TECHNICAL REPORT 2014

SENS

Swico

SLRS

Signs of change

There is currently a great deal of development under way in the recycling industry, both internationally and here in Switzerland, and various areas of legislation that apply to us are currently being amended.

The revision of the Environmental Protection Act (EPA) has not only aroused considerable political discussion, but has also aroused debate in the industry. It is clear to all concerned that the framework conditions for our future business activities are in the process of being redefined. Many stakeholder groups are attempting to anchor their highly specific interests in the Act in order to ensure the most convenient possible starting point for their future activities. This will make it extremely difficult to ultimately achieve legislation that provides the necessary framework but nevertheless provides companies with sufficient entrepreneurial freedom to set themselves apart on the national and international market.

From the perspective of the electrical and electronics sector, the revision of the Ordinance on the Return, Taking Back and Disposal of Electrical and Electronic Equipment (ORDEE) is at least as important as that of the EPA. Here, in addition to the process-related issues associated with the existence of compulsory and voluntary return systems in the same market, there is also the question of the future state of technology in Switzerland. How far can and will Switzerland align itself with the situation in the European Union? Is the new CENELEC standard suitable as a basis for the state of technology in Switzerland? Do we want to continue to distinguish ourselves from the EU in this regard? What form might such a distinction take, and what would the advantages and disadvantages be?

All of these questions should be discussed and debated in an advisory group. We have a great deal of work ahead, but we are in a good position: the Federal Office for the Environment (FOEN) recognises our wealth of know-how, which secures us an influential voice in the revision process.

We are therefore convinced that the revision of both the EPA and the ORDEE will lead us into a successful future in terms of ecology and environment, and that Switzerland will continue to be seen internationally as a model for success!

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SENS Foundation, Swico and SLRS: competent and sustainable

For around 20 years, the three take-back systems of SENS, Swico and the Swiss Lighting Recycling Foundation (SLRS) have been guaranteeing the resource-efficient return, reuse and proper disposal of electrical and electronic devices. Increasing take-back quantities bear witness to the success of the three systems.

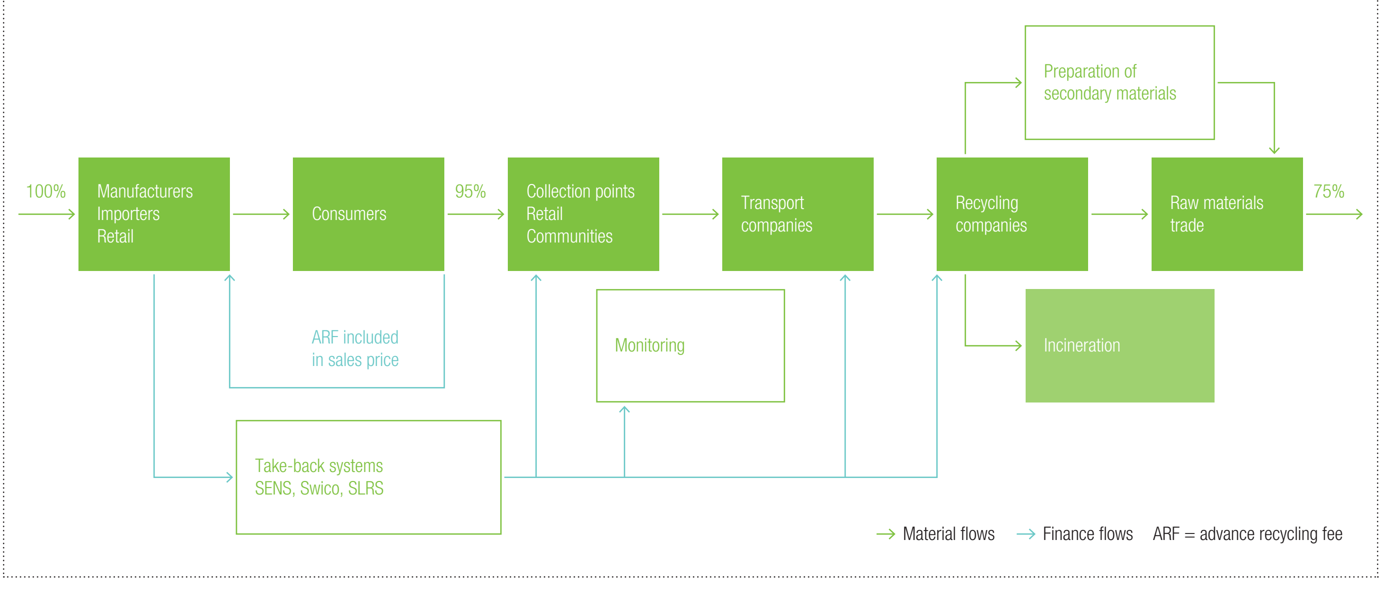
In Switzerland, there are three take-back systems for electrical and electronic devices. There are historical reasons for the existence of three systems, as in the early years of institutionalised recycling, industry-specific systems were established. The aim of these was to guarantee proximity to the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

In 2013, the three systems disposed of over 128,000 tonnes[1] of old electrical and electronic devices. This means that Swico, the SENS Foundation and SLRS have also made a significant contribution to reintroducing valuable resources into the production cycle. The international networking of the three organisations at a European level – for example as members of the WEEE Forum (Forum for Waste Electrical and Electronic Equipment) – will allow them to help set cross-border standards for the recycling of electrical and electronic devices.

The Ordinance on the Return, Taking Back and Disposal of Electrical and Electronic Equipment (ORDEE) 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.

Overview of the take-back systems



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. The quantity of recycled refrigerators, freezers and air conditioners did not increase further in 2013. This represents the first time the volumes of recycled cooling equipment has reached saturation point.

Swico

Swico Recycling is a special fund within the Swiss Industrial Association for Information, Communication and Organisation Technology (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. It focuses on equipment relating to IT, consumer electronics, office, telecommunications, graphical industry and measurement and medical technology, such as photocopiers, printers, televisions, MP3 players, mobile phones, digital cameras, etc. Close cooperation with Empa, a research and service institution for materials science and technology development within the ETH, makes a significant contribution to Swico being able to implement high-quality standards on a uniform basis across all disposal services nationwide.

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

En route for Europe

In 2013, the joint Technical Commission of Swico and the SENS Foundation intensified its work on the future requirements for a unified audit system for the whole of Europe. It looked particularly closely at the introduction of the private WEEELABEX standard as well as at the development of the CENELEC standards envisaged as becoming binding in the review process of the European Union's WEEE Directive.

In recent years, individual representatives of the Swico / SENS Technical Commission have been intensively involved in drafting the WEEELABEX standard and preparing its implementation. In 2012 and 2013, a special task force prepared the audit documents that served as the basis for the first WEEELABEX auditor training in Prague on 9 and 10 July 2013. Since then, four auditors from Swico and SENS have completed their training as WEEELABEX lead auditors.

The development of the CENELEC EN 50625 standard was carried out in parallel under great pressure of time from the European Commission. A broadly based standardisation committee with 50 members included a member of the Swico / SENS Technical Commission. At the time of writing, an extensive set of standards is being drawn up that will also influence auditing in Switzerland from 2015 or 2016 onwards. How and as of when the CENELEC standard is to be implemented in Switzerland are still open questions.

The 10-member-strong Swico / SENS Technical Commission held four whole-day meetings throughout 2013. These sessions were used to discuss the results of the audits as well as technical issues. The technical rules of Swico, SENS and SLRS and their uniform application were also regularly on the agenda. As every year, a session of further training was also held in 2013. One of the crucial issues last year was to be up to date as regards, inter alia, the amendments to the relevant environmental provisions. The Technical Commission's auditors, operating on behalf of Swico and SENS, perform audits of the partner operations as regards compliance not only with the technical but also with the statutory provisions. The Cantons of Zurich, Aargau, Thurgau and, more recently, St. Gallen as well have entrusted the performance of these audits to Swico and SENS. For a change, the subject matter of the further-education course was an update of knowledge concerning the technology for recycling electronic waste, and this subject was handled by Professor Rainer Bunge of the Hochschule für Technik Rapperswil and a representative of a recycling operation. This subject also triggered a huge controversial debate amongst the participants and with the speakers about the pros and cons of intensive manual processing compared with mechanised processing. Given the possibility of recovering finely distributed quantities of valuable and / or critical metals, it seems that wet processing routes are also likely to be used more in recovery installations.

Ueli Kasser

First European e-waste standard EN 50625-1 now ratified

The development of the European series of standards for the treatment of waste electrical and electronic equipment is progressing at a most unusually fast rate for standardisation work. The general standard came into force recently. It establishes the basis for the standards to follow for individual categories of equipment, such as lamps, monitors and photovoltaic panels. These more specific standards will contain references to the general standard, and together they will form the EN 50625 series.

Pressure from the European Commission

The foundations have been laid. At the end of the year, EN 50625-1 "Collection, Logistics and Treatment Requirements for WEEE – Part 1: General Treatment Requirements" was adopted with 96% of all weighted votes cast in favour. In the time since then, the standard has been ratified and is likely to be published in the official languages of English, French and German by mid-2014. The great speed, which is far from typical for standardisation work, is to be explained by the fact that the European Commission has given the European standardisation organisation, CEN / CENELEC, a remit. Its intention is to establish the level of technology for the treatment of waste electrical and electronic equipment compulsory through this series of standards with the next review of the European Union's WEEE Directive (likely to be issued in 2016 or 2017). That would give these standards the force of law in all countries belonging to the European Union. The European standardisation body, CEN / CENELEC, thus has the task of completing the entire series of standards (Figure 1) by the end of 2015.

Processes laid down as compulsory

The CEN / CENELEC series of standards is to be considered as completed once positive votes have been obtained from all the standards bodies in the individual countries. For EN 50625-1, at least 71% of the weighted national votes are required plus the simple majority of all the countries. The votes of the big countries, such as Germany, France, the United Kingdom and Italy, are weighted with 42 points. Small countries, like Switzerland and the Netherlands, have 10 weighted points. Within the countries, it is in turn committees within the standards bodies that decide on how their countries' vote is to be cast in accordance with procedures laid down for the purpose. Switzerland too, as a member of the European standards organisation, is able to exert its influence on the form of the system of standards. EN 50625-1 has been accepted in 18 countries, with 14 abstentions and a vote against from Bulgaria. The explanation for most of the abstentions is likely to be a lack of interest or a lack of resources for formulating an opinion. What impact an abstention really has can only be a matter for speculation. In the case of the United Kingdom, the information has seeped out that its abstention came about because of massive differences of opinion within the responsible national organisation.

Extensive consultations

Before any vote is held, however, the draft standards are usually sent to the national organisations for consultation several times over. To date, it has been, in particular, the big national organisations that have made active use of these consultations. As far as the general standard is concerned, two rounds of consultations were held, and these resulted in proposals for nearly a thousand amendments and additions from more than 20 countries. The Swico / SENS Technical Audit Department also made its input into the consultation through the Swiss standards organisation, Electrosuisse. After all, the European series of standards arose originally out of the Swico and SENS standards.[1]

These were taken as the input for development of the WEEELABEX standards, which began five years ago, and they subsequently served as the initial input for the CEN / CENELEC standards.[2]

Committee with 50 members

The drafting of the standards, processing them and deciding on the motions arising out of the consultations are the tasks of TC111X. This is one of 72 technical committees. It works on standards related to the environment and set up Working Group 6 for the EN 50625 series. Over time, its membership has swollen to nearly 50 representatives of associated organisations and various associations of manufacturers, metal recyclers and facilities processing e-waste. It is, however, only the representatives of the national standards organisations that have the right to vote. Working Group 6 takes all the decisions, but entrusts project groups with producing drafts. That may appear to be an extravagant method of working, but it is an efficient and orderly one that is able to leverage the members' wealth of experience.

Thirteen documents making up the EN 50625 series

Figure 1 shows the stages reached in processing all the documents envisaged within the EN 50625 series. There are five European standards (EN) and eight technical specifications (TS). The technical specifications are just as binding as the standards themselves, except that they contain limit values and target values as well as instructions for taking samples of material and specific details for performing tests. If necessary, it is easier to amend them and to adapt them to developments than is the case with standards. Of the five standards, the general one has already been accepted and ratified. The lamps standard has recently been submitted to the countries for them to vote on it, while the other three are still only at the draft stage and are to be sent for consultation in the course of the current year. As far as the standard

Collection, Logistics and Treatment Requirements for WEEE

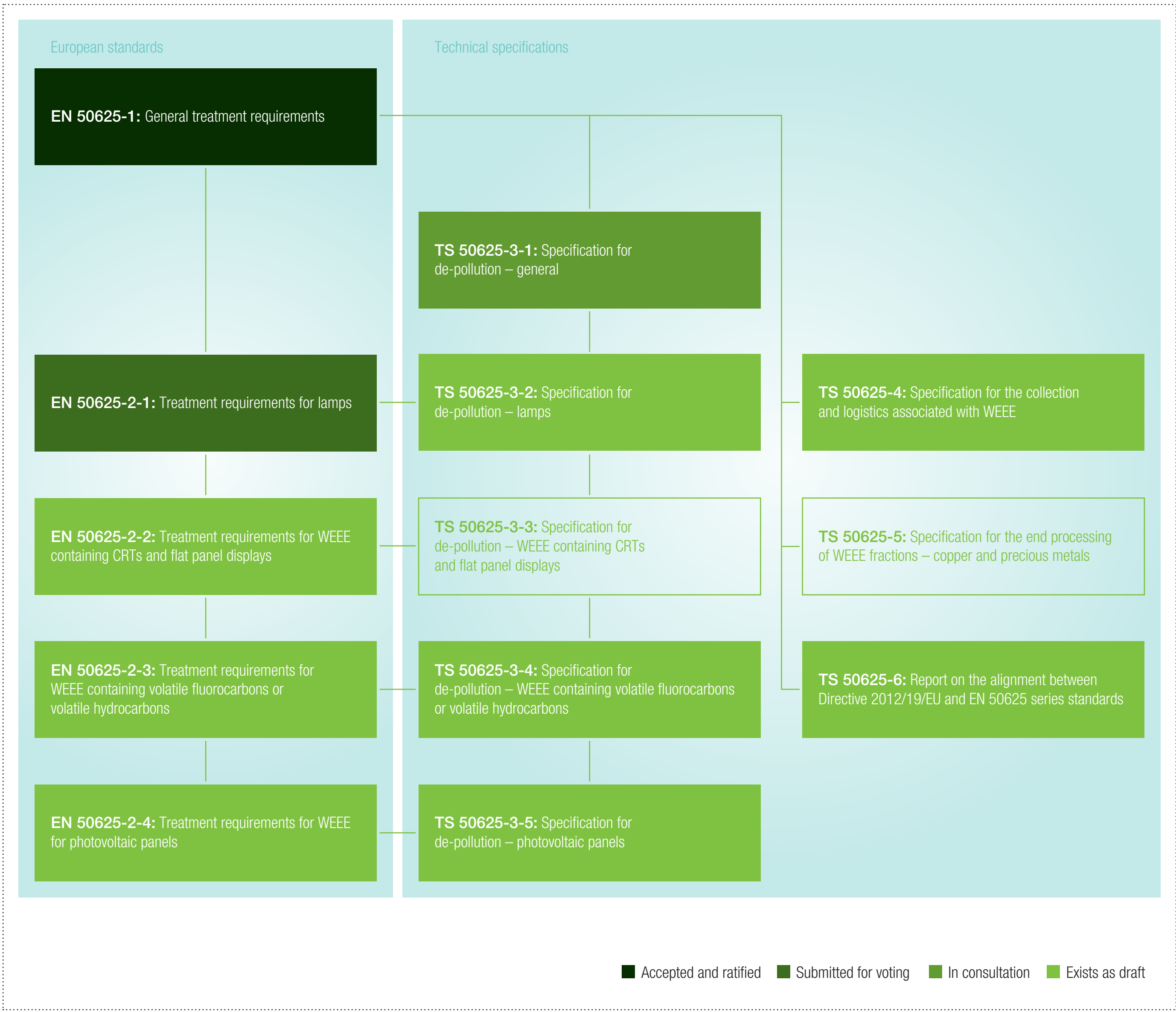


Figure 1: Structure, interrelationships and stage of the EN 50625 series on the collection, logistics and treatment of waste electrical and electronic equipment (February 2014)

