandate of auditing the recycling companies and dismantling plants as an independent body. The team of auditors led by Kurt Münger was made up of seven people, including Patrick Wäger.

**From the pioneering phase to the European standard**

Patrick embodies the development of auditing activities for Swico and later for SENS like few others. From the pioneering phase, in which an auditing system including processing regulations for waste electronic equipment had to be developed from scratch on Swico's behalf, over the extension of the scope to include consumer electronics (among other things) and the strengthened cooperative relationship with SENS at inspection activity level, to the development of the SN EN 50 625 series of standards as the new norm for assessing recycling companies' activities, he's seen everything at close quarters as an auditor. Over the 25 years of cooperation, he had the pleasure of working with all the managing directors at SENS (Robbie Hediger, Corina Schneider, Patrick Lampert and Heidi Luck) and Swico (Jakob Hildebrand, Peter Bornand, Paul Brändli and Jean-Marc Hensch), as well as with more than 20 SENS and Swico auditors who were active during this time.

**A record-breaking number of audits**

During his time as a member and temporary deputy leader of the Empa audit team, Patrick probably conducted about 150 audits, many of them as lead auditor, together with SENS or Swico auditors. His auditing activities took him all over Switzerland – by train – and gave him insights into numerous recycling companies and dismantling plants. The list of recycling companies that he audited reads like a 'who's who' of the Swiss electrical and electronic recycling scene over the past 25 years. Some of the companies, such as Compaq, Drisa or UGE, no longer exist nowadays in the same form.

Patrick Wäger
Head of the Technology
and Society Department, Empa

'To have been involved in this pioneering project from the very beginning and to have contributed to the success story of the Swiss take-back systems for waste electrical and electronic equipment together with the players involved was a real privilege. It fills me with joy and probably a little pride too. I will always have fond memories of this extraordinarily exciting, instructive time and the people I was able to tread this path with!'

**Research as the backbone**
Due to his excellent knowledge of French (Patrick spent his childhood and teenage years as a 'Swiss abroad' in France, among other countries), the focus of his audit activities soon shifted to French-speaking Switzerland. Audits by Swiss recycling companies' follow-up handlers also regularly took him to Germany, France, the Netherlands and Austria. In addition to his auditing activities, Patrick has also repeatedly been involved in projects aimed at further developing the SENS and Swico Recycling take-back systems for waste electrical and electronic equipment in his capacity as a member of Empa's team of auditors. On behalf of the WEEE Forum and with the support of SENS and Swico Recycling, he therefore led a European study on defining brominated flame retardants in plastics from the processing of waste electrical and electronic equipment. This culminated in a publication in the renowned Environmental Science & Technology journal, which was awarded the title 'Best Policy Analysis Paper of 2011' in 2012.

**Appointment to the role of department manager**
When he was appointed Head of Empa's Technology & Society Department in May 2016, Patrick took on new responsibilities, which forced him to severely restrict his involvement in Empa's team of auditors. He is officially leaving the audit team on 31 March 2019 at his own request. We would like to thank him for 25 years of tireless commitment to SENS' and Swico Recycling's concerns and wish him all the best for the future!

# Recycling photovoltaics too

Roman Eppenberger

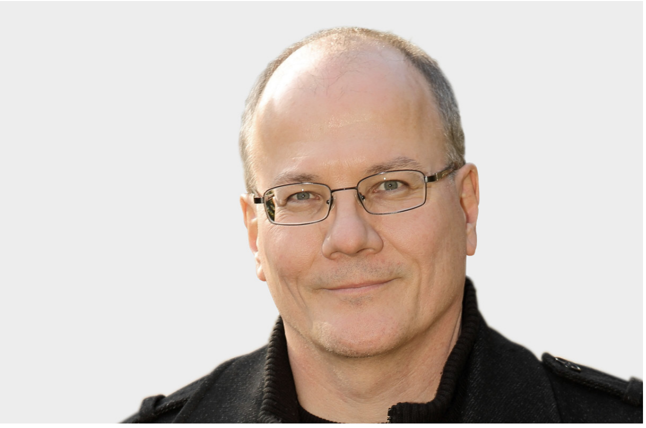
**Photovoltaic recycling is a Europe-wide topic. While the take-back quantities are still small, the potential is huge.**

The quantities of photovoltaic (PV) modules being taken back are still very low. The installed volume per year is far higher. This is considered to be positive, as it points towards the fact that installed PV modules have a long service life. The take-back quantity in 2018 was even down on 2017, because a recall by a manufacturer had increased the quantity at that time. The take-back volume is on the rise, but very moderately so.

