Swico, SENS, SLRS

Technical Report 2017

FOREWORD

Money, environment, trust

Every year, Swico, SENS and SLRS present the most important findings from the specialist work of their technical commissions. 2017 is no exception. However, we think it is important to take a brief look at other aspects of return systems in this editorial.

All systems let their contracts expire in 2016 and negotiated new terms with their partners for 2017. This allowed them to adjust services and prices, whether up or down, to the current circumstances. This process has not always been easy; the systems have seen it all: from annoyances caused by media campaigns through to attempts at political pressure. However, the Federal Council is still absolutely convinced that these systems work well and are reliable overall. In mid-February, it expressed its confidence in them in a response to a parliamentary motion and continued to emphasise the principles of private initiative, industry solidarity and self-organisation. The fact the federal administration could do much more to ensure system integrity in the area of law enforcement, however, is a different matter altogether.

The quality requirements for collection, transport and recycling are progressively increasing. And, as a result, also the use of resources. The right thing to do is therefore to scrutinise the planned stricter requirements with a critical eye. Is the effort required to recover the last molecule of an exotic metal really responsible? And not primarily for financial reasons, but also for environmental ones. The environmental impact of additional transports, complex processes and high energy use can result in a negative overall environmental footprint. Recycling then becomes a counter-productive marketing scam, an empty gesture.

The aim is therefore not only to keep an eye on the financial costs in the interest of the stakeholders involved but also to maintain a balance in terms of the environmental impact. Considerable scientific, technical and practical expertise is needed to know whether something is environmentally beneficial. This is why it makes sense that the list of the authors of this technical report reads like a "who's who" of Swiss technical experts in this field. Without their expertise, it would not be possible to handle further development of the requirements for good recycling in such a way that they make both financial and environmental sense. And that has to be our ultimate goal.

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SENS Foundation, Swico, SLRS: competent and sustainable

For more than 20 years, the three take-back systems of SENS, 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. Increasing take-back quantities bear witness to the success of the three systems.

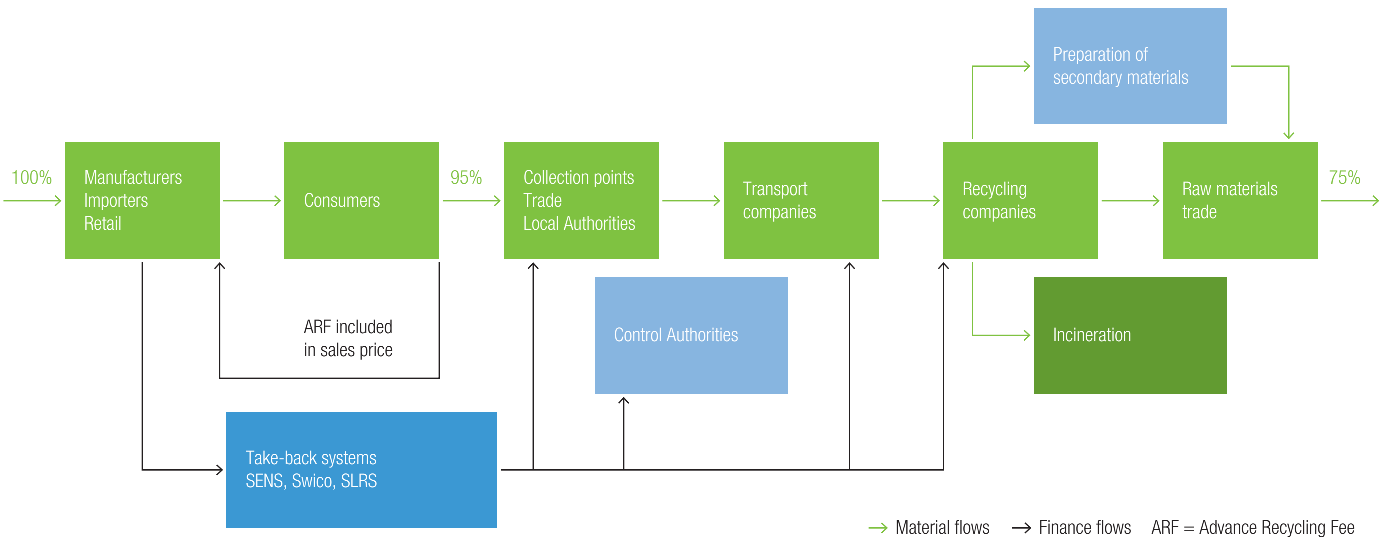
In Switzerland, there are three take-back systems for electrical and electronic devices. There are historical reasons for the existence of three systems, as in the early years of institutionalised recycling, industry-specific systems were established. The aim of these was to guarantee proximity to the 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, Swico, the SENS Foundation or the Swiss Lighting Recycling Foundation (SLRS) is now responsible for recycling.

In 2016, the three systems disposed of around 131,800 tonnes[1] of old electrical and electronic equipment. This means that Swico, the SENS Foundation 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 equipment.

The Ordinance on the Return, Taking Back and Disposal of Electrical and Electronic Equipment (VREG) obliges retailers, manufacturers and importers to take back devices 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 devices, an advance recycling fee (ARF) is included in the sale price for these devices. The ARF is an efficient financing instrument which guarantees that Swico, the SENS Foundation and SLRS can ensure proper processing of the devices in their respective area and face the challenges of the future.

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

Figure: Overview of the take-back system



SENS Foundation

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

Swico

Swico Recycling is a special fund within the Swiss Industrial Association Swico and deals exclusively with cost-covering recycling of old equipment. Swico aims to extract raw materials and dispose of 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 Empa, a research and service institute for material sciences and technology development within ETH, plays a crucial role in ensuring that Swico can enforce high and uniform quality standards throughout Switzerland with all waste management services.

Swiss Lighting Recycling -Foundation (SLRS)

The Swiss Lighting Recycling Foundation (SLRS) bears the basic responsibility for lamps and lighting equipment. SLRS deals with the organisation of comprehensive waste disposal systems for lamps and lighting equipment across the whole of Switzerland. In order to finance these activities, SLRS administers a fund each for lamps and lighting equipment, which is fed from the relevant ARF. Training and sensitisation of the 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.

Heinz Böni / Roman Eppenberger

SN EN 50625 series and state-of-the-art

2016 was shaped by the discussion about the implementation of the standard series SN EN 50625. Over the course of these discussions, the SENS and Swico systems have decided to go their separate ways. As per 1 January 2017, the recycling companies in Switzerland will be audited based on two different technical principles, but will use the same report templates.

After a two-year pilot phase to introduce the SN EN 50625, SENS eRecycling decided to wait with its definitive roll-out and to continue to audit the contract partners according to the state-of-the-art in Switzerland. The valid technical regulations of Swico and SENS were declared state-of-the-art in Switzerland by the Swiss Federal Office for the Environment (FOEN) in a letter on 10 April 2012. At the same time, the FOEN has been working together with the cantons, recycling companies and schemes since the end of 2014 as part of the amendment to the Ordinance on the Return, Take-Back and Disposal of Electrical and Electronic Equipment (VREG) to update the technology level.

State-of-the-art

The article stating the VREG's purpose notes that the Ordinance aims to ensure that "... electrical and electronic equipment which is not to be used further is disposed of in an environmentally friendly manner and in accordance with the state-of-the-art…". State-of-the-art according to Article 3 of the new Waste Ordinance (VVEA) describes the current state of development of processes, facilities and operating modes that is successful for comparable systems or activities in Switzerland or abroad. It also describes those which have been used successfully in tests, which can be transferred to other systems or activities according to the rules of technology, and which are economically viable for a medium-sized, financially healthy company in the relevant industry.

From the outset, the implementation of the Cenelec standard series SN EN 50625 in Switzerland was subject to the condition that the new regulations are at least equivalent or stricter, but may not be less strict than the valid technical regulations and thus have to be consistent with the state-of-the-art in Switzerland. An additional document, Cenelec-CH, was thus drafted. It documents those provisions that the Cenelec standard does not cover which are, however, required in the state-of-the-art in Switzerland. This document will be revised upon submission of the updated state-of-the-art in accordance with the VREG.

Technical commissions

Regardless of the different paths the schemes have taken since January 2017, the audits will continue to be carried out together. The joint Technical Commission will also be continued to coordinate the auditing activities and batch test execution. The joint commission will meet less frequently. At the same time, however, the separate Technical Commissions of SENS and Swico will gain more standing. They are to be selectively expanded at Swico together with the recyclers. Daniel Savi from Büro für Umweltchemie GmbH has joined the SENS auditor team. He has replaced Ueli Kasser, who has retired.

Esther Thiébaud

Consistently high volumes processed

Following a steep increase in 2015, the processed volumes remained consistently high this year. While the volume of processed electronic devices is steadily declining due to the decrease in heavy CRT monitors, categories such as small electrical appliances and refrigerators continued to rise.

In 2016, the Swico and SENS recyclers processed around 131,800 tonnes of electrical and electronic equipment. Compared to the previous year, this represents a slight drop of 0.2 per cent. (Table 1 and Figure 1). The sharpest decrease was seen in the processing of non-VREG devices which are not included in the lists of the Ordinance on the Return, Take-back and disposal of Electrical and Electronic Equipment (VREG). The volume of processed electronic devices also fell, which can be attributed to the further decline in heavy CRT monitors of computers and TV sets. As in the previous year, the volumes of processed small electrical appliances and refrigerators increased again by 12 per cent and 6 per cent respectively. The volume of photovoltaic equipment is still just under 100 tonnes.