[1] Swico Recycling / SENS: Technical regulations on the recycling of electrical and electronic appliances; PART I: GENERAL TECHNICAL REGULATIONS; PART II: DIRECTIVES and adaptations, 3 March 2009.

[2] A detailed report on the development history of the standard was published in the 2013 Technical Report from Swico, SENS and SLRS.

Figure 2: One of several project groups: representatives of Philips, Indaver, Dela and the take-back systems operating in Spain, Germany, the United Kingdom, France and Switzerland

for refrigeration appliances is concerned, the existing EN 50574-1 is to be adapted to the structure of EN 50625 without any material changes being made to it. The standard on the treatment requirements for photovoltaic panels, on the other hand, is to be a totally new one.

Technical specifications

The technical specifications have so far made even less progress. One reason for this is that they are a lower priority; another is that the consultation and voting procedures for them are simpler. On the other hand, limit values in particular, such as those for pollutants in fractions, are often controversial. They are defined in the technical specifications and lead to intense discussions and numerous motions for amendments. That has most certainly been the commission's experience, for instance with TS 50625-3-1, the only TS document so far sent for consultation. The consultation discussion took up four full-day meetings and two web conferences lasting several hours.

Initial consequences in Switzerland too

It is clear that demand for a standard exists, and the standardisation work has gained in importance since the European Union placed the matter in the hands of the European standardisation organisation. Working Group 6 under TC111X in the field of environmental standards is being observed critically, and lobbying has intensified. The fact that the EN 50625 series (although still only at the development stage) has already been incorporated in the national law transposing the WEEE Directive, for example in the Netherlands, is a clear indication of its growing importance in recycling practice. In the case of Switzerland, it has still not been decided whether the level of technology will be defined through the EN standard in the corresponding Ordinance on the Return, Taking Back and Disposal of Electrical and Electronic Equipment (ORDEE). At all events, Swico, SENS and SLRS are willing to lay down contractually that the standards are to be binding in the context of their partnerships with the recycling facilities. It ought not to be forgotten that this set of standards had its roots in an initiative taken by Switzerland. Their introduction in practice is unlikely to bring about major changes.

Esther Müller / Geri Hug

Consistently high volumes of processed devices

Just under 128,000 tonnes of electrical and electronic devices were recycled in 2013, almost the same quantity as in the previous year. The quantities and the processing of the resulting groups of materials are also barely different from the previous year.

In comparison with the previous year, the quantity of electrical and electronic devices processed by SENS and Swico recyclers fell slightly by 1% to 127,900 tonnes (Table 1, Figure 1). This corresponds to a quantity of 16 kilograms per inhabitant per year, which means that Switzerland continues to play a leading role in comparison with other European countries. There were some significant variations within the various device categories. Small electrical devices continued to see a significant increase, this time by 19% to 3,500 tonnes. Lamp recycling was up 15%, returning to the level of previous years following a decline in 2012. The quantity of recycled electronic devices fell by 2,300 tonnes, however, and the devices not included in the lists of the Ordinance on the Return, Taking Back and Disposal of Electrical and Electronic Equipment (ORDEE) by 2,000 tonnes. The decline in electronic devices is due primarily to the fall in the numbers in recycled cathode ray tube (CRT) screens.

Material balance of SENS and Swico recyclers

A detailed material balance of recycled electrical and electronic devices can be prepared on the basis of the material flow data issued by recyclers on an annual basis (Figure 2). The biggest material group resulting from processing is metals with around 55% of the total in terms of mass, followed by plastics (14%) and plastic-metal composites (13%). The glass from CRT processing accounts for a share of 7%. Printed circuit boards, which contain particularly valuable materials, and harmful substances make up just 1 to 2% of the total quantity processed. The quantities of the individual groups of recyclable materials and harmful substances have changed little since 2012. While the quantity of harmful substances appears small in comparison with recyclable materials, their removal and environmentally sound disposal represent two of the most important functions of SENS and Swico recyclers. The often manual process of removing harmful substances takes place primarily in around 90 disassembly facilities with whom the recyclers cooperate. In addition to various harmful substances, these facilities also manually disassemble particularly valuable device parts and components.

Recycling rate of over 75%

The total recycling rate across all device categories and recycling facilities amounts to over 75%. The largest recyclable material group is again metals, which are primarily processed in large smelting works in other European countries. The proportion of plastics entering into material recovery increased again this year. Plastic-metal composites also leave Switzerland and go on to be separated into pure metal and plastic groups in a complex treatment process. Glass groups (screen glass, plate glass and recycling glass from lamps), as well as cables, printed circuit boards and batteries are processed further.

Table 1: Total quantity of electrical and electronic devices in Switzerland in tonnes from material flow analysis

Year	Large electrical devices	Refrigerators, freezers and air conditioners	Small electrical devices	Electronic devices	Lamps	Non-ORDEE 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	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
Changes on previous year	**1%**	**–5%**	**19%**	**–4%**	**15%**	**–33%**	**–1%**

Figure 1: Developments in quantities of recycled devices in Switzerland in tonnes

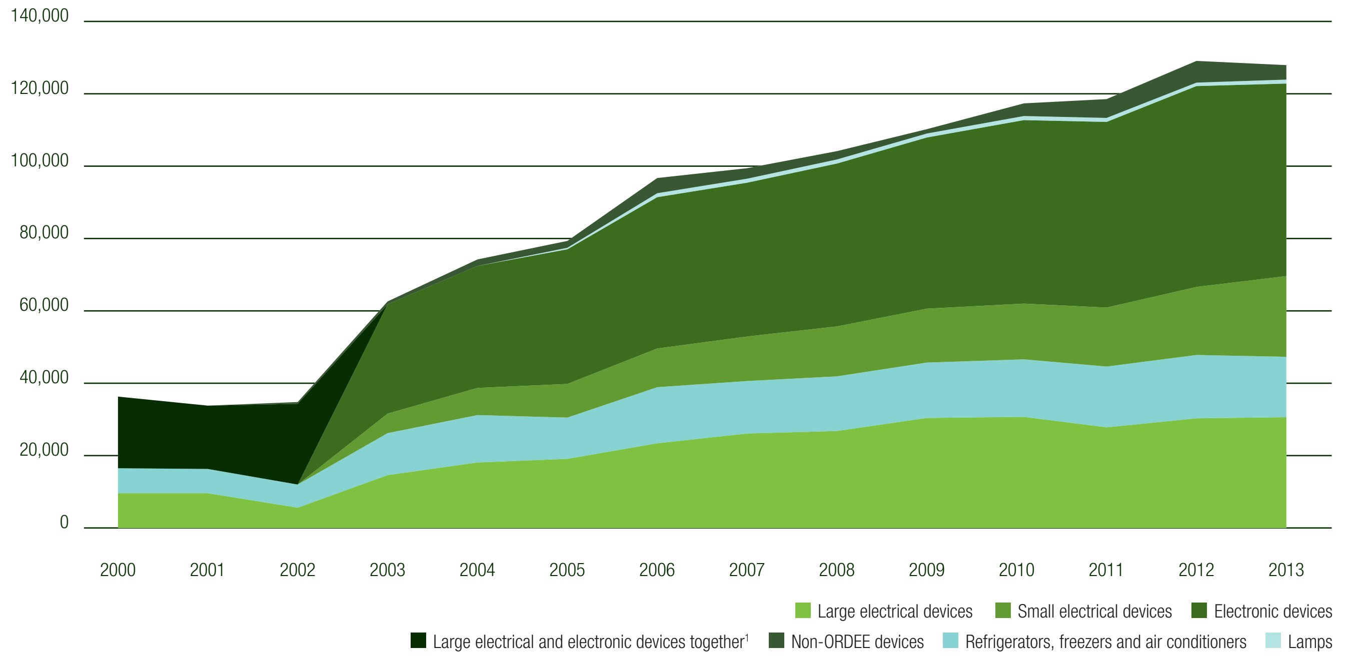
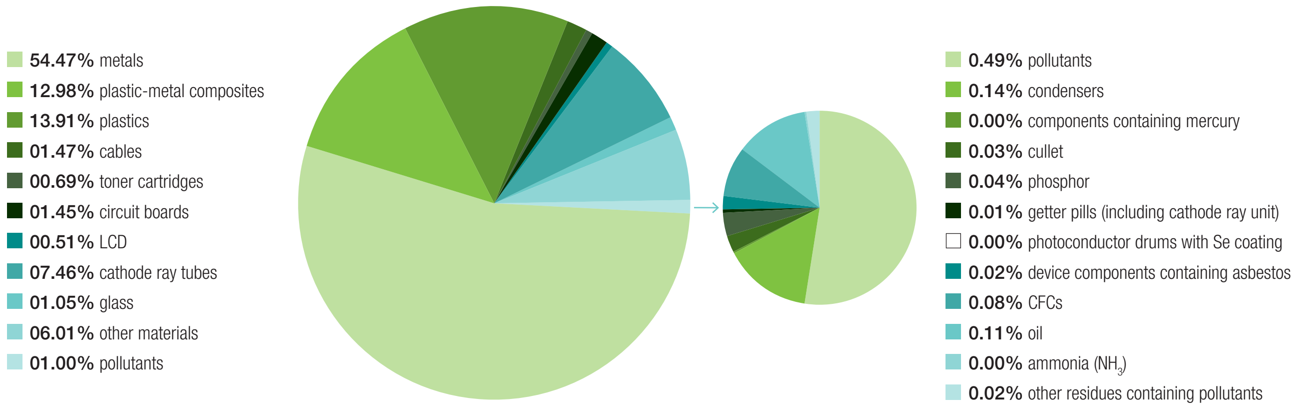


Figure 2: Composition of the resulting material groups as a percentage in 2012



Pollutants which make up a total of just 1 % of the fractions generated are listed separately.

Table 2: Swico quantities collected and composition by device type

	Quantity[4]	Ø-weight	Metals	Plastics	Plastic-metal composites	Cables	Glass and/or LCD modules	Circuit boards	Pollutants	Other[5]	Total	Increase/decrease compared to 2012
PC monitors, CRT	173,000	18 kg	452 t	613 t	292 t	79 t	1,347 t	282 t	0.2 t	14 t	3,080 t	–44 %
PC monitors, LCD	464,000	5.8 kg	1,146 t	641 t		11 t	675 t	186 t	8.7 t	12 t	2679t	6 %
PCs / servers	380,000	13 kg	4,048 t	283 t	13 t	151 t		410 t	16 t		4,921 t	–3 %
Notebook computers	370,000	3.3 kg	370 t	344 t	124 t	6 t	107 t	177 t	84 t	5.1 t	1,219 t	–4 %
Printers	498,000	10 kg	1,746 t	2,649 t	303 t	27 t	34 t	86 t	1.5 t	80 t	4,927 t	–6 %
Large-scale photocopiers / equipment	42,000	164 kg	3,750 t	229 t	2,507 t	125 t	4.1 t	50 t	56 t	168 t	6,889 t	23 %
IT, mixe[2]	412,000	9 kg	2,016 t	118 t	1,359 t	68 t	1.6 t	26 t	30 t	89 t	3,708 t	–11 %
CRT televisions	430,000	29 kg	1,229 t	2,549 t	415 t	43 t	8,062 t	153 t	12 t	6.8 t	12,470 t	–25 %
LCD televisions	139,000	16 kg	896 t	322 t		43 t	558 t	265 t	20 t	75 t	2,180 t	10 %
Consumer electronics, mixed[3]	2,096,000	4.8 kg	5,448 t	320 t	3,674 t	182 t	4.3 t	70 t	81 t	240 t	10,020 t	–7 %
Telephones, mobile	590,000	0.16 kg	15 t	34 t			4.9 t	21 t	19 t		94 t	34 %
Telephones, other	1,341,000	2.2 kg	1,568 t	92 t	1,057 t	53 t	1.2 t	20 t	23 t	69 t	2,883 t	25 %
Cameras / video cameras	275,000	0.6 kg	89 t	5.2 t	60 t	3 t	0.1 t	1.1 t	1.3 t	3.9 t	163 t	18 %
Dental											70 t	4 %
Total in Tonnen			**22,771 t**	**8,201 t**	**9,805t**	**791 t**	**10,800t**	**1,749t**	**353t**	**763t**	**55,304t[6]**	
Total in Prozent			**41 %**	**15%**	**18%**	**1.4%**	**20%**	**3.2%**	**0.6%**	**1.4%**	**100%**	

First significant decline in processed visual display units (VDUs)

The quantities of electronic devices taken back by Swico fell by around 10% on 2012. As already mentioned, this decline is attributable to the decline in returned cathode ray tubes (CRT computer monitors –44% and CRT TV sets –25%). While these devices have not been on sale for several years now, the take-back rate has remained very high in recent years. It now appears that existing stocks of CRT devices in Switzerland are slowly but surely on the decline. Other devices such as laptops, printers and LCD TV sets have fallen, although the reasons for this are difficult to assess. The take-back rate of mobile phones and smartphones rose by a further 34%, which is attributable to the consistently high sales of smartphones. Telephones are increasingly being replaced by mobile phones or VoIP systems, resulting in an increased take-back rate of 25%.