However, the topic of PV is definitely one that the public is interested in: Spreitenbach's environment arena has dedicated a separate area to renewable energies – and thus to PV too. The environment arena's management staff is repeatedly asked whether PV modules are recycled at all, or it hears that PV modules are not being recycled. The environment arena therefore contacted SENS eRecycling to set up a PV recycling exhibition and to provide the public with correct information. There were ultimately two exhibitions.

A marble run, which playfully communicates the recycling of PV modules in the individual groups metal, glass and plastic, was set up in the Recyclingcity exhibition area. It's an exhibit for everyone and, according to the environment arena, is being actively used.


Exhibition OG2



Max Chopard-Acklin
Exhibitions Project Manager,
Switzerland Environment Arena

Statement on PV recycling exhibitions,
SENS Foundation

“The SENS Foundation’s interesting exhibitions on the topic of photovoltaic recycling go down well with visitors to the environment arena. They illustrate in an easy-to-understand way what components PV modules are made up of and that the majority of the materials used can be returned to the material cycle through the recycling process.”

The second exhibition is on the top floor in the renewable energies section. Questions about recycling are always asked on guided tours relating to renewable energies and thus to PV. Positioned at the exit to the stairwell, the subject of recycling PV modules can be integrated into the tour well. The audience can be given an overview of the groups being produced in a few short sentences.


Exhibition EG

One question that keeps cropping up is “Where are PV modules recycled?”. The answer is: like all other flat glass, PV modules are sent to and processed in the EU. SENS eRecycling therefore has the PV modules refurbished in Germany. There are no flat glass recyclers in Switzerland.

**Why isn’t it worthwhile to have one?**
Mainly for economic reasons, since glass is a material of little value. The metal content in a PV module is constantly decreasing and, from an economic point of view, plastic recycling is only associated with costs. No recyclers have dealt with that to date. SENS eRecycling is keen to see whether the Swiss recycling industry will address this issue.

# Controlled recovery of climate-changing gases from refrigerators

Geri Hug and Niklaus Renner

**The number of refrigerators that entered the reverse production process increased by 6% in 2018. Around 370,000 appliances were processed at Switzerland's three largest plants. The trend towards appliances with ever higher proportions of environmentally friendly VHCs (volatile hydrocarbons) has all but stagnated over the past year: 65% of appliances with VHC compressors were returned to the material cycle, while 70% with VHC foamed insulation were sent back. The ammonia-operated absorber appliances have been in decline for years, accounting for 2.5% at present. The environmentally harmful substances from the refrigerator return flow were recovered at great expense and destroyed in a controlled manner.**

**Relevance of refrigerator treatment**
The 90% recovery rate for both refrigerants and propellants that is to be achieved according to the Swico/SENS Technical Regulations and the CENELEC Standards[1] is significant in two respects. On the one hand, the VFCs (volatile fluorinated carbons) contained in compressors and PU insulation foams have to be removed from recycling processes and destroyed in a controlled manner, since they have an ozone-depleting effect. At the same time, these substances have a global warming potential that is about 1,000 to more than 10,000 times greater than that of $CO_2$. This is also why recovering the refrigerants and propellants, subsequently combusting them at high temperatures and converting them into $CO_2$ and into water, acids and salts (which have far less of an impact on the climate) makes a key contribution to environmental protection.

In 2018, for example, the amount of greenhouse gas saved by refrigerator recycling was more than 300,000 tonnes of $CO_2$ equivalents. Such an amount of carbon dioxide corresponds to the emissions given off by modern passenger cars over a total distance of 2.3 billion kilometres!