Materials recycling

Recyclables and hazardous substances are obtained through manual and automatic processing of the Electrical and electronic equipment processed (Figure 2). The largest material fraction is that of metals, at 59 per cent. Compared to the previous year, the proportion of plastics-metal mixtures (18 per cent) and plastics (8 per cent) has not changed. The proportion of glass from cathode ray tube processing has dropped and is now only 4 per cent. The particularly valuable printed circuit boards account for only 1.3 per cent of the total volume. Nevertheless, it is often worthwhile to manually remove particularly valuable materials before automatic processing. The recovered recyclable material fractions are recycled or utilised thermally where possible. Metals are recovered in large, mostly European smelting plants. About 60 per cent of the plastics-metal mixtures enter another processing stage, in which pure metal and plastics fractions are separated; around 40 per cent is utilised thermally in incinerators. The volume of plastics recycled increased from the previous year from 64 per cent to 73 per cent. Glass fractions (screen glass, plate glass and recycled glass from lamps), as well as cables, printed circuit boards and batteries are processed further. This results in a total recycling rate of materials of around 73 per cent that is unchanged from the previous year.

Hazardous substance removal

The proportion of hazardous substances generated remained constant and is less than one per cent. (Figure 2). However, their removal is one of the most important tasks of the Swiss recycling companies besides reintroducing the material fractions into the cycle. Hazardous-substance removal is also carried out manually to a large extent. For example,

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

Year	Large electrical appliances	Refrigerators, freezers and air conditioners	Small electrical devices	Electronic devices	Lighting equipment	Photo-voltaics	Non-VREG devices	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	2’800	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
Change compared to previous year	**–1%**	**6%**	**12%**	**–6%**	**0%**	**0%**	**–37%**	**–0.2%**

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

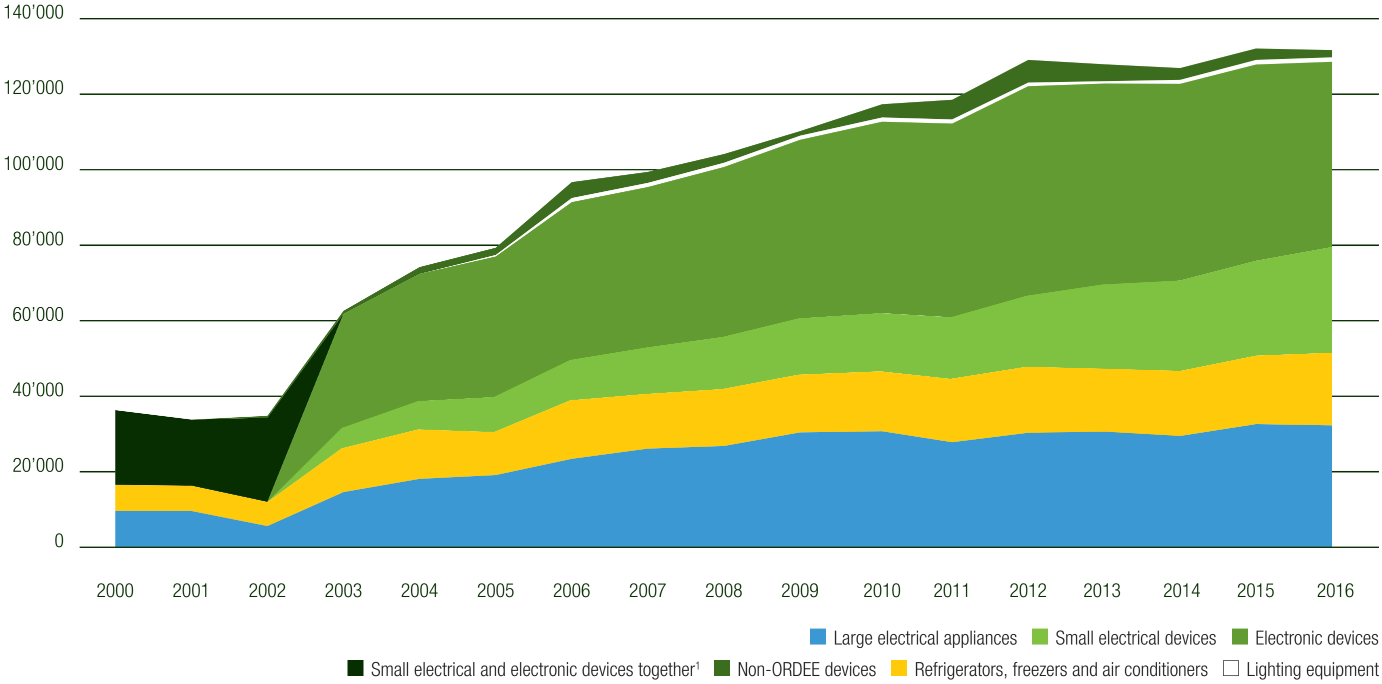
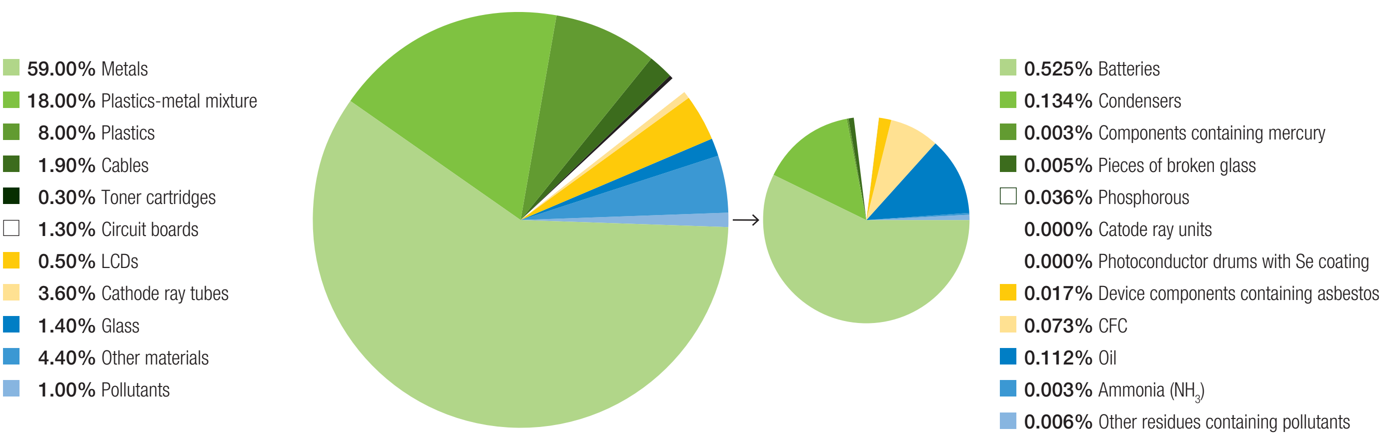


Figure 2: Composition of the material groups generated in per cent in 2016



Hazardous substances, which altogether account for only 1% of the produced fractions, are shown separately.

[1] Small electrical & electronic devices together: this number is also greater than the 49,000 tonnes of electronic equipment in Table 1 since this also includes equipment which A-signatories have disposed of via direct contracts.

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

	Number[4]	Average weight	Metals	Plastics	Plastics-metal mixtures	Cables	Glass and/ or LCD modules	Circuit boards	Pollu-tants	Other[5]	Total	Increase/de-crease compa-red to 2015
PC monitors, CRTs	70	18 kg	184 t	250 t	119 t	32 t	550 t	115 t	0.1 t	6 t	1'257 t	-39%
PC monitors, LCD	625	6.1 kg	1'503 t	1'211 t	73 t	47 t	598 t	271 t	35.1 t	95 t	3'834 t	29.7%
PCs/servers	395	11 kg	3'706 t	259 t	12 t	138 t		375 t	14 t		4'506 t	–15.3%
Laptops	425	2.8 kg	355 t	331 t	120 t	6.0 t	103 t	170 t	81 t	4.9 t	1'171 t	–3.6%
Printers	540	12 kg	2'233 t	3'390 t	388 t	34 t	43 t	110 t	1.9 t	102 t	6'303 t	3%
Large copiers/ appliances	55	137 kg	4'104 t	282 t	2'695 t	136 t	5.0 t	61 t	65 t	193 t	7'540 t	17%
IT mixed[2]		3.4 kg	1'148 t	76 t	760 t	38 t	1.1 t	16 t	18 t	53 t	2'111 t	1%
CRT TVs	621	25 kg	752 t	1'560 t	254 t	27 t	4'934 t	93 t	7 t	4.1 t	7'631 t	–34%
LCD TVs	310	19 kg	1'830 t	681 t	399 t	52 t	332 t	318 t	42 t	132 t	3'786 t	51.8%
Consumer electronics, mixed[3]	204	3.5 kg	6'062 t	402 t	4'015 t	202 t	5.7 t	87 t	96 t	281 t	11'151 t	–0.8%
Mobile phones	3'151	0.20 kg	23 t	51 t			7.5 t	32 t	29 t		143 t	-5%
Remaining phones	710	1.8 kg	1'454 t	96 t	963 t	48 t	1.4 t	21 t	23 t	67 t	2'674 t	–3.6%
Photo/video	1'486	0.90 kg	88 t	5.8 t	58 t	2.9 t	0.1 t	1.3 t	1.4 t	4.1 t	162 t	–6.8%
Dental	180										93 t[6]	8%
Total in tonnes			**23'443**	**8'595**	**9'857**	**765**	**6'581**	**1'671**	**414**	**943**	**52'362**	–4.3%
Total percentage			**45%**	**16%**	**19%**	**1.5%**	**13%**	**3.2%**	**0.8%**	**1.8%**	**100%**	

condensers in large household appliances are removed, as well as batteries from electronic devices or the background lighting of flat-screen displays, scanners and photocopiers. The removal of hazardous substances and the handling of these hazardous substances has to be constantly adapted to changing technologies and the latest findings. Nevertheless, companies must be able to take back appliances of all generations with their respective hazardous substances, to remove the hazardous substances and dispose of the appliances in an environmentally sound manner, which places high demands on the work of the recycling companies and requires robust quality assurance systems.