The composition of the individual device categories is investigated by means of processing tests carried out by Swico recyclers and supervised by Empa. In this process, a previously defined quantity of devices is collected and the resulting material groups are documented. The detailed quantities of electronic devices taken back and their composition can be found in Table 2.

[1] Until 2002, small electrical and electronic devices were recorded together.
[2] IT equipment, mixed, without monitors, PCs / servers, notebook computers, printers, large-scale copiers and equipment.
[3] Consumer electronics, mixed, not including televisions.
[4] Projection.
[5] Packaging and other waste, toner cartridges.
[6] This figure is higher than the 53,200 tonnes of electronic devices in Table 1 for two reasons: firstly, it includes around 2,000 tonnes which are included under "Non-ORDEE devices" in Table 1, and secondly, this figure relates to the volumes taken back, which are often slightly greater than the volumes processed as some devices remain in storage for the period in question.

Geri Hug / Niklaus Renner

Refrigerators and freezers

Again in 2013, SENS refrigerator and freezer recyclers processed over a third of a million appliances at stage 1 (removal of refrigerant from compressors) and stage 2 (extraction of propellant from the PU insulation foam). As in recent years, approximately 4% of these appliances were recycled at a facility outside Switzerland. Following a continuous increase in the quantities processed over the last 10 years, at 17,300 tonnes the total tonnage of refrigerators and freezers dismantled in 2013 was very slightly lower than in the previous year (–1%).

HC and CFC compressors level for the first time

The decline in the proportion of CFC-based compressors since 2003 and the simultaneous increase in the share of HC compressors received for recycling have been progressing in a linear manner. According to the figures for 2013, this trend has accelerated hugely within just one year (see "kinks" in Figure 1): while in 2012 60% of the refrigerators and freezers received for recycling were of the CFC type, in 2013 this figure was just 48%. During the same period, the proportion of HC compressors rose from 37% to 48%, which means that the balance between CFC and HC compressor appliances predicted in the last Technical Report for 2014 to 2016 was already reached in 2013. It is to be assumed that this development will continue at least at an equally rapid rate in the coming year, which would result in a proportion of almost two-thirds for HC compressors in 2014. The share of absorption systems containing ammonia stagnated at some 3%.

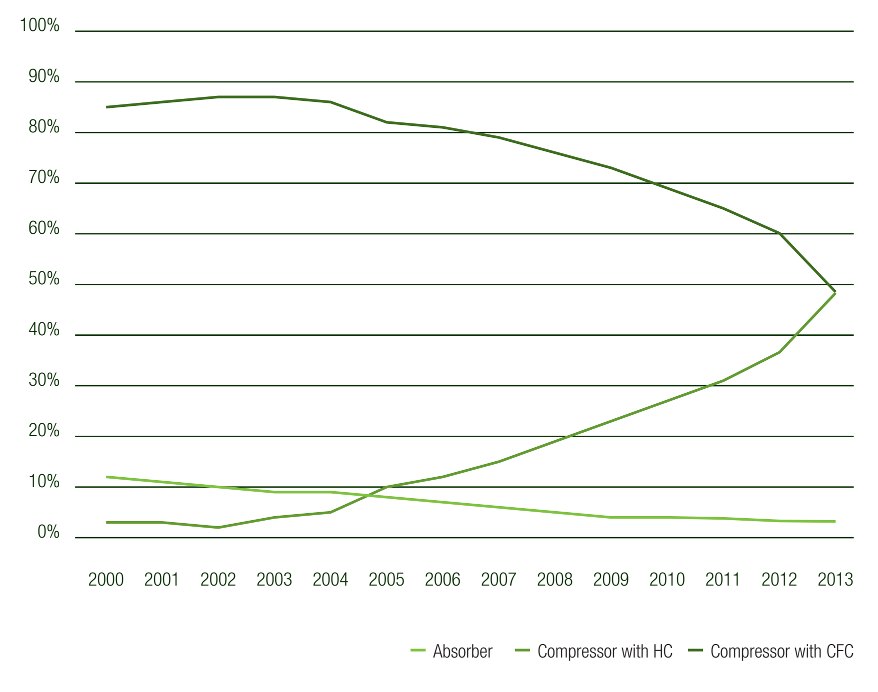
High performance, falling recovery rates

The general reduction in the quantity of extracted refrigerant observed since 2002 continued in 2013. While "just" 95 grams of refrigerant compound were recovered in the previous year, this figure fell to 89 grams in 2013. This reduction is in no way associated with any decline in recycling performance, but reflects the drop in the high proportion of cooling circuits containing HCs: a HC compressor contains only approximately 40% of the refrigerant found in a conventional CFC compressor. As a result of this development the specific quantity of refrigerant will continue to fall steadily in the future until it reaches around 60 to 70 grams. This will however undoubtedly not be the case until long after 2020, as the proportion of CFC compressors is asymptotically approaching the 0% mark. The fact that the specific quantity of recovered oil has fallen from 214 to 196 grams suggests that, with HC compressors, it is not only the quantity of refrigerant but also the quantity of oil that is lower.

HC-foamed refrigerator and freezer numbers continue to rise

While the curve is flatter than for CFC compressors, the numbers of CFC-foamed appliance housings are also declining continuously, having fallen from 47% last year to now 43%. The proportion of housings insulated with HC (cyclopentane) foam rose

Figure 1: Development in appliance types treated at stage 1 (CFC and HC compressors as well as absorption systems containing ammonia)



from 53% to 57%, following a trend reversal already observed in 2012.

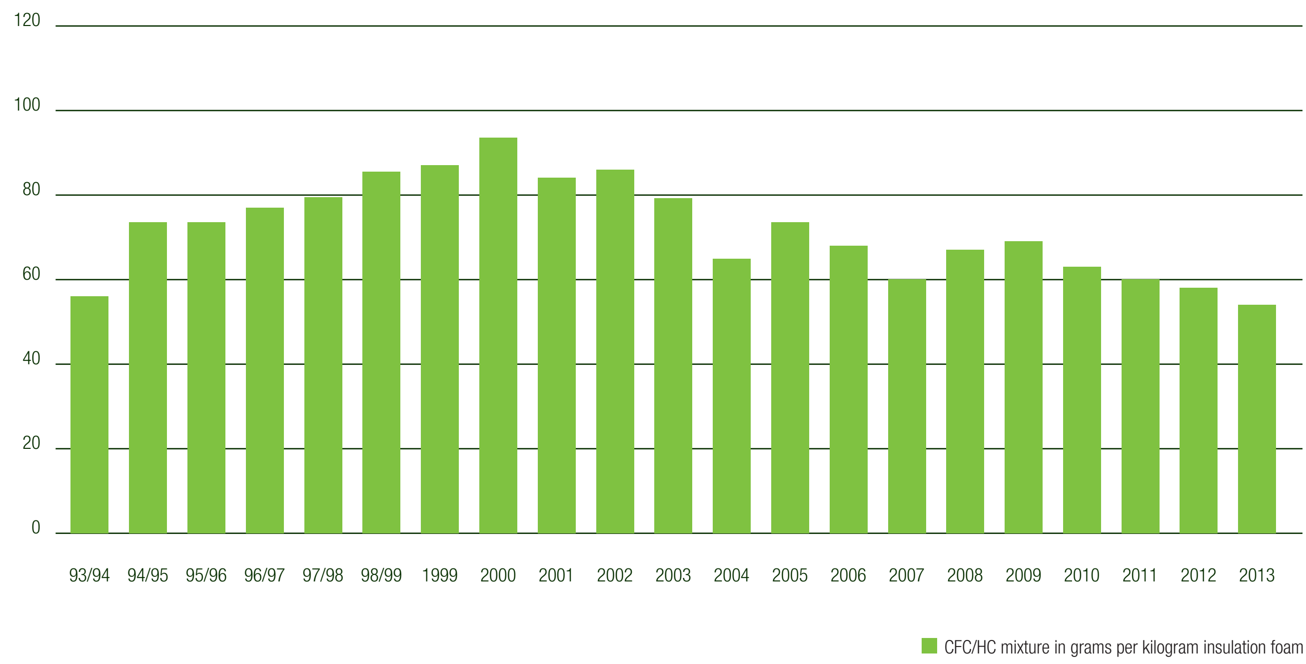
As CFC- and HC-foamed appliance housings are processed together on the same production lines as opposed to separately, a decline in the recovery of propellants (stage 2) has also been observed since 2001. Similarly to stage 1, the propellants evacuated in stage 2 are also collected as a mixture. The rising numbers of HC appliance housings and the lower HC quantities in the polyurethane (PU) foam are therefore also being observed here in the form of lower recovery rates. While quantities of over 80 grams per kilogram of PU were recovered at the turn of the millennium, these values fell (with some fluctuations) to below 60 grams for the first time to reach 58 grams in 2012 (Figure 2), followed by an average of 54 grams of propellant mixture per kilogram PU in 2013. Based on the assumption (reinforced by analyses and manufacturer data) that the specific quantity of cyclopentane per kilogram of PU at the end of an appliance's lifetime is around 40 grams, this makes it possible to forecast a time horizon of 2020, by which time the average propellant recovery rate will settle at this level.

High environmental relevance

The processing facilities are equally efficient in the recovery of both CFC (CFC-11) and HC (cyclopentane). Hydrocarbon is completely non-critical in terms of ozone-depleting potential, and based on the global-warming potential of CFC-11 the effect is tiny. Despite this, joint processing using existing highly sophisticated facilities (low-temperature condensation) makes sense in guaranteeing that CFC appliance housings can be disposed of in an environmentally sound manner, as long as they continue to be returned.

The recycling of refrigerators and freezers is highly significant for climate protection. By ensuring that refrigerants and propellants are not released, and that they are destroyed in a controlled environment (high-temperature incineration), recyclers prevent huge quantities of greenhouse gases from reaching the atmosphere. In the year under review, for example, the recovery of greenhouse gases amounted to approximately 470,000 tonnes of CO_2 equivalent. Such a quantity of carbon dioxide corresponds to the emissions produced by modern cars over a distance of three billion kilometres.

Figure 2: CFC / HC recovered from PU insulation foam (stage 2)



Patrick Wäger / Rolf Widmer

Lithium-ion cells and their disposal

The number of lithium-ion cells used in portable electronic devices in recent years has increased at a veritably explosive rate. The reasons for this are that lithium-ion cells have a high energy density, virtually no memory effect[1] and hardly any charging losses. Their negative side is that there is a risk of fire both during their useful life and in their disposal. This contribution sets out to explain what a lithium-ion cell is, what dangers arise from lithium-ion cells and what impacts these have on their storage and disposal.

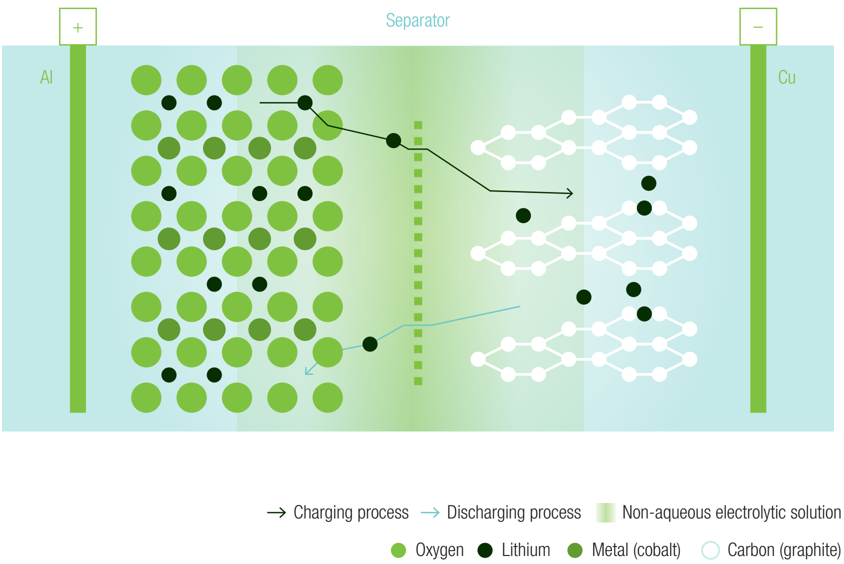
What is a lithium-ion cell?

In lithium-ion cells, lithium ions are pushed to and fro between an anode and a cathode during the charging and discharging processes. In this system, which is sometimes also called a "rocking chair", no chemical reactions occur. In other words no highly reactive, metallic lithium is formed. The fundamental structure of a secondary battery like this is very similar for all the established technologies (see box).

All commercial lithium-ion cells have graphite anodes. The essential differences between the cells lie in the composition of the cathode material. Iron-phosphate cathodes are regarded as the most dependable and most favourably priced technology but have a lower energy density. Nickel and cobalt cathodes display high energy densities but are less dependable and less durable, while the properties of manganese cathodes are between the others.

Box

Batteries are electro-chemical cells that are able to convert the stored chemical energy directly into electricity. Primary batteries transform chemical energy irreversibly into electricity, whereas in the case of secondary batteries it is possible for the process to be reversed (recharging). A battery is comprised of several individual cells each containing the basic elements of anode, cathode and electrolyte. When the redox reaction occurs in the cell, cations are reduced on the cathode side during discharge (i.e. electrons are added to them) while anions are oxidised on the anode side (i.e. electrons are removed from them). During charging, this process is reversed. The electrodes are kept apart by a separator, which is permeable for ions in the electrolyte.



Schematic structure of a lithium-ion cell (positive electrode: $LiCoO_2$; negative electrode: Li graphite)

[1] Memory effect is the term applied to the loss in capacity which occurs if a rechargeable or secondary battery is drained very frequently.