**High proportions of VHC compressors and VHC insulation foams**
The drop in the proportion of VFC-operated compressors that has been observed since 2003 and the simultaneous increase in the percentage of VHC compressors entering the recycling process was linear for a long time. The trend has sped up enormously since 2013. Whereas 60% of the VFC-type refrigeration systems were still being recycled in 2012 (the survey year), the figure was just 41% and 33% in 2015 and 2017 respectively. This percentage remained unchanged in 2018. In the same way, the proportion of VHC compressors rose steadily to 64.5% in 2018. The share of ammonia-containing absorber systems fell slightly from 3% to 2.5%.

The downward curve in the appliance housings' VFC-containing insulation foams, which is more or less parallel to the trend in compressors, also flattened last year, amounting to 31% in 2018. The proportion of appliance housings with VHC insulation accounted for just under 70%. The figures also remain practically unchanged compared to the previous year. Cf. Fig. 1.

[1] CENELEC SN EN 50625 2-3 standard and the 50625 3-4 technical specifications

## Declining recovery volumes

The amount of refrigerant recovered per appliance dropped from 70g (2017) to 57g in the current reporting period, while compressor oil fell from 168g to 138g – a reduction of around 18%. In the case of propellants, volumes fell from 39g/kg to 37g/kg of PU foam (-5%) over the same period (cf. Fig. 2). These declining recovery volumes are inconsistent with the constant ratios of VFC and VHC appliances. Higher proportions of the VHC appliances would have explained the decreases in the refrigerant and propellant volumes, since their filling quantities and concentrations in the PU foam are considerably lower than in the VFC appliances. But the discrepancy cannot be declared to be conclusive, because the circumstances have been found to be stagnating. Alleged reasons such as the appliance class being recorded incorrectly in some cases cannot be given, since the recovery volumes refer to the total number of treated appliances. It remains to be seen how the figures will develop over the course of 2019.

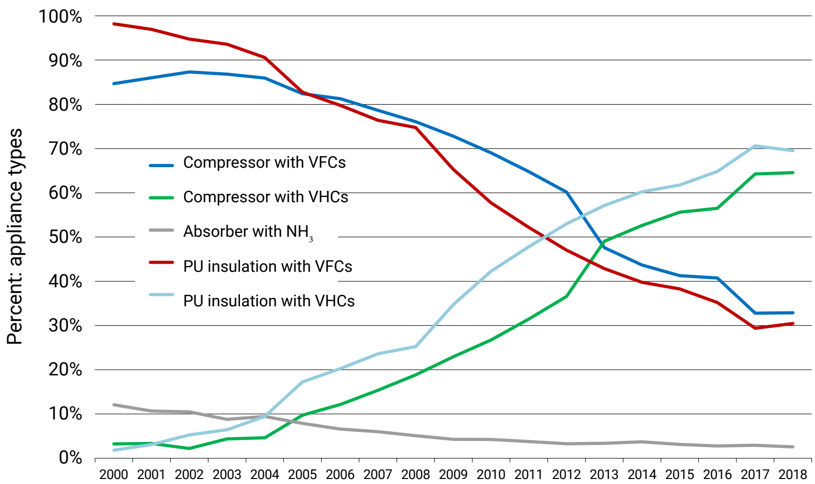



Figure 1: Proportions of the respective refrigeration appliance types in treatment stages 1 and 2 (percent)

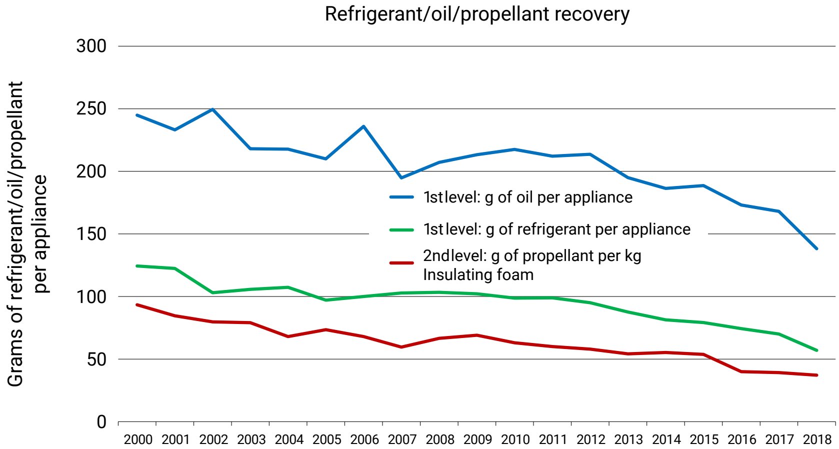



Figure 2: Refrigerant/compressor oil/propellant recovery (grams per appliance)