Take-back and composition of electronic equipment

Based on market basket analyses and targeted processing tests of certain product groups, Swico Recycling performed a detailed examination of the take-back amounts of electronic equipment and their composition (Table 2). In 2016, Swico Recycling took back 52,362 tonnes of electronic equipment, 4.3 per cent less than in the previous year. In terms of weight, at over 30 per cent, the take-back of CRT monitors and CRT TV sets decreased most significantly, whereas the number of taken-back LCD monitors, LCD TVs and laptops saw the steepest rise. The number of mobile phones and smartphones collected increased only slightly. The market basket analysis arrived at a somewhat lower average weight for mobile phones compared to 2015, which yields a weight-based decrease of 5 per cent. The number of taken-back devices in the mixed IT and CE categories increased, while the average weight decreased.

The composition of the individual appliance categories is determined by means of processing tests carried out by Swico recycling companies and supervised by Empa. In this process, a previously defined number of appliances is collected and the resulting fractions are documented. The detailed volumes of electronic devices taken back and their composition are shown in Table 2.

2 IT equipment, mixed, without monitors, PCs/servers, laptops, printers, large copiers and appliances.

3 Consumer electronics, mixed, not including televisions.

4 Projection, Cumulative number in 1000s.

5 Packaging and other waste, toner cartridges.

6 This number is larger than the 49,000 tonnes of electronic equipment in Table 1, since this also includes electronic devices which A-signatories have disposed of via direct contracts.

Flora Conte, Anahide Bondolfi

When devices are dismantled, society becomes more cohesive

The around 80 SENS and Swico dismantling companies in Switzerland not only make an environmental contribution to sustainable development but also support a social cause and help people in very different life circumstances.

After being collected at the official SENS and Swico collection points and businesses, approx. 30,000 tonnes of waste electrical and electronic equipment were manually processed in the around 80 dismantling companies in Switzerland in 2016. The dismantling companies remove the harmful substances before the material is shredded by recycling company. Most dismantling companies do more than remove harmful substances. They take the devices apart and sort the fractions so that a lot of metal and plastic no longer needs to be processed in the shredder.

It is becoming increasingly apparent to SENS-Swico's Technical Commission that the harmful substances in waste electrical and electronic equipment can be removed particularly reliably by manually dismantling the devices. This is because the fractions, regardless of whether they are valuable or dangerous, can be cleanly separated and securely stored this way. This conserves resources and protects the environment.

There are generally two kinds of dismantling companies: private firms and organisations for social integration. On the one hand, around 30 private companies from areas such as waste or transport operate as dismantling companies. They generate secondary income by removing harmful substances from large household appliances. Between one and three people are usually responsible for dismantling activities in a company. The tasks can be flexibly scheduled and offer employees variety, not just during an apprenticeship as a recycler. The dismantled devices are then recycled in the shredder.

On the other hand, more than 50 dismantling companies combine their activities with social integration. Competent support staff provide the employees in these companies with technical and organisational help. Some dismantling companies work directly with the social authorities, while others acquire their own customers, e.g. for simple industrial work, in addition to their SENS and Swico activities. It is almost always Swico material that is processed, but also small SENS devices.

The waste electrical and electronic equipment is generally broken down into individual parts in other companies, and the quality of the fractions is high. The quality is particularly high when there are employees who have worked in the company for several years. However, they often only stay a few months. This is why certain companies specialise in one device type, e.g. flat. More than half of the over 50 dismantling companies have 15 jobs or more. Almost 1,000 people work in social dismantling companies as part-time, full-time, temporary or permanent employees in Switzerland.

People are generally employed at a dismantling company with social aims to reintegrate them into the job market. While some institutions work a lot with young people, others focus on the long-term unemployed. These individuals will retire soon and are only rarely able to find a new job. People who are not able to work in a "traditional" working environment encounter a structured daily routine and an open-minded social setting in a dismantling company. This applies to, for example:

- People with a mental or physical disability
- People with alcohol or drug addictions
- Prisoners or people sentenced to community service
- Asylum seekers

At the beginning, the work does not require much in the way of qualifications and is highly flexible without the usual time pressure and competition. The work may not be physically demanding and is suitable for both men and women. Working at the company can give employees the opportunity to obtain a good reference and pursue further training, for example, in other areas such as security, logistics, recycling, hazardous goods or in administration.

People with many different backgrounds thus work in dismantling companies. Individuals get a second chance in a sector that also protects the environment. SENS and Swico's activities not only drive sustainable development at the environmental level. Socially responsible dismantling companies in particular also make a very valuable contribution to social sustainability.

Jobs in a dismantling company with a social purpose

The figures and facts in this article were estimated on the basis of the SENS and Swico dismantling company audit logs from the years 2015 and 2016, which the authors conducted themselves.

LAMPS

Roman Eppenberger

LED lamps and LED lights still uncommon in recycling

LED lamps and lights are taking the market by storm. How is this technology changing everyday lighting and recycling? An overview.

LEDs are all the rage

Energy-saving lamps were the first to benefit from the ban on light bulbs. Even though they are more energy-efficient, they contain mercury, which is harmful to the environment and human health. LED lamps have thus established themselves as an energy-saving and environmentally friendly alternative. LEDs replace light bulbs, energy-saving lamps and rod-shaped fluorescent lighting. Consumers like the fact that the lamp is already integrated into the new LED lights. Even though they are not yet banned, halogen light bulbs are also being pushed from the market by LED lights.

LEDs have both environmental and emotional benefits. They are available in a wide range of hues and light colours. There is actually no longer a reason to buy alternatives to LEDs. Street lighting is also gradually being replaced by LED lights.

LEDs are multifunctional

LEDs are multifunctional and can be integrated into control systems. They can therefore be combined with many applications, such as loudspeakers, photovoltaics or WiFi. It is even possible to switch them on with a smartphone. And many possibilities have not yet been fully exhausted, LED technology has a great future.

LEDs, however, also present a challenge at the recycling level. As already mentioned, the LED lamps are permanently integrated into the light and can only be replaced to a limited extent. Lights and lamps are increasingly becoming an inseparable unit. This means that lamps will no longer be sold or collected separately over the medium-term, only whole lights.

More advantages from an environmental standpoint

However, the advantages of LED lights still outweigh the disadvantages. They use much less electricity for comparable light output and do not contain mercury. And they also do not need any ballast units, which used to contain condensers with PCBs. From the standpoint of contaminants as a whole, there is a considerable advantage. Oekopol GmbH has been analysing the harmful substances in LEDs on behalf of the German Federal Environment Agency. According to this study, there are still harmful substances in the LED lamps, mainly in the semi-conductor components. However, the quantities are so low that they do not negatively impact on the environment and human beings. Compared to the harmful mercury in energy-saving lamps, LED lamps are harmless.

Challenge in collection logistics and recycling

The LED trend presents a challenge at various levels in recycling terms. Today's conventional lamps are so multifaceted and LED retrofit lights designed to be deceptively similar to energy-saving lamps that it is now difficult for technical staff and consumers to properly classify the lights. As a result, all lamps are currently being collected together, regardless of whether they contain mercury or use LED technology. The triage to sort lamps into those that contain mercury and LEDs therefore has to be carried out with extreme care. Today's lamp recycling systems are designed to sort out the material that contains mercury, and LED lamps cannot be recycled in these systems.

LED lamps and lights are processed in recycling systems for small electrical household appliances. It is currently not technically or commercially interesting to recycle the LED elements or rare metals in the semi-conductors. The quantities to be recycled are simply too small. The technical feasibility is currently being researched to be ready for industrialisation, if necessary.

Recycling quantities lag behind the trend

Sales of LED lamps or lights have exploded on the market, but the return system is slow to take shape. The estimated portion of returns of rod-shaped LED lamps in Switzerland is less than 0.2% and non-rod-shaped LED lamps less than 1.4% (2015 figures). This is a good sign, on the one hand, because it is an indication of the long service life of the products. Most LED lamps and lights are designed to function for 25,000 hours and more. Exact figures are not available because the LED lamps are not yet collected and reported separately. However, once these quantities increase, exact reporting will be necessary.

Sources:
Oekopol GmbH (www.oekopol.de), «Expertise Leuchtdioden»

Rolf Widmer

Swico and SENS regulate the collection and transport of lithium batteries in accordance with ADR 2017

The "LIB[7] in WEEE" working group drafts explanations and recommendations for the collection and transport of waste electrical and electronic equipment (WEEE) containing LIBs in consultation with the Federal Roads Office (Astra). Starting this year, the new rules of ADR 2017 and the provisions derived on this basis in the Swico SENS LIB data sheet apply.

The new special provision SV 636, which regulates the transport of WEEE containing LIBs, went into force at the beginning of the year together with ADR 2017, the European Agreement concerning the International Carriage of Dangerous Goods by Road. Essentially this means that the provisions outlined in the TC Swico SENS data sheet entitled "Collection and Transport of Waste Electrical and Electronic Devices containing LIBs" are now valid. These state, among other things, that all WEEE containing LIBs is to be transported in an unpackaged state. This means that the complex process of sorting and labelling WEEE containing LIBs required by ADR 2015 is no longer necessary to a large extent. The device acts as protective packaging for this WEEE, which prevents it from being damaged. As a result, there are still no provisions for bulk material, e.g. in containers for WEEE containing LIBs, in the ADR 2017 and this is therefore not permitted.

Swico SENS LIB data sheet

To further lower the risk during transport, the Swico and SENS scheme operators conform to SN EN 50625-1:2014 and require damaged WEEE devices that clearly contain defective LIBs (e.g. bloated mobile phones), as well as loose LIBs to always be sorted out and packed in Inobat steel containers for battery collection. This requires trained staff on site to recognise and sort out these kinds of LIBs as well as supervision of customers to ensure which WEEE is put into the containers provided. Defective WEEE containing LIBs which is received by Batrec Industrie AG in the Inobat collection is now statistically recorded there. There are currently no figures but, according to Batrec, the incoming quantity is low.