Dangers in handling lithium-ion batteries

The media repeatedly report on incidents with lithium-ion batteries, be it in mobile telephones, notebook computers, electronic cigarettes, batteries in electric vehicles or even aircraft. The most spectacular cases include the battery fires in two Boeing 787 Dreamliner aircrafts early in 2013, which led to the new type of aeroplane being grounded for several months. Although lithium-ion batteries do not contain any highly reactive elementary lithium, they can, nonetheless, catch fire if, for instance, electric short circuits cause high temperatures and the inflammable parts of the battery (electrolyte, separator and housing) are ignited.

Figure 1: Burning lithium-ion battery

According to reports from the safety testing and certification organisation Underwriter Laboratories in the course of one year (2012/13) the US Consumer Product Safety Commission documented 467 incidents with lithium-ion batteries in all parts of the world, of which 353 were fires (which should be compared with the worldwide quantity of this type of battery produced, which exceeded four billion units in 2012).

The most frequent cause indicated for battery failures is internal short circuits. It is possible for such short circuits to come about through either mechanical or thermal loads. Thermal loading, in particular, may cause the separator to melt, causing a sudden release of energy. Another source of danger is exothermic decomposition reactions of the cell chemicals if overloaded, especially during charging.

Underwriter Laboratories are currently working with NASA and the Oak Ridge National Laboratory to develop improved battery test procedures, paying particular attention to internal short circuits. There is a risk with the commonest forms of test procedure, such as needle penetration, that insufficient consideration will be given to local short circuits on account of the small surface area of the defects in the separators, which may be followed by a rapid increase in temperature and a possible fire.

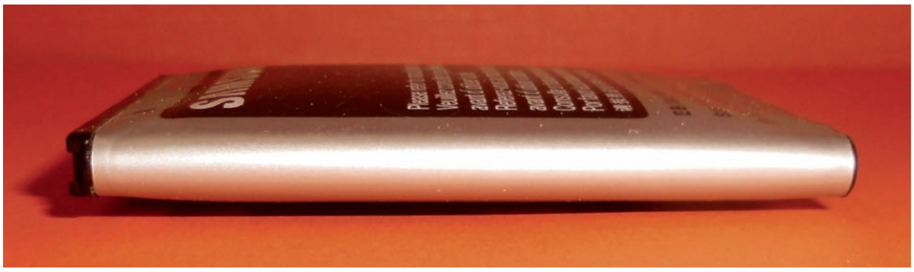


Figure 2: Mobile telephone with a swollen, defective lithium-ion battery

At present, none of the institutions in Switzerland that are responsible for or interested in fires in the broadest sense systematically records cases of fire ignited by lithium-ion or other batteries. The one with the greatest awareness is Inobat, an organisation that disposes of batteries and that has been increasingly ascertaining fire damage during the collection and transport of used batteries, most probably to be ascribed to defective or damaged lithium-ion batteries.

A further threat to health and the environment comes from the combustion gases released when a lithium-ion battery catches fire. Since the electrolytes used in them contain fluorine, it is possible for various toxic compounds to be released if they catch fire, including hydrofluoric acid (HF). Investigations of the health hazard posed by combustion gases resulting from burning lithium-ion batteries arrive at different conclusions as to how great the potential danger is (Ditch and De Vries, 2013; Ribière et al., 2011). Measurements made on a real warehouse fire, however, show no increased HF values.

Storage and disposal of lithium-ion batteries

Reports not only cover incidents arising from the use of lithium-ion but increasingly also fires in the recycling chain due to the improper handling of electrical and electronic waste still containing lithium-ion batteries.

Figure 3: Fire of a container filled with used electrical and electronic equipment

In general, the following safety rules should be observed:

- Compliance with all the provisions indicated by the particular manufacturer and the safety data sheets
- Prevention of external short circuits by protecting the battery poles, for example by using pole caps
- Prevention of internal short circuits through protection against mechanical damage
- Immediate correct disposal of damaged products even if damage is only minor
- Avoidance of exposure to continuous high temperatures (caused, for instance, by direct sunlight)

Avoiding fires caused by lithium-ion batteries calls for greater care across the board in handling used electrical and electronic equipment, in other words:

- No mechanical loads when collecting the devices
- Unloading containers by hand, not by tipping

The organisation responsible for the disposal of lithium-ion batteries arising during the recycling and / or dismantling of used electrical and electronic devices in Switzerland is Inobat (www.inobat.ch). In its information brochure on advice for battery collections in points of sale, Inobat makes the point that, as a general rule, there is no problem in storing lithium-ion batteries along with other batteries removed from equipment. Inobat offers specially lined boxes with a refractory filling (PyroBubbles®) capable of preventing fires (Figure 2) for the collection and transport of lithium-ion batteries suffering visible damage (swelling) or heating and also for lithium-ion batteries that have been used to power models (since, according to Inobat, these usually have a high cobalt content and must be regarded as particularly dangerous). PyroBubbles® is comprised of very light, foamed glass beads (SiO_2) with very good flow properties. It can reliably restrict or even prevent an open (electric) fire, since the beads melt and form an airtight seal around the source of the fire, suffocating it, and also provide good thermal insulation for neighbouring parts, such as cables or battery cells, against overheating.

At present, the lithium-ion batteries collected by Inobat are separated from other batteries and passed on to battery recyclers. Given that lithium is still a comparatively cheap raw material, today's recycling processes for batteries are focusing especially on the recovery of aluminium, cobalt, copper and nickel. Seen in purely technical terms, however, several processes would also be capable of recovering lithium in the form of lithium carbonate (Li_2CO_3). Examples are the hydrometallurgical processes from Batrec, Recupyl and Toxco.

Figure 4: Fireproof box with a refractory lining material (PyroBubbles®) provided by Inobat for visibly damaged (swollen) or overheated lithium-ion batteries

SURVEY OF HOW LONG ELECTRONIC DEVICES REMAIN IN CIRCULATION

Martin Streicher-Porte

Off for recycling – but when?

In a pay-as-you-go pension scheme, such as Switzerland's statutory OASI system, dwindling numbers of younger persons have to finance the pensions of increasing numbers of elderly people, and, depending on the demographic trends, that may turn into a problem. Now, what has this got to do with recycling? A recycling system that is paid for out of disposal charges levied in advance functions in a similar way to a pay-as-you-go pension scheme. The charges collected when new equipment is sold are used to cover the costs incurred by the equipment taken back that same year. Many factors need to be considered to make sure that costs do not get out of control and that realistic sums are budgeted. One of these factors is how many years go by between an item of equipment being sold and it being handed in to a collecting point in the take-back system.

The University of Applied Sciences and Arts of Northwestern Switzerland (FHNW) has carried out research under contract from Swico to establish how long electronic devices remain in circulation. "Circulation" is defined for this purpose as the time that elapses between the sale and the acceptance at a take-back point in the recycling system. The data captured in the research was the name of the manufacturer, the model type and the date of the accepted return of mobile telephones and notebook computers. In most cases, it is no longer possible to establish the precise date of sale of items, so the manufacturer's data was used to establish the date of manufacture instead. The time that elapsed between the date of manufacture and the take-back date was defined as the period of circulation. The project covered take-back collecting points throughout Switzerland.

Figure 1: Circulation time of mobile telephones

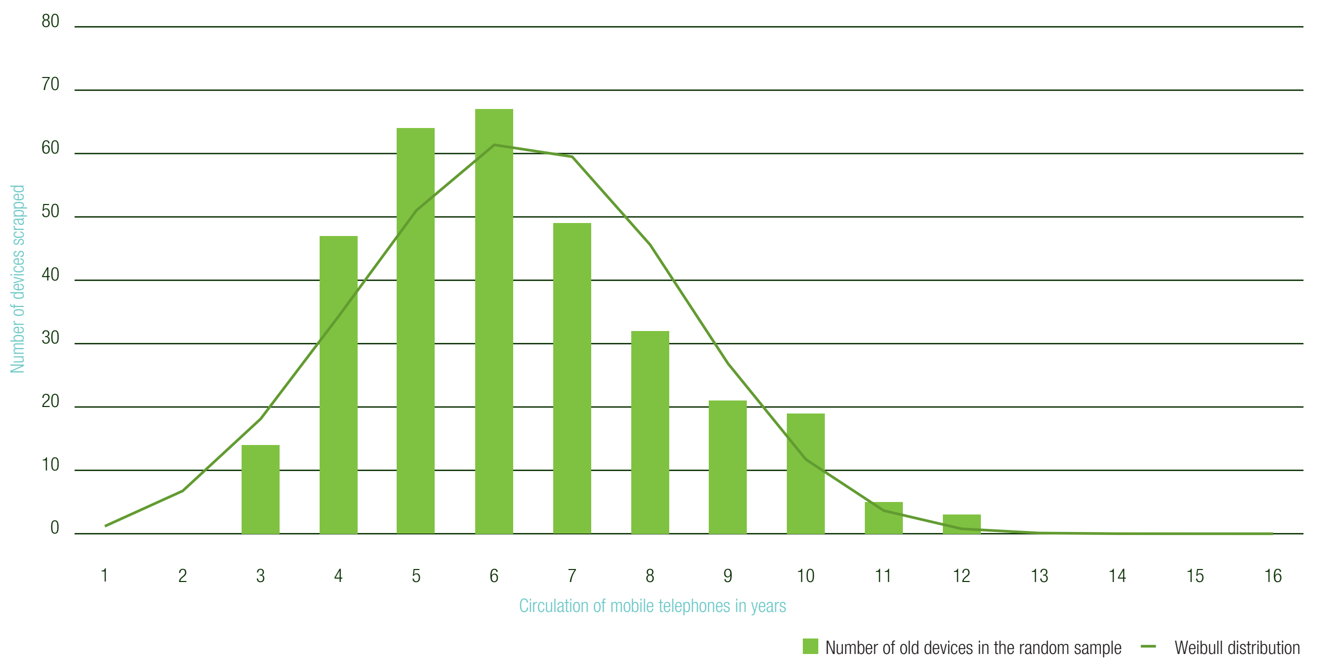
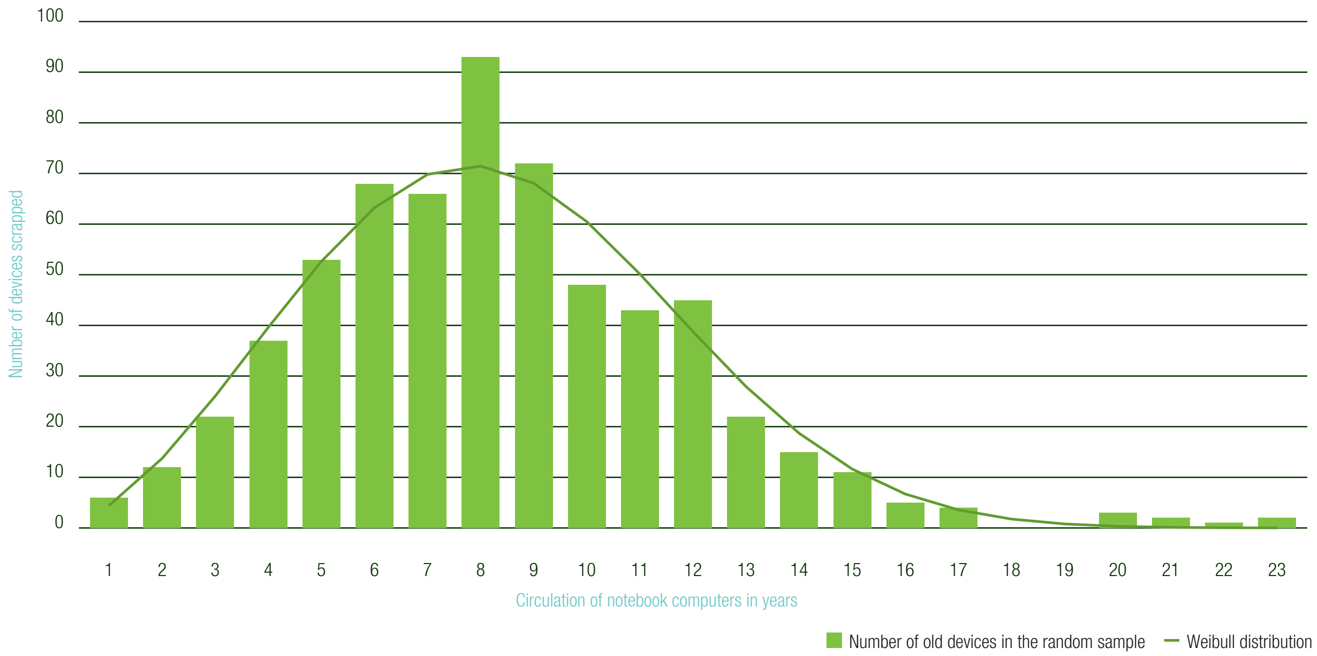


Abbildung 2: Circulation time of notebook computers



Many devices taken back after eight years

The periods notebook computers spend in circulation do, of course, vary in the shape of a bell-like curve. This was used to establish a distribution (Weibull), and from that, a mean period of circulation of 8.3 years was then computed. A similar data analysis for mobile telephones showed a period of circulation of 8.1 years (Figures 1 and 2). Since the surveys were carried out during two periods of time with a gap between them, it was also possible to establish a trend, namely that there was a slight reduction in periods of circulation between 2012 and 2013. It will require further surveys in future to confirm whether or not such items will end up in recycling faster and faster.

The period of circulation is not the same as the working life, at the end of which a device still capable of functioning is replaced by a new one but not disposed of immediately. The decommissioned device may be put into temporary storage, sold, given away, cannibalised for spare parts or kept in reserve. The technical service life of a device is not the same as its period in circulation either. The technical service life comes to an end as soon as a device no longer functions, and may thus be shorter or longer than the period of circulation considered here.

The bigger the device, the faster it is sent for recycling

The researchers also analysed flat screens and printers. However, the volume of data available for these is too small to be able to detect precise distributions and changes. Despite that, the circulation given can be taken to indicate that bigger items of equipment are disposed of faster than smaller ones. Bulky used equipment occupies space and is thus more likely to be handed over for recycling than devices that fit in a drawer (typically the case with mobile telephones).

Conclusion

The research has established that electronic devices remain in circulation for a relatively long period of time compared with their generally relatively short working life, taking the example of mobile telephones.[1] There are certainly good arguments for targeted advertising to promote speedy disposal, especially of smaller devices. Swico, however, intends to use the data collected especially for fine tuning the disposal charges that are paid in advance as precisely as possible with the expected return flows of equipment.