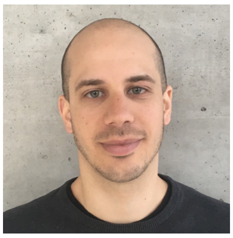
A look into a refrigerator treatment system

**Anahide Bondolfi**
**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 started working in the electronic waste sector in 2006 while writing her Master's thesis in South Africa, in collaboration with the Swiss Federal Laboratories for Materials Science and Technology (EMPA). Ms Bondolfi then spent nearly 10 years working as an environmental consultant and project manager at two Swiss environmental consulting companies (leBird in Prilly and Sofies in Geneva). In January 2017, she founded Abeco Sàrl. Ms Bondolfi has been a member of the Swico/SENS Technical Commission since 2015. She carries out nearly half the audits on the Swico and SENS dismantling workshops. Ms Bondolfi has also audited some recyclers and collection points for SENS since 2016.

**Heinz Böni**
**Head of the Swico Conformity Assessment Body 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.

**Flora Conte**
**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 SENS Technical Inspection, 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 management board of the SENS Foundation and is the Head of the Technology & Quality Division. In this position, he coordinates the Swico/SENS Technical Commission in conjunction with Heinz Böni.



**Michael Gasser**
**Swico Conformity Assessment Body 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 Technical Audit Department of SENS and Swico since 2017. He has recorded the annual material flows and audited Swico recyclers since 2018.

**Roger Gnos**
**Technical Inspection, Swico Hazardous Materials Officer and Member of the TC**
Roger Gnos has been heavily involved in recycling since 1991 and has experienced and helped to shape the evolution of waste electrical equipment recycling. He worked as a plant manager in an electronic waste processing company for almost 20 years. He has been working at Swico Recycling for around eight years, advising collection points and fulfilling the role of hazardous materials officer. But he is also fascinated by the technology and the people behind the recycling process.

**Arthur Haarman**

**Swico Conformity Assessment Body SN EN 50625, Empa**

Arthur Haarman completed a Master's degree in industrial ecology at the Delft University of Technology and Leiden University. Since 2015, he has worked as a research associate at Empa in the Technology and Society Department. His areas of expertise include the development of quantitative instruments such as material flow analyses and life cycle assessments for the optimisation of (electronic) waste management systems and the conception and evaluation of waste sampling and test campaigns. He is part of the Technical Audit Department of SENS and Swico and has audited Swico recyclers since 2017.

**Dr Geri Hug**

**SENS TC, IPSO ECO AG**

After studying chemistry and then completing his dissertation at the Institute of Organic Chemistry at the University of Zurich, Geri Hug worked as a research assistant and project manager at IPSO ECO AG in Rothenburg (formerly Roos+Partner AG based in Lucerne). He was a partner from 1994 to 2011 and also Managing Director of IPSO ECO AG from 1997 to 2016. Geri Hug has worked as an environmental consultant in various industries, supervising environmental audits and preparing environmental impact reports in accordance with the Swiss Ordinance on the Environmental Impact Assessment. He also prepared short reports and risk assessments according to the Swiss Major Accidents Ordinance, as well as performing operational and product life cycle assessments and validating environmental reports. Geri Hug was SENS eRecycling's inspection officer for the Electrical and Electronic Waste Disposal Division and was lead auditor for environmental management systems according to ISO 14001 at SGS. He was a member of the CENELEC Working Group for the Development of Standards for the Environmentally Sound Recycling of Refrigerators. Geri Hug has been available to SENS/Swico TC for project work since March 2019.

**Niklaus Renner**

**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 lamps 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.

**Daniel Savi**

**Sens TC, Office for Environmental Chemistry**

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, where he focuses on the health hazards and environmental effects associated with construction work and waste recovery. He has been a partner and managing director of the company since 2015.