Swico and SENS have decided that WEEE which is collected but not sorted out, i.e. equipment which could contain these kinds of LIBs, is only to be collected and transported in recommended containers with a volume of < 3 m^3 and a height of < 1.5 m (e.g. pallets with a maximum of 3 frames, if necessary, with lining). SENS also allows guaranteed LIB-free devices to still be treated as bulk materials, but this has to be verified by quality assurance.

The ADR rules are changing quickly with respect to LIBs. Another change to the SV 636 was passed for the next amendment to ADR 2019 last autumn. Essentially a new special provision, 670, will be introduced which only applies for WEEE containing LIBs and adopts most of the current text. Loose WEEE containing LIBs is still not permitted. However, SV 670 completely exempts WEEE containing LIBs whose LIBs are not the main source of energy (e.g. backup batteries)! In addition, SV 670 stipulates packaging requirements such as suitable measures which have to be undertaken to minimise damage to the devices when filling containers or handling packaging, e.g. through the use of rubber mats, or that packaging is made and sealed in such a way to prevent the goods from being lost during transport, e.g. with covers, resilient interior linings and enclosures for transport. SV 636 will only be valid with no changes for ‹loose› LIBS, and will be modified accordingly. The content of the current Swico and SENS specifications and LIB data sheets will not change.

In the meantime, Germany has proposed a multilateral agreement (M303) to already enter the new SV 670 into force in 2017. Austria has already signed the agreement, thus triggering its entry into force. ASTRA will also ratify this treaty for Switzerland in consultation with the LIB work group.

ADR 2017 requires that "… a quality assurance system is in place to ensure that the total amount of lithium cells or batteries per transport unit does not exceed 333 kg. The total quantity of lithium cells and batteries in the mix may be assessed by means of a statistical method included in the quality assurance system. A copy of the quality assurance records shall be made available to the competent authority upon request."

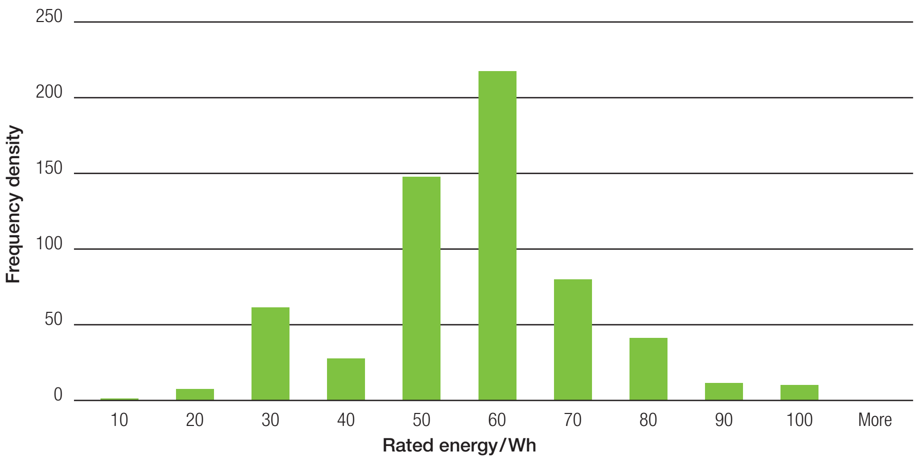
Swico and SENS are currently testing whether this requirement can be met through their analyses of market baskets and batch tests. The Empa evaluations of the battery data collected at Batrec from the Swico batch tests of 2015–16 have produced initial results. In these tests, a total of 46,892 kg of WEEE (pre-determined batches of ICT and consumer electronic devices without monitors) was processed and these produced the following results for batteries:

- 283.6 kg batteries were removed (mass fraction w=0,60 %),
- 214.0 kg of which were LIBs (75.5 %). The total LIB mass fraction is thus 0.46 %.
- 211.4 kg of which were li-ion batteries (98.7 %); the rest were li-metal batteries.
- 3.7 kg (1.7 %) of which were single cells; the rest were multicell batteries.
- of the total of 666 LIBs, 24 units were defective (= 4.0 kg, which equates to 13 cells); although most were damaged by the shredder and only 3 units (5 ‰) were already previously defective.
- of the 600 readable LIBs from Swico WEEE, the largest group had rated energy in the range of 50 Wh to 60 Wh, and none had more than 100 Wh.

To reach the exemption limit of 333 kg, the total load of this kind of mixture would need to have a weight of over 72 t. This is at least a factor of 3 above the maximum vehicle freights, which means this kind of mixture is currently far below the exemption limit. These analyses will be expanded to other device categories containing LIBs, and should be able to serve as quality assurance records for transports. One group which should be investigated is the sorted-out SENS devices containing LIBs, which come into being when the WEEE that does not contain LIBs is collected in containers for bulk materials. Its LIB mass fraction will probably increase considerably and compliance with the exemption limit could be problematic.

Examples of LIBs from the Swico mix batch tests: a) single cell, b) laptop battery

Figure: Histogram of the rated capacities of the LIBs taken in the batch test



[7] LIB stands for lithium-metal and lithium-ion cells and batteries.

Daniel Savi

Current state of knowledge about modern condensers

We still do not know everything about the liquids in PCB-free condensers. More needs to be known about what the liquids contain so that the future rules for handling PCB-free condensers can be developed. A study commissioned by SENS and Swico identifies which substances can occur in liquid or dissolved form in PCB-free condensers. A review of the literature has already been carried out to document the current state of knowledge. But which substances occur and with what frequency in condensers? A sample will be taken to answer this question as it pertains to the recycling of waste electrical and electronic equipment in Switzerland today.

Swiss recycling companies manually remove the condensers from waste electrical and electronic equipment if they are larger than the size of a thumb. This rule was established to ensure the environmentally friendly disposal of PCBs in the condensers. Thirty years have passed since the ban on PCBs was imposed in 1986. One question that is frequently asked is the percentage of condensers containing PCBs being recycled today. Various studies, including studies conducted by SENS and Swico in Switzerland (2007, 2009), have shown that the percentage of condensers containing PCBs is steadily decreasing, and they can no longer be found in certain device categories. One exception are FL lights: their ballast units still use a high percentage of condensers with PCBs. Based on their audits, the auditors in the Technical Audit Department know that condensers containing PCBs are not as common any more, but they still occur in the devices with some regularity. The recyclers, in particular, are currently questioning the requirement to remove them. Many believe that the requirement to remove PCBs will go into effect at the same time that condensers containing PCBs disappear. However, from the Technical Audit Department's point of view, this is an unresolved question.

Classification of hazardous substances

The SN EN 50625, the technical provisions of SENS and Swico and the WEEE Directive all stipulate that, in addition to condensers containing PCBs, "electrolyte condensers which contain hazardous substances" with a height > 25 mm, a diameter > 25 mm or a similar proportional volume must also be removed from waste electrical and electronic equipment. The wording of this provision raises several questions. It is not clear, on the one hand, why electrolyte condensers are explicitly mentioned because many other film condensers can also contain liquids. If the goal of prior removal is to prevent harmful substances from spreading unchecked over the fractions, the rule would have to be logically applied to all condensers which contain large quantities of liquids. In addition, the term "hazardous substances" is not defined in any of the rules. The Technical Audit Department will therefore have to define which substances are to be considered hazardous. For logical reasons, this definition will rely on criteria related to ecotoxicity and persistence in the environment that apply equally to all substances. To ensure that the large number of potential substances can be assessed, these criteria will have to be based on an existing classification system for substance toxicity. Predestined for this are the H sets in the globally harmonised system to classify and label chemicals. With this kind of rule system, all substances – even those that are still unknown today – could be broken down into hazardous and non-hazardous.

Evaluation of the contents of modern condensers

The liquid and dissolved substances found in PCB-free condensers are currently being evaluated by the Office for Environmental Chemistry in a study commissioned by SENS and Swico. The literature has already been surveyed for existing knowledge about the liquid contents of PCB-free condensers. Liquid contents can act as electrolytes, typically in aluminium electrolyte condensers. However, liquid substances are also used as a dielectric in a number of condensers, i.e. an electrical isolator. PCBs have also assumed this function in condensers. Due to their size, power condensers are the main focus of interest. Different mixtures can be used as an electrolyte and as a dielectric. The manufacturer declarations about condensers are not very helpful with respect to the liquid contents. Often no contents at all are declared, sometimes only substance groups that yield little useful information about the specific chemicals used. The most accurate information can be found in a study of patent specifications. However, it often remains unclear how widespread the use of the patented condenser technology is in the condensers sold.

The liquid contents must be able to conduct the electricity in electrolyte condensers. To do this, charged particles, known as ions, are dissolved in solvents. According to manufacturers' specifications, ethylene glycol and y-butyrolactono are particularly common solvents. Mixed acids supply the dissolved ions necessary, e.g. phthalic acids. The literature describes a number of other acids that can be used in condensers. It is currently still very unclear which acids actually occur in the electrolyte condensers that are disposed of today. In film condensers with liquid impregnation, the liquid contents must meet completely different requirements. These liquids are not allowed to conduct electricity. In addition, they also have to remain stable at higher temperatures and over longer periods of time. PCBs were previously used for this function until they were banned. Today natural oils such as castor oil or soybean oil with additives can fulfil this function. Apparently, however, the industry frequently uses mineral oils that consist of a complex blend of hydrocarbons. Phthalates and diarylalkanes are suitable as liquids for this function. Diarylalkanes are particularly widespread in microwave condensers.