[1] On the basis of market surveys and on the assumption that every Swiss resident over 12 years of age has a smartphone, it can be computed that these smartphones are replaced every 22 months (sources: Swico, EITO, 2014).

Ueli Kasser / Patrick Wäger

From hazardous waste to a source of raw materials – another loop completed

It is the luminescent layer adhering to the inside of the glass of energy-saving and fluorescent lamps that makes them hazardous waste. The lamps are collected separately, broken up in specialised recycling facilities and separated into their constituent parts. One of the substances that arises is luminescent powder, a highly toxic material which until recently in Germany had to be deposited in disused salt mines. Today, it is possible to use it as a source of raw materials for rare earths.

From landfill to a high-grade raw material

We will never fail to be astonished at how rapidly technical progress can occur, particularly in the field of waste. Just a couple of years ago, hardly anyone would have thought that a new raw material would be created out of the highly toxic luminescent powder containing mercury. It used to be thought that processing the mercury was too difficult and expensive and that it could not be worthwhile to separate the mixture of dozens of elements and compounds. The individual elements may well have been expensive, but the quantities of each were too small, the waste specialists used to argue. The fact is now that it does seem to work after all. Since 2012, the Solvay group has had a plant operating in the French Vallée de la Chimie to the south of Lyon which accepts luminescent powder from used lamps from the whole of Europe and recycles it (Figure 1). The precondition is that the luminescent powder must satisfy criteria laid down by the plant operator as regards composition and purity. Depending on the quality of the luminescent powder delivered, those supplying it, including recycling centres in Switzerland, are even paid for it, whereas up until recently it was they who had to pay high charges to have it dumped underground (Figure 1).

Figure 1: In the Vallée de la Chimie to the south of Lyon (France) a new plant for recovering rare earths from the luminescent powder used in energy-saving and fluorescent lamps has been erected next to the vanillin production line

Luminescence from rare earths

The luminescent powder adhering to the inside of the glass is a key element in energy-saving and luminescent lamps. The mercury vapour in the lamp is excited by the electrical current and gives off ultraviolet light, which is converted into visible light by the luminescent powder. This conversion is due to a group of metals known as rare earths, of which a total of 17 exist, and they all have similar properties (Figure 2). The selection of these elements or their compounds and the mixing ratio determine the quality of the light and its colour tone, and many different combinations are possible.

Steep upward curve

The interest in rare-earth elements has grown sharply in recent decades. The applications for them include not only as a luminescent substance in lamps, monitors and luminous figures but also in the manufacture of glasses, permanent magnets, catalysts and alloys.[1] The worldwide production of rare earths was still less than 20,000 tonnes in 1980, but has grown to some 110,000 tones today, with China said to dominate the market with a share of some 85%.[2,3] This trend in volumes has been reflected in prices too. For most representatives of the rare-earth elements these went up more than 10-fold between 2006 and 2011, and not the least reason for that has been China's tightening of its export restrictions. More recently, the prices on the commodities markets have eased again somewhat. In February 2014, the prices listed for a kilogramme of the oxide form of the most important rare earths used in luminescent powder were in the range of 10 to 1,000 Swiss francs.[4]

Figure 2: The 17 rare-earth elements (scandium, yttrium and the 15 lanthanides)

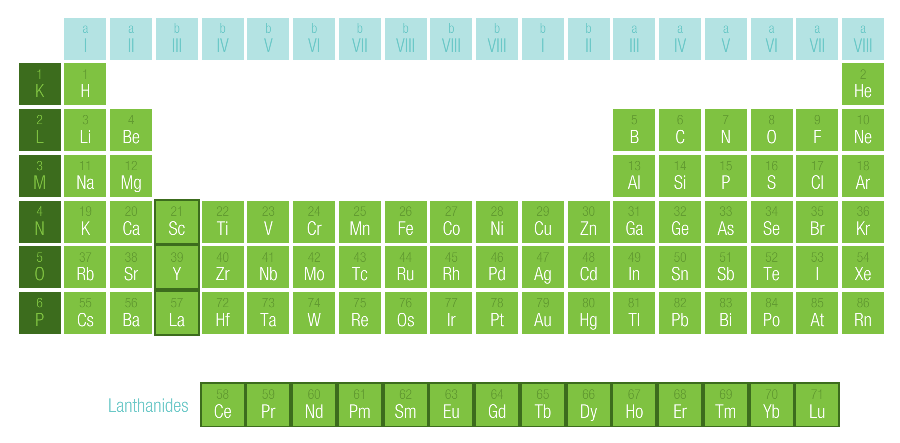


Figure 3: Drums filled with luminescent powder from a German lamp recycler ready for dumping underground (2010)

Figure 4: Luminescent-powder waste from gas-discharge lamps: a mixture of glass, mercury, rare earths and contaminants

Investment risks

Even if prices like that constitute incentives, the risks are still very considerable. First of all, it is necessary to invest money in plants and know-how. In the final analysis, high prices also encourage the search for technical and/or chemical alternatives, which might, in turn, lead to a collapse of the demand side. Secondly, price trends are influenced by strategic considerations of the principal producing country (namely China), by competitive situations on the raw-material side (primary and secondary) and by technological developments. That makes it all the more gratifying that the Solvay chemical group has taken the initiative of shouldering the risks of this investment.

Beetle as symbol

The Solvay Aroma Performance project in Lyon was launched under the name of Coléop'terre and co-financed by the European Union's LIFE+ environmental fund. *Coléoptère* is the French term for "beetle". It thus symbolises a creature that lives in the earth. The chemical, processing and environment-engineering challenges are huge. The glass, the impurities and other compounds for which there is no use all need to be removed (Figure 3). The concentrations of the rare-earth elements in the luminescent-powder waste are not very great. The highly toxic, mobile and unusable mercury has to be precipitated and isolated. The presence of the mercury and the use of strong acids necessitate sustainable investments and high maintenance to ensure purification of the waste air and wastewater from the processes. At the end, the rare earths are separated from one another chemically. That is a tough assignment, given that the rare-earth elements have very similar chemical properties.

Quantitatively insignificant – qualitatively of a high grade

The system just described is also to be used for processing the luminescent-powder wastes from Swiss recycling plants. The thousand or so tonnes of lamps[5] processed in Switzerland annually result in roughly 25 tonnes of luminescent-powder waste that is to undergo further processing in France. There are, however, certain optimisations and shifts in the luminescent-powder processing that should be completed first. The resultant output at the end of the process is a series of rare-earth elements in a comparatively small yield with a purity of over 99.9%. They are thus indistinguishable from products from primary production. The other side to this high-grade recycling is a comparatively large quantity of waste containing mercury that cannot be incinerated. Representatives of the Swico/SENS Technical Commission have thus decided that in the course of the current year they will analyse the situation in the French plant as regards emissions and waste processing, evaluate it and, if appropriate, formulate measures. Such on-the-spot audits of secondary and tertiary destinations contribute to ensuring that when recycling is done abroad it is also arranged so that it is environmentally correct.

1 D. Schüler, M. Buchert, R. Liu, S. Dittrich and C. Merz, "Study on Rare Earths and Their Recycling", Darmstadt: Öko-Institut e. V., 2011.

2 A. V. Naumov, "Review of the World Market of Rare-Earth Metals", published in Izvestiya VUZ, Tsvetnaya Metallurgiya, No. 1, pp. 22–31, 2008.

3 US Geological Survey, "Mineral Commodity Summaries 2013", US Department of the Interior, 2013.

4 www.metal-pages.com, consulted on 21 February 2014.

5 See article "Volumes" in this Technical Report.

PHOTOVOLTAICS

Roman Eppenberger

Standardisation of photovoltaic recycling

PV modules can still produce electricity when faulty. However, the individual PV modules are not dangerous. Despite this, even faulty PV modules need to be handled with extreme care. The risk of cuts is high. Therefore, the processes for storage and transport need to be robust and safe to make sure that the faulty and old PV modules cannot cause any damage.

The solar sector is booming – as was already described in our 2013 Technical Report. Now, after some 15 years in use, the first photovoltaic panels are slowly, even if hesitantly, being returned. The time has therefore come to determine what the recycling processes are to be and to get them set up.

The European Union has decided to include photovoltaic panels within the scope of its directive on waste electrical and electronic equipment (WEEE), 2012/19/EU. However, there are significant differences between photovoltaic panels and other WEEE categories. For this reason, the photovoltaic panels must be collected through a special channel, and it is not permitted to mix them with all the rest of the WEEE.

A technical group was set up under CENELEC TC111X WG6 and has determined recycling for the new WEEE category of photovoltaic panels. The CENELEC EN 50625-2-4 standard has created the necessary framework conditions for this. The most important items from this standard are presented below.

General handling of photovoltaic panels

For safety reasons, there is a fundamental prohibition on the pre-crushing or compacting of photovoltaic panels for optimised transport. Such panels may still be capable of producing electricity even if damaged, which is why even defective panels have to be handled very carefully. The processes for their storage and transport have to be arranged to be robust and safe, so that neither defective photovoltaic panels nor worn ones can cause any damage.

Brief summary of the technical requirements for recycling

During the first treatment stage, a manual one, the photovoltaic panels are separated from cables and all metallic parts, such as frames and chassis.

At the latest before going into mechanical recycling, the panels must have been identified and sorted. A fundamental distinction is made between two technologies that must also be dealt with differently in the recycling process:

- Crystalline silicon panels
- Thin-film panels

As far as the crystalline silicon panels are concerned, a distinction is still made between mono-crystalline and multi-crystalline ones, but this differentiation is of no significance when it comes to recycling them.

Crystalline silicon photovoltaic panels are uncritical and are dealt with like plate glass in the recycling process. They are shredded, and the glass is separated from metals, plastics and ceramic components.

On the other hand, there is a potential risk that thin-film photovoltaic panels may contain cadmium telluride and lead and thus represent a big threat to the environment. For this reason, the standard makes provisions for special limit values for cadmium and lead in the recycled glass. Particular attention is also to be paid to the limit values when handling these environmentally hazardous substances.

Recycling glass is generally to be done with caution

During the recycling process, attention must generally be paid to minimising the occurrence of dust, since glass dust is a danger to the health of the personnel. It is true that no limit values have yet been laid down, but work is in progress. If water is used to reduce the amount of dust, then the standard lays down that that water must be processed in a closed circuit. In addition, recycling operators are required to monitor dust emissions in order to ensure the safety of their personnel.

Desirability of reprocessing photovoltaic panels

The directive also states that recovery of the photovoltaic panels would be desirable. That is, however, a demand that is not yet feasible, since development of the process is still at the research stage, and it is not yet suitable for industrial use. The recycling of photovoltaic panels is thus inconceivable at the current point in time.

Emil Franov

How looking for pollutants keeps the recycling quality of electrical and electronic equipment high

When recycling electrical and electronic waste, avoiding the release of pollutants is one of the most important environmental criteria. But how can one be sure that the contract parties are sticking to the relevant regulations and the pollutants are genuinely separated from the recycling circuit? Over the years, the Technical Audit Department of SENS, Swico and SLRS has developed and optimised a system of key figures, chemical analyses and batch tests which checks exactly this at a number of levels and thus maintains the quality of recycling at a very high level.

Ever since the Technical Audit Department set up by Swico, SENS and SLRS started its work, one of its most important tasks has been to verify that no pollutants make their way into the environment as a result of the recycling operations. The pollutants ought not to be released directly; nor should they be transported further along with usable fractions. The recycling processes must be designed in such a way that complete removal of the pollutants is guaranteed at all times.

The duty to de-pollute components by removing harmful substances from them is an important preventive measure. Batteries and capacitors exceeding a certain size must be taken out so that they are not damaged in subsequent processing. This prevents pollutants from escaping and the contamination of fractions of valuable substances. One big challenge facing the Technical Audit Department when performing annual audits is thus to be convinced that the pollutants are indeed being removed in accordance with the provisions.

An important indicator for this is to be found in the key figures for the numbers of capacitors and batteries removed, which are determined for each batch tested and extrapolated through the annual figures of the recycling operation. There are big differences in the numbers of capacitors and batteries for each type of equipment. It is very difficult to interpret the key figures without detailed knowledge of the mixture of equipment processed. In order to make it less necessary to rely on such interpretations when performing audits, the operating companies are required to keep detailed documentation of a nature that is suitable for providing information on the quantity of capacitors removed in relation to the equipment processed. This permits a check in greater detail of the extent of de-pollution, which is also particularly useful if random checks of equipment from which pollutants ought to have been removed point to qualitative shortcomings (such as the presence of capacitors that ought to have been removed).

Independently of that, the quality of the fractions produced by mechanical processing is verified by means of a chemical analysis looking for the most important pollutants. For the representative annual sample it is the finest fraction from the process that is taken. The reason for selecting the finest fraction is that it has the largest surface area and would thus also have the highest concentration of pollutants. The pollutants remain sticking to the surface in the form of an oily film in the case of polychlorinated biphenyls (PCBs) or as a fine dust in the case of solid pollutants.

The following guideline values apply for the interpretation of the results:

- Cadmium (Cd): 100 mg / kg (0.1 %)
- PCBs: 50 mg / kg[1]
- Copper (Cu): 10,000 mg / kg (1.0 %)

If the guideline values are exceeded for one or several pollutants, suitable countermeasures must be introduced to bring the process in line with the guideline values. In this, the guideline value for copper has a particular status in that it is also an indicator of how completely copper has been separated as a valuable substance and whether it can be returned to the material cycle. The level of cadmium in the fraction analysed is an indicator for the proportion of batteries removed, and the level of PCBs is an indicator for the proportion of capacitors removed.

In addition, analyses are also performed in conjunction with the batch tests that take place every two years. The auditors keep a very close eye on the batch tests. A more extensive chemical analysis is carried out, analysing not only cadmium, PCBs and copper but also toxic heavy metals, namely mercury, lead and zinc. The market for electrical and electronic equipment is, however, very fast moving. Pollutants that have been known for a long time already, such as cadmium, PCBs and mercury, are now being prohibited or restricted for more and more applications. So substitute substances are appearing on the market, but these are often not free from negative environmental effects, which were unknown or underestimated at the time of their introduction. It is thus crucial to be constantly looking out for the emergence of new pollutants. This is done by pooling experience, partly within the Technical Audit Department of Swico, SENS and SLRS and partly also in the direct discussion with the recyclers, primarily during the batch tests. During these, the fractions are also examined for new pollutants, and, if meaningful, these are integrated in the programme of measurements.