**Rolf Widmer**

**Swico Conformity Assessment Body SN EN 50625, Empa**

Rolf Widmer completed his studies to become a qualified electrical engineer (MSc ETH EE) and his postgraduate studies (MAS) at the NADEL Centre for Development and Cooperation at ETH Zurich, where he spent several years researching new manufacturing processes for semiconductor components at the Institute for Quantum Electronics. Today, he works in Empa's Technology & Society Lab, the materials research institute of the ETH Domain. Rolf Widmer is currently leading several projects in the field of electronic waste management and, in this respect, is researching closed material cycles for the likes of rare metals or problematic plastics and glasses. Electronic waste increasingly also includes embedded electric equipment for electromobility, energy systems and buildings. He has been a member of the Swico TC for many years.

# 18 Links

### International links

↗ www.weee-forum.org
The WEEE Forum (Forum for Waste Electrical and Electronic Equipment) is the European association of 41 systems for the collection and recycling of electrical and electronic equipment.

↗ www.step-initiative.org
Solving the E-waste Problem (StEP) is an international initiative led by the United Nations University (UNU), which not only brings together key players operating in the fields of manufacturing, reusing and recycling electrical and electronic equipment, but also governmental and international organisations. Three other 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 of 22 March 1989 is also known as the Basel Convention.

↗ www.weee-europe.com
WEEE Europe AG is an association comprising 15 European take-back systems. Since January 2015, it has been enabling manufacturers and other market participants to meet their various national obligations from a single source.

### National links

↗ www.eRecycling.ch/en/
↗ www.swico.ch/en/
↗ www.slrs.ch

↗ www.swissrecycling.ch
As an umbrella organisation, Swiss Recycling promotes the interests of all of Switzerland's recycling organisations that are active in the separate collection industry.

↗ www.empa.ch/care
Since the start of Swico's recycling activities in 1994, Empa (the research institute of the ETH Domain for Materials Science and Technology) has been responsible for auditing recycling partners – as a conformity assessment agency for Swico Recycling's partners. The 'CARE – Critical Materials and Resource Efficiency' Group led by Heinz Böni is responsible for this.

↗ www.bafu.admin.ch
The Federal Office for the Environment (FOEN) offers a range of further information and news on the topic of recycling electrical and electronic equipment on its website under 'Waste'.

### Cantons with delegated enforcement

↗ www.awel.zh.ch
On the website of the Office of Waste, Water, Energy and Air (WWEA), under 'Waste, raw materials and contaminated sites', you will find a range of information that is directly important to recycling electrical and electronic equipment.

↗ www.ag.ch/bvu
The website of the Canton of Aargau's Department of Construction, Transport and the Environment offers further information under 'Environment, nature and landscape'. This information also covers the topics of recycling and utilising raw materials.

↗ www.umwelt.tg.ch
On the website of the Canton of Thurgau's Department for the Environment, under 'Waste', you will find regionally relevant information on the recycling of electrical and electronic equipment.

↗ www.afu.sg.ch
The website of the St. Gallen Department for the Environment and Energy contains general information and data sheets on individual topics, plus information on current topics under 'Environmental information' and 'Environmental facts'.

↗ www.ar.ch/afu
On the website of the Appenzell Ausserrhoden Department for the Environment, you will find general information and publications relating to individual topics concerning the environment.

↗ www.interkantlab.ch
The website of the Canton of Schaffhausen's Intercantonal Laboratory offers further information on the topic of recycling electrical and electronic equipment under 'Information on certain waste'.

↗ www.umwelt.bl.ch
The website of the Canton of Basel-Landschaft's Department for Environmental Protection and Energy (DEE) provides information on recycling and utilising raw materials in electrical and electronic equipment under 'Waste/waste that is subject to inspection requirements/electronic waste'.

↗ www.zg.ch/afu
On the website of the Canton of Zug's Department for Environmental Protection, under 'Waste management', you will find general information and data sheets on waste. Detailed information on the collection of the individual recyclable groups can be obtained from the Special-Purpose Association for Waste Recycling in Zug's Residential Communities (ZEBA) at ↗ www.zebazug.ch.

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# Technical report 2019

**Swico, SENS and SLRS**
News about electrical
and electronics recycling

EVERYTHING
IS ENDLESS

OUR STRENGTHS ARE
IN THE CYCLE

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