45 substances in PCB-free condensers identified

In the literature review, the authors identified 45 substances that are used in PCB-free condensers found in electrical and electronic equipment. The function of most of these substances in the condenser is also sufficiently well known. Do these substances only include those that have to be classified as "hazardous"? To answer this question, we determined the H-sets for all contents identified. A classification system was then developed that defines which H-sets qualify a substance as "hazardous". This classification system will be discussed by the Technical Audit Departments of SENS and Swico before it can also be published in a revised form. In the current version, there are ten hazardous substances which can occur in PCB-free condensers. They are listed in Table 1. This list is only temporary and can change over the course of the study.

Survey and analysis of condensers

The study is to be continued throughout the year. A sample of condensers from collected devices is planned in the SENS and Swico system. From these samples, the condensers that contain PCBs and are those suspected of containing PCBs are sorted out and, on the other hand, the contents of the PCB-free condensers must be determined. The focus is naturally on the question of whether the hazardous substances found in the literature review actually occur in the condensers in recycling. The samples are currently being planned. The concept envisages sorting condensers by device category. We hope this will allow us to determine in which device categories certain condensers types occur. The separated condensers will then be grouped into those containing PCBs, those suspected of containing PCBs and those containing no PCBs. The same size was selected for condensers from large household appliances and lights to make it possible to arrive at a conclusion about the percentage of condensers containing PCBs which are being recycled today. The condensers with no PCBs in all device categories will be classified by type. The composition of the liquid contents will then be analysed from a selection of these condensers. The selection should be made in such a way that the picture which emerges of the substances used is as complete as possible. The exact analysis concept will only be drafted once the collected types are known. This process was selected to cover the maximum types of condensers at a reasonable cost for the analysis. The results of this study should help to define the future disposal practices for condensers containing no PCBs.

Condensers from dishwashers

Table: Temporary list of hazardous substances and their use in condensers

Trivial name	CAS no.	Use/function
Polychlorinated biphenyls	1336-36-3	Dielectric
1-Chlornaphthalene	90-13-1	Dielectric
1-Methylnaphthalene	90-12-0	Aluminium electrolyte condenser/electrolyte
2.6-Diisopropylnaphthalene	24157-81-1	Microwave condensers/dielectric
Biphenyl	92-52-4	Dielectric
Boric acid	11113-50-1	Electrolyte
Butylated hydroxyanisole	25013-16-5	Addition of dielectric soy oil for preservation
Diisobutyl phthalate	84-69-5	Dielectric
Naphthalene	91-20-3	Electrolyte
Triphenyl phosphate	115-86-6	Electrolyte

Heinz Böni / Rolf Widmer

A closer look at the recycling performance of Swico's processing partners

Between mid-2015 and mid-2016, a batch test was conducted with a predetermined input amount at six Swico recycling partners that rely on mechanical processing. In addition to determining the recycling and recovery quotas, the test was also designed to compare the performances of the companies.

For the first time in Europe, the input quantity tested in a batch test (in accordance with Cenelec 50625-1: Test batch processing) was comprised of a mixture of information and communication technology devices and consumer electronics that was virtually the same for all companies. Over a period of around three weeks, a combination of devices was defined which correspond to the average composition of the material flow in the Swico system (not including monitors).

Determining the recycling and recovery quotas in accordance with Cenelec

The Swiss standard SN EN 50625-1:2014 defines how recycling and recovery quotas have to be determined. According to this standard, the process starts with the untreated waste electrical and electronic devices and ends "… when the end-of-waste

Table 1: Categories of the end uses of the various fraction percentages (excerpt)

Final fraction	Final technology	Final use* R	OMR	ER	TD	OD	Basis and assumptions
Aluminium fraction "pure"	Aluminium melt	95%	1%		4		95% Al recovery; 1% other metals as reduction agents; 4% all other organic fractions;
Aluminium fraction "not pure"	Aluminium melt	90%	1%		9%		90% Al recovery; 1% other metals as reduction agents; 9% all other organic fractions;
Batteries dry	Battery recycling	50%			50%		50% metal recovery; 50% plastics with no use in smelter
Lead batteries	Battery recycling	94%			6%		67% lead recovery; 2% other metals; 6% organic parts/hot technology; 21% sulphuric acid recovery; 4% plastics
Iron fraction "pure"	Steelwork special	97%		3%			90% Fe recovery; 5% mineral fraction; 2% other metals; 3% other organic fractions
Iron fraction "not pure"	Steelworks traditional	92%		8%			85% Fe recovery; 5% mineral fraction; 2% other metals; 8% other organic fractions
Plastic/ other organic compounds	Household waste incinerator			62%	33%	5%	62% organic percentages used for fuel substitution (R1 system); 33% organic percentages for thermal disposal; 5% inorganic percentages for disposal (landfill)
Capacitor	Special waste incinerator				100%		
Recovered plastics	Plastics recovery	51%		32%	17%		50% plastics for recycling; 1% metals; 32% plastics for use as energy; 17% plastics for thermal disposal
Copper and grey metals "pure"	Copper smelter «special»	95%		5%			75% Cu recovery; 20% other metals; 5% plastics used for fuel substitution
Copper and grey metals "not pur"	Copper smelter «special»	90%		10%			70% Cu recovery; 20% other metals; 10% plastics used for fuel substitution
Printed circuit boards/ mobile phones	Copper smelter «special»	30%		65%	5%		30% other metals; 65% plastics used for fuel substitution; 5% no use – "cold technologies"

* R = Recycling; OMR = Other Material Recovery; ER = Energy Recovery; TD = Thermal Disposal; OD = Other Disposal (e.g. landfill)

status for fractions is achieved or with the final recovery or disposal of fractions". When the quotas are determined, this includes each individual step of every operator in the treatment chain. All fraction percentages must be allocated to a final use in the last treatment step for all fractions that are recovered or disposed of. For example, during final treatment, e.g. in a smelting plant, the amounts that can be recycled (R) must be determined along with the amounts that are used for example in the process as reduction agents (OMR=Other Material Recovery) and end up in the slag.

In a joint statement of the European associations CECED, Digitaleurope, WEEE Forum and EERA from June 2016 on the proposed amendment to Article 11 of the European Waste Framework Directive to adopt new rules for calculating quotas, it was put forth that these quotas should not be calculated based on the weight of the input waste entering the final recycling process, but instead based on the weight of municipal waste recycled as provided for in the Cenelec standard. This means that the recycling quota can only include the mass fraction recycled (output of material recycling).

For the Swico batch tests, the quotas were determined in accordance with SN EN50625-1:2014, whereby standardised categories of final uses of the various fraction percentages were used for the final processes (see Table 1). These were adjusted in those cases where the company was able to provide evidence of better values to the final user and document these values accordingly.

Input composition and processed weights

Table 2 shows the specified input composition and the deviations from this formula expressed as percentages. The deviations were relatively low for all device types in five companies (see Technical Report 2016), while the sixth company was not able to satisfy the requirements for the conditioning of radios (-16.8 %) and speakers/loud speakers (+18.9 %). In addition, in individual cases there were deviations between the total weights in the companies and those recorded during conditioning. These deviations were taken into account in the interpretation of the results.

Table 2: Conditioning of the batches

Device type	Specification		Deviation from specification
	Quantity [t]	Percentage	
PC/servers	2,850	23.9%	0.1 – 2.9%
Printers	2,570	21.6%	-0.1 – 3.4%
Radios	2,000	16.8%	-0.5 – 0.2%*
Speakers/loud speakers	1,470	12.3%	-0.5 – 0.3%*
Landline telephones	750	6.3%	-5.3 – 0.1%
Keyboards	630	5.3%	0 – 0.7%
Notebooks, laptops, powerbooks	600	5.0%	-1.6 – 0.5%
Switches	450	3.8%	-3.8 – 0%
Routers/modems	300	2.5%	-0.3 – 1.5%
Amplifiers	300	2.5%	-2.5 – 2.6%
Total	**11,920**	**100.0%**	

* One company had much larger deviations

High rate of manual initial dismantling

In all companies, hazardous substances are manually removed in the initial treatment stage and the devices are partially pre-dismantled to prepare them for the subsequent mechanical stages. Manual processing produces a considerable number of fractions, which are either sent directly to an end process or disposed of in a waste incineration plant (ASR) or specialised company. Depending on the company structure and the subsequent processing technology, the total processed weight accounted for by the mass fraction of the manually generated end fractions fluctuates between around 10 % and 50 %. Even though a higher percentage of pure fractions can be sent directly to the last treatment stage as the rate of initial manual dismantling increases, the achieved recycling quotas of companies with a high rate of manual dismantling tends to be better, but not in every case. For example, the company with the lowest rate of initial manual dismantling achieved the highest recycling quotas, while the company with the highest rate of manual dismantling achieved good but not the best quotas.

Metal recycling and plastics recovery

If a high recycling quota is to be achieved, metal recycling must be maximised on the one hand, and as much plastic as possible must be recycled on the other. These must meet the requirements stipulated in TS 50625-3-1. According to these specifications, evidence must be provided that the total bromine content for these kinds of plastics is below 2,000 ppm. In addition, according to the provisions of the Federal Office for the Environment (FOEN), evidence must be provided that the brominated substances Penta and Octa BDE are each below 1,000 ppm. A limit of 100 ppm applies for cadmium, and a limit of 50 ppm for PCB. This evidence is not standardised in Switzerland but will become more important in the future. The target values for recycling can only be reached by recycling more plastic for material purposes.

The total metal weight that can be recycled reaches 47–56 % of the total weight, the greatest percentage of which is accounted for by iron (34–42 %). The other metals are primarily aluminium and copper which are recovered in a relatively pure state or mixed depending on the technology used (see Table 3).