To sum up, it can be said that this audit procedure, which has been developed and optimised over the years by the Technical Audit Department, has proven its value as an important measure in the quality assurance of the recycling of electrical and electronic waste.

[1] Six reference PCB congeners are determined in accordance with DIN 51 527, part 1, and weighted on the basis of their LAGA codes.

Rolf Widmer

Disposal of CRT glass

The massive use of cathode ray tubes has most definitely come to an end (in OECD countries) or is declining rapidly (in developing countries). Surprisingly, the return of old equipment in Switzerland has continued to increase for much longer than had been expected on the basis of model calculations and, according to feedback received from the recyclers, did not reach its peak until as late as 2012, with approximately 11,000 tonnes of CRT glass per year. This quantity tallies well with the expected peak returns; it was, however, not reached until roughly seven years later than had been forecast.

The manufacture of cathode ray tubes (CRTs) has died out in most countries (see, for example, www.crtsite.com → CRTs→ Prototypes → PREV), and the few remaining manufacturing facilities are operating in aspiring countries like India, China and Malaysia – but even there their days are numbered. The newer technology of flat panel displays (FPDs) now entirely dominates the world market. Various technologies are in use for generating the points of light on the screen, but the one dominating at the time of writing is the liquid crystal display (LCD) with two different sources of backlighting: fluorescent lamps and light-emitting diodes (LEDs). These LCD screens have almost completely displaced CRTs in computer monitors and television sets. The Swiss consumers completed this transition fairly early on, and as long as 15 and 10 years ago, respectively, sales of CRT screens for computers and television sets collapsed (Figure 1). From 2007 onwards, this technology had totally disappeared from the shop shelves. Even newer technologies are now, however, already making progress, and they are going to oust LCDs in the foreseeable future (Figure 2).

Modelling was used to estimate the pattern of the returns of CRTs in Switzerland from 2007 onwards. Figure 3 shows the various quantities of CRT glass arising over time. It illustrates, on the one hand, the stock of CRT glass in Switzerland (CRT stock)reaching its maximum of roughly 100,000 tonnes around 2000 and, on the other hand, the annual flows of glass through sales (CRT in), the modelled return (CRT out) and the actual returns (Swico Recycling) through the Swico take-back system. It appears that the returns are going to start declining from 2013 onwards, with 17% less than in the previous year. It is striking that the modelled peak value of around 12,000 tonnes tallies well with the actual level of returns. Working on the assumptions that television sets have a working life of 10 years and computer monitors one of 7 years, the point of peak return levels forecast by modelling was, however, missed by at least 7 years.

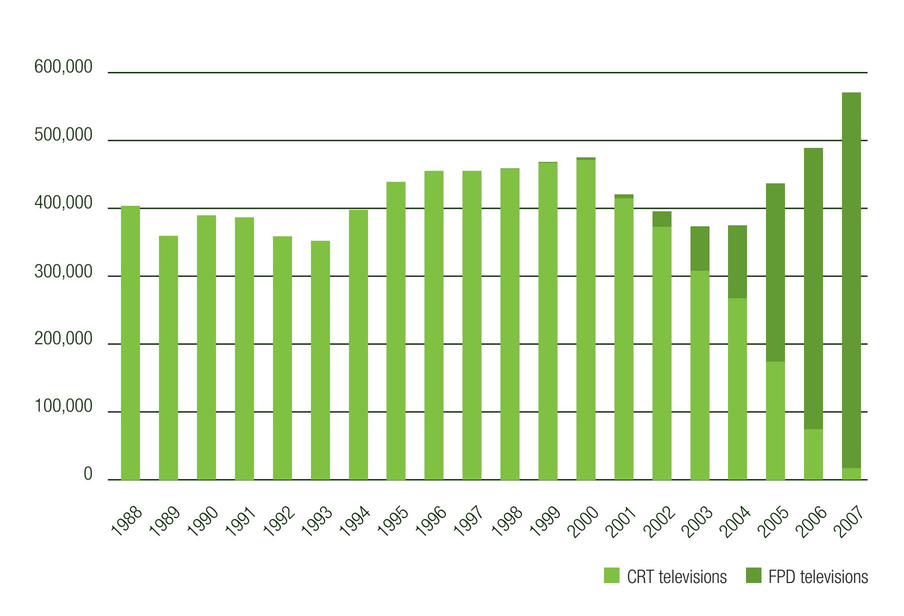
Until not long ago, the recycling of CRT glass was directed towards the manufacture of new CRTs. The collapse of the CRT market occurring in parallel with increasing quantities of secondary CRT glass made it indispensable to find new disposal routes. In the meantime, the demand for unleaded CRT glass has been sustained by using it in the manufacture of glassware (particularly bottles).

The European Union's packaging directive lays down a maximum permitted value of 100 ppm for the aggregate total of heavy metals, namely Pb, Cd, Hg and Cr VI. For container glass, an exceptional value of 250 ppm currently applies for an unspecified period of time (although levels in excess of 200 ppm have to be declared). The reason for allowing this is that there are already higher concentrations of lead and other heavy metals in the waste glass collected. It is thus understandable that both the industry and the government started by turning down the idea of processing CRT glass into bottle glass, so as to prevent an additional lead input. It has, however, been shown more recently that the lead that is already in the system cannot come to any significant extent from CRTs and that sorting technology has been radically improved, making it possible to stay within the limit values for lead. Most of the lead-free glass fraction from CRTs delivered to Germany (Figure 5) was already used in the manufacture of bottles in 2013. That means that a good solution has been found for most CRT glass (with this fraction accounting for just under two-thirds of the total mass).

At the time of writing, there is still less clarity as to what possibilities might exist for using leaded CRT glass. Currently, there are basically three strategies being pursued by recipients of waste: 1) holding it in a temporary store, 2) incorporating it in landfills as a substitute for construction materials and 3) using it to replace silica as a fluxing agent for slag in lead and copper works. There is still some controversy surrounding the issue as to whether the third of these strategies would permit the lead to be separated from the glass, since the reduction of lead oxide requires a temperature of at least 1,200 to 1,300°C, which is not always reached. So lead is dumped in the slag and not recovered for use. Only a few thousand tonnes of silica are required every year, so it would be necessary to establish temporary storage facilities to be able to stockpile the leaded glass for some time as it arises. Despite all this, a combination of these three applications seems to constitute a feasible approach for the disposal of the glass still held in store.

Exporting used CRTs, to developing countries, even for use in the manufacture of new CRTs is becoming increasingly controversial, since the exporting countries lose control over the final fate of the leaded glass (it is, after all, never going to return to the exporting country in the form of CRTs). It seems probable that the CRT stocks in the developing countries will remain in existence for longer than those in the richer countries, given that cheap second-hand CRTs are being imported in large quantities from the OECD countries and now have a longer service life thanks to specialist repairs and maintenance carried out by qualified service personnel. Nonetheless, CRTs

Sales of television sets in Switzerland



Sales of computer monitors in Switzerland

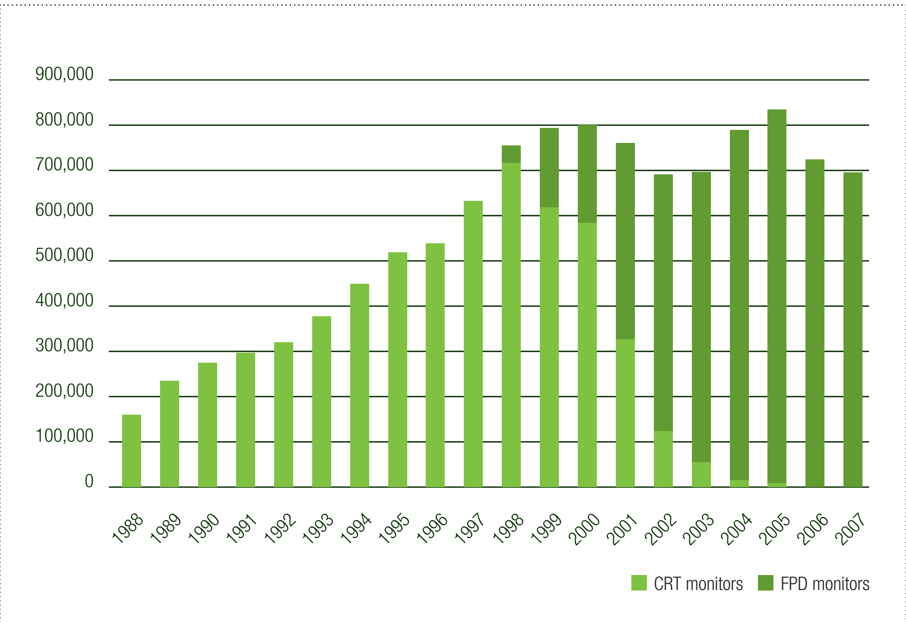


Figure 1: The diagrams show how quickly CRT technology has been replaced by LCDs for computer monitors and television sets in Switzerland

are soon going to disappear from the shop shelves in the developing countries too, which is a cause for concern, given the lack of recycling infrastructures in those countries. It is thus a definite possibility that a considerable proportion of the used CRT glass will finish up on more or less unofficial dumps in the developing countries, where recycling constitutes a threat to the environment, since it is performed in such a way that harmful substances like lead are released.

Against this background, especially now that we have passed the peak return flows in Switzerland and considering the rapid shifts in the global flows of CRT glass, there are various questions that Swico as a responsible system operator must face up to:

- What is going to be the future pattern of quantities of equipment incorporating used CRTs in Switzerland?
- What are the likely and acceptable treatment technologies for CRT glass and the intended uses for it? The question that follows from this is: Are the applicable technical provisions still in keeping with the times?

Current technical regulations, Directive 2: ICT and entertainment equipment CRTs

- CRTs must be ventilated prior to manual or mechanical processing (implosion risk). Precautions must be taken at all times to prevent the release of pollutants that might be harmful to health or the environment, in particular luminescent substances when ventilating, dismantling and grinding open CRTs or broken glass from them and also when handling and transporting them. The applicable environmental and workplace-safety provisions must be complied with.
- CRT glass (from the front or cone of the tubes and also mixtures) must go through material recycling, for instance for the manufacture of CRTs or special grades of glass, in the ceramics industry, in smelting works or in other suitable recycling processes. In so doing, hazardous substances like lead must not be permitted to make their way into applications for which there is no technical need for them. The controlling boards must be informed of the disposal route.

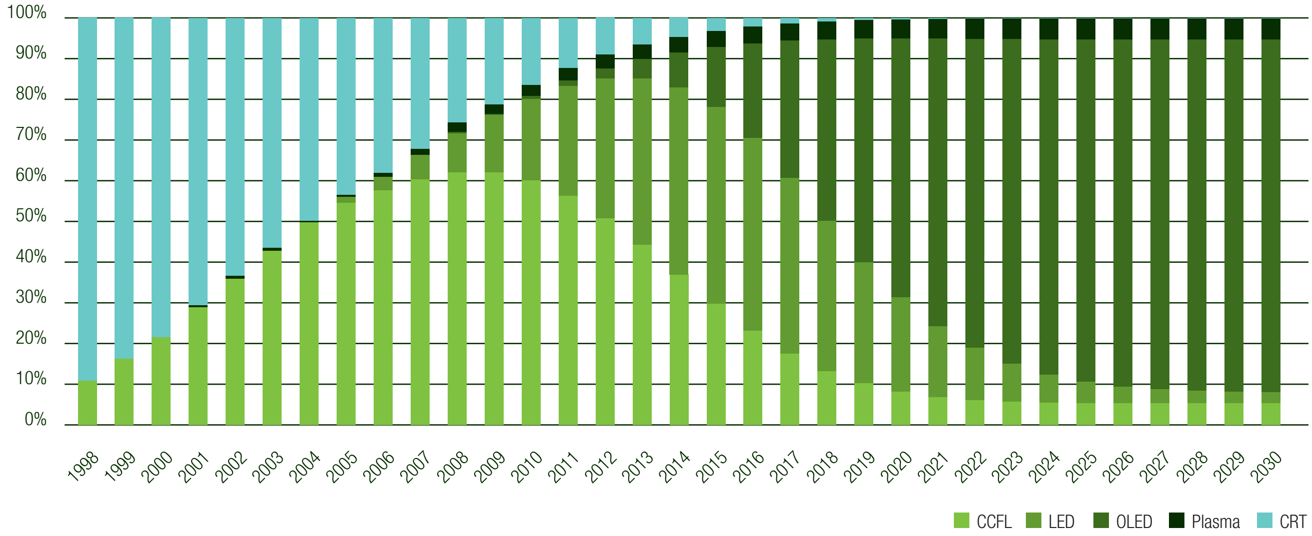


Figure 2: Projection of the shares of the screen technologies likely to be available (from 1998 until 2030)