While the differences in metal recovery are relatively small, the companies vary greatly in terms of the way they recycle plastic. This fluctuates between almost 0 % and 15 %, which directly impacts on the achieved quotas (see below). Accordingly, the weights for recovery for energy use and thermal disposal in a waste incineration plant vary between 28 % and 43 %. This may also be the result of inadequate separation in the mechanical processes, which leads to large volumes of metal in the shredder light fraction and thus also negatively affects the recycling quota (RQ).

Table 3: Ranges of the final fractions and the final uses

Final fraction	End uses	Range Min [%]	Max [%]
Metals		47	56
- Fe	R	34	42
- Cu	R	0.7	6.1
- Al	R	0.3	5.4
- Other metals	R	4	17
Plastics		14	30
- Recycling	R	0.3	15
- Use for energy	UE	17	26
- Thermal disposal	TD	0.5	6.5
Other		5	16
- Use for energy	UE	0.1	9
- Thermal disposal	TD	2	8
Total waste incinerator		**28**	**43**

Condensers from manual dismantling

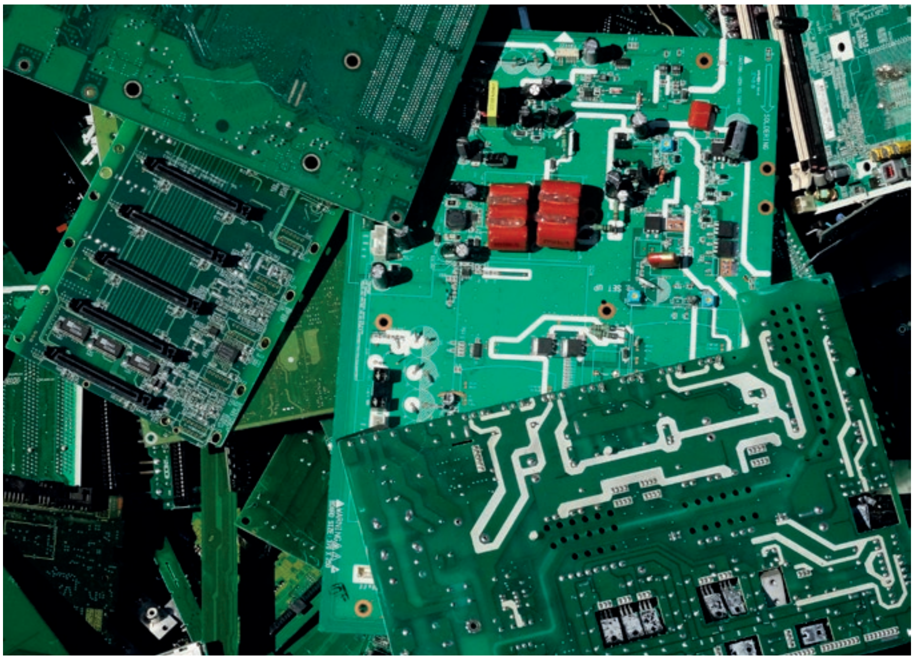
Results and outlook

The results of the tests show a high fluctuation range for the quotas achieved. Values between 53.8 % and 70.8 % were determined for the recycling quotas, and between 84.5 % and 93.3 % for the recovery quotas. While the recovery quotas are consistently above the target value of 75 %, two companies do not yet reach the target value of 65 % for recycling.

It must be noted here that European countries often report fantastically high recycling and recovery quotas. From our perspective, this is an inadmissible simplification of the (unclear) calculation models and disregard for the requirements of the regulations as laid down in EN 50625-1:2014. Pursuant to the will of the EU Commission, the standard will determine the status of technology in Europe and is to be defined as part of the next amendment to the WEEE Directive. It is therefore essential that the calculation methods are harmonised in line with the previously mentioned statement of the European associations.

The findings gained from the project allow Swico's processing partners to make a comparable estimate of their recycling performance and identify

Printed circuit board fractions from manual processing



Printed circuit boards from manual dismantling.

measures for improvement. As part of the operational inspections by Empa, regular batch tests will also be carried out in the future in accordance with the specifications of SN EN 50625-1:2014. Here the required target values must be achieved regardless of the input composition. If the target values are not achieved once more, this may result in the termination of the cooperation agreement.

Since 15 August 2015, stricter requirements have applied in accordance with the European WEEE Directive. The target values were raised by 5% so that they are now 70% for recycling and 80% for recovery in the case of categories 3 und 4. SENS and Swico have not yet introduced the higher quotas, so the previous minimum quotas still apply.

The specifications for the recycling and recovery targets involve a weight-based assessment, which only takes into account the large material flows and ignores the recovery of rare technical metals. In addition, the target values do not say anything about the associated environmental performance. Under the scope of an ETH research project headed up by Empa, the scientific principles assessing the environmental performance of the treatment of electronic scrap will therefore be investigated. Results are expected in autumn 2017 and will be incorporated into the Technical Report 2018.

Rolf Widmer / Heinz Böni

Flat panel displays with mercury continue to dominate the market

In the second half of 2016, batch tests were carried out at several recycling companies to determine recycling and recovery rates and the composition of flat panel display devices.

Three of the six companies only dismantled TV sets and PC monitors. For every batch test, at least 5 t or 250 FPD units were provided in accordance with SN EN 50625-1:2014 in such a way that the combination of devices to be dismantled was as representative as possible for normal operations (size and age of the devices). The test planning was discussed with the assigned inspection experts, the tests carried out independently and the results and the photo documentation handed over to the inspection experts. To determine the recycling and recovery rates, the following treatment steps through to end use were depicted with values from RepTool for the generated dismantling fractions (Table 2).

The following tables illustrate the results of the tests in anonymised form. The respective minimum or maximum value is listed for the values determined.

Table 1: Parameters of the batch tests

Flat panel displays	TV sets		PC monitors	
	min	max	min	max
Total weight/kg	3 047	5 143	1 354	9 271
No. of devices	250	332	250	1 930
% of CCFL	74%	89%	88%	100%
% of LEDs	11%	26%	0%	12%
Average weight/kg	12.2	18.3	4.8	5.7

Either 5 t or 250 units are permitted for manual FPD dismantling. Most companies interpret the number of 250 FPDs as the minimum requirement. Particularly striking is the average weight of TV sets, which is three times as large as that of PC monitors. Recycling of LED devices still occurs at a much lower rate than recycling of CCFL devices containing mercury.

Table 2: Percentage-based mass fractions of the output fractions generated from the devices as well as their modelled percentages in the categories: Recycling (R), Other Material Recovery (OMR) plus Energy Recovery (ER).

Output fractions	Treatment/use	TV sets		PC monitors		Model	
		min	max	min	max	R	OMR+ER
Iron "pure"	for recycling	37.2	46.6	30.2	37.4	97	3
Cr-Ni steel "pure"	for recycling	0.0	0.3	0.1	0.4	97	3
Aluminium "pure"	for recycling	3.9	5.1	6.0	7.5	95	1
Copper or brass "pure"	for recycling	0.0	0.0	0.0	0.4	90	10
Plastics "PS mix"	for further processing	5.8	17.5	14.8	31.0	90	10
Plastics "PMMA"	for recycling	5.1	16.2	15.8	15.8	90	10
Plastics "PS mix toxic"	for incineration	12.9	12.9	21.5	21.5	0	62
Plastics "PS metal mix"	for further processing	5.4	22.4	0.0	0.0	60	26
Printed circuit boards	for recycling in copper foundry	7.1	9.7	6.4	7.2	30	65
Cables and plugs	for further processing	0.8	2.7	0.9	4.6	50	31
Background lighting CCFL	for disposal	0.8	1.0	0.2	0.9	0	0
Background lighting LED	for disposal	0.1	0.2	0.1	0.1	0	0
LCD panels	for incineration (possible storage	7.3	8.7	7.7	16.5	0	62
Speakers	for further processing	2.0	2.4	0.3	0.3	97	3
Power supply	for further processing	1.4	1.4	0.0	0.0	76	23
Fans	for further processing	0.0	0.0	2.7	2.7	76	23
Waste	for incineration	4.0	4.6	0.3	3.4	0	62
Condensers	for (therm.) disposal	0.3	0.3	0.3	0.3	0	0

According to the results, the two fractions with the largest weight are the ‹pure› metals (Fe, Al, Cu), of which up to 97% can be recovered; as well as the plastics, which can be recovered on average up to 70% (TV) and 83% (PC).

Table 3: Achieved recycling and recovery rates (Recycling Rate=MR/input and Recovery Rate=(MR + ER + OMR)/input

Rates	TV sets		PC monitors	
	min	max	min	max
Recycling rate	65.3%	75.4%	60.3%	80.3%
Recovery rate	88.3%	93.1%	87.1%	95.2%

The target for the recovery rate is 75% and is clearly exceeded by all companies (Table 3). The target for the recycling rate is 65% is exceeded, but by much less, by all companies except one. The main reason why the recycling target was not or just barely met is the high amount of plastics that is disposed of by these companies in incinerators. One reason for this difference in processing may be that some companies recycle the plastics because they assume they are safe based on their own sample inspections, while others, lacking evidence that the plastics are safe, follow a careful and correct strategy and dispose of them thermally. The continued high CCFL percentage (Table 1) in the area of background lighting shows how legitimate the regulations to prevent the release of mercury still are. In particular, FPD devices must be treated as though they contain mercury as laid down in SN EN50625-2-2:2015 “Treatment requirements for ... CRTs and FDPs ...” FDP devices are treated as though they contain mercury if nothing else can be determined. Waste electronic and electrical equipment containing mercury may not be crushed, pressed or manipulated before the hazardous substances are extracted. Appropriate and effective measures must be undertaken and documented showing that mercury is verifiably monitored and removed. Mercury must be verifiably removed from fractions that could be contaminated with mercury (e.g. circuit boards or housing) before they can be sent to be recycled. The mercury concentrations in the air of all working areas identified by the risk assessment(s) and in the affected contractors must be monitored regularly.