CRT stock and flows in Switzerland

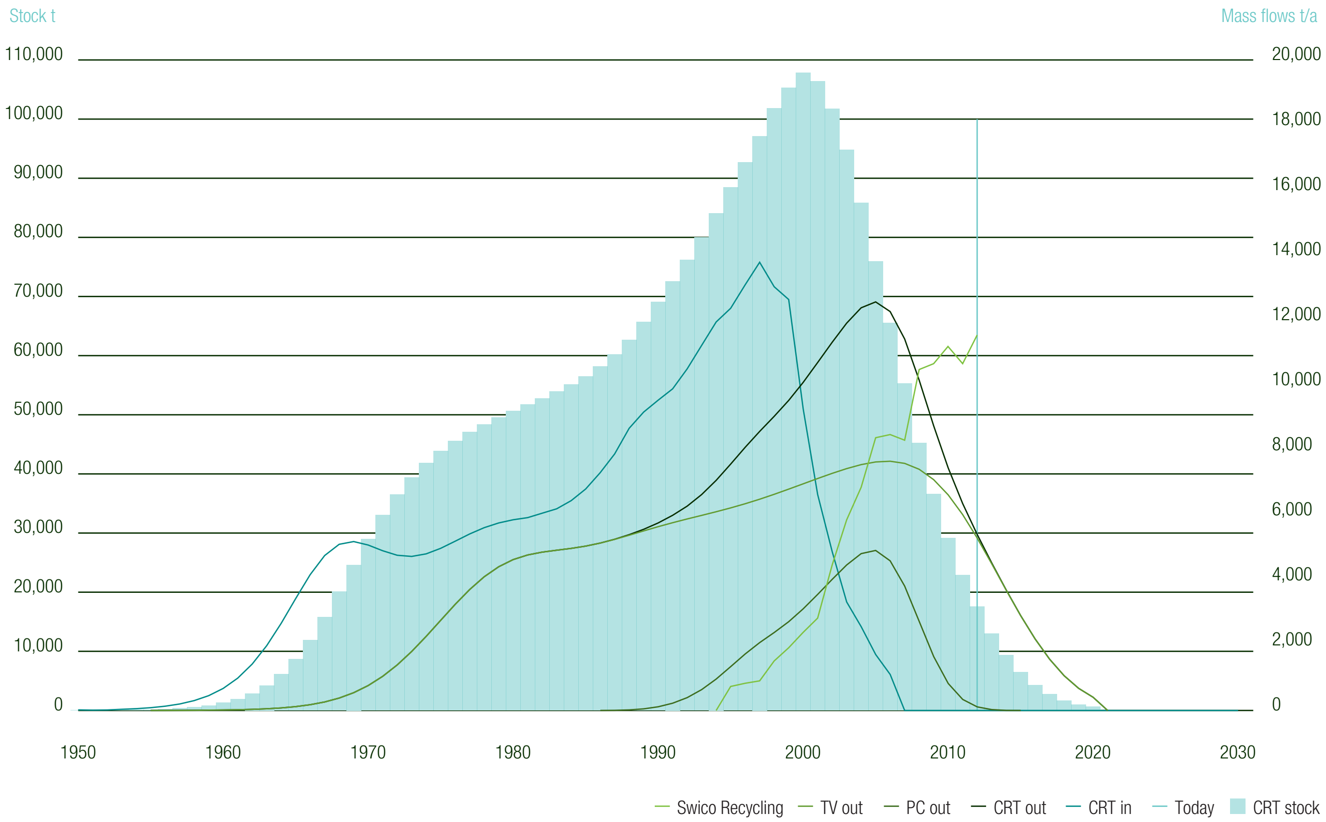


Figure 3: Various quantities of CRT glass plotted over time (in tonnes or tonnes per year), legend: CRT stock = CRT glass present in Switzerland, CRT in = CRT glass contained in the annual sales of devices, CRT out = modelled returns of glass, Swico Recycling = actual return, today = 2012

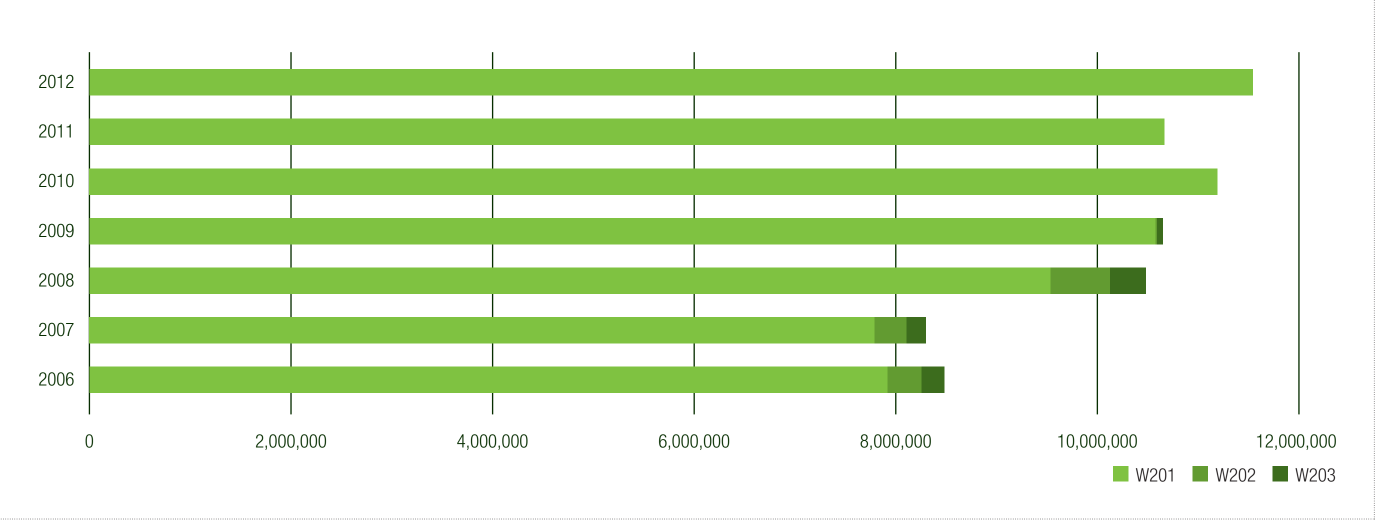


Figure 4: The diagram shows the trend and composition of the annual quantities returned through Swico. Up until just a few years ago, the crushed CRT glass was still sometimes sorted into different glass types (W201 = whole CRTs [with / without neck], W202 = CRT front glass, W203 = CRT cone glass), sources: Swico material flow, Empa.

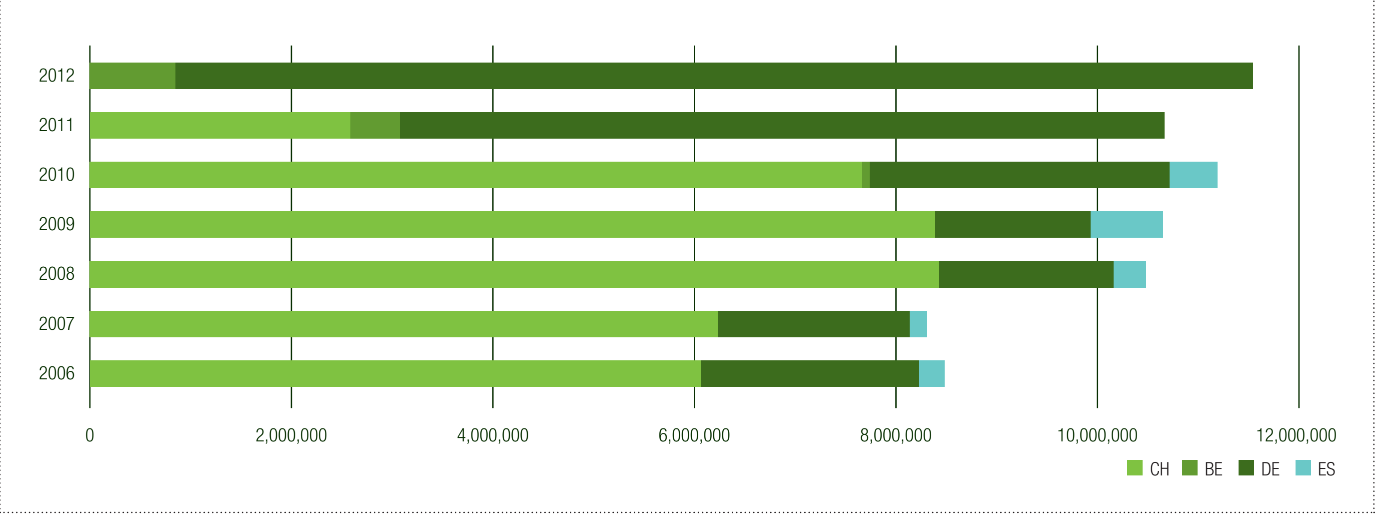


Figure 5: The diagram shows the annual volumes in kilograms returned through Swico, broken down by country of destination. Up until 2010, SwissGlas was by far and away the biggest secondary taker and recycler of Swiss CRT glass. Since then, the largest proportion of this glass has been going to Germany for recycling.

In order to discuss these issues with as full a knowledge of the facts as possible, Swico has commissioned Empa to carry out a small-scale project with the aim of obtaining decision support as regards the recycling of CRT devices and recommendations for amendments to the technical provisions. The project involves the following work steps:

- Forecast of the quantities of CRT equipment arising over time in Switzerland between 2014 and 2020; in this, the existing model ought to be corrected in such a way as to give a good reflection of the past decade
- Compilation of the existing and upcoming recycling technologies for CRTs and the uses available for the CRT glass
- Discussion of the outcomes of the first two work steps; in this, equipment incorporating CRTs ought to be considered in the general context of equipment incorporating a screen, in other words the flat-screen technologies following CRTs (such as plasma, LCD and OLED).

This work began in February 2014 and ought to be completed in the course of 2014.

Heinz Böni / Patrick Wäger

No problem in disposing of scrap cables?

In 2012, the Swico and SENS recycling plant processed roughly 3,100 tonnes of scrap cables partly inside and partly outside of the Swico/SENS system. Approximately one-third of this was done in countries neighbouring on Switzerland. To this has to be added the quantity which the recyclers shred themselves. It is estimated that scrap cables account for around 3% of the total amount of electrical and electronic waste. Scrap cables contain valuable metals like copper and aluminium as well as various plastic insulators. In order to prevent distortion of competition, it is important to ensure that the requirements governing scrap-cable recycling are the same for all processors. How cables are recycled is thus a key element in audits.

Scrap cables constitute an important source of raw material on account of their metal content. Scrap cables from the treatment of equipment by Swico and SENS are either processed by the contractual partners themselves (separation into plastics and metals) or they make their way into the scrap trade or directly into the hands of cable recyclers in Switzerland or elsewhere.

The nature of the processing performed by the various recipients of scrap cables is assessed using the form for material flow reporting (*Stoffflussnachweis*). The recipients of scrap are required to declare their processes, the output fractions, the proportions of each one and who the takers are. This information is a key element in the annual audit of each operator. There are, however, limits to material flow reporting if the scrap cables pass through several stages in the scrap trade before reaching a recycler. The dependability of the information obtained is further reduced by the fact that the reporting forms are often inadequately completed.

Requirements governing treatment

It is possible for cables to contain problematic pollutants. For that reason, they have to be separated by specialist companies in possession of a disposal permit for insulating material and metal waste. The purpose of this is to prevent cables from being shipped through the metal trade to the emerging countries for incineration in the open air, which constitutes a threat to health and the environment.

Cables are made of a conductor (such as copper or aluminium) and an insulator. The principal insulation material is PVC-based plastic. Whatever the cable, the problematic pollutants are primarily to be found as additives in this insulating material. Older cables, for instance, may contain lead compounds in relatively high concentrations. In years gone by, high PCB levels were found as well. Other problematic additives are fire-proofing materials containing antimony or bromine, as well as cadmium compounds. Newer generations of cables generally no longer incorporate problematic levels of pollutants in the form of additives.

When processing scrap cables it is essential to prevent plastic insulating material containing pollutants from being used as a raw material for the manufacture of plastic products. Copper and aluminium cables have to be handled separately from one another. The conductors and the material from the metal sheathing (for instance lead or iron) must be recovered and mechanically or manually separated from the plastic insulating material (PVC, PE, etc.). Clean, single-grade plastics can be recycled as material, provided they satisfy the requirements of the Chemical Risk Reduction Ordinance (ORRChem)[1]. This lays down the limits for the metals lead, chromium and mercury (<0.1%), cadmium (<0.01%) and for brominated flame retardants (PBB and PBDE: <0.1%). Plastics not satisfying these requirements have to be incinerated in a suitable installation. It is prohibited to carry out direct material recycling without reporting in accordance with the ORRChem.

Are exports possible?

Applying the Ordinance on Movements of Waste (VeVA),[2] scrap cables and insulation waste from the recycling of scrap cables are to be classified as "other waste subject to control" or as "special waste". That means that recyclers of scrap cables and/or takers of fractions from processing in Switzerland have a duty to transport the separated insulation wastes as special waste with an accompanying document.

Scrap cable is listed as "green" in the European Waste Catalogue[3] and in the OECD lists.[4] That means that scrap cables from the territory of the European Union can be traded and transported within the OECD without restrictions. Recycling insulation material from cables is regarded an established practice. The statutory requirements for handling scrap cables are thus significantly stricter in Switzerland than in the European Union.

Given the different waste-declaration practices in Switzerland and the European Union, there is a risk of distortion of competition, since cable recyclers outside of Switzerland are able to recycle the material of plastic insulation materials, whereas this has to be incinerated in Switzerland if the limit values contained in the ORRChem are exceeded. In order to prevent such distortion, the cable deliveries to foreign recyclers are being more thoroughly audited in the course of the current year. This ought to prevent cables from making their way through the trade to developing and emerging countries – with the corresponding negative impacts on the environment and health.

Maximising recycling, avoiding dispersal of pollutants

From the economic point of view, the aim of recycling scrap cables is primarily to recover the non-ferrous metals contained in them. In the material recycling of the plastics from the insulating material, attention must be paid to ensuring that no pollutants migrate into the plastic granulates (mostly PVC). Admittedly, experience has shown that the pollutant levels in the cables from electrical and electronic equipment is lower, for instance, than in earthing cables or the cables used in domestic installations, but these are not usually processed separately from one another. That makes it correspondingly important for this point also to be covered by the Swico and SENS company audits.

Figure 1: Millberry copper cable

Figure 2: Copper granulate from cable recycling

Figure 3: Aluminium granulate from cable recycling

[1] Ordinance on the Reduction of Risks relating to the Use of Certain Particularly Dangerous Substances, Preparations and Articles (Chemical Risk Reduction Ordinance, ORRChem) of 18 May 2005 (status as of 1 January 2014).

[2] DETEC Ordinance on Lists for the Movement of Waste of 18 October 2005 (status as of 1 January 2010).

[3] Commission Decision of 16 January 2001 amending Decision 2000 / 532 / EC on a waste catalogue.

[4] OECD Decision C(2001)107 / FINAL regarding lists of waste.

Rolf Widmer

EWAS: E-Waste Academy Scientists Edition 2013

There are many different ecological, economic and social challenges that have to be faced up to in connection with the management of e-waste – and all stakeholders must be involved in the solutions to them. The StEP E-Waste Academy (EWA) is a pioneering concept for the development of e-waste research and management capacities for promoting multi-stakeholder partnerships and worldwide cooperation.

The EWA Scientists Edition (EWAS), which used to be known as the StEP E-Waste Summer School, brings young researchers from all over the world together to discuss solutions from very different disciplinary perspectives. EWAS has set itself the target of being the leading forum for young scientists in this matter, where they can share their knowledge, exchange views with experts from academia, industry and politics and develop cooperation partnerships. EWAS encourages innovative, scientifically sound research into solving e-waste problems. The four EWAS editions held to date, between 2009 and 2013, were extremely successful and confirm not only the need for interdisciplinary research in this field but also its great value. On every occasion, the participants and expert lecturers are asked to rate EWAS by completing a detailed questionnaire. To date, the concept has always met with very positive feedback and has naturally been slightly adapted each time in the light of the suggestions made. This is illustrated in Figure 1, which is representative of all the other diagrams too.