The mercury, but also the flame retardant problem, will still continue to affect FPD treatment for some time as a result of these rules.

Some of the fractions generated:
1) Fe ‹pure›, 2) Plastic housing ‹mix›, 3) FPD panels,
4) PMMA panes, 5) Circuit boards, 6) CCFL background lights.

Geri Hug / Niklaus Renner

HC containing compressors becoming more popular

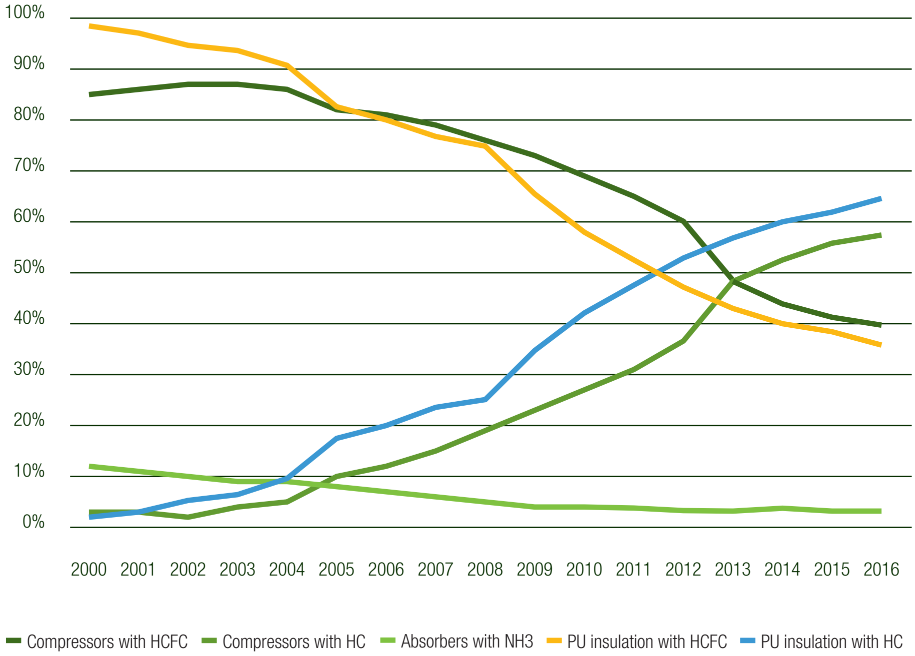
In 2016, 360,000 refrigerators or 18,000 tonnes of material were recycled by the four highly specialised Swiss recycling companies, which is virtually the same as the total figures from the previous year. In contrast, the gap between the HC devices and the old CFC/HCFC devices is steadily increasing: 57 per cent of the devices recycled at stage 1 (refrigerants) and 64 per cent of those recycled at stage 2 (propellants) are now climate-friendly HC devices. Despite this positive development in terms of climate change, it is still extremely important not to compromise the strict quality requirements of the recycling process until the environmentally harmful substances have been removed from the last remaining conventional refrigerators and these substances destroyed in a controlled manner.

HC-CFC gap widens further

In the current reporting period, already 57 per cent of the waste equipment processed at stage 1 had compressors powered by hydrocarbons (HC), which represents a slight increase of one per cent compared to last year. In contrast, the percentage of CFC compressors declined in the same period from 41 per cent to 40 per cent. The number of devices with absorber systems containing ammoniac (NH3) stagnated at 3 per cent (Fig. 1).

Currently, the insulation of 64 per cent of the refrigerators that enter the recycling process is made of cyclopentane-foamed polyurethane (PU), so that the increase in the percentage of modern devices from the previous year also fell within the predicted range for processing stage 2 (increase of two per cent).

Figure 1: Development of the device types processed at stage 1 (compressors containing CFC/HCFC and HC, absorption systems containing ammonia) and at stage 2 (PU insulation foam containing CFC and HC))

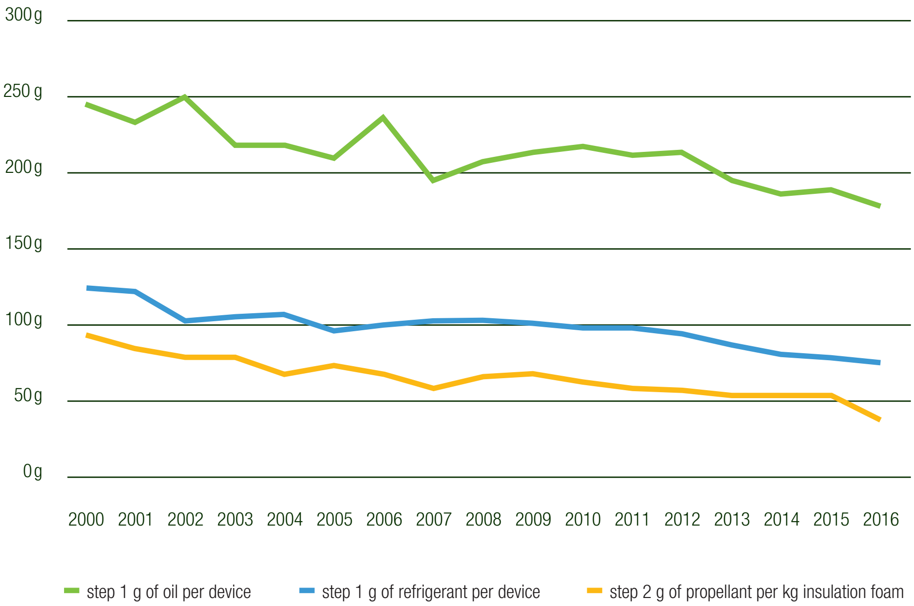


Declining recovery amounts with unchanged performance

The lower quantities of refrigerants and propellants recovered in the past few years could result in disillusionment with the supposed decline in the quality of recycling plants. However, this conclusion would be wrong. Since used HC devices which have much lower compressor-filling quantities or HC concentration in their PU foam than CFC devices have also been making their way into the dismantling process, it is clear that the quantities of refrigerant and propellant recovered as mixtures are decreasing. In addition, hydrocarbons have a lower specific weight than the halogenated compounds. For these reasons – and also because the absolute numbers of HC devices are constantly on the rise – the recovered quantities have been declining for years. The quality of the plants is still high in an international comparison and selective technical optimisations continue to take place.

Whereas in 2000, the quantity of refrigerant removed from the compressors totalled 125 g, between 2008 and 2011 it was only 100 g (stage 1), thus continuing its downward trend. In 2015, it reached a level of 79 g and is only 76 g (decrease of 4 per cent) in the current survey period. This represents a decrease in quantity of almost 40 per cent since 2000. While the fill weight of the compressor oil still fluctuated at 245 g in 2000, this figure also fell over the long term – with individual temporary highs – to its current level of 173 g (a decrease of 8 per cent compared to the previous year). It is therefore evident

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



that devices with HC compressors not only have lower refrigerant fill levels but also lower compressor oil fill levels than conventional CFC compressors.

A similar trend can be seen at stage 2: 90 g per kilogram of PU was recovered in 2000, but this figure declined steadily from this point on. The abrupt drop from 53 g to 39 g from reporting period 2015 to 2016 can be attributed primarily to the changed calculation basis. The value incorporated into the figure for the average weight of the PU foam was increased from 3.5 to 4.5 kg per housing in device categories 1 – 3 based on data from the last five reporting periods; the reason is the generally higher PU quantities in the HC devices. This change resulted in a significant yet artificial decline in the recovery quantity by 26 per cent. The low value stands in contrast to the actual quantity of recovered propellant per housing, which still amounted to 176 g in 2016. This means that the decrease (without discontinuity due to the changed PU weight percentages) from the previous year was only 6 per cent, which is consistent with the long-term trend (see Fig. 2).

Practice makes perfect

The stated aim of refrigerator recycling is to recover substances harmful to the ozone that contribute to greenhouse gases followed by their controlled destruction. The trend of shifting away from conventional CFCs and HCFCs to ozone-friendly hydrocarbons with marginal relevance for greenhouse gases which can also observed in the flow of waste equipment since 2000 is continuing.

However, the positive development is not a reason to ease the strict SENS requirements. It will also be extremely important in the future not to compromise the strict quality requirements of the recycling process until substances which are harmful to the environment have been removed from the last remaining conventional refrigerators and these substances are destroyed in a controlled manner.

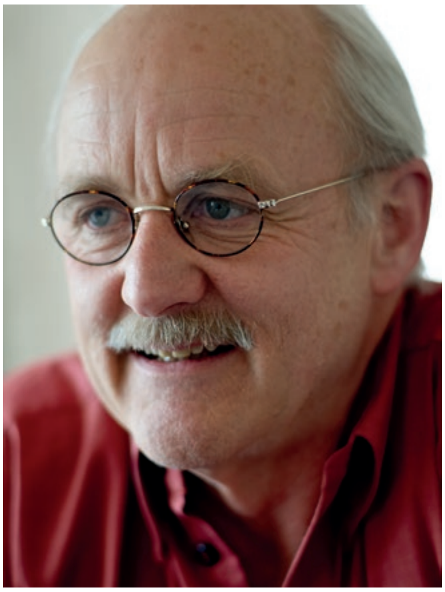
In 2016, 370,000 tonnes of carbon dioxide were prevented from entering the atmosphere as a result. Thanks to increasing percentages of hydrocarbon-driven compressors and insulation containing HC foam, the quantity of avoided CO_2 equivalents fell by 4.6 per cent compared to the previous year. The overall CO_2 savings in 2016 corresponded to emissions that an average Swiss car would have produced orbiting the earth a hypothetical 68,500 times or travelling to the moon and back 3,500 times. We have good reasons to be proud.