EWAS offers the participants a varied syllabus in an innovative framework of various teaching and learning methods with a balanced blend of lectures by experts, presentations by participants, panel discussions, excursions, workshops and group work. EWAS's declared objective is

- to share and discuss existing knowledge and topical research issues and also to identify gaps in research which are to become part of the future agenda of international e-waste research;
- to leverage synergies in multidisciplinary research and to establish networks of young scientists to act as multipliers in the particular academic and geographic areas; and
- to build up capacities for top-grade, scientific research and to link these with industry, academia and politics.

Overall experience 2009–2013

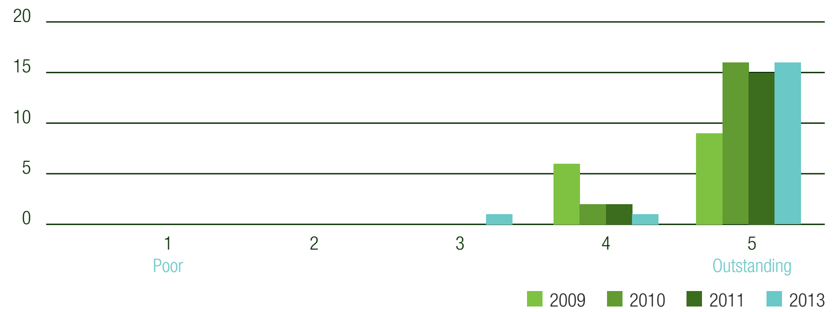


Figure 1: Participants' rating of EWAS (from 2009 to 2013)

All the EWAS editions to date have been held in Europe (Netherlands, Belgium and Switzerland) in order to be able to benefit from as direct an access as possible to experts and industry. Given Europe's leading position in the treatment of e-waste and the development and implementation of the technology and legislation necessary for that, this continent is an attractive destination for young researchers.

The organisational leadership of EWAS lies with the United Nations University, or, to be more precise, with the secretariat of StEP, the global initiative for "solving the e-waste problem". The planning and preparation of each EWAS takes between six and nine months. EWAS is financed predominantly with money from sponsors and StEP members, with donations from sympathisers as well, so that most of the costs of between EUR 100,000 and 150,000 per edition are covered. Financial support for EWAS to date has come, for instance, from the NVMP (Dutch Foundation for the Disposal of Metal and Electrical Products), Swico, Philips Consumer Lifestyle, Umicore, Dell, Nokia and Hewlett-Packard. Many others, such as Empa, Sims Recycling, Flection, Immark, Ruag and Cablofer have supported the operation of EWAS with contributions in kind (conducted tours, materials, rooms, etc.). Students pay a contribution depending on their means, and the experts waive all fees.

The most recent EWAS 2013 on the subject of "visualising e-waste futures" took place in Switzerland in December, and the hosts were the secretariat of the Basel Convention in Geneva and Empa in St. Gallen. Swico was a principal sponsor. Experts from key stakeholder groups in academia, industry, government and NGOs from all over the world agreed to play

Figure 2: Growing interest around the world – trend in the number of applications from 2009 to 2013

18 AP (Asia-Pacific)
25 AF (Africa)
17 NG (Nigeria)
04 GH (Ghana)
01 CM (Cameroon)
01 ZA (South Africa)
01 EG (Egypt)
01 SN (Senegal)
30 EU (Europa)
12 LA (Latin America)
05 NA (North America)

their part in contributing top-level specialist lectures throughout the 10-day programme:

- Christina Meskers, Umicore, and Markus Zils, McKinsey, on the subject of "Securing future supplies: raw materials and resource politics"
- Jean-Marc Hensch, Swico, on the subject of "Sysy tem boot up – ingredients for successful and sustainable take-back systems"
- Costas Velis, University of Leeds, on the subject of "The future of informal recycling: integrating the informal sector in resource management"
- Ibrahim Shafii, BRSMEAS, and Shunichi Honda, Japanese ministry of the environment, on the subject of "Negotiating multilateral environmental agreements – process, pitfalls and perspectives"
- Tatiana Terekhova, BRSMEAS; Eelco Smit, Philips; Jonathan Perry, Dell; Vittoria Luda di Cortemiglia, UNICRI, and David Rochat, SOFIES – panel discusa sion on the subject of "Illegal transboundary flows"
- Peter Kirby, University of Oxford, on the subject of "Tracing transboundary flows"
- Stephanie Adrian, USEPA, and Jonathan Perry, Dell, on the subject of "Policy directions globally: looking ahead at evolving e-waste policies"
- Jaco Huisman, UN University, on the subject of "Assessing future volumes: trade flows, forecasts, models and scenarios"

The participants were a well-mixed group of PhD students and postdocs from various disciplines and countries. The size of the group was deliberately kept small with 10 women and 10 men so as to facilitate active, individual participation and close interaction amongst all of them. The participants are always chosen carefully in accordance with their research skills, applying the usual scientific methodology of a review process of their research work. The following three examples have been chosen to give an

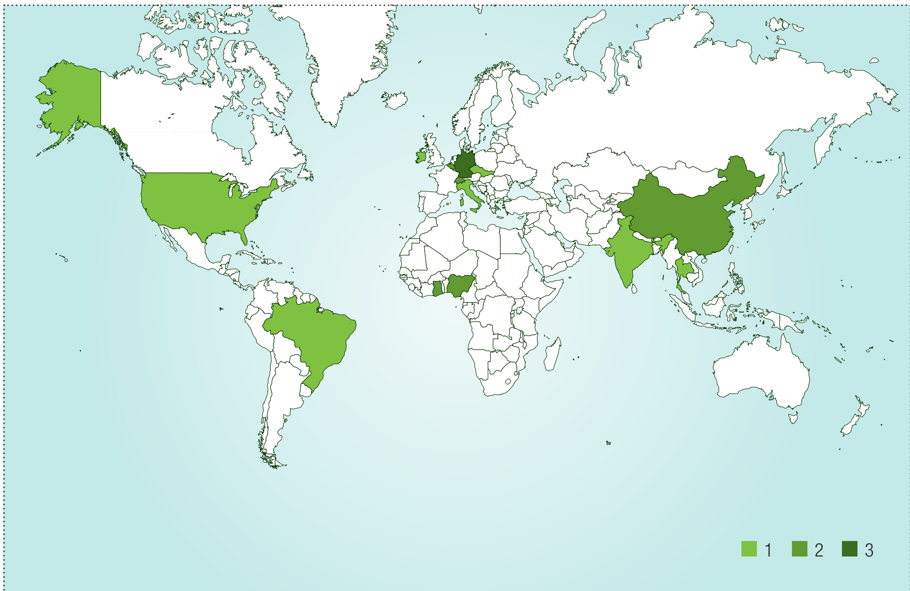


Figure 3: Twenty EWAS participants in 2013 from 13 countries (Belgium: 2, Brazil: 1, China: 2, Czech Republic: 1, Germany: 3, Ghana: 2, India: 1, Ireland: 1, Italy: 1, Nigeria: 2, Switzerland: 2, Thailand: 1, USA: 1)

impression of the quality and variety of the research currently being conducted by participants from developing countries:

- Wenjie Wu from the Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences: she is doing research on “the impact of waste household appliances trade-in program on Chinese WEEE management”
- Vincent Kyere of the Catholic University College of Ghana: he is doing research on “the exploratory assessment of e-waste governance structures in Africa: a case study of Ghana”
- Omotayo Sindiku of the University of Ibadan, Nigeria: she is doing research on “the inventory of PBDE in e-waste polymers in Nigeria material flow”

One important central feature of EWAS is participation in a joint group project. In earlier editions, the students have had the task of developing an e-waste workshop and of presenting it at the World Resources Forum in Davos. Last time, they were asked to optimise e-waste management in developing countries taking the example of Ghana. The participants at EWAS 2013 had the task of developing role play following the PlayDecide methodology. Scripts for the game were proposed via the internet by participants at earlier EWAS editions. The participants selected a script from Ghana as the best of all. The premiere of the completed role play was presented at a public session organised by the secretariat of the Basel Convention in Geneva at the end of EWAS.

Figure 4: Visit to Cablofer Recycling SA

Figure 5: Visit to Ruag and preparations for the analysis of the Swico shopping basket

Figure 6: As a break from the intensive work, Sunday’s excursion took the group up the Säntis in arctic conditions

AUTHORS

Heinz Böni

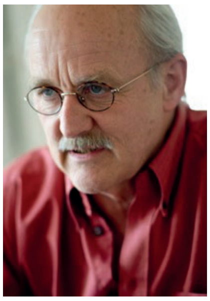
After graduating as an agricultural engineer at ETH Zurich, and a post-graduate course in domestic waster supply construction and water conservation (NDS / EAWAG), Heinz Böni worked as a research associate at EAWAG Dübendorf. After holding the position of project manager at the ORL Institute of ETH Zurich 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 and interim head of the Technology and Society Department. From 2009 he has held the position of Head of the Technical Audit Department of Swico Recycling, and has been an audit expert for Swico and the SENS Foundation since 2007.

Geri Hug

After studies in chemistry and subsequent thesis at the Institute of Organic Chemistry, University of Zurich, Geri Hug was a research associate and project manager at Roos+Partner AG in Lucerne. From 1994 to 2011 he was a partner, and from 1997 managing director of Roos+Partner AG. In addition to environmental consulting in 15 sectors in accordance with the EAC codes, he also accompanies environmental audits and environmental compatibility reports to UVPV standards. In addition, Geri Hug produces short reports and risk analyses according to StFV, ecological assessments on operations and products, and validates environmental reports. Geri Hug is an auditor for electrical and electronic waste disposal at the SENS Foundation and lead auditor at SGS for environmental management systems in accordance with ISO 14001. He is a member of the CENELEC working group for the development of standards on the environmentally compatible recycling of cooling appliances.

Roman Eppenberger

Roman Eppenberger completed his studies at ETH Zurich, graduating as an electrical engineer. In tandem with his professional activities, he completed the post-graduate course Executive MBA at Fachhochschule Ostschweiz. 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. From 2012, Roman Eppenberger has been a member of the management board of the SENS Foundation and is the Head of the Operations Division. In this position, he coordinates the Swico / SENS Technical Commission in conjunction with Heinz Böni.



Ueli Kasser

Chemist, dipl. chem. / lic. phil. nat. at Bern University and ETH Zurich as well as completed post-graduate courses (INDEL, post-graduate course on problems in the developing countries). After initially working as a freelance contributor in radioecology, ecotoxicology and occupational hygiene, he became a co-owner of ökoscience – a consulting office for applied ecology in Zurich and project manager for air hygiene, environmental consulting and ecotoxicology. Ueli Kasser is currently the proprietor of Büro für Umweltchemie in Zurich, which specialises in consulting services for waste, chemical security, building material ecology and interior air quality. In addition to his teaching activity, he is an auditor for environmental management systems in accordance with ISO 14001. From the middle of the 1990s, Ueli Kasser has been a technical auditor of recycling companies on behalf of the SENS Foundation and has been responsible for drawing up auditing standards and guidelines. He is a representative of the SENS Foundation in the European Association and is a consultant on the European WEEELABEX standards project.

Emil Franov

After studying as an environmental scientist at ETH Zurich, focussing on analytical environmental chemistry and aquatic systems, Emil Franov worked for five years as an environmental consultant within an international service company. From 2001 on, he worked at Carbotech AG in Basel as a consultant and project manager focussing on environmental consultancy, ecological assessments and compliance with environmental requirements (environmental audits, key environmental figures, environment law, etc.). He has various customers for annual economical assessments and key environmental figure surveys based on a range of international standards. Since 2002, he has been an audit expert and member of the Technical Commission at SENS Foundation. Emil Franov is a department manager and member of the executive board at Carbotech AG.

Esther Müller

After training as an environmental engineer focussing on resources and disposal technology at ETH Zurich, Esther Müller worked as a project manager for contaminated sites at BMG Engineering AG in Schlieren. From 2007, she has been working as a research associate in the CARE (Critical Materials and Resource Efficiency) group at Empa in analysis and modelling national and global material flows in conjunction with highly promising future technologies and materials. Esther Müller has been working on her thesis since 2012.

Niklaus Renner

Niklaus Renner studied environmental sciences at ETH Zurich. He has been a research associate at Roos+Partner AG, Lucerne, since 2007. 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. In addition, Niklaus Renner's tasks include monitoring environmental law, applying the legal compliance tool LCS.pro and internal environmental conformity audits. Audits for the environmental inspectorate AGVS (car trade association) and, from 2013, accompanying soil protection measures for construction projects round off his profile.

Rolf Widmer

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

Martin Streicher-Porte

Following on from his study of the environmental natural sciences at the Federal Institute of Technology in Zurich and his dissertation, Martin Streicher-Porte took on a scientific job at Empa in the field of informal recycling. As head of the energy section at Swico, the Swiss trade association for IT and consumer electronics, he was the expert for all aspects of the energy efficiency of IT and consumer-electronic products and liaison with Brussels. As a scientist and lecturer, Martin Streicher-Porte conducts research and teaching at the University of Applied Sciences and Arts of Northwestern Switzerland in the field of the recycling of composite materials.

Patrick Wäger

After studying chemistry at ETH Zurich and a subsequent thesis at the ETH Institute for Toxicology and Zurich University, Patrick Wäger was for two years an environmental consultant at Elektrowatt Ingenieurunternehmung, Zurich. Since then, he has been a research associate and project manager at Empa, collaborating on numerous research projects on waste disposal and recovering materials from end-of-life products. He is a technical auditor for the SENS Foundation and Swico Recycling and was temporarily lead auditor for environmental management systems according to ISO 14001. Patrick Wäger has various lecturing assignments in environment and resource management and, among other things, is a member of the management board of Swiss academic society for environmental research and ecology (SAGUF). His work currently focuses on researching strategies for a more sustainable way of dealing with non-renewable raw materials, in particular rare metals.

International links

www.ewasteguide.info
A collection of information and sources on all matters involving the recycling of electrical and electronic equipment.

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 9 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".

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