UELI KASSER AND THE TC

Daniel Savi

Committed to environmentally-friendly recycling

At the end of 2016, Ueli Kasser relinquished his mandate as a Technical Consultant of the Technical Monitoring Office of SENS and Swico. With the departure of Ueli Kasser, the SENS team is losing a member who has shaped the development of SENS and, in particular, the technical specifications for recycling activities almost from Day 1. SENS and Swico would like to thank Ueli Kasser for the successful working relationship.



Ueli Kasser discusses the technical specifications of recycling

Ueli Kasser's first job for SENS was drafting the technical requirements for the disposal of electrical equipment. He wrote them in 1996 when the SENS system went from a straight return system for cooling system disposal to an extensive return system for private electrical appliances. Ueli Kasser also played an important role in writing parts of the TC's technical report and showcased the inspection activities of the Technical Monitoring Office of SENS in this report to the general public for the first time in 1997. Back then, the quantity of waste electrical and electronic equipment disposed of in the SENS system was still small compared to today. In 1997, for example, around 2,000 tonnes of electrical and electronic devices were disposed of in the SENS system. At the time, the return system underwent rapid change as did the scope of the monitoring activities. As early as in 1998, the quantity of devices disposed of had grown to 15,000 tonnes and in the same year 11 new recycling companies were licensed. The 2000 Technical Report lists 20 recycling companies that were inspected by the TC, 12 of them by Ueli Kasser. From 2005 onwards, Ueli Kasser managed the SENS TC and ensured that the monitoring experts carried out uniform inspection activities and consistently interpreted the guidelines. Already in 2007 management was initially internalised by SENS and shortly thereafter the joint Technical Inspection Office of SENS and Swico was formed. Ueli Kasser assumed the role of a technical consultant, coordinator and supporter of the SENS Swico TC. At the same time, he helped to define a practical formulation for the new European rules for the recycling of waste electrical and electronic equipment under the WEEE Forum and later the CENELEC standards commission.

Target specifications instead of technology bans

It was always important to Ueli Kasser to formulate requirements for recycling as target specifications. His priorities were preventing harmful emissions from entering the environment and ensuring a high rate of recycling of valuable materials. In many discussions, he insisted that target specifications needed to be formulated based around the technology, and that specific processes may never be defined as permanent. The recyclers should always have the opportunity to select the process they felt was best to reach the set goals on their own. With clearly structured thinking and processes, he revised many drafts for new or changed specifications for unclear formulations and unnecessary language. As a trained chemist, he had an excellent grasp of how to turn ideas into feasible practical specifications. SENS thanks Ueli Kasser for his significant contribution to the clearly formulated rules for environmentally friendly recycling of waste electrical and electronic equipment, which serve as a model internationally. SENS and Swico would like to thank Ueli Kasser for his valuable work over the last twenty years and wish him all the very best in this next phase of his life.

AUTHORS

Heinz Böni

After graduating as a Rural Engineer at ETH Zurich and completing a postgraduate degree in Sanitary Engineering and Water Protection (NDS/EAWAG), Heinz Böni worked as a researcher at EAWAG Dübendorf. After working as project manager at the ORL Institute of ETH Zurich and at UNICEF in Nepal, Heinz Böni was appointed to manage the branch office of the engineering company Büro für Kies+Abfall AG in St. Gallen. He then spent several years as co-owner and managing director of Ecopartner GmbH in St. Gallen. Since 2001 he is at Empa, where he heads the CARE group (Critical Materials and Resource Efficiency). Since 2009 he is Head of the Conformity Assessment body and auditor of Swico Recycling.

Roman Eppenberger

Roman Eppenberger completed his degree in electrical engineering at ETH Zurich. While he was working, he completed a postgraduate Executive MBA at the University of Applied Sciences of Eastern Switzerland. He gained his initial industry experience as an engineer and project manager in the field of robotics for medicine and pharmaceuticals. As a product manager, he moved to the contactless unit of Legic (Kaba), where he was responsible for the global procurement of semi-conductor products. Roman Eppenberger has been employed by the SENS Foundation as a member of the Executive Board since 2012 and is responsible for the Technology & Quality division. In this role, he coordinates the Swico/SENS Technical Commission together with Heinz Böni.

Emil Franov

After studying Environmental Sciences at ETH Zurich with a focus on analytical environmental chemistry and aquatic systems, Emil Franov worked for five years as an environmental consultant in an international service company. Since 2001 he has worked at Carbotech AG in Basel as a consultant and project manager with a focus on environmental consulting, eco-balances and compliance with environmental requirements (environmental audits, environmental indicators, environmental law, etc.). He has several mandates for performing annual company eco-balances and environmental indicator surveys according to various international standards. Since 2002 he has been an inspector and member of the Technical Commission of the SENS Foundation. Emil Franov is Divisional Director and Member of the Executive Committee of Carbotech AG.

Esther Thiébaud

After graduating as an Environmental Engineer with an emphasis on Material Balance and Disposal Technology at ETH Zurich, Esther Thiébaud worked as a project manager in the area of contaminated sites at BMG Engineering AG in Schlieren. Since 2007 she has worked as a research associate in the CARE group (Critical Materials and Resource Efficiency) of Empa in the area of analysis and modelling of national and global material flows in connection with advanced technologies and the materials contained therein. Esther Thiébaud has been working on her dissertation since 2012.

Dr. Geri Hug

After completing a degree in chemistry and a subsequent dissertation at the Organic Chemistry Institute of the University of Zurich, Geri Hug worked as a researcher and project manager at Roos + Partner AG in Lucerne. He was a partner at Roos + Partner AG from 1994 to 2011 and also managing director from 1997. He offers environmental consultancy in 15 industry sectors according to EAC codes, supports environmental audits and prepares environmental reports in accordance with the Ordinance on Environmental Impact Assessment (UVPV). Geri Hug prepares short reports and risk analyses pursuant to the Major Accident Ordinance (MAO) as well as operational and product life cycle assessments, and validates environmental reports. Geri Hug is the Control Officer of the SENS Foundation in the field of electrical and electronic waste disposal and lead auditor for environmental management systems pursuant to ISO 14001 at SGS. He is a member of the CENELEC Working Group on the development of standards for the environmentally friendly recycling of refrigerators.

Flora Conte

Flora Conte completed her Master’s degree in environmental sciences, with a major in biogeochemistry and pollutant dynamics, at ETH Zurich. She has been working in the environmental consulting department of Carbotech AG since 2013. She manages various projects in areas such as renewable energy, recycling and entrepreneurship at national and international level. She has been a member of the SENS/Swico Technical Commission since 2015 and an auditor for SENS/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 involved in setting up and managing small companies in Switzerland and abroad.

Anahide Bondolfi

Anahide Bondolfi completed her Bachelor’s degree in biology and her Master’s degree in environmental science at the University of Lausanne. She began her work in the field of waste electrical and electronic equipment in South Africa in 2006 as part of her Master›s thesis, which she wrote in cooperation with the Swiss Federal Laboratories for Materials Science and Technology (EMPA). She has been working as an environmental consultant since 2007. She manages projects at national and international level, and teaches at various institutes in the areas of waste, waste electrical and electronic equipment, sustainable procurement and ecolabels. Under the scope of international projects, she coaches and audits recycling and dismantling companies (waste electrical and electronic equipment) abroad. She has been a member of the Swico/SENS Technical Commission since 2015. She audits collection points and dismantling companies and partners of both systems. Anahide Bondolfi has also been auditing SENS recyclers since 2016.

Rolf Widmer

Rolf Widmer graduated in Electrical Engineering (MSc. ETH EE) and completed his postgraduate degree on developing countries (NADEL, MAS) at the ETH in Zurich. For several years he carried out research at the Institute of Quantum Electronics of the ETH and today works at the Technology and Society Lab of Empa, the materials research institute of the ETH domain. Rolf Widmer currently directs several projects in the field of electronic waste management. In this connection he works on closed material cycles of electro mobility. His special interest is the recovery of rare metals, which are increasingly accumulating in “urban mines”.

AUTHORS

Daniel Savi

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.

Patrick Wäger

Patrick Wäger studied chemistry at ETH Zurich and obtained a PhD in environmental sciences at the Institute of Toxicology of the ETH and University of Zurich. Before joining Empa for research project in the field of waste disposal, he worked as an environmental consultant at Elektrowatt Engineering Ltd. in Zurich. In the past few years his research focused on geochemically scarce and critical raw materials. Since 2016 he is Head of Empa's Technology and Society Laboratory.

Niklaus Renner

Niklaus Renner studied Environmental Sciences at ETH Zurich. Since 2007 he has worked as a research associate at Roos + Partner AG Lucerne. In the context of various studies, he is concerned with the environmental compatibility of scrap metal and waste equipment recycling. For the SENS and SLRS Foundations his involvement included a survey on the mercury content of fractions in the processing of lamps. In addition, Niklaus Renner's tasks include monitoring environmental law, maintaining the legal compliance tool LCS.pro and internal environmental law conformity audits. Operating inspections for the environmental inspectorate UPSA (Car Industry Association) and, since 2013, construction site soil analysis complete his profile.

LINKS

Internationale links

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

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

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

www.weee-europe.com
WEEE Europe AG is an amalgamation of 15 European take-back systems and, as of January 2015, will allow manufacturers and other market players to fulfil their various national obligations from a single source.

National links

www.eRecycling.ch

www.swicorecycling.ch

www.slrs.ch

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

www.empa.ch
The Swiss Federal Laboratories for Materials Testing and Research (Empa) is a Swiss research institute for applied materials science and technology.

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

Cantons with devolved powers

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

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

www.umwelt.tg.ch
On the website of the Office for the Environment of the Canton of Thurgau, the «Waste» section provides relevant regional information about the recycling of electrical and electronic equipment.

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

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

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

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

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

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